APPENDICES

APPENDIX ONE.

SUMMARY OF OBSERVATIONS FROM ARCHIVED BUILDING ACCOUNTS

The building accounts here referenced were mainly transcribed from original, archived documents by the author. Some are published transcriptions by others. Those archive bundles referenced are fewer than those consulted, though the story of them all is remarkably consistent. Appendix Five offers all transcribed material.

Earth and Earth-Lime Mortars

Relatively few historic texts discuss the use of earth for building (see Appendix Ten), but evidence of the use of earth for masonry construction of all status, and as part of plastering schemes for interior use, is commonly found in archived building accounts, in association with stone buildings but also with timber-frames (Appendix Five).

Earth, or even sand for mortar is not always mentioned, although lime usually is, it being common when a house was being built on a landed estate, for the earth and/or the sand for mortars to be sourced immediately locally, on the estate, with only the labour involved in its digging or carriage recorded (as at Creech Grange), and this not always. Earth was less likely to be recorded than sand, as much of the earth for mortars might be won during the excavation of foundations and cellars, and the cost of its digging recorded in general labourers accounts.

Sometimes the use of earth for building mortar is explicit. In the account for the building of All Souls College, Oxford, 1438-1443, 289 quarters of lime were delivered in 1438, but also 312 loads of sand and 'red earth with sand for making mortar' (Walker 2010). There are numerous payments to daubers in 1441 and 1442 and deliveries of sand, lime and '36 loads of clay bought for the interior walls of the College'.

In Bedale in the 15thC, where cruck houses and 'stoned-cruck' houses were common, earth mortars are being prepared from 'clay', sand and quite possibly lime, lest the latter was for plaster finishes and limewashes only. Much of this was for the daubing of wattle in-fill panels. In 1442-43, William Godale, carpenter, built a 'small house' in Bedale (NYCCRO ZBA 11/8/1/10). Apart from the necessary timber and pad-stones, he used 7 cart-loads of clay, 3 quarters of burnt lime and two cartloads of sand. Both sand and lime may have been for the improvement of the clay, as well as for lime finishes. Similar may be seen in the York Bridgemasters' accounts from the same period (Stell 2003), although most masonry used in association with mainly timber-frame buildings was of brick, particularly for chimneys. Whether for mixing with the clay, or for finishes, the volumes of lime would be less than those of clay or even sand that might be used to improve the clay, and this is evident in the quantities given. Sand, lime and clay are regular entries, with an apparent distinction between clay or earth and 'lute', which is a term for the finest of clays. Lute is explicitly associated with daubing, as in 1488, when 'three cart-loads of lute called dobyng earth' were paid for. Straw or hay to reduce shrinkage is commonly accounted, but also dung, which performed a similar purpose, being fibre-rich. On analysis, most earth and earth-lime mortars in North Yorkshire used earth with very fine clay and silt content, predominately (Copsey, Gourley, Allen 2010). Similar can be seen in the same period in York.

In the accounts for the building of the Shambles and Guildhall in Plymouth 1606-1607 (Welch 1967), stone, earth, sand and lime are delivered regularly to site, within the same weeks, and from week one – clearly indicating the use of earth mortars improved with both sand and with lime. The volumes of earth delivered much exceed the volumes of both sand and lime. Lime ashes are delivered as well as lime, probably for use in floors. Hair, along with lime and sand, as well as earth, appear first in week five, indicating daubing and finish plastering of completed sections of masonry.

There are regular payments to labourers for 'beating mortar'. As Henry Best made clear in 1641, the beating of earth (or earth-lime mortars) was as important as was the beating of lime or lime: sand mortars to their quality. The account for the building of Plympton Free School, 1663-71 shows the delivery of a great deal of lime, but no mention of earth is made and relatively small volumes of sand are delivered, only whilst the stone slate roof is being laid, along with smaller volumes of lime than before. Before this, alongside plasterers' wages are regular deliveries of hair and lime, as well as payments for the quenching of large volumes of lime (three men slaked 40 bushels in a day on one occasion). Smaller volumes of 'white hair' appear alongside significant volumes of 'haire', indicating the use of white hair in finish coats, ordinary hair in backing coats, probably of earth and hair, as no sand appears in the plastering account. The lime is being 'quenched' and used (Plymouth archives 234/35). Plentiful lime is delivered to site at Laverstock, West Dorset, in 1720, but no sand at all, suggesting the use of earth-lime mortar (Wiltshire archives G23/1/67). The account for the building of a house in Thing Hill (Hereford archives B43/29) makes the use of clay mortars for the stonework explicit:

"March 3
7 loads of stone
4th 22 loads of clay; 2 load of scaffold poles
5th 24 loads of stone and clay; a load of poles
6th 9 loads of stone and clay
7th 15 more
9th 15 more
10th 18 loads of stone
11th 19 loads of stone and clay
one load of lath, 5? Of heart and 3 ? of sap (inches probably)

12th 20 load of stone and clay
13th 44 loads of same
14th 48 loads of stone and clay
16th 9 of same
17th 8 loads of stone."

A similar pattern is observable before and after this monthly account. No lime at all is accounted for, indicating that the local clay soil offered quite sufficient tenacity and workability in the view of the masons. A subsequent account for mending' (house) walls contains, apart from the cost of labour, the cost of carrying 2 cartloads of clay; 5 cartloads of sand and 6 quarters of lime, whilst another, for 'making anew' one wall of a house seems to use only one quarter of burnt lime and one cartload of sand. If this was for the repair of wattle and daub panels, however, the earth of these might be recycled. The same year, six cartloads of stone and twelve cartloads of clay were carried to a house; later, three cartloads of wattelyng and seven cartloads of clay. No lime was used, apparently. Where it was, it was coming from Crakehall and Burton-on-Ure, the later a pure carboniferous limestone. On one occasion, there is an entry for 'one sieve for sifting burnt lime', suggesting, perhaps, that the lime was pulverised and sieved before slaking with earth or sand. Also in Bedale, but much later (1755-56) a short building account shows sand being dug on the site, as well as sieves for the lime:

Jonathan Sowler making bricks (44,000) in the Park 15-10-0
Thomas Thompson for mason work 22-2-3
Hodgson for digging sand hole
Mr Theakston for lime 6-10-0
William Horner for lime 4-17-0
A treekle hogshead for the brickyard…
For a hair sive…
For a fine sive. (ZBA 13/4/5)

For the building of a stone farmhouse in Normanby, near Malton, in 1733-34, 181 loads of stone and 86 loads of mortar were used. No lime is mentioned, although the house was built by the Thornton Estate, where there were numerous lime kilns in operation. The sub-soils of the Vale of Pickering typically contain an optimum balance of very fine sand and silt and clay, so lime may have been considered unnecessary, at least for structural mortars. (NYCCRO, Hill Estate Archive, as yet uncatalogued 1733-34 Account Book). The account for the building of the Paper Mill in Ellerburn is lacking in mention of either lime or earth, although '2 plates for mortars' are accounted. The earth for the mortar will have been sourced on site and estate lime kilns were only about 100 yards away. The cost of getting both, therefore, will have been included in the labourers' or the masons' accounts. Notably, the pantiles for the roof were imported from Holland into Scarborough and carried from there in carts. The cost of these exceeded the entire labour costs of both stonemasons and labourers. The building remains today and was built using earth-lime mortars, pointed with lime rich mortars. After 1735, the Thornton Estate repaired and rebuilt 55 houses and barns in Scalby, Burniston, Newby, Langdon and Cloughton, all now part of Scarborough. Many were of stoned cruck construction, others simply of stone, the accounts having been preceded by a detailed condition survey. These works were accounted for in detail. 'Mortar' used was of earth, with smaller deliveries of lime, although neither are much mentioned, as above. All stone building was valued by the 'rood' and this rate may very well have included the cost of sourcing and mixing mortars. In the 1780s, a subsequent incumbent of the Thornton Estate built numerous new houses in the same villages, converting many of the houses repaired in the 1730s into barns and beast-houses.

In Malton, the intended addition of lime to an otherwise earth mortar in a variety of small contracts, 1734-1808, is explicit (NYCRO ZPB III 5-2-1)
At other times it can be readily deduced – Thomas Storey built a barn and two stables at South Cave, East Yorkshire, in 1778. He charged for 'pointing the walls with lime and hair inside and out'. Lime was delivered to site during the works, but no sand, and the addition of hair to pointing mortars is typical in lime pointing over earth-lime bedding mortars in Yorkshire (Copsey 2010; 2019). In Malton, distinction tends to be drawn between 'daubing and plaistering', as also at Mapperton, in Somerset. In another barn at Holm, near South Cave, built this time of brick in 1779, a plaster floor was run at 6d per yard. Some of the latest uses of earth for mortar are in Malton (1799) and in Headingly, Leeds 1783-1805. In the former, Luccock, the mason agreed 'to build a tenement in the cow pasture of Malton Fields…6s per rood for walling stone, 1s 6d per rood for mortar without lime; 11s 9d without pointing, 12s 6d, if pointed" (NYCRO ZPB – 9-6), whilst at Headingly, a school and a dwelling house were built using earth and sand mortars, with no lime in evidence. Later still, on the Goddard's Estate in Swindon in 1864, works done to a beerhouse and to some quarry cottages were executed in a mortar of lime and 'dirt'. This may be ordinary earth; it may be road scrapings. In East Sussex in 1736, an account for the building of an Oast House lists materials thus,
"Paid for bricks and tiles 8-17-0
Paid for 5 load of Lime 3-0-0
Paid for a Bushel of Tarris 0-5-0
Paid for carrying Loam & sand
…For 13 tun of timber also 19-10-0
Allowed for the Rearing 0-15-0" (East Sussex Archives ACC 8648/3/25/5).

This shows similar patterns of mortar use as in North Yorkshire and across the UK at this time. Lime, loam and sand are also listed for the extension of the associated dwelling house in 1737. Much less reliance was placed upon earth mortars for major works at Stanmer Park in 1722, owned by Henry Pelham (East Sussex archives ACC 6077/22/11) but the list of materials used for the different mortars was meticulous and instructive, with much more sea than pit sand used, perhaps of necessity, as well as significant volumes of clay and lesser volumes of loam, the latter perhaps reflecting the preference that persisted in London even after this date for applying an earth backing coat to ceilings, if no longer to walls (Campbell 1747). Sea-sand usually contained calcium carbonate, in the form of sea-shell fragments. Almost 1 million ordinary bricks, as well as 71,000 'Dutch clinkers' (for diaper work, presumably) were used, costing twice as much as the chalk lime used to bind them and more than twice what the bricklayers were paid to lay them:

"1235 loads of sea sand
339 loads of Land sand
12 loads of Loome £0-6-0 carriage £1-10-0
44 loads of gravel
114 loads of Clay £4-5-0 carriage £28-17-6
110 loads of small chalk
1111 1/8 loads of Lyme £480-4-3 Carriage 29-1-3/4
19 ¼ bushels of Tarriss £3-15-5
1770 bushels of Cow hair £59-0-0 carriage £10-13-0"

At Stanmer, there were three supervising professionals, a Measurer, a clerk of works and a 'Surveyor', who received two payments of £398 10s, a significant proportion of the wage bill. 50 years later, the brick house at Stanmer was re-faced with stone ashlar.

Where earth was bought and brought in, it routinely appears in building accounts, typically alongside deliveries of sand and of lime (Oxford, Plymouth).

The almshouses in Sherborne, Dorset were built between 1440-44, with immediately local dressed rubble stone mainly, but with Ham stone dressings and windows brought some 12 miles from the other side of Yeovil. Quarrying began in Easter week 1440, and continued throughout the works. The first delivery of materials other than stone was of 1 load of sand, 15 loads of clay and sand and 19 sacks of lime – quicklime, as well as a sieve to 'sift sand'. This would clearly indicate the use of earth-lime mortars. Later, along with stone, 10 loads of clay, 14 sacks of lime, as well as more sand. A similar pattern persists throughout the project, interspersed with wage accounts for masons, labourers, carpenters and heliers (roofers). In one account (no.18) from 1442-43 there are payments to masons, mainly stone-layers, payments to labourers serving them, 53 quarters of lime 'bought at divers places for the work', 76 loads of clay and sand bought for the same, 8 windows of freestone from Symmes (of Norton-sub-Hampden), 10 loads of freestone and 2 dozen hurdles for scaffold (Dorset Archives D/BOH/E24).

The account for the building and repairing of the House in Newton Ferrers, Northants in 1579 (Fitzwilliam Misc Vol 432) clearly indicates the use of earth or earth lime building mortars, the daubing of the walls with the same and its overlaying with haired lime, delivered as 'plaister'. Not only laths provided the base for the daub, but also reed. All plastered interior walls were lime washed.

Within the same ownership, but in Setchy, near King's Lynn, Norfolk, in 1674, the same blend of materials is evident during the construction of a new stable, with 12 loads of clay dug and carried from Runton, 6 chalder of lime delivered and 65 loads of stone and further deliveries of stone, sand and clay. The use of clay, with or without lime was not because the building was a stable, as a later account (1675) shows:

"October 10 paid Tho: Handly Mason for worke at Tho: Wilson's House
Paid for brick for the same worke
Paid for a load of clay for the same worke
Paid for a load of sand for the same worke"

The absence of lime does not mean it was not used (although it may), this entry was from the general accounts, and lime was often accounted for separately and as a global amount consumed on numerous sites and such an account for general lime-burning in 1694 is included in the Setchy accounts and billed by the lime-burner, who was not, therefore, directly employed. (Much later, in 1843, this situation persists, but with two men being paid wages in lump for the burning of lime between 4th February and 23rd December (illustrating the 'lime season' locally as well)). On August 9th, 1675, William Grasby, 'the Mortarman' was paid by the Agent for 6 days work and in 1693 John Sutton received payment 'for digging mortar for himself and ye other men,' as was 'Bradery's wife for digging Mortar by the Loade – 33 loads'. That mortar could simply be dug, in this case, indicates that it required little improvement, beyond, perhaps, and by no means necessarily, the addition of a little quicklime. For general repair and building works around the Peterborough estate of the Fitzwilliam's in 1714, lime, sand, and stone, but also 'mortar' almost certainly denoting 'earth mortar' are frequent entries (Fitzwilliam Misc Vol 96). If it is earth mortar, it is being as often used to lay bricks as to lay stone, and smaller volumes of quicklime are regularly delivered at the same time as much larger volumes of 'mortar'. 'Mud' is explicitly used in the setting of arches of the Angel public house.

Lime Burning

Lime-burning was frequently 'contracted out' even when the lime kilns were owned by those for whom the house or other buildings were being constructed. Occasionally, as at West Rayson, East Yorkshire, in 1766, (**D DEV/56/47),** it would be supplied by the bricklayer along with his labour. A summary of 'values for building' in Amphill, Bedfordshire from 1693 (Wiltshire archives 9/28/61), states clearly that brickwork, tiling, plastering and rendering rates include the cost of materials, as well as their supply – the tradesmen are 'to find all', with separate measured rates for the labour. The activities, as well as a wide variety of materials, are all given measured rates. This is not an account, as such, but a list of 'terms' and general expectation at the time. A similar document survives from Wardour Castle, 1698 (Wiltshire archives

2667/22/1B/1), with rates given for carpentry and masonry jobs by measured rates of the 'square' (for some) as well the square yard and the square foot.

Lime burning was generally seen and was pursued as a specialist occupation, and lime burners would be brought in to operate existing kilns, or to build and operate kilns specifically for the project in hand. This happened at Bolsover Castle in 1613, for example, when most of the lime-burner's assistants were women, one of them his wife (Knoop & Jones 1934). At Trerrible, 1724, Stanmer Park, 1720, Sapcote, 1801, Milton Hall, Bolsover Castle 1612, Tattershall Castle 1434, Scampston, Moccas Court, Dore Church, Hereford and Marske Hall, bricks as well as lime were burnt on site. There were 10 lime kilns operating at Tattershall, each producing 7 ½ cartloads of quicklime per burn; the fuel was charcoal (Simpson 1960). At Marske Hall in the 1620s, the stonemason (Thomas Stott) was also the lime-burner, a kiln having been built on site (NYCCRO ZAZ/75 & 76).

The works to Dore Church in 1633 (Hereford Archives BRI16/1) were relatively minor in scale, mostly roofing, with 36,000 tiles, and yet a lime kiln was built on site to provide for these. The account for the lime-burning is unusually thorough. Between April and September 205 man days were spent 'making lime'; 42 ½ man days digging stone for the lime burners and many days 'drawing stone to the kiln' between May and October. 162 man days were spent 'cleaving wood for the lime-burners'. On August 30th, 16 bushels of hair were delivered. Even so, 102 barrels of lime were bought in between March and the end of November, indicating, perhaps, that the local 'stone lime' was not considered appropriate for use in plaster finishes. The York Bridgemasters had their own lime kiln in Castlegate, but also regularly purchased lime on the quay-sides, typically 'from a stranger', as well as plaster, which term included gypsum plaster, which might also be burned in the city, in the 'plaster kilns' mentioned on occasion. The kilns were wood-fired, but the 'plaster kiln' used turf, requiring a much lower firing temperature. The plaster was routinely 'pounded' before use, as was the lime. There were floors of earth, as well, perhaps, as solid walls – a payment is made in 1472 for 'making a wall of earth in the house of William Fraunk' (Stell 2003), although this may be a general term for lathed and daubed stud walls. The building account of York Minster, much of it covering the same period (Brown 1862, translated by Copsey), also shows gypsum, as well as lime being burned in kilns in the masons yard, which at that time was close to the site of St Mary's Abbey, adjacent the cemetery there. Sea-coal, supplemented with faggots, was the fuel ('sea-coal' indicates the use of coal shipped by sea from the Newcastle area). Gypsum mostly appears in the account in apparent association with floor tiling, although, given the general use of Plaster of Paris around the city it is named after, even for exterior renders (Rondelet 1803; Martin 1825), its use for some plastering, or for small volume addition to pure lime plasters at the Minster cannot be ruled out. It was a higher status material and was used extensively during the construction of Nonsuch Palace by Henry VIII, with at least 429 hundredweight accounted for in 1538, purchased in London (Dent 1970). If this was, as is likely, used for plasters as well as for modelled statuary, hair was added, a great deal appearing alongside the plaster in the account, as well, perhaps, as sand or other aggregate, at least on occasion.

Lime Pits

At Marske, in 1619, a 'lime pytt' had been made in association with the building of a dovecote, which may have been for the storage of slaked lime (slaked beneath a thick layer of sand), but seems to have been rather part of the burning process:

"A lyme pytt betwixt 9 and 10 (yards?) at ye boddom, 4 yardes highe and proportionable as they shall be directed by Christopher Orton and well fylled.
£3 for burning and making ye pytt.
60 loade of coal with some wood"

A 'lime pitt' was made during the building of Sadborow House, near Chard, Somerset in 1773 (Dorset Archives D-MHM/8871/A). Sadborow is built substantially of Ham Hill limestone ashlar. Most of the lime used was from Uplime on the Devon-Dorset border, burned and unburned seemingly, as there was a kiln on the site. Uplime sits upon the lower (blue) lias formation, so that the lime may have been at least feebly hydraulic, although there are also outcrops of high calcium lime (Bull 2010). Lime from Uplime was used for the plastering as much as for the build, which might suggest a low hydraulicity, if there was any at all. The upper beds of Blue Lias limestone may offer very little by way of hydraulic set (Holmes pers comm) and Uplime, as its name suggests, sits high above Lyme Regis, from which more energetically hydraulic lias lime was deployed historically, largely for water works. Hydraulic lime could not be long – or much at all - stored in a lime pit without setting hard. Later, in October, firs are carried to the lime pit – perhaps to line it; perhaps to cover it over the winter, or else to keep lime and sand separate, the sand being to insulate and preserve, not to mix in. That some lime was being laid down as thick putty, and other lime in the form of quicklime (being used more) is made clear, however, by the summary lime accounts. Lime putty might here be being used not only for plaster finish coats, but also as the mortar (on its own) for laying the fine ashlar:

"1773
Three pitts of lime to new house
165 hogsheads of lime to new house at 2d each
30 hogsheads to Stable
10 hogsheads of lime to former house

1774
330 hogsheads of lime burnt with culm to new house
373 hogsheads of lime to offices, burnt with culm
77 hogsheads of lime to Mr Walsh building, burnt with culm

33 hogsheads of lime to dressing to garden, burnt with culm
140 hogsheads to garden wall
466 ½ hogsheads of lime sold at 1s 9d per hogshead, burnt with culm
195 hogsheads of lime to Plasterers, burnt with culm
15 hogsheads of lime to plasterers from Uplyme
20 hogsheads of lime to Plasterers from Pitt
The rest of Pitt Lime was used to Garden, Stable & Brewhouse"

De L'Orme (1567), Ware (1738) and others suggest that where lime must be laid down, or stored (it would otherwise air-slake), particularly for plastering, that a deep pit be excavated, well-filled with quicklime and covered with a layer of sand (or earth) up to three feet deep. Water sufficient to slake the lime would then be evenly poured through the sand; the lime would slake and then be preserved in best condition and prevented from drying out, by both the moist ground and the sand covering. The sand was not expected to be mixed with the lime and steps were taken to provide a permeable barrier between the two. Hassenfratz (1825) indicated the use of willow hurdles. Perhaps the firs delivered to the lime pit at Sadborow were for this purpose.

Sourcing of Lime

Most of the lime used at York Minster was magnesian lime, though high in calcium, although 45 loads of what would have been nearly pure oolitic limestone were purchased of John Sawmon of Broughton (near Malton) in 1421, on top of 16 loads of the same of the vicar of Broughton in 1419. Numerous casks of plaster were purchased in 1479, some from Buttercrambe, some from as far away as Gainsborough, both of which were connected to York by navigable rivers. The lime was being slaked to a dry hydrate initially, with the only entry in English (1580) recording payments for 'sleckinge, beating and sifting of lime'.

Alternatively, and if an established, commercial lime burning operation was close by, then lime from this would be bought in. Lime would be mostly carried by cart or wagon, but, occasionally by boat, along rivers (Rockingham Mausoleum, Ashley House) or even around the coast (Plymouth Guildhall and Shambles). Lime was always paid for by the cart-load or the bushel or the quarter or the peck, and the price of these (actually precise quantities (a cart-load might be 4 bushels), but its quantity always had a local volume. It was supplied either loose, or in sacks, occasionally in hogsheads. It was more likely supplied in barrels (mainly as quicklime, but sometimes already slaked to a dry hydrate) when the distances were greater. Over short distances, loose loads or quicklime in sacks was considered less likely to air slake in transit. Most often, the lime is identified as just that – local limestone or chalk, depending upon location (chalk at Stanmer Park, eg). 'Limestone for lime' is a common entry, or simply 'lime'. Occasionally, the lime is from a named source – from Knottingley, via canal, river and road, for the Rockingham Mausoleum; lime from Barough (Barrow-on-Soar, a Blue Lias lime) for Kirby Muxloe Castle in the

1480s, and again, much later, for the plastering of cellars and other underground works in Sheffield in the 1860s. Knottingley lime was used for the building of a high status town house in Beverley, East Yorkshire, in 1716 for the Hothams. This was a 'magnesian lime' with possibly feebly hydraulic properties, although its magnesian content was very low and the lime was in reality a high calcium lime. Knottingley is some way from Beverley, although rivers connected it to the Humber. Locally, chalk was abundant, so this represents a conscious decision to use a 'stone lime' by a family with the resources to carry this a fair distance. The walls were to be 2, 3, 4, 4 ½ and 5 bricks thick, according to where they were in the building, so slimness of construction did not inform the choice of lime; its probably feeble hydraulicity may have done. The bricks were burned in Hotham's own kilns. Other significant (and later) deliveries of lime are simply for 'lime' and will probably be chalk lime for plastering.

At Beverley, and most commonly generally, the works were governed by the simplest of agreements:

March 30th 1715

Mem. I then agreed with Sir Charles Hotham to erect him a building 20 yards long according to the dimensions specified in a place containing work-space, brewhouse, laundry and coal-hole, to be floored, one pair of stairs to answer both chambers, the baulks to be of ash…doors and window-frames to be of oak…Sir Charles finding all materials. Thomas Robinson

Most certainly, all along and across the limestone belt of England, as well as across the chalk formation, lime kilns were abundant. Where limestone had to be brought in to predominantly other geologies, lime kilns are less abundant and are located at road-sides or upon the banks of rivers, the limestone brought to them for burning. Lime kilns were essential wherever building became established, and in order for towns of even villages to expand. This was so even where earth mortars were the most common material of construction, as lime mortars and lime were essential components of this pattern of building, providing more durable finishes and limewashes. As the British sought to expand and develop the colony upon Vancouver Island, James Douglas, the Governor, advertised firstly in the UK for lime-burners. Lime had to be sourced locally in so remote a situation. Bricks and other building materials were imported initially from Britain and from New England, before Douglas set about attracting brickmakers, but an active lime burning industry was an essential preliminary to all of this, initially using shell middens sold and supplied to the Hudson Bay Company by the Songhees first nation (Reksten T 1986), later using quarried limestone.

In common with the 'convention' of the historic texts and specifications, and as explained by Pasley in 1826, 'lime' in building accounts generally refers to 'quicklime', with slaked lime clearly distinguished from this when already hydrated, whether to a powder or to a pure lime plaster. At Wardour, for example, the roofer takes delivery of '2 sacks or 6 bushels of lime'. Immediately afterwards, and after a labour charge for 'lath plastering', 10 bushels of 'slackt lime' appears, probably – because of the bushel measure, a sieved dry hydrate to be run to a putty before or during mixing. The Wardour account also notes that '30 foot solid, *or a mason's perche,* at Wardour is a load in carriage and requires a bushel of lime' and 22 tons of sand (2667/22/1B/1). Such precise definition of measures and of quantities is rare. Later in the same account,

"Agreed with Barret, Mason to face ashler-way 2249 ft superficial at 3d per ft
To him for laying 5528 ft cube at ½ d per foot.
Sacks of lime for 5868 ft cube, 65 for stone-work; for 3625 ft square for tyling, 32 sacks; for 1928 ft square for ceiling, 8 ½ sacks, in all 105."

Lime Processing.
Lime-burning was most often done with coal, otherwise with wood or, occasionally, with charcoal. Wood was a relatively scarce material across the UK after the 13th century. Wherever coal – even of poor quality, as in North Yorkshire, could be sourced, it would be the preferred fuel for lime-burning, contrary to much received wisdom, and this is evident in the archives consulted. Poor, shallow seams of sulphurous coal in the Vale of York and upon its margins, were used for little else than lime-burning (Tuke 1800), and were chased through the Hambleton Hills largely for this purpose. Often, where wood was used, the kilns were owned by a landed estate, exploiting managed woodlands. Coal was used to burn lime at Beverley (1722), Moccas Court (1773), Marske Hall (1622), Nunnington (1673) and Oulston (1794-96), as well as at Sadborow House in Somerset in 1775, along with culm, both imported into Lyme Regis and carried to Chard. Coal was the fuel at Rochester Castle (1368), supplied by the master of the works, the lime being chalk lime supplied by the lime-burner (Knoop & Jones 1933 & 1967).

Lime and other materials would appear to be brought to site on a 'just in time' basis. There is no explicit reference in any of the archives consulted to the laying down of lime putty; only minimal reference to 'lime pitts', and these references are open to alternative interpretation - the Huggate Enclosure Act requires the provision of a 'mortar pit', not a lime pit and the 'lime pytt' mentioned at Marske Hall may be rather a pit kiln, given its context, lest the Limeburner was slaking the lime, as it emerged from the kiln, as at Bolsover. 'Clamp' kilns built over a pit were not uncommon, especially for more temporary lime burning to service a particular project. 'Lime houses' are more often referred to, although still only occasionally (Newburgh, others). 'Lime houses' were common enough on sites, comparable in some ways to the masons lodge, where stone was carved undercover, and especially where quicklime might be stored to be slaked initially to a dry hydrate, but also where the mortar was mixed directly to a coarse stuff. Where lime putty was required, this, too, might be processed in the lime house. There was one at Newburgh Priory in the 19thC, servicing the various demands for lime on the estate. Mortar might be mixed at the lime house before being used soon afterwards. The Bolsover account gives more detail than most of the mixing process, whilst also illustrating the 'just in time' nature of the process. Between the 15th and 29th of May, 1613, we see 'Labourers at sifting and harling of lime; drawing and carrying of water; serving the layers; women carrying sand; the limeburner and 6 women at the kiln; limestone getting and breaking'. 'Harling' in this usage must indicate the pressing, dragging and pushing of the lime and mortar with a hoe, not the throwing of the lime, the former being an archaic meaning of the word *('dialectal, British: to drag, scrape, or pull (an object) usually along the ground'* (Miriam Webster Online Dictionary). Alternatively, it simply means the carrying of the mixed mortar, perhaps on sleds. Elsewhere, we see 'tempering the mortar and harling the lime', suggesting that the quicklime is slaked to powder before being sieved and is then worked to a thick paste before being mixed with the sand and worked over once more. Elsewhere again, 'carrying water and slecking and harling lime; serving layers and freemasons'; other times 'labourers serving layers and making mortar', whilst also 'at the lime kiln and at sand and filling stone getting'. Filling stone was frequently carried and even put in place by male and female labourers before grouting, in all probability, although this is not mentioned explicitly. Making of grout and grouting of the walls is explicitly mentioned throughout the building of Sadborow House, Somerset, after 1774. Hot lime grouting is a common requirement of 19thC specifications across the UK and in Canada, but is rarely explicitly mentioned in the building accounts consulted.

A flint field wall with brick buttresses and quoins was built at Whatcombe, part of the Bindon Abbey Estate, Wool, Dorset in 1820. Months of flint-picking in the fields, much of it by women, runs parallel with lime burning, sand and brick deliveries, clearly indicating hot mixing of mortars, the early stiffening of which is a boon for the builder of flint walls, allowing steady progress without the swimming of the little porous and knobbly stones. The estate rented the use of a kiln at a nearby farm (D-WLC/AE/19)

On May 7th 1872, one man spent a day 'making mortar for Watson's buildings'; the following day, 5 men were working on the same buildings (NYCCRO ZDV Newburgh Estates Accounts and Wages Books 1851-1939). A similar pattern is evident throughout the accounts. Working on the New Mill in December 1872, the 19th is spent 'making mortar for slating', the roof is laid on during the 20th and 22nd and coping installed on the 23rd. In January 1874, plaster was being made on the 23rd January and plastering done on the 29th and 30th, six and seven days later. In March 1881, J Scott spent a day 'making mortar at Newburgh (in the lime house) for Winter Cottage' and then '3 or 4 men' worked at Winter Cottage over the following 6 days. Open-sided roofed structures can be seen in some late medieval illustrations of building sites, with mortar, or plaster banked to be knocked up to a mortar immediately before use. During the construction of Oulston Hall, 1794-96, 'plaister' was brought in from Cusworth, typically in 1 ½ ton loads, along with 'white plaister' and 'common mortar', as well as 'common plaister', but numerous entries for burning kilns of lime (with coal), interspersed with deliveries of stone, would indicate the presence of a site kiln and the hot mixing and immediate use of building mortars, the lime burning contained within the 'Carpenters and Masons' account. In 1795, lime is explicitly burned 'for plaister' and limeburning and plastering are contemporaneous entries in the account. (Doncaster archives DD DC/HI/2/1). The lime accounts for the building of a stone bridge at Nunnington in 1673, suggests that the lime held in a lime house might be already slaked to a dry hydrate, as well as being freshly burned and slaked on site, as well as the recycling, for burning, in this case, of stone from standing buildings (NYCCRO ZKZ/3/2/1/6), indicating a certain haste to get the bridge built:

"Paid by lime which Grahame had in his Lime House which was delivered out for the use of the said bridge 40 chalder
For burning the said (extra) 25 chalder, the fellows got stones out of the barne wall."

In 19thC specifications, as for the building of a Vicarage in Leinwardine, Herefordshire (AA 61/37), it is a normal requirement that 'the lime…be kept under cover to prevent weather until slacking' and the lime house performed this function. 'Plaster' is sometimes bought in (York, elsewhere) already made up, which might imply some laying down, but this is always in the context of plastering, usually plastering over daub or earth, as at Laverstock, Mapperton (Machin 1983), and so is likely to be composed of just lime, and numerous other accounts indicate the delivery of quicklime just before and during plastering activity, suggesting that this quicklime is slaked and used promptly, perhaps to a dry hydrate, as sieves are frequently purchased, to be produced, sieved and run to a putty just before, or during, mixing to a mortar. At Oulston in the 1790s, 'burning lime for plaster' and subsequent plastering are consecutive entries in the account. Similarly, lime delivery and plastering are side by side in the later account for Laverstock Farm, Somerset, the building having been completed (Wiltshire archives G23/1/67). At Malvern Hall, Solihull (op cit) between May and October 1784, lime was delivered from Birmingham every day or two, totalling 798 quarters of quicklime. An account of deliveries of materials to a project in Sheffield very clearly shows that the mortars are being mixed and used throughout the period, almost certainly hot. The account runs from March until August. The account for three weeks in April, 1813, is typical:

April 2nd 1 day leading rubbish
3rd 1 day leading rubbish
6th 1 day leading stones
1 load lime
1 load sand
8th 1 day leading stone
9th 4000 bricks
1 load stone
10th 2 load sand

1000 bricks
12th 1 load lime
500 bricks
15th 1 load lime
2000 bricks
leading rubbish
17th 2 load sand
1000 bricks
leading rubbish
19th 2500 bricks
20th 1500 bricks
2000 bricks
21st 1 load lime
2000 bricks
23rd 2500 bricks
1 load lime (Sheffield archives SIS 2 (1-35). Bills etc Roberts and Cadman Builders, Sheffield).

Nomination of the source of the lime becomes more common in the 19thC, within architects' specifications. North Grimston lime is specified in Malton in 1860, a probably feebly hydraulic lime from 5 miles away; 'blue lias lime' in Warwick in 1863 (Warwickshire Archives CR 734/6), although this was the dominant geology of the district. Blue Lias lime was also used for brickwork in the building of a cow-shed in Bailie (near Wimborne, Dorset), as well as for concrete floors and wall footings. But this was in 1897, and cement was also used, to bed slates that formed a damp course and brick paviours were to be grouted with Portland cement (PE/SML: IN 2/2/2). This simple account offers a clear glimpse into this transitional period for mortars, as architects specifications became the norm, even for ancillary buildings.

Re-use of Materials

When an old house, particularly of higher status, or other building was being displaced, it was a common requirement for sound earlier materials to be re-used, particularly in the case of structural timbers, brick and stone. Before the building of the new house at Plumley in 1792, payments are made to take down the old house, as well as to 'sort old stuff' before building of the new house commences (Wiltshire Archives 1369/4/40). On occasion, the builder is required to account for sound materials not re-used on site but taken away for use elsewhere or for storage, and on occasion, an agreed value for these salvaged materials is deducted from the cost of the new build. Prior to the building of six houses in Hammersmith in 1728, beyond the general agreement concerning dimensions and thicknesses of walls, there is a requirement that the bricklayers 'allow for all ye old materials as they are standing at 25 shillings per rodd for ye brickwork; 8s per square for plaintiling and 7s 6d per square for pantileing & to pull all down, dig ye foundations, cellars, well & Bogg houses & clear ye premises etc.' (West Sussex ADD MS 30 754). Such explicit recycling of materials is evident at Plumley in 1792, Warwick in 1863 and at Stanmer Park in 1722. Similar was not uncommon in Malton (Fleece late 18thC, see Appendix Six).

'Stone from the yard' was also a common entry in small-scale building agreements in Malton, as well as 'lime from My Lord' here and elsewhere, an estate owning the lime kilns. At Malvern Hall, Solihull, there is a detailed account of re-used brick and wood (Warwicks archive CR 1291/318-319) and stone was not only recycled, but was reworked to different profiles.

Who is doing what?

In many cases, especially outside of urban centres, masons perform most of the work – plastering, roofing, as well as stone and bricklaying – not associated with carpentry or joinery (see Appendix Six). In some cases, the roofers do the plastering (Wardour Banqueting House), although some of this will be upon the roof itself, as at Wardour in 1698, when the roofer is paid for plastering 488 yards of lath during the roofing and then, explicitly, for 'plastering on wall'. In the associated materials account, 100 sacks of quicklime were supplied for 'tyling and plastering', 102 for the stonework. Masons carried out the daubing of earth base-coats (Mapperton), before the later arrival of more specialist plasterers, who applied the lime finishes, including, at Mapperton, the pointing of the dressed Hamstone windows with a similarly pure lime. Wardour also has a number of entries for 'hair for the mason', which will be for addition to pointing mortars, appearing at the end of the building account, at the same time as the clearing of 'rubbige'.

At Dover, the carrying of water is accounted, it being carried to the site along with the 'lime from the kiln to the work' (p47). The kilns were on the beach, 'made by us below the cliff'. (Colvin 1971). Unquestionably, the mortars were of sand and chalk lime. No pozzolans are mentioned. Chalk lime was also used at Winchester Castle in 1222, burned on site, the fuel being wood. Some 'cement' was used and the account has payment for 'one box to measure lime', indicating that the proportioning of materials was not haphazard. Here too, the mortars were of sand and lime, as a separate account for the 'Treasury door' illustrates: "For three carts to carry water and chalk during the week…For the purchase of 30 sesters of lime…for 40 potts of red sand…for 100 potts of white sand…" (Colvin 1971). The same is true of Westminster Palace, 1259. The lime was burned using 'old oaks in Windsor Forest', carried on the Thames, although some was purchased from 'Agnes the Lime-burner of London'; sand was brought by the cart-load (Colvin 1971). Both lime and brick kilns were built for the construction of Nonsuch Palace in 1538, the lime kilns producing 10 loads per burn. The brick kilns produced some 600,000 bricks. Lime was then carried from the kilns to 'the place', where it seems to have been mixed with sand and heaped for delivery to the bricklayers. 20 wheelbarrows were brought from Hampton Court, as well as pails 'to put mortar in for the masons and rough-layers to set their stone with', and a 'bushel measure for lime'. It was chalk lime, mostly fresh-quarried, but stone from a displaced village and church was also 'mined' for burning. Small volumes of wax and resin were purchased 'to make cement for the masons' (Dent 1970). Some 795,000 bricks were used in the building of Ashley House, near Guildford between 1602 and 1604, and 11,705 bushels of quicklime, the latter brought in one bushel sacks by boat from Kingston. 1,547 bushels were 'spent in plasteringe' with hair sourced from tanneries in Leatherhead, Weybridge and Staines. Rosen and pitch were used for 'sementinge' and at least one of the bricklayers – Ferdinando – may have been from abroad. 'White vernishe' was used to seal the greate Chamber chimney piece. Sand was sourced on site. No mixing is explicitly referenced, although the wheeling or carrying of 'sande to the lyme' or of sand 'for the lyme' is. The brickwork was coloured with a red and black pigmented wash from 1603 onwards (Blackman 1977). At Bolsover, water was carried to the kiln, indicating that slaking and mortar-making were done as soon as the quicklime was drawn from the kiln and carried to the works, entries for the carrying of mortar and the 'serving of the mason' being frequent. Bolsover was relatively unusual, even in this period for being built with sand-lime mortars. Inigo Jones's Queen's House was built 1616-1618, around the same time as Bolsover Castle, using bricks mainly, faced with Portland stone ashlar. '44 loads of flints' were also used, perhaps to be crushed for silica aggregate, but more likely as in-fill. The lime was chalk lime, almost certainly hot mixed, and sieved, Avery, Browne and others being paid for 'slacking, sifting and wetting of lime into mortar at 12d the hundred.' (Chettle, undated). Similar may be seen at Edinburgh Castle in 1626 (Scott Milne 1893) in a payment to 'ane barrowman half ane day at the riddilling and mixing of the sand and lyme,' and coupled deliveries of volumes of lime and sand in their typical mixing proportion, as in 'for 12 laid of lyme and 24 laid of sand.' Also in Edinburgh, in 1754, the specification for the Exchange building demands 'good mortar made of lime mixed and made up with sea-sand', as well as walls 'grouted and filled up with mortar of lime and sea-sand, and the rubble walls…harled as they are carried up.' Paving was to be laid over a base of 'clay, lime and smiddy culm' and 'secured with pan-cratch or terras (trass) sufficiently beat and prepared', interior paving 'bedded in lime to prevent shifting.'(Contract 1754). Sea sand generally contained significant volumes of calcium carbonate, in the form of sea-shells.

Winter working

The building accounts present a clear pattern of winter-working as 'normal' where necessary, or where alternative, interior work was not available to be performed during the winter months, when the hours worked could be longer (with candle-light) and where the need for protection could be kept to a minimum or avoided altogether, such sheltered working was preferred. Bolsover Castle (and others) account for the winter thatching of unfinished wall-tops, but pointing works and structural works to vaults continue. Here, and elsewhere, and especially during a major construction project, the winter months were spent in preparation for full-scale construction in the spring (typically from March onwards) – with stone being quarried and dressed and carried to site. At Edinburgh Castle in 1626 (Scott Mylne 1893) the masons worked until the middle of October, work perhaps interrupted by the death of John Mylne, the master mason and architect, as much as by the weather. At Beaumaris Castle in Wales, plasterers and carpenters were among 1000 workers kept on through the winter of 1295-96 on top of the masons, stone-cutters and quarrymen also retained, with mortars being mixed and stone broken for the lime kilns; stone and timber brought to site (Colvin 1963). At the Rockingham Mausoleum (Sheffield Archives WWM A 225), masons continued building throughout the winter of 1785. On the Newburgh Priory estate, the masons were working in much the same pattern, winter or summer, during the second half of the 19thC, when a number of houses were being built or upgraded. On larger projects, the scheduling of the works to include the effecting of interior works during the winter months was possible and desirable to both parties – more work being achieved and longer hours worked, despite the shorter hours of daylight; it was less so on smaller projects. The wall-tops were routinely thatched during the building of Sadborow House, from late November onwards, and candles are a regular purchase, as they are elsewhere, as winter works moved inside or to more sheltered parts of the building. At Sadborow, the removal of the thatch wall-covering is done in March. Drains were commonly laid during the winter months, and foundations dug (Bolsover, others). Building work at St Bartholomew's Hospital continued throughout the winter of 1569, with 4 loads of stone, 3 barrels of lyme and 2 barrowes delivered on January 28th (the aggregate may have been earth), and 2 barrels of sand and 2 loads of sand on 3rd February (Gloucestershire Archives GBR K1/15). At Dyrham Park in 1692, substantial and regular deliveries of lime by the sack were made into November. (Glos. D1799 A102). In an account for the building of an aisle and 'repairing and beautifying' Canon Frome church 1716/17 (Hereford Archives R93 8351), the building works are carried out through the summer, with roofing and some bricklaying during September and October (with 18,000 bricks accounted for in November). November, December and January were devoted to internal plastering, paving, finishing the (mainly timber) porch, the Chancel being paved, plastered and lime washed during January, whilst the carpenter squared and sawed timber for the steeple. This may be seen as simply prudent scheduling of the works to take account not only of the weather, but of daylight hours as well. The building of the high status bridge at Scampston Hall between 1760-61 shows a clear pattern of winter working, with regular payments to George Wilson, mason, that continue into January 1761, preceded in October and December by the delivery of 163 loads of Ebberston stone and some more brick, 126,000 bricks having been delivered in August 1760. Lime was delivered from Malton in October, with full payment for lime made to Percival Luccock, a Malton stonemason who would later work on the Hall, on January 10th 1761, as well as payment of a significant sum, £49, to Wilson. After January, however, the next deliveries begin on April 21st. (Account Book no.3; Scampston Hall Library).

The growing use of cement in the later 19thC, both natural and Portland, did not obviate the need for some wall-top protection during winter working, of course. Masons in East Sussex in 1850 (BRN/15, 16, 17) were still using natural cement for many tasks (they were monumental masons), occasionally using Portland cement, for instance, to 'build and cope' a wall 'with concrete', using 30 paving bricks, 12 tiles and 3 gallons of cement for the latter, but also charged for 'thatching walls to prevent frost from destroying the new work'.

Many projects do, indeed, begin in the Spring, but perhaps for the reasons above as much as because of the fear of frost. There is less of a tendency for the works to cease for the winter, having been started in the Spring, with, as at Bolsover above, works carrying on into the winter, but with progressively shifting emphasis as the light diminished. Working outside in January and February remains a matter of necessity over desire in the 21st century, in northern Europe, at least, and can never be as productive due to the shortness, as much as to the cold or wetness, of the days.

Valuation of work and relations of production

Much of the work was performed by 'piece-rate' or measured rate, with day-rates reserved for employed work-teams and for 'extras' or for elements of the build that were less usual, more unpredictable or even quite new (the cornices at Treribble, e.g.), particularly as neo-classical fashions became established. It was not that local masons could not make these, just that they might be more complex and less easily accommodated within long-established measured rates for more vernacular detailing. During the 19thC contract 'by gross' becomes more common, a sum agreed with a local mason who might then employ others. Apart from in Malton, no documentary evidence has been found in the archives to indicate that the award of such contracts had been preceded by a competitive tender process and, in rural areas, this might be considered unlikely, the masons trading on reputation, but agreeing a global sum in advance. Even these agreements were subject to final measure, at least on occasion, and subject to disputes – the mason (in Dorset) who built Chuddington church, as evidenced by correspondence, became increasingly desperate for final payment over a 5 year period, during which the parish and the architect resisted such payment. Powell (1980) says that payment by measured rates had frequently led to disputes between client and craftspeople, prompting the shift to payment in 'gross'. However, the Chuddington case suggests the latter was no guarantee that disputes would not occur, or that competitive tendering did not reduce the resentment or sense of grievance felt by a mason being paid less than he felt he was due. Legally, competitive tendering, as today, favoured the carrying of losses by the contractor, and, as today, this was often willingly enforced by architects keen to remain in a client's good books, and in hope of further work. In another document in the same bundle, the mason at Chuddington can be seen 'sharing the risk', subcontracting with two fellow masons to perform works to another church at Mosterton some eight years earlier. Illustrating the dilemma for any contractor not able to be on site himself, when measured rates do not form the basis of valuation, he includes a penalty of 2s 6d to each of them on each occasion, should they ‘leave or neglect the work and go away drinking at any time’ (D 754/B4). Late payment was not unusual, particularly when the clients were wealthy landowners. The masons at Aldby Park, near Malton, waited over 5 years for payment, completing the works in 1726 and still awaiting payment in the 1730s. This would have been unsustainable for most. A brief insight into the mechanisms and the tensions of measured rates is offered by a bricklayer and roofer’s letter from Fulham after completion of works:

“For Plain Tyling 22 ½ squares and 4 feet
For old pantyling 17 sq and 43 feet
For new pan Tiling the house, office and washouse 2 ½ sq and 7 feet
For 4 rods and ? feet of Brickwork

Sir, I have measured this work and will stand by it. Except day works, as for white washing and stopping, Mr Hall did not insist on a second measurement, but is willing to let it pass, tho’ my amount is less than his in that affair. I shall have Mr Taylors account ready by Saturday next and will be that day at Home. Francis Hutchinson, Fulham November 22nd 1737.” (West Sussex Archives ADD MS 30 754).

In 1872-73,a bill from Collins and Cullis, Builders of Tewkesbury, their address being the Timber, Tile and Stone Yard, illustrates the shift away from individual trades being paid separately, and by separate agreements, towards general builders, most of the staff employed, as well as the imposition of competitive tendering. They invoice for the building of a ‘Billiard Room etc as per contract: £529-0-0, with an ‘extra’ marble chimney piece at £15-15-0 and then offer an itemised break-down. Similar may be seen in Sheffield (**SIS/3/7/2),** plastering being an exception – the collection of Roberts & Cadman papers includes several accounts with a named plasterer, who seems to be ‘self-employed’, although doing all of the plastering works associated with the wider building works performed ‘in-house’.

Pozzolans and ‘cements’

Pozzolanic materials or ‘cement’ appear in numerous accounts, including medieval accounts, but in small volume. Tarras/Terrace/Trass is the most common (brick dust would be readily and freely available on any site where bricks were being used, as, probably, would be wood ash, both common ‘vernacular’ pozzolans). In East Yorkshire, a simple account records the use of 8 chaldrons of lime and of one bushel of ‘siment’ in the building of a brick stable and privy (U DOG/4/21).
Trass is bought in at Kingsthorpe House in 1774, and at Badminton in the 1740s, where it was used in association with paving and the laying of wall copings – this association is common elsewhere. ‘Lime ashes’ are commonly delivered and purchased as a separate item, but are again generally associated with the laying of floors, often being spread as a base (and a buffer) to masonry paving laid otherwise upon the ground. They were used in the vaults at

Badminton. 'Smiddy dust' also appears and this seems to have been added to some pointing mortars. In Peterborough, upon properties owned by the Fitzwilliam Estate, there is a common distinction between 'smiddy dust for pointing', 'mortar' and 'lime and hair'. Lime and hair is as common a description for plastering mortars as is 'plaster', although it had more uses, particularly in roofing works (for pointing or 'torching' roof tiles or stone slates, along with moss for both, which regularly occurs, or for lime 'sheeting' over lath and beneath pantiles, a continuous plaster coat laid between the tile laths). If not for paving and exposed copings, trass would be used in the construction of cisterns, as well as other pozzolans, such as during the building of extensions at the house of the Earl of Holland in Kensington in 1639. Notably, the bricks used were the highest fired and least porous also:

"For digging two cisterns
In the cisterne att I brick in length…and for making the center
Tarras for the cisterne
For a bricklayer 3 daies to lay the cisterne with clinkers." (West Yorks archives WYL100**)**.

At Badminton in 1740, 61 feet superficial 'flatt stock brick paving in 'Tarras' is accounted for, with 5 hods of tarras (mortar) also used for 'terracing ye wall' in the garden and two loads of coal ashes in the raising of the wine vault (QJ3/11).

Above- ground works are accomplished using 'mortar', which given the period and location may well be of earth-lime. Marble, Portland and Purbeck, as well as local stone paviours and 447 feet of Bremen stone slabs were laid mostly in trass mortar, but some in common mortar, the latter within the house. Trass was also used for the garden wall copings. During refurbishment of the Angel Inn in Peterborough in 1714 (Northants Archive, Fitzwilliam Misc Vol 96), 1 ½ bushels of shells (lump lime) and 2 bushels of 'Dust' were used to 'pave the cellar floors'. The 'dust' would be either smithy waste or lime ashes. A later entry is for 1½ bushels of shells 'for pointing' and 5 bushels of 'smidy dust'. Coal ash was used by the slater at Sadborow House in 1775, to be added to the lime. Trass was used during the construction of St Mary's Chapel in Dorset in 1785, for the bedding of Portland, Purbeck and black marble flags to the interior, as well as for 'the gutter round the terrace'. Except for 2 hundreds of plaster, no lime is mentioned. However, the chapel is built of the finest Portland stone ashlar, much of it circular, inside and out and the plaster is most likely thick lime putty (Dorset Archives D-WLC/AE/19B). Two sieves are purchased 'for sieving sand', although there is no other mention of sand in the account. Bricklayers were also active at the chapel, though the value of their contribution was an eighth of that of the stonemasons, so lime and sand must have been supplied by the Bindon Estate. Wilkins (1799) required the addition of smithy dust to pointing mortars at Bayham Abbey, 'to match' the existing mortars, also requiring that the mortars be used hot.

Lime putty mortar was used for ‘grinded or hewen bricks laid in rowes and with white joints’ for the exterior elevations of a new house in Croome Dabifort, Worcestershire in 1641 for Lord Coventry (Gloucestershire Archives QVI/1). The bricklayer was from St Martins-in-the-Field, London – his employment alone a clear expression of status. The first floor was ‘painted’, otherwise colour-washed.

‘Sieves’ frequently appear, sometimes with a further entry for ‘riddling’ the mortar (also the sand, on occasion). This may indicate several procedures – the lime might be slaked to a dry hydrate and sieved before mixing with the sand, or with hair and water, almost immediately (which is the balance of probability in most cases), but lime run to a thick paste might also be pushed or poured through a sieve, as was common enough in the 19th and even the 20th centuries.

Beating or ‘pounding’ of lime mortars or plasters is also quite regularly accounted, although it is often the case that the cost of processing lime to mortars is lost in either the general labourers’ or in the masons accounts. Freshly burned or bought- in plaster is routinely pounded in the York Bridgemasters’ accounts, although this might be substantially of pure lime, with smaller amounts of fine sand or limestone dust added, reflecting the assiduous beating in the Yemen of stiff lime putty, the only intended use for which is limewash over earth plaster (Borelli 1992). Traditionally in the Yemen, two men would beat the lime putty for up to three days, with one day considered the minimum time.

Building accounts offer vivid snap-shots of material uses during construction activity, as well as of their rhythm, and the patterns of employment and remuneration. All would suggest the ‘just-in-time’ nature of building in all periods, for which the hot mixing of mortars were optimal, with storage and delay reserved only for particular deployments of particular mortars for which immediate or very prompt use would not be ideal.

APPENDIX TWO

REVIEW OF RECENT ACADEMIC AND TECHNICAL LITERATURE

More recent academic or technical literature focused upon either earth-lime or hot mixed lime mortars is sparse, to say the least. Although technical books aimed at builders and building professionals continued to discuss traditional slaking methods as late as 1950 (Newbold & Lucas) and although the 1951 British Standard Code of Conduct 121-201 detailed the sand-slaking of more hydraulic limes, shortly after this time, hot mixing seems to have largely ceased around the UK – preserved only in the practice of some individual craftsmen for whom it still seemed the obvious means of delivering effective and workable mortars, where they had continued access to quicklime locally and where they worked as independent craftspeople, insulated from the standards-based specification of architects and engineers. The Ministry of Works Guide to Lime

Mortars (1951) details the running of fat lime to putty, which the BS Code of Conduct above had understood should be achieved initially with around two volumes of water, albeit with the quicklime added to the water, in general contradiction to historic prescriptions that the water always be added to the quicklime. It retained understanding, however, of the necessary slaking water to quicklime ratio and was a probable response to the higher reactivity of some modern quicklimes. It also discussed the appropriate use of 1:3:12, 1:2:9 and 1:1:6 mortars and preserved good understanding of the need for relative softness and good workability. It indicated that 1:2 or 1:3 fat lime mortars were the most appropriate mixes for building with porous sandstones and limestones and that only 1:3:12 (a mix with significantly less tenacity than a 1:2 fat lime mortar) might otherwise be deployed for such masonry when rapid initial set was 'essential'. The Code of Conduct had assumed that putty was the most appropriate form of lime binder. It also recognised the continued preference for the slaking of natural hydraulic limes on site and detailed the sand-slaking method of doing so (as did the 1964 edition of Modern Practical Building, this time edited by Lucas alone). Over coming decades, this method, as indicated for the processing of slow-slaking and late-slaking-prone hydraulic limes - and which involved placing the quicklime in a ring of sand, adding the water necessary only to slake the free lime before banking over with sand and leaving for at least 12 hours, and frequently for 36, before mixing the sand and somewhat slaked lime to be 'banked' for up to 10 days more before use - would be frequently confused with more straightforward and efficient hot mixing methods. Where this confusion held sway, hot mixing was perceived as over-cumbersome and 'impractical' on the modern building site, a perception that pervaded the first mention of traditional slaking methods in the conservation literature: John Ashurst's discussion of 'slaking lime with sand' in the English Heritage Practical Conservation series of 1988. Ashurst described in detail the production and laying down of lime putty mortar, offering just a paragraph to hot mixing, drawn substantially, it would seem, from a partial reading of Dossie (1771), or from Partington's partial quoting of the same (1825), or even from Burnell (1857):

"A variation on the slaking procedure, which has a long tradition behind it, is to slake the quicklime in a pit, already mixed with the sand which is to be combined as mortar or plaster. The lime needs to be in small lumps so it can be accurately batched by volume against the sand. The process requires time and space and is really only practicable in long programmes of repair or restoration, where it is intended to lay up quantities of lime putty and sand for a long time. The technique has, however, a distinct advantage over more familiar mixing procedures in that this early marriage between binder material and aggregate encourages the covering of all the aggregate particles with a lime paste in a way and to a degree which can never be matched by conventional modern mixing." (Ashurst & Ashurst 1988 3)

He sets aside the obvious mechanical and performance benefits of hot mixing due mostly to his perception that the method, as he understands it, is more complicated and inefficient than slaking lime to putty and then storing it for up to three months before use, after which it might be an irritation, at least, to mix with sand.

The terminology persisted, however, along with the recognition that 'slaking lime with sand' was a traditional method (Zacharopoulou G 1993 & 1998). Zachropoulou offered a coherent summary of traditional slaking methods in a paper published in Lime News (1993) and later adopted by the European Commission (1998) as a summary not only of current understanding, but of necessary further research. One of these necessities was the undertaking of a comprehensive review of historic literature. It has taken until now for this to be achieved. With interpretation in the light of this review, Zachropoulou's text remains a seminal document, despite her clear assumption that hydraulic limes had always represented a 'technological advance':

Table 4

SLAKING METHODS	ADVANTAGES	DISADVANTAGES
DRY SLAKING	• suitable for hydraulic limes • easy to store • easy to carry	• uncertain hydration • unsuitable for the best quality plasterwork
WET SLAKING	• ensures complete hydration • finer average particle size *that* • increases plasticity	• unsuitable for hydraulic limes • dangerous process (produces heat and extreme causticity)
SLAKING LIME WITH SAND	• encourages the covering of all aggregates with a lime paste • requires less water to achieve workability • produce more durable mortars: fewer capillary pores but less liable to cracking due to shrinkage	• requires time and space for storing *and therefore* • practicable for very important conservation work

(1998). All three of the slaking methods detailed may be effected by hot mix methods, and generally were: slaking to a dry hydrate; slaking to a thick paste are alternative preliminaries to prompt engagement of either with sand, and whilst both remain very hot. 'Slaking lime with sand' would be interpreted, in the light of this review, to describe the mixing of pulverised quicklime and sand before the addition of water to both to effect the slake. Alternatively, each method could be used to slake the lime on its own, for storage or for mixing when cold with sand. 'Sand-slaking' of hydraulic limes was such a method, the lime and sand not being mixed until after the cooling of the lime – the sand was merely a convenient receptacle in which the slaking took place and slaking might as often be performed on the ground or in a mortar box (Treussart 1842).

When Pat Gibbons began to investigate the possibilities and potential of hot mixing after 1992 (1993), the perception that sand-slaking was the most common method persisted, reinforced by the constriction of the sources consulted by several of those engaged by Gibbons's enquiries (Holmes 1993; Lynch 1998) generally within the period when natural hydraulic limes were being used in engineering works, for concretes and, briefly, for above-ground construction. Holmes looked at later 19thC architect's specifications; Lynch at brick-laying manuals from 1890 – 1925. Holmes compounded the mis-impression by quoting at length from Vicat, including the engineer's dismissal of the value of fat limes (as well as of feebly hydraulic limes) for 'any purpose', as well as his celebration of energetically hydraulic limes for general, above-ground construction. Holmes had also found 19thC references to the use of hot mortars for construction in winter, and for hot mixed concretes (using Blue Lias lime, as had been common during the 19thC), and for hot lime grouts. His focus gave the inadvertent impression that hot mixing was in many ways 'exceptional', for exceptional purposes and situations, and certainly not the norm, usually produced from pure or nearly pure limes. This paper, without intending to, gave momentum to the trend towards the use of NHL above ground. Smith's translation of Vicat's book was republished in 1998. Few seemed to notice that he had been almost as dismissive of NHLs at the time, preferring his own proprietary artificial hydraulic lime, a precursor of Portland cement in its methods of production and artificial blending of limestone and clay. The lime was burned first and run to a thick, dough-like consistency before being mixed with clay. Balls of this mixture were then fired once more. The prohibition of and presumption against fat limes that Vicat had sought had also been enacted in the architect's specifications Holmes had consulted. Whilst pure limes had been very much used historically – if not ubiquitously so used – they had often been augmented by the addition on site of small volumes of pozzolan, and frequently with significant proportions of brick dust, a relatively unenergetic pozzolan which had, however, enhanced their effective porosity. Beyond this, conservators by this time had been using even overly lean lime putty mortars, often with small volume pozzolanic addition, with success since 1975. What little published output there had been (or ever was) from the English Heritage Smeaton Project (1992; 1993) had demonstrated the durability in extreme climates of fat lime and brick dust mortars – typically 1 slaked lime: 3 sand: 1 brick dust. It had been the rolling out of lime putty mortars and the necessary accompanying skill and experience across an industry more familiar with cement-gauged lime or simply just cement mortars that had been and continued to be problematic at this time, as well as the 'expert' insistence upon the use of a form of lime for the primary binder that had not been much used to this end in the past, and which was a nuisance to mix with sand, as well as to store before this.

Gibbons's TAN 01, Historic Scotland's guide to lime mortars, however, extended these more limited perceptions to include a variety of hot mixing methods, for immediate, hot use and for cold. It remains one of the most useful guides to all aspects of lime use, requiring only relatively minor updates.

Gibbons established the Scottish Lime Centre Trust and pioneered the use of NHL-gauged hot mixes (2000), at the same time as producing a cadre of professionals and practitioners aware of and engaged with the benefits of hot mixing, with or without pozzolanic or NHL addition, and a number of practitioners who discovered hot mixing via Gibbons continued to use hot mixes of all kinds even after the sudden rush toward NHL-use further south swamped and suppressed any further discussion of hot mixing within the Building Limes Forum, as well as within UK Heritage Agencies generally. In their practice, Scottish masons quickly ironed out the slight confusions within early discussions of the method.

After 1997, however, the drift towards general, ungauged NHL use, assisted by an English Heritage moratorium upon the use of hybrid air lime: NHL mortars (albeit only upon EH grant-funded projects), continued to gain momentum, despite qualms and concerns expressed by stone conservators David Carrington and Nick Durnan in the same issue of Lime News as carried John Ashurst's and others' celebration of the potential of NHLs, whether British or imported. In 1998, also in Lime News, Swann and Hughes assessed the potential of imported NHLs for use in conservation, concluding after exhaustive laboratory analysis that only NHL 2.0 had any such potential, and that even this was a preliminary conclusion which should be subjected to further analysis before firm conclusions could be drawn.

Hot mixing substantially disappeared from the literature once more, except in the occasional academic paper not aimed at practical instruction or application. The exception was Gerard Lynch, whose writings dwelt extensively on traditional craft practice and hot mixing (1994; 1998; 2007). However, Lynch placed undue emphasis on feebly and more hydraulic lime use – he under-estimated the extent of fat lime use historically and over-emphasised the routine use of hydraulic limes and was generally content to equate a modern NHL 2.0 with feebly hydraulic lime, which it was not, being much harder and lower in free lime than any of the historic feebly hydraulic limes. Swann & Hughes had indicated that Vicat's criteria would have identified the St Astier NHL 2.0, at least, as eminently hydraulic. Lynch came to insist that bricklayers 'always' used at least feebly hydraulic limes, whereas such preference was geographically and historically specific; and later to insist that bricklayers 'never' used their mortars hot, reinforcing the sand-slaking method as it had been applied to hydraulic limes. Beyond this, and in the context of generally unfounded assertions that modern, pure quicklimes were 'inauthentic', poorly reflecting the nature of 'common limes' used historically. This position is unsustainable in the context of a thorough review of the literature and of building accounts, although he repeated the assertion in 2017 - he concluded (1998) that the growing use of NHLs for conservation better reflected historic practice than the use of putty lime. He did, however, promote the idea of 'hybrid' air lime and NHL mortars, reflecting similar promotion by Gibbons in Scotland, albeit using air quicklime, not putty, as Lynch recommended. Lynch had further given the impression (1998), almost inevitably if the sand-slaking of hydraulic limes was taken as the norm, that traditional mixing was typically performed with shovels and hoes, not with machines. This is contradicted by historic texts from the 18thC onwards and there is ample archaeological evidence of mortar mills being used during the medieval period. Lynch tellingly deconstructed the implausibility of large-scale site production of lime putty during the 19thC building boom in the UK, but offers an alternative narrative that was only marginally more practical and which entailed multiple handling of materials and mortar, which 'mix and go' hot mix methods for fat or feebly hydraulic limes do not. He further maintained that modern health and safety regulations made site hot mixing impossible – a myth that has persisted until today amongst those who have not observed the process. Gibbons had already moved to this deeper understanding, having written in Lime News (1997) that "traditionally, mortars were often produced using techniques which brought the sand into contact with hot, slaking lime" and wondering if this process might generate 'mildly hydraulic reactions'. Gibbons's comment was the last textual reference to hot mixing within the BLF, following a positive evaluation of their potential by Douglas Johnston in the 1996 Lime News, which was devoted to the proceedings of an international lime conference hosted by Historic Scotland. The following year, the full embrace of imported and domestic NHLs for all purposes began in earnest (Ashurst 1997), with producers and lime suppliers keen to service this new – and for some, unexpected – market demand. Ashurst's uncritical commendation; the failure to understand quite why overly lean putty lime mortars were so potentially problematic, and the commercial consequences of this; salesmanship and very generous profit-margins (particularly when dry hydrated NHL was used as a base for designed, value-added 'products') combined to promote an accelerating wave of NHL-use across the industry.

Meanwhile, in academic circles, some, at least, were looking at hot mixing. Bakolas et al (1995) had first floated the idea that residual lime lumps in an old mortar indicated a hot mix method, although poor mixing by the masons continued to be entertained as a possibility. This notion continued to gain traction, however, until Callebaut (2000) had the revolutionary notion of hot mixing a mortar in a laboratory and comparing its character with samples of lime lump-bearing historic mortars, finding them to be very similar. He noted previous theories that such lime inclusions were the incorporated calcite crust that forms on the surface of a stored lime putty, reflecting the long-standing cognitive bias that 'matured' lime putty had always been the ubiquitous binder of construction. Callebaut's insight was followed up by Leslie and Gibbons in the same year, who noted the function of hot mixing in the deposition of lime lumps, whilst also stressing the potential of the method to offer good bond characteristics and weather resistance. Their research into the provenance of lime lumps was reinforced by Hughes, Leslie, and Callebaut in 2001, who concluded that lime lumps could be 'viewed as near ubiquitous in the general groundmass of the binder of a historic, traditionally produced mortar', as well as by Hughes, Banfill et al (2002), who also floated the notion that such carbonated lumps offered some advantage in the deeper set of the mortar, as well as in potential autogeneous healing, being readily available for redistribution by free water within a mortar. General acceptance of this theory grew swiftly and, once accepted, demonstrated to even the casual observer that hot mixing had been all but universal, and certainly ubiquitous historically, and into the 20thC. McAfee, a stonemason, had made the connection somewhat earlier, first expressed in print in 1997.

Moropoulou & Zendrie (1996) had looked in depth at the possibility that hot mixing explained the longevity and 'high strength' of ancient mortars, from the Roman and medieval periods, although most of those looked at contained some siliceous addition, especially brick dust. Most of the mortars analysed were 70-80% calcite, with some quartz, feldspar and silicate aggregates. The Roman mortars had endured better than the medieval mortars within the Arsenal Tower, Mount Athos, and this was attributed to the enhanced pozzolanic reaction during hot mixing.

Hughes, Swift et al (2002) carried out a significant study of the differences in mortar preparation and character using commercial quicklime from Shap in Cumbria (fired at high temperature) and the same host limestone burned in a small-scale kiln to traditional temperatures. There can be no certainty, however, that their burning (they noted 50% unhydrated lime in their own burn), or their slaking methods were drawn from historic evidence, or even that their hot mix method was founded upon craft practice, though they mixed lime, sand and water together directly – they do not say whether or not this was first pulverised. The absence of pulverisation would make such a method problematic to say the least and would have demanded more slaking water than ideally to break down the lumps sufficiently in this context. They found that the slaking temperature of the commercial quicklime was somewhat higher than that of their own lime – 73 degrees C versus 55 - 62 degrees C. There is no reason why a properly burned pure or nearly pure quicklime, slaked with just sufficient water, will not readily reach a temperature of 100 degrees C, and it may be said that the slake of neither lime reached the necessary minimum temperature of 100 degrees C, indicating the use of too much slaking water in the first instance. Such flaws of practical experience attach to many academic researches into hot mixing. They noted a greater surface area in the lower-temperature slaked calcium hydroxide, but this is contradicted by the provisional findings of Miller (1960). The experiment, however, did contribute to the acceptance that the presence of residual lime lumps, some containing limestone core, was a clear indicator of hot mixing.

Alan Forster, an 'alumni' of Gibbons's SLCT wrote a paper advertising the historic precedence, as well as the eminent workability and mechanical benefits of hot mixing in terms of durability and tenacity, or 'toughness', whilst also distributing a few 'red herrings' about why such mechanical improvements came about (sand-etching during the slake, primarily, an idea of Gibbons', albeit Forster expressed scepticism about this). He also gave currency to the myth, sown by Lynch after McKay (a 20thC writer on bricklaying, in reality counselling against the immediate use of late-slaking NHLs. Pure or nearly pure limes slake within minutes and late-slaking is a minimal risk thereafter, and would not have the force to lift bricks), that a hot placed mortar might 'jack' the brickwork due to late-slaking. This was achieved in the laboratory (Hughes & Taylor 2005), but this plainly reflected an absence of craft understanding of mixing method and application. Specifications throughout the 19thC (Fuller & Jones 1859; Barry 1847) call for the hot or same day use of all bedding mortars, whether for brick or stonework, and mortar analysis shows around an equal frequency of hot and cold use of hot mixed mortars with all substrates (Revie, see Appendix Eight). Quoting Gibbons, Forster asserted hot mixing methods that saw the sand and the substantially slaked quicklime mixed for immediate or prompt use, reflecting the experience of Scottish masons who had continued to pursue the logic of TAN 01 (1995). Masons working with these materials, especially in their typical modern rendition as powdered or kibbled quicklime, will quickly have come to appreciate the benefits of mixing quicklime and sand from the start and to have seen much less virtue in the more long-winded, sand slake-leave-mix-bank-leave-before use method, which also invariably, and in the absence of intensive beating, delivers a shorter, less workable mortar. In similar ways, they would have quickly seen the advantages of hot or warm use of the mortars. McAfee (2000) had indicated the use of hot mixed mortars for stonework, as well as the advantages of hot use. Forster also made the connection, as well as noting that traditional mortars tended to be binder-rich (1:1 to 1: 2.5) and associating this with the slaking method and the ubiquity of quicklime, not slaked lime, mixed at 1:3 or richer in lime than this, points later reinforced by Lynch (2007). Forster concluded that the physical properties of a hot mixed mortar, particularly in terms of pore structure and bonding characteristics, were the key factors in their apparently superior performance compared to cold, putty lime mortars. In fact, Forster's and Gibbons's theories about larger pore size (and although this definition is relative) have since been confounded by Wiggins (2017; 2018; 2019). The process of laying down lime putty concentrates the 1 micron pores (the optimum size for efficient capillarity), and increases their proportion in the mortar, as well as the connectivity of the pores (Hansen et al 2007). Importantly, however, so does the beating of a fresh mortar (Michoinová & Rovnaníková 2008) and the routine beating of freshly mixed mortar is a constant through time, referred to frequently in medieval and later building texts, as well as by Alberti and subsequent writers about lime, its preparation and use (see Appendices Five & Nine). The role of thermo-dynamics in the particular properties of hot mixes, as well as the role of some steam-slaking, have yet to be explored, but Miller (1960) offered some clues to this, at least, examining the effect upon particle size and surface area of slaking quicklime with different volumes of water as well as with slaking water of different temperature. Both have a marked effect upon particle size, as does the minimum temperature of the slake, which can only be guaranteed by the use of small, 'just sufficient' volumes of slaking water to quicklime, such volumes producing the smallest particle size and the greatest surface area and porosity, an effect only enhanced by the use of powdered quicklime and the more so if the slaking water is already hot, lest the temperature of the slaking water approaches boiling point.

Hedin (1963), referenced in Elert, Rodriguez-Navarro et al (2000), had demonstrated that slaking with hot water produced ‘particles of the smallest possible size’, as well as that if the slaking temperature rise was slow, as well as tardily rising during hydration, then the mortar would be ‘unplastic’, lacking the workability of an efficiently effected slake. These parameters had been known for almost as long as quicklime had been made or used, being given ‘scientific’ expression by Gillmore (1864) and by Richardson (1897), the latter of whom indicated that to slake a fat lime to a dry hydrate, 1 volume of water to the volume of the quicklime be added, whilst to slake to a thick paste, 2 to 2 ½ times the volume of water be added. Neither amount would chill nor burn the lime and both would deliver the necessary character of the lime to maximise tenacity and bond, as well as workability. The increased mortar proportion was considered, and, research by Lewin showing that putty lime binds poorly with silica sand after carbonation was quoted to illustrate the possible consequence of lime-leaneness in modern mortars and to advance the theory that additional lime equated to greater and more expansive bond and cohesiveness. Forster’s most compelling theory was that the complete drying of porous aggregates during an initial dry slake, followed by the saturation of such dried but porous aggregates with binder-rich water led to ‘deeper’ bonds within the mortar than might be achieved using impermeable sand aggregates.

Limestone and brick aggregates were very common historically; both are eminently porous. He also posits the theory that very high temperatures during the slake (of up to 450 Degrees C) might enhance performance by inducing pozzolanic reaction in clays or other aggregates (such temperatures would have burned the lime, reducing its power, and would have been avoided historically, in the same way as would have been temperatures significantly below 100 degrees C, when the quicklime was drowned), then dismisses this possibility, saying that 800 degrees C is required for such reactions to occur. Boynton (1980) would disagree, maintaining that the primary set of lime stabilised clay soils is the result of the pozzolanic reaction of the lime and the clays, though the addition even of quicklime into a clay soil at a proportion of 3% by weight – a common proportion for the sub-bases of roads still today – would generate not much heat at all. Boynton and Gutschick (1964) had already insisted that ‘dirty’ sands used historically (which they may, like Vicat have confused with earth-lime mortars), delivered very weak hydraulic activity to traditional mortars in the USA due to similar pozzolanic, or at least, ‘pseudo-pozzolanic’, reactions during hot mixing, and it is notable that Vitruvius – if the translation may be trusted – suggests a lime-lean 1 slaked lime: 3 aggregate proportion for pit sand only – and 1:2 for river or sea-sand. Pit sand, even in 1750 (Langley), was assumed to contain loam and clay, which might react pozzolanically, whereas sea and river sand were assumed to be clean and without such contamination.

By 2007, Lynch seemed more open to the notion of immediate use, as well as to wet-slaking, allowing for prompt use or storage of pre-mixed coarse-stuff for later use. The Myth of the Mix (2007) firmly made the link between the hot mixing method and efficiently produced mortars with at least twice the lime content of modern putty lime mortars mixed by volume at 1:3, such lime-rich mixes being the natural outcome of mixing unslaked lime with sand at a proportion of 1:3, the lime typically doubling in volume during the slake whilst producing an immediately useful mortar. He quoted the Scottish Lime Centre Trust database of mortar samples to observe, quite rightly, that 1:1 ½ or 1:2 are the most commonly encountered mortar proportions on analysis, both of these being consistent with a 1 quicklime: 3 sand starting point in the case of fat limes; 1:1 or 1:2 when less expansive hydraulic limes were used. He puts undue emphasis upon hot mixing to a dry slake, though there is some evidence historically that brick-layers did have a preference for this method, it offering a less 'sticky' mortar. (Miller (1960) had established that dry hydrate had a coarser particle size). He pointed out the inevitable volumes of free water in even a dense lime putty and the inadequacy, therefore, of mixing this by volume alone. He did not, however, advocate the modern use of hot mixes at all and asserted the equivalence of NHLs 2.0, 3.5 and 5.0 with traditional categories of feebly, moderately and eminently hydraulic, in keeping with the cognitive bias – and heritage agency policy - at the time. He would maintain this in 2017, but with a more critical analysis of the particular production methods and character of modern NHLs, coupled with familiar assertions about the long-term preference of bricklayers for feebly hydraulic limes (true in London after around 1820; much less true or possible elsewhere in the UK, or the world, without the use of pozzolans); the absence of hot use in bricklaying practice. As always, and for a long time uniquely, Lynch applied good craft understanding to his analysis, but a sometimes flawed logic drawn from the historically specific context of his trusted sources, and the already entrenched 20th C prejudices against pure lime that they reflected. He maintains, for example, that the slow carbonation of pure lime mortars in a brick wall was a 'problem' to be solved by the use feebly hydraulic grey chalk limes which rarely had a clay content above 6%, somehow obviating slow and steady setting when, in these, between 85 and 90% of the set still relied upon carbonation. Lynch's particular concern about the unavailability of feebly hydraulic limes (shared by Holmes (1998)), remained as valid in 2017 as before, however, and are shared by all concerned about the excessive hardness and historically low free lime content of currently available NHLs, as well as for the full palette of materials to be available for like-for-like repair.

Meanwhile – and to an extent that cannot be usefully covered within the confines of this thesis – the vast majority of academic research into 'traditional lime mortars' was almost entirely focused upon lime putty and its properties. Many of these papers were outputs of the Getty Institute's long-term 'lime mortars project', during which hot mixed lime mortars were barely, if ever, mentioned. This confusion may be indicated by Hansen, Rodriguez and Van Belen (2008), which accepted the definition of a traditional lime mortar as being of high calcium or dolomitic lime putty, as well as the (somehow American) assumption that hydraulic lime mortars were the norm in European practice from the moment during the 18thC that their properties and composition were more properly understood (p10). Hansen et al (2008) had shown over the course of a long-term study of lime putties at various stages of 'maturation' that it took 16 years of such maturation for any significant mechanical benefit to accrue over and above the day of production, as gauged by its meeting the ASTMS standard. Even 2 year old lime putty failed to meet this standard, and displayed poor water retentivity and plasticity. They concluded only that the aging of lime putty does not guarantee improved quality. The 2008 paper did acknowledge suggestions that 'dry or hot slaking' without the intermediary phase of running to lime putty for later use, had been 'an important and prevailing historic practice for both high calcium and natural hydraulic limes', referencing Callebaut (2000), but saw more usefulness for future research in comparing lime putty and modern dry hydrated lime.

Copsey (2010) wrote a paper primarily about the apparent ubiquity of earth-lime mortars of construction in North Yorkshire, mentioning eminently breathable, lime rich hot mixed mortars as being essential for use as finishes in association with such mortars, as well as the historic precedence for doing so and his experience by then of the durability of the latter in a region where over-lean lime putty mortars had long been considered problematic and where the specification of NHL 5.0 had become routine, whatever the nature of the bedding mortars or, indeed, the stone.

The demonstration of such durability was magnified by Malinowski & Hansen (2011), detailing the project to replace cement renders applied to Lacko Castle, Sweden in the 1960s with both lime putty and with hot mixed lime renders, in part by way of comparing their manipulation and performance, in both use and application. Holmstrom (1993) had some time before detailed the successful use of feebly and pure lime finishes in the historic centre of Stockholm since the early 1970s, induced by the recognition of the damaging effects of cement and overly hydraulic lime mortars, inadvertently indicating that, perhaps, the 'lime revival' had begun in Sweden, not, in fact, the UK. Holmstrom doubted the relevance to the actual performance of lime mortars of most standard tests and stressed the need for relatively swift carbonation of emplaced lime mortars, counselling against over enthusiastic subsequent wetting, which would obstruct the ingress of carbon dioxide. He misdiagnosed the provenance of residual lime lumps (he used lime putty), but suspected that they had a favourable effect upon deeper carbonation. Notably, though backing coats might be feebly hydraulic, he insisted that, in Swedish 'best practice', the final coat should be made with a pure lime binder, overlaid with air limewashes and noted that these had proved durable in the Scandinavian climate. He observed that, in his experience, 'both a good quality lime and a high porosity are essential to get a durable mortar' (p32) and he later wondered (1996), and with prescience, if the drift towards NHLs might lead to the same problems for traditional structures as had been meted out by the use of cement.

At Lacko the lime was burned on site from locally sourced material. Malinowski set out to test theories expressed by Gibbons and Forster about better bond, improved pore structure, workability and durability delivered by the hot mix method. The heat of the slake was considered crucial, whether or not the mortars were applied cold. Occasional incidences of late slaking were attributed to 'hot spots' in the kiln which has vitrified small volumes of silica in the host limestone. She noted 'traditional practice' locally, which had been to slake quicklime by aspersion, producing a coarse dry hydrate which was then given water sufficient to pour it through a sieve into a lime pit. This reflected 19thC plastering practice (Nicholson 1819; Millar (1897) in the UK, guaranteeing the necessary temperature of the slake and avoiding the possibility of drowning the lime, and may have had similar duration of precedence in Sweden, of course. The slaking procedure adopted was to slake the lime with the sand in a closed box, with temperatures of up to 400 degrees C generated – most certainly burning the lime, at least in part, but not chilling it, because the slaking and slaked lime was left covered for 24 hours. This was then mixed to a mortar consistency in a roller pan mixer and left to 'mature' for a minimum period of one month. Despite the apparent departure from traditional prescriptions, the craftsmen felt the workability of both the hot mixed and the putty lime mortar to be good, as well as the plasticity, ease of spread and adhesion. However, the lime putty mortar was perceived to be 'leaner' ('shorter'), to be less sticky and more prone to over-rapid drying, especially upon a brick substrate, whilst the hot mixed mortar presented excellent water retentivity, being slower and steadier in its loss of water, which the plasterers recognised as an important advantage. Overall, the craftsmen "preferred the hot mortars". On testing, and despite their slower overall carbonation, the hot mixed mortars were tougher after 1 year and neither mortar had suffered any frost damage 6 years on; the putty lime mortars absorbed more water, faster, after carbonation than did the hot mixes. Both had been mixed to a proportion of 1 slaked lime to 2 and the putty had been made to traditional lime: water proportions, not drowned. Finally, the Swedish National Property Board opted to use hot mixed mortars in the future, due to practical, logistical and cost implications – reflecting historic priorities: there was a shorter production process from lime burning to the application of plaster to the wall (this would have been even shorter had the mortars not been laid down for a month); there would be no need to burn the lime a year in advance to allow for the long laying down of lime putty, and no need to build lime pits to facilitate this; the material had displayed good workability and ease of application whilst exhibiting good physical properties, and had been preferred by the craftsmen.

The balance of Malinowski and Hansen's work between scientific investigation and craft knowledge, giving equal weight to the perceptions of the users of the material, was significant and important. It presaged the significant 'difference' in the 'hot mix revival' that began across the UK in 2012/13 to previous upheavals in the conservation industry – it was substantially driven by craftspeople, aided and abetted by professionals – surveyors, engineers and material scientists – who had begun their careers at or associated with the Scottish Lime Centre Trust and Pat Gibbons. These craftspeople were based in Ireland, England and Scandinavia, as well as in Scotland and the climates of three of the four countries had quickly exposed the deficiencies, in terms of compatible and mechanical performance, of cement, strongly cementitious cement-lime and energetically hydraulic mortars.

Chris Pennock (2013) had spent some twenty years researching and trialling pozzolanic air lime mortars for use in the repair of Trondheim cathedral, using locally burned, as well as commercial quicklimes, both pure and feebly hydraulic, settling upon a range of pozzolanic addition of between 4 and 13%, depending upon location and exposure, in a very cold part of northern Europe.

Limited research and observation of original mortars, and the reading of some, at least, of the texts reviewed above, as well as simple trial and error, had led other craftspeople into hot mixing, most often with powdered or kibbled and commercially available quicklimes. Over the previous decade, they had accumulated a body of real-world examples of successful – and sometimes unexpectedly good – performance from these traditional, lime-rich mortars, establishing their compatibility, their mechanical, structural and visual similarity to old mortars, and observing the drying of fabric to which they were applied, as well as their inherent frost resilience. After 2012, papers detailing their conclusions and the outcomes of their ongoing research and experiment, as well as their enthusiasm for the mortars produced by hot mixing began to emerge: Copsey (2013; 2015; 2016); Pennock (2015); Durnan (2016); Copsey (2019).

Copsey (2013) sought to make the case for the ubiquity of earth-lime and hot mixed lime mortars historically, as well as for their appropriate durability and capacity to dry out building fabric, drawing mainly upon experience and observation, but also on limited literature research. As a consequence, his expostulated mixing method – mixing powdered quicklime immediately with aggregates before slaking, which produced mortars of eminent workability – was overly narrow, although this method had ample historic precedent and had been historically adjudged to produce the 'best', 'toughest' and most cohesive and adhesive mortar (De la Faye 1777; Dossie 1771; Semple 1750; Martin 1825 etc). Instructively, Copsey's was the only paper among hundreds presented at HMC13, that touched upon hot mixing; in 2010 his paper had been one of only two to look at earth-lime mortars. The primary weight of research presented assumed that lime putty had been the stuff of historic mortars; with some looking at NHLs and assorted modern repair mortars or conservation materials (such as nano-lime). In 2010, however, Marinowitz et al (2010) had presented conclusions from a study of medieval German building accounts. These accounts show slaking of lime to a dry hydrate for storage or transportation as well as hot mixing, but this latter deduction was not always made. Lime mills evident in northern Germany in 1447 are indicated to have been used to pulverise quicklime 'for the production of a fast-binding hot mortar'. It may have been a mortar mill. The authors also drew attention to the frequency with which those mixing the mortar (which was strictly overseen by local authorities) were called 'mortar cooks', clearly suggestive of hot mixing methods. 1:2 is identified as the most commonly found mortar proportion in this period and it was noted that contemporary descriptions in 16thC Zurich show ‘unslaked lime…being worked with sand and water.’

Copsey (2015 & 2016) corrected the previous narrowness of definition on the back of extensive analysis of a growing number of old texts, including a fuller range of hot mixing and other slaking methods, all of which had been duly tested in practice. The case made was otherwise the same.

Mulholland (2017) examined the effect of protein addition to traditional mortars in reducing initial shrinkage, and found this, not only to have been common historically, but to have had a positive effect.

The fullest expression of Copsey’s research into old texts, as well as into some of the lessons to be derived from archived building accounts, coupled with practical guidance on the preparation and use of hot mixed lime mortars in a modern context was published in book form in February 2019.

Pennock (2015) detailed the extensive research and practical experiment that had informed the choice of matching mildly pozzolanic hot mixed mortars for the repair and partial rebuilding of Nidaros Cathedral, Trondheim. This research reflected the spirit of 18^{th} and 19^{th} century engineers and is an instructive and eminently useful document.

Durnan (2016), who like many conservators wary of the drift towards NHL use for stone conservation (1997) had been increasingly forced, on occasion, to use NHLs for such purposes by their blanket specification and, particularly by their apparent economic advantage in the hands of competitors (a situation reflected in the plastering trades), had immediately embraced hot mixes in 2014, but not uncritically. He had experimented, trialled and then used hot mixes upon major projects and was thereby convinced of their appropriate performance and eminent usefulness compared to the alternatives. His paper offered a summary of his conclusions, case studies and recommended conservation mixes.

In Ireland, the Building Limes Forum produced a Hot Lime Mortars Guide, as did HES and after 2013, the Hot Lime Mortars Project was undertaken, a joint project between Irish and Scottish professionals and practitioners. This focused upon pure lime and NHL-gauged lime mortars, all of them hot mixed, analysed in the laboratory and in situ. The objective of the report was to demonstrate the authenticity and compatibility, as well as the historic ubiquity of hot mixed lime mortars in Ireland (where earth-lime mortars are also ubiquitous), offering evaluation of materials and performance and practical guidance about mortar design and application. In its inter-disciplinary approach and its practical outcomes, the HLM Project epitomised the ethos of the ‘hot mix revival’ and represented a major contribution to the debate.

Historic Environment Scotland began issuing commissioned Technical Papers in 2018. Three have been published; three more are in preparation.

TP 28 (Artiz) covered the specification of hot mixed mortars, exhibited scepticism consistent with the more general attachment of its author to pre-mixed mortars, many of them containing performance-inhibiting additives (Artiz 2019), reflecting the common 20thC prejudice against capillary active, and much more than 'vapour permeable' mortars for use in association with original, capillary active masonry fabric. Reflecting a common 'blind-spot', Artiz considered that a mortar needed to be softer than the stone only, not of equal softness and effective porosity to the mortars binding this stone, and offered an 'example' gauged mortar for granite masonry with a high NHL content and a lower than typical quicklime content. The over-cautious nature of the advice was not, however, inappropriate.

Many of the assumptions of the author of TP 28 were contradicted by the research included in TP 27 (Wiggins 2018). The central findings of Wiggins's research were that traditional, typically hot mixed lime mortars offer excellent functional performance, particularly in terms of capillarity and effective porosity due to their high free lime content and that calcium carbonate typically displays a high density of inter-connected 1 micron pores, optimally sized for the maximum efficiency of capillary activity. Such mortars have kept traditional buildings dry, as a result, mitigating natural and unnatural decay mechanisms. The frost resilience and demonstrable durability of such mortars resides in their high free lime content more than it does in their method of preparation, but hot mixing was always the most efficient method of producing immediately workable, useable mortars of appropriately high free lime content. Wiggins drew a critical distinction between overall porosity and vapour permeability, as expressed in laboratory testing and effective porosity - the ability of the pore structure and pore size distribution to rapidly evacuate received moisture from the fabric of a building, rather than to retain it or to obstruct its egress. Only free lime could provide such a 'conveyor belt', though the same pore structure was, of course, typical of limestone, allowing for the enhancement with limestone aggregate of the inadequacy of free lime in other types of mortar. More surprisingly, to those who had not observed the behaviour of NHL mortars in situ, Wiggins's research outcome that, in terms of effective porosity, a 1:3 NHL: sand mortar was only minimally greater than that of a 1:3 CEMII: sand mortar may be seen as 'game-changing'. Beyond this, and as importantly, Wiggins demonstrated that the addition of chemical air entrainers, and/or of water repellents, all but eliminated capillarity, and therefore, effective porosity. The conclusions of this research were that compatible functional performance was best achieved using like-for-like hot mixed mortars, processed in similar ways to historically. In the absence of this possibility, mitigation might be offered by using NHLs of highest possible free lime content, mixed at a traditional proportion of 1:2 and including a good percentage of either added free lime or limestone aggregate – with the caution that mixing NHLs at 1:2 might still produce mortars of excessive brittleness and compressive strength.

TP 29 (Frew 2018) represented an on-site review of – typically NHL-gauged – hot mixed mortars used for repair and conservation in Scotland between 1997 and 2016, with visual analysis of their condition and performance. The paper stressed the essential corollary of using necessarily porous materials – good architectural detailing. Of all mortars reviewed, the majority being lime harling projects in often exposed and very wet environments, the only 'damage' or 'decay' was in the immediate vicinity of failed or inadequately maintained weathering detail or rainwater goods. The general assessment, therefore, was that all hot mixed mortars had done well, were in excellent condition and had preserved the fabric from damp. This, in contrast to the general performance of more hydraulic and cementitious mortars deployed to the same ends during the same time period and before.

At the same time, regular, well-attended 'hot mix days' were organised around the UK and Ireland intended to educate fellow craftspeople and professionals in the benefits and use of hot mixed mortars (and the potential hazards of blanket NHL-use). All presentations given at these events were freely shared. In 2017, Trondheim Cathedral in Norway, in partnership with the British BLF and the Nordic Limes Forum, hosted a conference entitled 'Rediscovering Traditional Mortars', attended by 230 people, mainly from northern Europe, but also from North America and Australia. Once again, all presentations were shared. Hot mixing has extended its reach increasingly around the world. Historic England commissioned an NHL Research project (Figuieredo 2018), which only accelerated the move towards hot mixes in its conclusions (see Introduction above), Wiggins's research (above), and his willingness to present this at 'hot mix days', only confirmed the hazards for historic fabric of modern NHLs, with and without air entrainers and other additives, and the benefit to the same of using hot mixed air lime mortars.

This research-only MA is part of the same continuum.

<u>Earth-lime literature.</u>

Most writing and research into earth mortars attaches to solid wall construction of earth, and largely in association with new build. Very few have examined, or even acknowledged, the ubiquity of earth-lime – of lime stabilised earth – mortars, although there is extensive technical literature about lime stabilised soil for road construction.

Boynton (1980) identifies pozzolanic reaction between clay and lime as the primary process by which lime stabilized soil sets (along with simple drying). He listed the changes that might be effected by the addition of even small volumes of air lime, the magnitude of these changes being determined by the nature of the clay itself and its precise chemical composition. This will be referenced elsewhere.

Warren (1999) states that the use of lime as a stabilizer of earths used in construction is 'an ancient tradition' but attributes the set of such mortars to slow carbonation.

The use of either cement or NHL for soil stabilization is generally counselled against in texts promoting the use of earths for new build (Houben & Guillard 1989; Minke (2006). Minke observes that the use of cement interferes with the binding power of clay and may result in compressive strengths lower than if no cement had been added.

Very few studies of craft practice with earth-lime mortars exist, and these focus primarily upon renders. Caron & Lynch (1988) looked at the use of earth-lime mortars commonly deployed in Alberta upon the houses of Ukrainian settlers. Most of the houses were of log or of basic timber-frame construction. Earths were used for chinking of structural logs, as well as for plasters within and without, the latter typically timber-clad, and also for floors, including for first floors over (and between) timber joists. These contained recipes much richer in lime than seems to have been typical historically.

Fernandes (2008) looked at traditional earth-lime mortars in Portugal, referencing remembered craft practice. This presented a number of key insights: that there was a general distinction in particle size – particularly relating to added or natural sand content – according to purpose, with coarser aggregates in earth mortars (for building) and fine sand aggregates in renders and plasters. The traditional method of mixing lime into earth mortars was identified as the 'ordinary method' used for lime : sand mortars – the lump lime being added into a ring of sieved moist earth mixed 50/50 with sand, around the circumference of a shallow pit, with water added to the quicklime in sufficient quantity to slake it to a paste before mixing it with the earth to form a mortar. For renders, although these were brushed down and rinsed, application was to minimally wetted substrates. Adobe (and adobe mortar) was also not uncommonly lime stabilised in Portuguese practice and earth-lime renders were applied over adobe as well as over stone. Base-coats were accounted to be between 2 and 4mm thick and to be given a 1mm thick 'lime putty layer'. Such mortars were being used well into the 20thC and examples looked at dated from the 1930s, complementing the analysis of earth (and lime) mortar-use in Georgia, USA carried out by Dawn Chapman (2014). Fernandes's paper was a much deeper examination than Faria, Tavares et al (2010), also emanating from Portugal, which had noted the addition of small amounts of air lime to some earth renders, but also contained the dubious assertion that masons had considered earth and earth-lime mortars as inferior, to be used only to save money or due to lime scarcity, these being not uncommon tropes within the conservation community generally, and completely at odds with the sheer ubiquity of earth-lime mortars the length and breadth of the limestone belt of England. As in Asturias, there seems to have been little tradition in the region of adding hair or grasses into earth or earth-lime mortars to resist shrinkage, which may explain the relative thinness of plaster coats.

Faria, Silva et al (2013) found air lime: sand and air lime-earth renders to be equally compatible with rammed earth substrates.

Pavia (2016) dealt with earth-lime plasters, suggesting that these were economically and technically superior to lime: sand mortars, as well as improving interior ambience (as Alberti had noted in 1460). All mixes trialled offered a high density of pores around 0.8 microns in size and were of similar capillarity, although this was at slight variance with the lime: sand control. Such a pore size offers very similar capillarity and effective porosity to 1 micron pores, suggesting an optimal compatibility (Wiggins, pers comm 2019).

Santos, Faria & Silva (2017) found no significance differences in the durability of earth, earth-air lime or earth-NHL exterior plasters, with the highest capillarity and greater surface cohesion in the earth-air lime variety, the earth-NHL having the least capillarity and surface cohesion of the three.

Rashmi et al (2014), exploring alternatives to sand aggregates due to the growing scarcity of suitable sands in India, concur with Boynton's essential analysis. They advise that when clay content exceeds 30%, lime should always be added, generally observing that the addition of lime 'can produce high and long lasting strength gains, improvements in shear strength and durability in severe environmental conditions' (p27) and that strength will be the greater the higher the volume of clay. With an average of 10% lime addition, a variety of earth mortars returned around 1 MPa of compressive strength, although a 50/50 mix of earth and sand with 10% lime addition achieved only 0.66 Mpa. Eires et al (2013) had found that 4% quicklime addition to an earth mortar gave twice the compressive strength generated with the same earth without lime addition and that the MPa after 4% quicklime addition was 25% greater than after the addition to the same earth of 4% Portland cement. 4% hydrated lime had a much less pronounced effect than quicklime, although, of course, the volume of the quicklime would have as much as doubled as it slaked. In accelerated erosion tests, the quicklime stabilised material was the most durable. They concluded that the use of quicklime demonstrated good performance, with 'better mechanical resistance (in dry and saturated conditions), reduced water absorption by capillarity (by 33% compared to either hydrated lime or cement) and reduced erosion, without compromising vapour permeability' (p968).

The Earth volume of the English Heritage Practical Conservation Series (2015) was the first such publication to treat earth mortars with appropriate seriousness and rigour, although the prevalence of earth-lime mortars for bedding and plastering was not especially emphasised and its reach historically and geographically was under-estimated. In this it reflected the then growing awareness that the addition of lime to earthen mortars had been far more common and generalised than had been previously understood. It offered useful technical analysis and practical guidance on the design and application of earth mortars. The prevalence of lime addition, not only to earth bedding mortars and plasters, but also to adobe blocks and bedding mortars, and to rammed earth has grown substantially since the preparation of this volume, to which Copsey contributed. It reflected the flaw in his 2010 HMC10 paper which, whilst it had elucidated the extensive geographical reach of earth mortars for masonry construction, as well as its high status use for this purpose, and had accurately described the typical use of lime rich pointing and plaster mortars in association with earth building and base-coat plaster mortars, had failed to appreciate the extent to which the earth mortars looked at (particularly in North Yorkshire) had routinely contained small volumes of air lime. This perception was corrected in Copsey (2019), as well as in Copsey (2013) and subsequently.

The earth-lime mortar literature offers glimpses into its effectiveness as a material. In use, such a mortar displays very similar properties of workability and bond to a hot mixed lime mortar, as well as offering a slow, steady set and ongoing deformability and both forms of lime mortar may be seen to be inherently compatible in terms of both compressive strength and capillarity.

Recent NHL Research

Research commissioned by Historic England and the Building Limes Forum, has put flesh on the bones of historic comment upon and distrust of NHLs, demonstrating their on-going strength development over years, not months, and for at least 3 years, during which time their 28-day strength may triple. Even these minimum strengths (2.0; 3.5 and 5.0 MPa) exceed – often dramatically – the typical strengths of historic, fat lime or feebly hydraulic lime mortars. The research – the mortars mixed by volume, as on site, not to the mixing by weight demanded by the standard and which offers deceptively high compressive strength figures - has clearly demonstrated the variability between brands or varieties of the NHL, as well as the dramatic variability within each brand. In several brands, the NHL 2.0 mortars exceed both the NHL 3.5 and NHL 5.0 mortars in compressive strength; the strongest mortar of all was made with an NHL 3.5. Bags of the same NHL, purchased on the same day in different parts of the UK, both tested independently in two laboratories, gave strength differences of 30% (Figueiredo 2018). None of this would have been a surprise to either craftsmen or engineers historically. As recently as 1980, Boynton pointed out the essential dilemma of NHL production:

"A major problem confronting most hydraulic lime manufacturers is lack of uniformity in the finished product, namely, shipping a lime with a Cementation Index of 0.92 one day, 0.70 the next, and so on. The chemical analyses in impure deposits frequently change abruptly from one ledge and stratum to another. Blending of stone to secure a composite analysis alleviates this problem to some extent but can never be pursued with the same flexibility available in Portland cement plants. Furthermore, the intensive analytical testing that it entails is costly. This chronic problem of quality control, more than any other factor, has forced hydraulic lime to lose position primarily to Portland cement and masonry cement…."

The majority of modern NHLs contain tri-calcium silicates, more particularly generated in the production of Portland cement, and similarly promoting flash-setting of mortars (Figueiredo 2018). These are a consequence of higher than traditional firing temperatures and were always considered a hazard to be avoided in the production of NHLs (Davy 1802; Hitchcock 1862; Eckel 1932). In France, the resultant tri-calcium silicate and aluminate clinker was sifted out before the slaking of quicklime for bagging as slaked lime after 1896, ground to a powder for separate sale (as grappier cement) and with some grappiers added back in to amend hydraulicity (Pulver 1922; Searle 1935), but the general consensus was that a 'proper' NHL should rely upon di-calcium silicate and aluminate for its set and its power, in similar fashion to pozzolanic mortars made with fat lime. On site, when hydraulic limes were prepared from lump quicklime, as was preferred by masons still in 1951 (BS Code of Conduct 121-201), such clinker could be selected out before or during slaking. It only held significant power after having been ground to a fine powder, and so may remain substantially inert in a mortar even when not removed. Geeson (1952) was certain that if all material that emerged from the kiln was finely ground before slaking, that the resultant binder was not an NHL at all, but a natural cement.

Each increase in strength represents a potential decrease in effective porosity and other recent research, (Wiggins 2017; 2018; 2019) has suggested that a typical NHL 3.5 mortar, mixed at 1:3 with a sand aggregate, has almost as little effective porosity as a 1:3 CEM-II: sand mortar.

This has been a surprise only to those people who have not looked closely at works above-ground performed with NHL mortars since 1997, which often display the same issues that are witnessed when traditional buildings have been treated with cement mortars – excessive and cumulative wetness of fabric; salt-induced decay of stone arrises; gradual, but progressive shrinkage of mortars from contact with the stone or brick, allowing further water ingress. In use, NHLs have poor workability and poor water retentivity. Common attempts – and even recommendations - to improve workability by the addition of air-entrainers, compromise both bond with substrates (US Bureau of Standards) and may all but eliminate effective porosity by all but eliminating capillarity (Torney 2013). The addition of water repellents, such as tallow, will have similar effect, blocking pores and preventing effective capillarity, which is often precisely their intent, based upon a mis-analysis of the necessary performance of porous and hygroscopic building fabric largely informed by the precepts of modern building technology (Wiggins & Copsey in Copsey 2019).

A further problem with NHLs in use is their over-arching demand for on-going hydration as their hydraulic set proceeds. The first time historic writings about lime begin to include discussion of the need for the sort of protection of mortars that has become routine with the use of over-lean lime putty and fast-setting and excessively strong NHL mortars - themselves overly lean in binder compared to traditional practice - was during the period in which such limes were being more routinely used for above-ground construction – at the tail-end of the 19thC (Sutcliffe 1898) and into the 20th (Frost 1925). Before this, military engineers in the USA (Totten 1842; Wright 1845; Gillmore 1886) had begun to use natural cement as a gauge to fat lime mortars, to assist the deep-setting of mortars in especially thick fortification walls. Some would point such structures with dense natural cement mortars, but always with the corollary that the walls be soaked with water after placement, as much and for as long as possible.

Such entreaties simply do not prevail during previous years, decades or centuries.

The inherently excellent water retentivity of lime rich fat lime mortars had never demanded such assiduous aftercare during curing as do NHL mortars, although the demand that bricks be wetted in summer and much less so in winter, and that wall-tops be protected from excessive rain (and possible subsequent frost attack) during winter was common (Moxon 1703). In hot weather, especially when relative humidity was also low, some protection might be necessary, some misting of the mortars also, but in the hottest, driest weather, works ceased (Frontinius). It was rarely so hot – or the relative humidity so low - in the UK that this would be necessary. An NHL mortar that receives inadequate on-going hydration risks being friable behind the apparently well-set face which has received hydration by default; it may lack tenacity and it may allow significantly greater water ingress, despite the reduced effective porosity of a properly cured NHL mortar. The interior may otherwise be a 'mush'. Uncarbonated lime may more readily leech out; the HE research indicating that even in a 'best-case' laboratory scenario, the free lime in modern NHLs will take up to 750 days to fully carbonate, whilst for pure limes in a similar environment, it takes 3 months. (Figueiredo 2018). This would suggest that the progression of the chemical, hydraulic set in an NHL somehow obstructs and inhibits the carbonation of the often relatively low free lime content. It has been routine over the last 20 years to recommend that NHL mortars receive on-going hydration for 7 (Artis), sometimes for 14 days. In fact, they require on-going hydration over the duration of their set to fully achieve necessary tenacity and 'body'– for up to three years, therefore, and it may be reasonably argued that the only location in which they may practically receive such on-going hydration is underwater, or underground.

*"Hydraulic lime…*undergoes a complex chemical change when in contact with water and " sets " to a hard mass. It does this equally well in air or under water, provided the mortar is supplied with sufficient water to ensure its adequate setting and subsequent hardening. If the supply of water is insufficient, the hardening will be incomplete." Searle 1935

Beyond this, and which may not be said of putty lime mortars, NHL mortars are typically harsh-working, due to their relatively low free lime content, which is typically somewhat lower in modern NHLs than it was in those used traditionally, such as the Blue Lias (Holmes & Wingate 1997). NHL mortars offer none of the eminent workability of lime-rich, hot mixed mortars whether with or without pozzolan. This matters most because workability facilitates good workmanship and ease of application, both of which were the priorities of craftspeople. Even an eminently hydraulic fat lime and pozzolan mortar may be produced without significant loss of workability.

Like-for-like repair demands the general use of hot mixed lime and earth-lime mortars – used either hot, warm or cold – and after previous analysis of existing mortars, and these mortars are now seen as being key to the compatible repair of traditional buildings in the UK and, increasingly, elsewhere. This demand is not onerous – hot mixes are a pleasure to use; they are cheaper to produce; they dry out buildings, raising their thermal performance and eliminating unnatural timber and masonry decay, and have a lower carbon footprint than either Portland cement or NHL mortars.

APPENDIX THREE

Material omitted from main account:

Concretes:

It may be reasonably asserted that the use of mass concrete for flooring, as well as for walls (typically stone or brick-faced) was imported into Britain by the Romans and substantially fell from use after the collapse of the Roman occupation. Thereafter, floors were typically of earth, modified with the addition of organic matter and with proteins, such as bull's blood. In higher status buildings, these earth floors would be overlaid with brick or with stone laid in mortars of earth, clay or, on occasion, of lime, or with a layer of 'lime ashes, or other ashes, between ground and flooring material, as evidenced by a number of archived building accounts (see Appendix One). The use of earth-lime and of lime mortars for floors, if this did diminish or die out after the Roman withdrawal, was re-imported by the Normans, very many of whose stone churches and fortifications were built with earth and earth-lime mortars. During the 19thC, in the UK, it became the norm to hot mix lime concretes for footings and floors using feebly and then moderately hydraulic lime. During the 20thC, this was displaced by Portland Cement.

Vitruvius treats of concrete in two forms – one for mass concrete construction, the other for floors. These were made with just slaked lime and sand, at a proportion of 1:3 if it was pit sand (which would contain clay); 1:2 with river or sea sand, ideally with a third part of potsherds 'pounded and sifted' to maximise pozzolanic reaction.

More complex mixes, however, for sea walls and the like, were clearly hot mixed:

> When these three ingredients (lime, rubble and pozzalana), forged in similar fashion by fire's intensity, meet in a single mixture, when this mixture is put into contact with water, the ingredients cling together as one and, stiffened by water, quickly solidify.

> Neither waves nor the force of water can dissolve them…. the moisture-starved heat latent in these types of ingredients, when satiated by water, boils together, and makes them combine (Vitruvius 1999 37).

Vitruvius also gives a detailed description of the manner of laying lime concrete floors within houses, the description being for the sub-base of mosaic or stone first floors. First, a layer of rubble 'no smaller than will fit in the hand' over a timber deck strewn with fern or straw. This would be followed by a mortared layer, mixed with 'rubble' at three to one with lime, or, if reused material, at 5:2, which should be laid and leveled and 'compacted by steady pounding' until about 8″ thick. Then a 4 inch layer of crushed terracotta and lime, at 3:1. This would receive the mosaic or tile. Vitruvius speaks only of 'lime', elsewhere of 'slaked lime', so that the mortars involved may be assumed to have been made with quicklime, which would be either unslaked or just slaked prior to mixing, as indicated by Pliny the Elder for the making of concrete cisterns:

> Cisterns should be made of five parts of pure, gravelly sand, two of the very strongest quicklime, and fragments of silex ((*finely ground silica stone, such as flint*) not exceeding a pound each in weight; when thus incorporated, the bottom and sides should be well beaten with iron rammers… (Pliny 2015 Chapter 52)

It is important to stress that the Romans looked not only to Greek example in the use of lime (and brick dust) for floors, but to long example from around the Mediterranean and the near east and that the basic procedures laid out by Vitruvius persisted in the region, as well as in more far-flung parts of the empire. The medieval walls of Valencia, a city founded by the Romans, were built of mass concrete, hot mixed, using a mixture of sand and, typically, graded river shingle up to 2 and 3 inches in size, strengthened by roughly distributed clay tiles and half-tiles laid into the formwork as ramming proceeded. It is termed 'Tapia Valenciana' in Spain, but might as reasonably be termed Tapia Romana. Except where Roman building traditions remained uninterrupted, such as in Spain, the use of lime and of pozzolanic concretes fell into dis-use, or was but vaguely remembered. Britain was largely repopulated by groups from northern Europe after the Roman withdrawal, the building traditions of which were dominated by timber-frame construction and the associated use of earth mortars. Roman remains were viewed as quarries, not as exemplars of good practice.

By the time of the Norman Conquest, there had been some revival in stone building, particularly of churches, using earth-lime and even lime mortars, mostly of Roman spolia (Ellerburn, St Andrews, Bywell, Appleton-le-Street, Hovingham), the use of which continued long after the Conquest (Holy Trinity, York; Crambe St Michaels, St Albans Cathedral).

Alberti quoted another to illustrate the typical lime concrete floor construction in Italy around 1460:

> For pavements not in the open, Varro recommends the following for its exceptional ability to stay dry: Dig to a depth of two feet, and pack down the soil, then lay a pavement of either rubble or brickwork. Leave a few openings for the water to drain away along channels; pile on some coal, then once this has been packed down and consolidated, cover it with a cake consisting of a mixture of gravel, lime, and ashes to a depth of a foot and a half. (Alberti 1460 89)



Hot mixed, rammed concrete, Valencia town wall.
Hot mixed concrete footing, Anglican Cathedral, Calgary, Alberta.

In the UK, in the medieval period, lime floors were of high status, although they were frequently reserved for upper floors, stone being the norm at groundfloor level. The accounts of the Duchy of Lancaster, 1313-1314 show that plastered lime floors were common enough by then, as was the discrete use of gypsum for decorative effect:

> Cost of the New Hall (within Pickering Castle)… building the stone walls of the Hall and chamber, getting and carrying 400 cartloads of stone, digging and carrying soil for mortar, buying 27 quarters of lime… lid-roofing the buildings with thin flags by piece-work, collecting moss for the same, plastering the floors of the upper room and several walls within the chamber, making a chimney piece of Plaster of Paris (Turton 1895 23).

The use of lime mortar for flooring during the Neolithic period may be considered the first architectural use of the material (Zacharopoulou 1998). By 1000 BC in the Middle East, such floors would typically contain fired brick or tile aggregate and dust, offering a modestly energetic pozzolanic set. Lime plasters later extended onto the walls as well, but were little used as a building mortar – these latter were typically of earth, as were the buildings themselves.

Marshall was ill-informed when in 1788 when he said that lime concrete floors were a 'new species of cottage flooring lately thought of' in the Vale of Pickering, but his careful description of the process remains an invaluable source:

> The materials are lime and sand; mixed in nearly the same proportion, and prepared in the same manner, as the common mortar of bricklayers; except, that for forming floors with is generally made stronger, and is always made up softer, than it is usually done for laying bricks in
> The *method*. The bed being prepared, the materials are carried on, in pails, in a state between paste and batter; laying them on four or five inches thick, and about one inch higher than the intended height of the floor, to allow for the settling, in drying. The whole being well worked over with a spade, the surface is smoothed with a trowel; and as it dries, is beaten, repeatedly, with a flat beater, to prevent cracking; the workman, in this operation, standing on planks.
> A fortnight or three weeks dry weather will render it stiff enough to walk upon. If, after the last beating, cross lines be deeply graven on the surface, a floor of cement has the appearance, as well as the usefulness, of a freestone floor. (Marshall. 1788 135-136)

The 'preparation of the bed' would include the laying down of brick or stone hardcore, as well, on many occasions, as evidenced by account books, a layer or blinding of lime ashes, or blacksmith's clinker, providing a potentially less permeable barrier between ground and flooring material.

Somewhat before Marshall, Neve had acknowledged the option of lime concrete floors, again incorporating some pozzolanic activity: 'Earthen floors are commonly made of Lome, and sometimes (for floors to make Malt on) of Lime, and Brooksand and Gun-dust, or Anvil dust from the Forge' (Neve 1726).

Ware (1758) offered similar advice:

> …The common floors used in mean buildings are made of **loam, well beaten and tempered with smith's dust, <u>and with or without an addition of lime.</u>** Some also make them of pure clay, ox blood and a moderate

> proportion of sharp sand, these three ingredients beaten together very strongly, and well spread, make a firm and good floor, and of a beautiful colour. (p123)

What is certain, however, is that the laying of a fat lime concrete floor was labour intensive, requiring extensive and regular pounding of the surface after laying, to close down shrinkage, which might continue for a long period. Marshall suggests 6 inches of surface – this would only prolong the tendency for shrinkage. In the author's experience, most lime concrete floors after this period were around 2″ thick and those that survive typically contain a proportion of brick aggregate and brick dust, to act both as pozzolan and shrinkage inhibitor, but also as porous aggregate.

Floors might also contain wood or coal ash, or may be of gypsum, usually with added aggregate. 'Lime ash' floors have often been interpreted as gypsum floors, but lime ashes were frequently delivered to construction sites, as evidenced by building accounts (see Appendix One), being the debris of quicklime and fuel ash at the bottom of a kiln. This was also laid as a less porous layer beneath stone or brick floors, and would almost certainly form the 'binder' of lime concretes, setting by pozzolanic reaction, as well as carbonation, and being somewhat lighter than a 'plain' fat lime concrete. In the author's experience, such floors were much more common, in the UK, at least, than were gypsum floors, which latter, in any case, could only be used for first or second floors, the hygroscopicity and water solubility of gypsum making their use upon the ground inadvisable.

> Lime-ash floors are formed in several ways, according to the locality. One of the most approved methods is the following: the sand to be used, after being well washed and freed from earth, is mixed with lime ashes, in the proportion of two- thirds sand to one-third lime ashes, both thoroughly mixed together. It is then, after being suffered to remain for two or three days, tempered with water, and laid on the ground, or other surface to be covered, to the depth of about 3 inches. In two or three days it becomes sufficiently hard to bear treading on, and is then beaten all over with a wooden mallet, till it becomes perfectly hard, using at the same time a trowel and a little water to render the surface as smooth as possible…. (Bruce Allen 1886 40)

Scott Burn (1860) recommends 2 parts clean sharp sand to 1 part lime ashes (fresh from the kiln) over a 6″ base of 'coarse gravel, or brick bats and lime-core'. The recipe offered by Martin (1829), a hybrid between an earth and a lime concrete, would also enjoy a feeble hydraulic set and would shrink less,

> We prepare a cheap cement mortar by kneading 2 parts of lime, 1 part of coal *(houille,* probably coal ash) well sieved and half a part of clay. This mortar is damped slowly and well stirred. Then it is left in a heap for several days after which it is beaten and stretched; it is then left to rest

> once more until it is flexible and pliable. This mortar can be used to create floors in attics. We apply it by layer, and when it is almost dry, we cover it in a light coat of good quicklime mixed in butter milk. (Martin 1829 45).

After the failure of traditionally timber-piled foundations at the new Customs House around 1815, according to Nicholson (1841) and others, the architect Robert Smirke extended the logic of grouting to the laying of building foundations. This was to become the norm through the 19th century in the UK, and generally with either feebly hydraulic chalk limes or, more routinely as the century progressed and with available rail transport, moderately hydraulic Blue Lias lime. Brees attributes the innovation to Ralph Walker at the East India Docks also in 1815, to be followed by Smirke at the Customs House (Brees 1852).

Previously, building footings – where piling was not necessary - were of brick or stone, wider than the walls above, as explained by Mortimer in 1708,

> Upon a good Foundation two Bricks or eighteen Inches thick for the heading Course is sufficient for the Ground-work of any common Structure, and six or seven Courses above the Earth to the Water-table, where the thickness of the Walls are abated, or taken in on either side the thickness of a Brick (p297).

For timber-frame buildings he recommended an early form of lime concrete:

> Where a Jamb is set upon moist Ground, dig the Earth two Foot deep, and after beating well, lay a Bed of Mortar, or Cement from either side to the Channel, and then lay a Bed of Cinders upon the Mortar, beat it well, and cover it with another Cement of Lime, Sand and Ashes, this will drink up the Moisture and make it dry. (Mortimer 1708, 299)

19th-century concretes were always mixed 'hot' in the UK, in France, incorporating just slaked lime. Such concrete in France was called 'beton'. In the USA (Gillmore 1864; 1886), the two methods were distinguished by English and French nomenclature, 'concrete' implying hot mixing; 'beton', the use of already slaked lime, both methods using naturally hydraulic lime. Gillmore (1871) says that in French practice, beton had always indicated the use of hydraulic lime, but that this had been slaked prior to mixing. The deployment of such concretes is attested by numerous authors (Vicat 1818; Nicholson, 1819; Davy, 1839; Bartholomew, 1840; Treussart 1842, Barry, 1847; Brees 1852; Sloane, 1852, who bemoaned its infrequent use in Philadelphia; Dobson, 1854; Burnell, 1857; Walsh, 1858; Jacques, 1860, proposing the material for mass wall construction; Scott Burn, 1860; Stephens & Scott Burn, 1861; Austin, 1862; Reid, 1869, although much advertising the use of Portland cement for concrete; Powell, 1889; Hammond, 1890, Heath, 1893; Sutcliffe, 1898; Richards 1901).

Pasley's is the most concise description of its method of preparation, with which others largely concur:

> Concrete is formed by mixing lime, coarse gravel and sand together, with a moderate quantity of water, which is usually done on a large square board, having a margin raised a little above it on three sides only. The lime used for this purpose has usually been reduced to fine powder by pounding or grinding it, whilst fresh from the kiln; and it is generally considered of so much importance not to slake it until ready for use, that it has been customary to mix it with the gravel and sand in a dry state for a little while, before the water was added; after which the whole of these ingredients have been intimately mixed, with as much expedition as possible, by employing two labourers to work together at each of the mixing boards, which being always placed as near to the spot previously prepared for the foundation as possible, the concrete is either thrown down at once or wheeled a little way and dropped down from a temporary scaffold with moveable planks…into the excavation, where it is spread and leveled, and trodden down or sometimes rammed by other labourers below….Concrete made in this manner, according to the system first introduced by Sir Robert Smirke, throws out a moderate heat on the slaking of the lime, and soon begins to set, forming in time a kind of artificial rock….(Pasley 1838 17).

Such concretes were surprisingly lean: 1 blue lias to 7 aggregate being the norm, although more like 1:6 when grey chalk lime was used (Bartholomew 1840). The aggregate typically was a mixture of smallish rubble and sand, much as was routinely dredged from the Thames, and which 'ballast' is still sold in builders merchants today for the making of concrete. By the end of the 19th century Portland cement was more used, this time mixed at 1:8 (Richards 1901), and as an option instead of Blue Lias at similar proportion.

Concretes: (aggregates and quicklime) "should be mixed together, and slaked like mortar, and always used hot" (Brees 1852)

Espinosa (1859) is non-specific about the use of slaked or unslaked lime, but offers some nuance concerning mixing procedure, probably using dry-slaked lime:

"When using sands of different grades, pozzalans or gravels to make concrete, one first mixes the lime with the finest of the sands or with the pozzalan, and when this is well mixed, continue to add in order of their size; in this way one makes a more homogenous mortar with greater facility" (p92)

Scott (1862) argued that mass concrete construction ought to adopted in the stead of brick or stone for the construction of fortifications, and that such labour could be efficiently executed by soldiers, a significant economy. Reid (1869) extended Scott's analysis to Portland cement concrete for the building of ordinary houses, not only for walls but roofs, as well, and for similar reasons of economy and liberation from skilled labour. His ideas were prescient, if somewhat before their time.

Benton (1893), a military engineer, detailed the traditional use in India of kankar, a feebly to moderately hydraulic lime, as well as of fat lime and surkhi concretes, surkhi being pounded brick and tile aggregate.

Totten offers the earliest recorded use of hybrid mortars of natural cement and lime, in 1838, swiftly followed by Wright (1845) who offers one of the earliest references to the making of concrete with natural cement. Gillmore (1871 & 1886) said that Wright had used 1 dry cement: ½ Rockland lime: 14 ½ cubic feet of well compacted sand for the corework mortars at Fort Warren, noting that American natural cements could be blended with an equal part of air lime without diminution of strength. He maintained that the 'English method' of hot mixing concrete had gained little traction in the US, where natural cement binder was always preferred for concretes, previously beton, which afforded 'immunity from the danger of partial slaking before use, superior homogeneity in the mass, and economy in the amount of lime required.' Gillmore also (1871), being perhaps the first to do so, suggested concretes made with gauges of Portland cement, as in 6 parts sand: 1 part hydraulic lime in powder: ½ a part Portland cement, pointing out that the latter cost twice as much as hydraulic lime at the time. Others, such as Burnell questioned the virtue of launching the mix from 10 feet or so above the trenches, as in English practice, worrying that this might lead to disaggregation, and suggested that the French method of pounding the concrete in layers might be preferable. Walker (1891) giving equivalence between blue lias and Portland cement concrete, either of which for footings should be a minimum of 9" thick, according to the Metropolitan Building Act, with at least 4 inches of projection beyond the intended wall-line above, and both to be mixed with 4 parts of broken bricks, two parts sharp sand and one part of either binder, and 'tipped from a height not exceeding 4 feet.' Heath (1893), whilst also embracing Portland cement, indicated that a lime concrete should comprise 1 broken stone: ¼ lime: ¼ brick dust for footings; but also suggested that 'A weak lime concrete for backing may be made of 6 broken stone to 3 of a mortar composed of 2 sand (or brick dust) to 1 lime, turned over and mixed together at least 7 times…'. Concretes were now being made more in the fashion of 'beton', except where blue lias lime continued to be used.

APPENDIX FOUR: A SUMMARY OF CONSENSUS WITHIN OLD TEXTS.

This is an edited and updated version of a section included in Copsey (2019) A Review of Historic Literature, HES Technical Paper 25.

- Building mortars should be made and used immediately or within a few days, except for plastering, where 'ordinary method' hot mixed coarse stuff might be laid down for a few days or between 1 and 2 weeks, or sometimes months, to allow for late slaking. Use within 5-7 days was typical for masonry construction, if it was not used on the day of mixing, a requirement that appears frequently in 19thC architects' specifications.
- Although little documentary record from the medieval period is readily accessible, the evidence of numerous images of medieval building sites across Europe – some more naturalistic than others – as well as from archived building accounts, is that mortars were mixed on site, immediately adjacent the works, and used immediately after mixing. Though some of the activity may be interpreted as the knocking up of previously slaked lime/mortar, some images show steam rising from the mortar being mixed, as well as its being carried to the masons on the scaffold. Others show the mortar being mixed to have been cut from a larger pile of coarse stuff. Some show mortar boxes, where the lime might be slaked alone, to be mixed whilst still very hot with sand or might be slaked with the sand in the box. Building accounts occasionally reference the delivery of 'plaster' mixed elsewhere' often in the context of otherwise earth or earth-lime mortar construction and daubing.
- This pattern is confirmed by surviving medieval and later building accounts, which show lime burning, lime slaking and mortar making going on at the same time as the building works proceed. Items paid for in some accounts include 'lime sieves', indicating that the mortars were being dry-slaked and screened, at least on the sites in question. Lime kilns were frequently built on site, appearing early in account books. Pam White's research into the accounts of Corfe Castle during the time of Edward I show the lime-burners arriving on site the week before the masons at the start of the building season (pers comm). Sand deliveries routinely appear in the same account as 'lime from the kiln'.
- Although later, the 1616 building account for the Queen's House in Greenwich shows a very similar pattern. Payments for bricks, lime, sand, wheelbarrows, shovels, pails, 'lime sieves', hogsheads to make water-tubs, and significant payments to stonemasons and bricklayers is accompanied by payments to "Samuel Avery, William Browne and others for slacking, sifting and wetting of lime into mortar at 12d the hundred". This 'just in time' pattern is evident in numerous other building accounts. Lime pits held pure, slaked and stored lime generally for use on its own as lime finishes over earth-lime or hot mixed lime base coats or bedding mortars, as well as over one or two-coat backing coats.
- Oft-quoted discussion by Vitruvius and Pliny of laying down pits of putty lime for periods of years (albeit made by the addition of water to

quicklime and of dense, dough-like consistency) was demonstrably for use in high status finish coats, and is discussed by them in this context. Pliny's quoting of Roman Building Regulations insisting upon 3 years of repose is a mis-translation (of very long-standing). The proscribed time was 3 months, a recommendation repeated by Alberti in 1460 and again, for certain limes, by Millar in 1897. Otherwise, up to 2 weeks is the normal recommendation.

- Three of the four traditional methods of slaking aim to maximise the temperature of the slake, within certain parameters – and this is considered important for final performance. If sufficient water to effect the slake is added either in one go, or steadily by sprinkling, the temperature of the slake will be 100 Degrees C or a little more. Too much water will suppress this necessary temperature (as will too much sand).
- The addition of insufficient water in the first instance (less than one-third of the weight of the lime in water, or one volume of water to the volume of lime) will lead to significantly greater slaking temperatures, but will invite the risk of 'burning' the lime and then its being 'chilled' when more, particularly cold, water is added before the slake is complete. This leads to unmixable particles and leaves the mortar 'short'. These are *not* the residual lumps found typically in hot mixed lime mortars, which are under- or over-burned quicklime, or later-carbonated quicklime that was not mixed in before placement.
- The addition of too much water – or throwing lump lime into an excess of water – will 'drown' the lime, preventing its reaching the minimum necessary temperature of 100 degrees C. This was considered to lead to a weaker mortar, lacking in binding power and tenacity.
- The method of slaking has a material effect upon character and performance, though this was rarely tested.
- All lime mortars, fat and hydraulic, should be well-beaten during and after the making. One author indicates an optimum period of beating of a typical batch, by one man, to be 8 hours. Mortar mills - built or (later) mechanical made this process easier and more efficient and, once available, were always preferred to hand-mixing. Beating was necessary to engage as much lime as possible and to reduce lime lumps relative to effective binder. Roller mills continue to produce the 'best' mortar today; though mortar from pan mixers is also very good. Hand-mixing should not be ruled out, however. Modern research (Michoinová and Rovnaníková 2008) would indicate that beating increases the proportion of 1 micron pores, and thus increases effective porosity and frost resilience (Wiggins 2018; 2019). Beating was generally considered to deliver 'tougher', 'stronger', more durable mortars.
- For all traditional methods, a minimum of necessary water was added to quicklime, not the other way around. Adding quicklime to water is routinely counselled against, as weakening its binding qualities. This was generally true also of limewashes, grouts and putty limes before the 20thC, when adding quicklime to water became the norm, perhaps in

response to more reactive quicklimes. However, quicklime was added to twice its volume of water in best practice, ensuring the necessary minimum temperature of the slake. There was occasional criticism that masons added too much water in the first instance, to produce a thinner paste that was easier to mix with the sand – this practice was always frowned upon.

- Lime run to putty was generally considered to produce a weaker mortar, with less bond, particularly if the lump lime was added to an excess of water, of which process Vicat seems the only occasional advocate, whilst at the same time condemning fat lime mortars for any purpose (and whilst acknowledging their universal use at the time).
- Putty lime was used for interior finish coat plasters and for high status limewashes, run to putty to facilitate the removal of lumps of under- or over-burned or otherwise slow slaking material. It was normally made by adding water to lump lime, diluted after slaking was complete or by adding water to dry hydrated lime a day or two before mixing.
- Putty lime was used alone as a mortar for gauged brickwork and sometimes for very finely jointed stone ashlar, situations where strength was of less importance, but the absence of lumps essential. It was typically mixed with a small volume of water to produce a dough-like putty and used immediately (hot) or soon after slaking (cold).
- Limewashes generally were made from quicklime and used immediately, whilst hot. This increases their bond to the substrates and hot lime has a high 'flowability' even whilst quite thick, with or without fine sand or chalk addition.
- Except for fine stuff – fine finish plaster – when it might be mixed 1:1 with very fine sand or marble dust, lime putty was *not* used as a binder before the 20thC, when it became common to gauge lime mortars with either Portland cement or gypsum, depending upon use and geography (gypsum was more commonly deployed in Spain, e.g. and as a binder), in response to the pressure for haste in modern building practice.
- It was commonly agreed in this latter period that a gauged mortar such as 1:3:12 or 1:2:9 had less 'tenacity' than a typical 1:3 fat or feebly hydraulic quicklime mortar, but that it reached an initial full-depth set much sooner. Carbonation had still to follow.
- The move away from fat and feebly hydraulic lime mortars (which were variable and the proper mixing and proportioning of which relied upon the mason's skill and experience) and towards hydraulic lime and gauged mortars made with industrially produced and 'reliable' ingredients which could be mixed by rote, coincides with the rise of architects and engineers and the undermining of the mason and bricklayers' authority (and remuneration) within the construction industry, as also with the prevalence of competitive tendering, the contract usually awarded to the lowest tender.
- Military engineers, in France, the USA, the UK and Spain, had led the move towards using hydraulic mortars 'in the air' as producing stronger and faster setting masonry better able to resist heavy ordnance. Initially,

they advocated the use of natural cements. Portland cement only became the norm and preference over natural cement towards the end of the 19thC, when its quality and reliability improved. US military engineers were the first to begin running fat lime to putty before gauging with natural cement. This practice then extended across Europe (and North America) using Portland cement, after the realisation that Portland cement mortars without lime addition offered mortars of poor workability, poor water retentivity, bond and extent of bond and delivered inherently leaky fabric. There was more focus in France upon the use of eminently hydraulic limes in this context, though some (Treussart, eg) continued to prefer fat limes plus pozzalans for water works. Vicat's advocacy of (his own patent) artificial hydraulic lime never caught on amongst fellow engineers.

- The trend towards harder and faster setting mortars for use in the air as well as in water was quickly embraced by architects keen to establish and assert their ascendancy within the construction process. This became the more so as industrially produced and 'reliable', 'idiot-proof' materials came onto the market. This was justified by assertions of a lack of durability in traditionally used mortars; by assertions of laziness and absence of integrity among craftsmen; and pretensions of scientific certainty. In fact, it might be argued (and with notable exceptions, of course), the decline in building quality and longevity, certainly of vernacular character and tradition, runs parallel to this shift away from craft tradition and the status of craftspeople within the building industry.
- Masons, bricklayers and plasterers had always chosen and preferred fat limes – whether pure or feebly hydraulic – before this shift, and even as it proceeded, until the earlier 20thC, at least – especially, but by no means exclusively, away from metropolitan centres. Lump lime was still commonly used in London after WWII, for example, and well within living memory in Yorkshire.
- Masons and bricklayers would use pozzolans as required. Many lime mortars in vernacular buildings show low volumes of brick or clay tile chips, even when no bricks were otherwise used in the structure. Charcoal and other ashes often seen in older lime mortars have been attributed to contamination from the fuel of firing. However, 95% of the quicklime comes out clean from the kiln, typically. There were other uses for such 'lime-ashes', a mixture of quicklime fragments and fuel ashes, which latter might offer feeble hydraulic set. The ashes were most probably added by the masons, therefore. No mention is made in historic texts of this practice – when pozzolans are recommended to be used, it is always as a significant proportion and rarely less than 1/3 part of the aggregate. *This is 'secret' craft practice, therefore, reflecting their primacy in mortar design.*
- Despite the urgings of architects and engineers throughout the 19thC, hydraulic limes were rarely used in the air for domestic or ordinary construction before the tail-end of the Century. They were almost immediately displaced by cement-lime mortars.

- As late as 1946, a RIBA Committee was suggesting they might be usefully deployed for new build, but that they were very variable in quality and lacked a Standard – indicating that their use was not then common. Ironically, therefore, the first time significant demand for the use of NHLs in the air was created, it was created by the Conservation industry.
- Quicklimes remained in common use even after WWII – especially in the case of hydraulic limes (particularly Blue Lias), which were preferred by many over the industrially hydrated versions of the same. High calcium quicklimes remained a common form of lime for the preparation of gauged mixes in the 1950s, though bagged hydrate was by then more common.
- Bagged hydrated lime should ideally be mixed to a putty 24 hours before use. The use of bagged hydrated lime became common for plastering in the first half of the 20thC, in the UK and USA. This could be readily mixed to traditional proportions.
- 'Hot Lime' grouting is frequently recommended – for brickwork and for stone core-work. A hot lime grout will penetrate deeper into the work and then stiffen through suction, evaporation and completion of the slake.
- Mention of the same is not uncommon in the 18thC – coupled with strong indications that this is not normal craft practice – but most authors are architects associated with the Palladian movement, referring back to Greek and Roman example and dismissive of more recently previous architectural style and, by extension, craft practice. Alberti in 1460 similarly looks back to a notional 'golden age'. He is the only author who specifically says (in the chapter on ornament) that lime putty should laid down for a minimum of 3 months, and is the only possible source for the lime revival's insistence on the same.
- Vitruvius clearly discusses hot mixing for general construction and his specification of 1 part of *slaked* lime to 3 parts of aggregate – which contradicts all later texts and apparent practice - is probably a mistranslation made centuries ago, or refers to the production of fat lime: aggregate: pozzalanic concretes. If true, it reflects the general 'contamination' of pit sands with loam and clays, which would proffer feeble pozzolanic reaction. When using sea sand or river sand, Vitruvius indicates mixing at 1:2. Vitruvius's work survives only in medieval translation, with many inconsistencies and incongruities reconciled as possible in the 16thC). French, and probably Spanish, concretes ('beton') were made with already slaked lime run to putty, although – as in American military practice in the 19thC – still mixed whilst very hot. Or else, where naturally hydraulic limes were used, the initial running to a slurry would counter-act inevitable late-slaking to some extent. French and Spanish practice *may* more closely reflect Roman traditions. Hot mixing of concretes was the norm in the UK, however. Gillmore (USA 1864) describes it as the 'English Method'.
- The 'ordinary' or 'common' method was almost universal for fat limes, as well as for hydraulic – lump lime slaked with just enough, or a slight

surplus of necessary water in a doughnut of sand, sand banked over to retain heat, and mixing done as soon as the slake was complete. Although the ring of sand method was common in France and Spain, it was not uncommon to slake the lump separately in a mortar box or in a pit – but generally still mixed whilst very hot. Moxon (1703) and Marshall (1780) consider this to produce a weaker mortar than when lime slakes more intimately with the sand.

- More hydraulic limes were sand-slaked – quicklime slaked in a ring of sand and banked over; only enough water to slake the free (air) lime being added (more than this would prematurely initiate the hydraulic set). This would be left undisturbed for between 12 -36 hours, to account for the inherently slow slaking of such limes. After this – and when the lime had cooled), the sand and lime hydrate would be mixed and banked for up to 10 more days to allow for late-slaking, to which the more hydraulic limes were prone), before mixing to a mortar for immediate use. This may not be characterised as 'hot mixing' – the sand is initially no more than a convenient receptacle and, as often, the hydraulic quicklime might be slaked and banked without sand addition.
- In the UK, feebly hydraulic limes were considered common limes with slightly enhanced setting power. They expanded similarly and slaked as readily. They were preferred for exterior use where available – particularly in London and the South-East of England. They were generally frowned upon by engineers as being little better than pure limes. 'Fat lime' often referred to both pure and feebly hydraulic lime, typically, with up to 6% clay content (Villeneuve).
- Hydraulic limes and natural cements were the norm for water or underground works – 'water limes'.
- Hydraulic lump lime was often ground to a powder before slaking, to accelerate the otherwise tardy slaking time. The use of hot water also accelerated the slaking of such limes.
- It is commonly asserted that limes used were often of poor quality. This may stem from frequent complaint in London about the poor quality of the lime – usually due to air slaking by the time of mixing. This was sometimes the case in London because the quicklimes, whether chalk lime or feebly hydraulic, was carried into the city from Kent or Surrey, along the Thames or other waterways. Smeaton built lime kilns at Mill Bay in Plymouth to provide the Blue Lias lime for Edystone Lighthouse, after observing that Blue Lias lump lime carried from Watchet, North Somerset by sea was too prone to air slaking in transit. Generally, however, most areas were served by local kilns and a customary limit of 12 miles was commonly understood to be the maximum distance it might be carried as unslaked lump (on waggons or by pack-horse) without detriment to its quality. Masons would judge this quality on mixing, and if it was too lean for some of the quicklime having air-slaked, more lime would be used to achieve the right 'feel'. In limestone areas, lime kilns are numerous; in sandstone areas, kilns tended to be built at road-sides, the limestone carried to them for burning. In

Cornwall, where Plymouth limestone was widely used, lime kilns were common along the banks of the River Tamar, or other navigable water courses, the raw stone brought to them; on the North Coast of Cornwall, an almost pure lime from ledges on the South Wales coast were burned.

- All authors stress the necessity for quicklime to be used fresh from the kiln. Even when quicklime has not partially air-slaked before being fully slaked, there is a common notion that it loses some quality the longer it is out of the kiln before slaking and that slaking it whilst it remains hot from the fire is optimal. Oral testimony from masons and plasterers using quicklime in the second half of the 20thC indicates that the quicklime tended to arrive on site still hot from the kiln; or as still hot coarse stuff. Residual heat in the lump lime would accelerate slaking times, perhaps, or even contribute to a minimal particle size.
- Lime: aggregate proportions were routinely expressed in quicklime: aggregate, except where explicitly stated otherwise.
- Optimum lime: aggregate proportions for fat and feebly hydraulic limes 1 quicklime: 3 aggregate or 1:2; for hydraulic limes: 1:2, moving towards 1:1 the more energetically hydraulic the lime.
- The bulk density of the particular lime or form of lime is importantly considered, though mortar ingredients were mixed by volume, not weight and the optimum proportions above were based upon mixing by volume. Scott – Royal Engineer, 1862 (a determined advocate of removing craft knowledge and experience from the mortar mixing equation) spelt out the necessity of attention to the variable bulk densities of different limes when mixing by volume. He set a 'datum' that the volume of 50 lbs (22.68 kg) of a given lime should determine the volume of the aggregate, so that one volume of quicklime weighing 50 lbs (22.68 kg) should be the volume of each of the 3 parts of sand for a fat lime; of 2 parts for hydraulic. Most craftsmen would have achieved similar, but by 'feel'.
- Military engineers tested materials extensively. Most agree that the optimum sand mix is 2 parts sharp sand to 1 part fine sand, although, on test, Totten (1838) asserted that the finest sand gave the strongest mortars of all.
- It is often asserted that 'dirty' sands were commonly used in the past. This has been sometimes (and illogically) used to justify the use of natural hydraulic limes. This is probably often based upon a misinterpretation of earth-lime mortars. It is a common and routine demand of old texts that sands for lime mortars should be clean and washed – frequently accompanied by detailed descriptions of the methods for washing the sand. Marshall discusses the regular use of 'road scrapings' in the Cotswolds, and whilst this may well have been common, it would offer calcareous aggregates with some clay and earth in this and other limestone regions where earth or earth-lime mortars were the norm for stone buildings until the early19thC. Some suggest that road-scrapings give a good aggregate(Marshall, 18thC); others (such as Scott (1862) and Pasley (1826)) condemn the inattentiveness of many

masons to the cleanness of their sand. Langley (1750) says that 'loamy' and less well-graded sand should be confined to internal use, whilst exterior mortars using the same lime should be made with clean, sharp sand and that the cleanness and sharpness of the sand was the key influence upon a mortar's durability. Pozzolanic mortars he details were all for use underground or underwater. Boynton (1980) and others saw that the presence of some loam and associated clay content offered a mildly pozzolanic reaction, suggesting that some masons might have seen advantage in this.

- Many consider that the addition of certain stone dusts or clays to mortars promoted a strengthening reaction. This would be most pronounced when the mortars were hot mixed. Dossie (1771) considers that the heat of the slake of powdered quicklime whilst mixed with the aggregate promoted positive reactions between the two. Psammites – clayey, shaley sandstones – were oft-mentioned, particularly in France, as giving aggregates that offered a pozzalanic reaction. 'Growan' a degraded granite sand with around 18-20% clay content, traditionally used on Dartmoor, seems to offer a clear pseudo-pozzolanic set, as does the addition of slate dust, in our experience. The use of iron-rich limestone dusts seems to offer similarly accelerated set.
- Typical fat lime: pozzalan (true pozzalan, brick dust and other fired clays, forge scales, wood ash): aggregate proportion for water works: 1:1:2. Often 1: 3 lime: pozzolan; sometimes 1:1.
- Concretes were typically hot mixed (when lime was the binder) and were surprisingly lean: 1:7 being typical for foundations and water works, the one being Blue Lias lime or (later) Portland cement. 1:8 or 1:6 opc:aggregate still common in 1950, depending on end finish.
- 1 slaked lime or other binder to 3 aggregate only became the norm with arrival of cement-lime mortars, eg 1:3:12; 1:2:9; 1:1:6. Reflects the extra setting power of the cement addition.
- The use of cement gauges was a conscious response to pressures of modern volume construction and time pressure – it was acknowledged that it did not give a 'better' mortar and that only the added cement or gypsum actually set, carbonation taking much longer (and perhaps inhibited, or even prevented by the fast-setting addition).
- Any less than 40% of cement in binder proportion delivers a weaker, less tenacious mortar than if the same proportions were expressed in lime alone (at the time) – but gain an initial set, more resilient to disruption by other trades (such as electricians and plumbers) much sooner (US Building Codes Committee 1923).
- Even in the 1950s, 1:1:6 was suggested *only* for brickwork in the depths of winter and for chimney cappings and roof flaunchings; otherwise 1:2:9 for exterior works and 1:3:12 for interior brickwork partition walls (Ministry of Works Advice Note No.6 and various publications aimed at technical college and architects' education). The Ministry of Works Advice Note indicated pure or feebly hydraulic lime mortar at 1:2-3 for bedding porous limestone and sandstone, with 1:3:12 indicated only

where a 'rapid set' was *essential*. Modern Portland cement is very much stronger than earlier 20thC Portland cement.

- Only once such gauging had become well-established did it become the norm to assume that fat and feebly hydraulic lime mortars were inherently 'bad' and gauged or more than feebly hydraulic lime mortars 'better'. This ideological trend has continued, with 1:1:6 commonly used all year round, if lime is added at all, and 1:2:9 or 1:3:12 mortars rarely any longer used by general builders.
- Gypsum gauging of fat lime for finishes (to walls and to mouldings) had a long history – gypsum gauging of base and second coats only arose in earlier 20thC in response to similar time pressures. It was not considered best practice – but pragmatic practice. Vitruvius said that gypsum gauging should not be done: "For these (ceiling finishes), gypsum is the last thing one wants to mix in; instead, they should be composed of marble sifted to a uniform consistency, so that one part will not anticipate the other in drying, but the whole will dry at a uniform rate…" and 20thC authors understood that only the additive set quickly – not the main body of the material.
- During 20thC industrially produced hydrated lime was commonly used – in cement-lime mortars but also for plastering, run to putty 24 hours before use to fatten for the latter purpose. Its ease of use, convenience of packaging, handling and transport and reliability were considered benefits, as well as its ' de-skilling' of mortar production, removing the skill and experience of the masons from the specification process.
- The first mentions of routine and absolutely necessary protection of newly emplaced mortars (other than the covering of wall-tops during winter) from sun, wind and rain, as well as of on-going wetting of new work are in association with the use of natural cements and natural hydraulic limes in the air.
- Similarly, greater emphasis was placed upon the liberal wetting of building materials and substrates with the increased use of hydraulic materials.
- Building materials should be pre-wetted, although some engineers asserted the contrary on the basis of empirical testing (Totten 1838). Essential for hydraulic limes; not always so for hot mixed fat limes, depending upon 'natural' moisture content, though generally to be recommended.
- No texts, with the exception of Burnell (1857), display any understanding of the principle of compatibility. The typical engineers' definition of the 'best' mortar was the 'hardest' achievable.
- It is a common assumption historically that pointing mortars should be tougher and more weather-resistant than bedding mortars. This is reflected in the use of lime-rich pointing mortars over earth - or lime stabilised earth - mortars and carries on as lime mortars become routine for bedding, with the use of feebly hydraulic or natural cement pointing mortars over fat lime bedding mortars, at least once repointing becomes necessary (eg Pasley 1826 and 1838). This continues into the 20thC with

the repointing of lime-built masonry (and the over-laying of generally sound lime pointing with) cement or cement-lime mortars. This relationship tends to be reversed in modern repair specifications, with a higher strength NHL specified for building than that specified for pointing over this. A small volume of pozzolan added to a fat lime mortar might toughen a pointing mortar without disrupting effective porosity or even much increasing ultimate compressive strength.

- Very few writers mention or discuss earth or earth-lime building or plastering mortars. Cato (160 BC) mentions earth, lime and sand as components of mortar; Vitruvius (20 BC) commends adobe construction (with earth mortar between the 'bricks'); Alberti mentions earth building, as well as earthen mortars for stone construction; Marshall notes the prevalence of earth mortars in the Vale of Pickering, North Yorkshire, as well as the routine use of road-scrapings in the Cotswolds. Neve details the use of loam for plaster basecoats, to be followed by lime finishes). Also in 1726, Bailey and Worlidge propose building and rendering with earth-lime mortars. This general absence contradicts the material evidence across Western Europe and indicates that earth mortars were very much hidden in craft and vernacular practice, or were considered unworthy of consideration by 'experts', a situation that persists today. It is likely that the friable and 'weak' fat lime mortars criticised by Vicat and others in the cause of promoting the use of hydraulic lime mortars in the air were, in fact, earth or earth-lime mortars for the most part. The sheer number of standing masonry structures that remain standing evidence the durability of inherently low strength mortars.
- Bricklayers began using lime-sand mortars sooner, in general, than stonemasons, although both had used lime-sand mortars as well – reflecting the relative 'thinness' of brick walls compared to stone – though some earth-built brickwork from the 17th C may still be found. Perhaps a majority of stone buildings across much of the UK – and on the limestone belt as commonly as elsewhere – built before 1900 were built with earth-lime mortars. Similarly across Europe and the Americas. In this scenario, lime mortars were used as finishes – either as pointing over earth-lime bedding mortars or as finish coat or limewash over earth plasters. This would affect the manner of their slaking and processing. Lump reduction and removal will have been given a higher priority, though lime lumps are usually evident in both pointing and plaster finish coats or earth or earth-lime mortars, as well as in earth-lime mortars themselves, which were frequently less assiduously mixed than lime mortars. Sieving may have been more common for such mortars. They may have been mixed wetter in the first instance and used after a period of rest, rather than hot.

The four traditional slaking methods:

- ‘**Ordinary’ or ‘common’ method**: lime slaked to a dry hydrate (facilitating screening) or to a dough-like paste, mixed immediately. Just enough or a little more than sufficient water to effect the slake added to the lump lime – either in one helping, or continuously by sprinkling. Used immediately or soon after. Used for fat and hydraulic limes. The latter took longer to slake. This method also encompasses mixing the sand and pulverised quicklime together before or whilst still slaking – hydraulic quicklimes were routinely pulverised before slaking to hasten slake; it had become common with fat limes also by 1826, according to Pasley. When starting with lump, and without first reducing the lime in relative isolation from the aggregate, many lumps will not breakdown sufficiently and will late-slake. Adding more water in one fell swoop once the slake has commenced will ‘chill’ the lime, generating a multitude of small lumps impossible to break down except by way of a powerful mortar mill. The first clear description of mixing pre-pulverised quicklime and sand together and slaking them together with incremental additions of water is by Dossie in 1771. This was considered to deliver a ‘stronger’, more tenacious mortar – as recent experience confirms. De la Faye, an advocate of slaking by immersion also states that “If we mix two parts of sand freshly extracted from the river with one part of powdered quicklime, it will create a very fatty and adherent mortar.” (1777).

- **Immersion**. Lump lime reduced to size of hen’s eggs dunked under water for seconds, or until slaking commenced; tipped out to slake to a dry hydrate, to be sieved as necessary to remove lumps, or tipped into barrels, and left to cook en masse – and stored in damp places for on going use – usually for fine stucco or plaster finishes. Uniquely, De la Faye proposes the latter as the preferred method for building mortars of the best quality. Likelihood that lime slaked by immersion was otherwise mixed whilst still very hot – experiment shows that mixing whilst still very hot delivers fattier, more workable mortar than when mixed cold. A variation on this is what French and Spanish engineers called ‘slaking by aspersion’ – the lump lime being spread on a platform or on the ground and sprinkled with water to slake to a fine powder.

- **Spontaneous**; air-slaking. Lump lime laid out on a platform in an open-sided shed and left to slake slowly by absorbing moisture from the air. Full slaking might take up to a year. Most concede that this was rarely done, for being impractical and carrying a risk of premature carbonation. Smeaton, however, asserts that this was a common procedure for Blue Lias hydraulic quicklime in the Bath area. He did not do it for the Eddystone Lighthouse, however. It may have been more common for slow-to-slake hydraulic limes than for fat and feebly hydraulic limes much more efficiently slaked by the ordinary method. Some assert that lime slaked this way is the ‘best’, even whilst acknowledging that it wasn’t much done.

- **Slaking pulverised or powdered quicklime with sand**.

  Sand and quicklime are mixed together before water is added. Water sufficient to effect a dry or a 'wet' slake may be added in one go or more incrementally – the more detailed descriptions of the method favour the latter – and mixing is vigorous and continual between each water addition. This may be done in small batches with a trowel, or with shovels and larries. It translates well into pan mixing. This method has been the most commonly deployed during the recent revival in hot mixing.

APPENDIX FIVE. TRANSCRIPTIONS FROM BUILDING ACCOUNTS HELD IN ARCHIVES AROUND ENGLAND. Consulted 2016-2019.

The bracketed reference is the reference used in the main text.

Public Archives visited:

North Yorkshire County Council Records Office;
British Library, Wetherby;
West Yorkshire Archives, Leeds;
Doncaster Archives;
Sheffield City Archives;
East Yorkshire Records Office, Beverley;
Herefordshire Archives & Records Office;
Dorset History Centre;
Plymouth and West Devon Archives;
Wiltshire and Swindon History Centre;
Gloucestershire Archives;
East Sussex Archives;
West Sussex Record Office;
Northamptonshire Archives;
Warwickshire County Records Office;
Hull History Centre.

Private Archives:

Scampston Hall, North Yorkshire;
Fitzwilliam Estate, Malton, North Yorkshire;
Hill family papers, Thornton Dale, North Yorkshire.

HULL HISTORY CENTRE (HHC)

U DDBA/4/43 (HHC 01)

Miss E Dunn, Howden/South Cave

Account with William Nelson of Howden for making 50,000 bricks on Holm Common at 5s 3d per thousand.

Agreement with Thomas Story of South Cave, 11th March 1778.

For building a barn, two stables at Cave at 1s 6d per rood

To point the walls with lime and hair inside and outside *[this would indicate the use of earth-lime bedding mortars].*
To tiling and pointing of the roof *[this is just as it was becoming common for lath and lime-sheeting to be used with pantiles (Marshall 1780), displacing back-pointing, specified in this instance].*
To paving the stables with stone upon edge
To allow for him to find scaffolds.

April 29th Leading with his cart tiles from Brough, 700 to a load.

May 3rd **6 chaldrons of lime at 11s 6d per chaldron**
Leading the same quantity at 3s per chaldron

April 29th 4 loads of tiles and raff from Brough to Cave

2 loads of timber from ditto to ditto
2 loads of timber from ditto to ditto.

Agreement with John Dunn, Carpenter for work upon building a barn and 2 stables at South Cave.

To sawing timber, 100 feet 2s 6d
To a single purling roof 10 foot is a square at 4/- the square
To 2 pair barn doors per square yard at 1s 4d
To 4 lintels
To 2 door heads
2 stables roofs 10 foot is a square at 2s 6d
To stable doors each 3s 4d
To hecks and mangers and posts setting down per yard at 1s.

1779 Received from Thomas Nell, lime for Miss E Dunn at Holm

1779 John Adamson, Bricklayer at Wighton *(Market Weighton)*. With E Dunn of Howden for building a barn at Holm.

March 20th A brick-length wall at 2/6 per rood
Tiling and pointing at 3/6 per square
Paving brick floor at 2 ½ d per square yard

June 1100 bricks
4 bushells of hair from Mrs Sutton

1779 John Adamson bricklayer.
June 8th Foundation walls to project 15 inch depth
19th 16 yards of rigstone
22nd 12 furr poles
Received from James Tupman 1 ½ chaldron of lime at 7/6
26th 3 load cobbles, nails and spikes.

June 18th John Adamson prices.

Brick of length wall at 2/6 per rood

An oven 7/6

Plaister floor running 6d per yard

Tiling and **pointing** 3/6 per square

Common paving with flatt brick 2 ½ d per yard

Brick of breadth wall

1 chaldron of lime

2000 bricks.

Notably, such building projects are beginning in March. Lime and bricks etc are arriving at the same time, indicating ongoing slaking, mixing and use during the build. Pricing is by measured rate.

U DDHO 15/4 (HHC 02)

Hotham Estate Archive. Scorborough.

March 30th 1715

Mem. I then agreed with Sir Charles Hotham to erect him a building 20 yards long according to the dimensions specified in a place containing work-space

(?), brewhouse, laundry and coal-hole, to be floored, one pair of stairs to answer both chambers, the baulks to be of ash…doors and window-frames to be of oak…Sir Charles finding all materials. Thomas Robinson

U DDHO/15/5 (HHC 03)

The Account Book of Disbursements for building the house in Beverly, begun July 1716. Sir Charles Hotham.

Walls 2, 3, 4, 4 ½ and 5 bricks thick.

William Bullock, Mason; William Trist, Bricklayer.

July 11th for **33 chaldron of Knottingly Lime at 14d a sack.**
Knottingly limestone is classified as a magnesian lime but contained only trace elements of magnesium, being a high calcium lime, in fact].

To William Thompson for sand digging;
To John Norrys the same

To Thomas Robinson for 2 quarters of lime

November. Haulage of 24,000 bricks

October 1716 11 1/3 chaldron of lime

1717 Account for 566,400 course bricks; 48,150 front bricks

Sept 20th
I then agreed with Sir Charles Hotham to furnish him with what quantity of coals he shall have occasion for his brick kilns for burning 300,000 bricks…

U DOG/4/21

1786 The Reverend Mr Ogle Dr to Richard Ombler for bricklayer work.

To 1 ½ brick length	£3 7s 3d
To 1 brick ditto	3s 6d
To tiling and underdrawing	£1 14s 6 ½ d

To paving stable 10s 2d
To 8 chaldrons of lime £2 16s
To making up the same
at 2s per chaldron 16s
To two days digging foundations 3s
To 24 days plastering chamber
and latting £2 8s
And building privy
To 12 days labouring
To one bushel of Simment at
6d
To day going to Brigham to
Chuse bricks 1s

1786 rough account of the same

12,050 bricks at 16/6 per 1000
9200 bricks at 16s per 1000

Lime – Ombler

Stable, 8 chaldron lime at 7s the chaldron

Bainton tyles

Stable 1210 tyles, stone ridging, nails

Hair – 3 stone at 2s a stone.

Kelk Barn 1791
2,500 tyles; 33.000 bricks
Lime 12 doz. at 12s the doz.

D DEV/56/47 (HHC04)

Constable family, Sewerby, Bridlington.

Expense of building a water corn mill at West Rayson 1766.

Bricks, 21,500 at 16s per thousand £17 4s

Pan Tyles 1550	£3 6s 9d
Ridge Tyles 30	7s 6d
Leading Brick, Tyles, Timber etc	£13 5s 6d
Smith's work, nales etc as per bill	£1 12s
Labourers wages	£4 1s 10d
Glasiers bill	7s 10d
A Mill Stone bought at Gainsbrough	£6
Leading ditto and Warfage	£1 8s 6d
Leading 2 mill stones from Lincoln	£1 10s
Belting Cloths as per bill	£2 15s 6d
Mill Wright's boarding 41 weeks at 5s	£10 5s
Mr Medley for iron work as per bill	£3 2s 5d
2 new Millstone Ropes	£1 10s
Bricklayer for workmanship and lime	**£15 13s**
Mill Wright's wages	£20 6s 3d
Ditto for making wheels etc as per bill	£37 6s 9d

£140-12-10

To construct the Oatmeal mill will cost about £5 15s

To building and completely finishing a Drying Kiln as per estimate: £29 18s 6d

DDPR 47/13 (HHC05)

Preston family of Moreby Hall.

John Bland, bricklayer. New house and barn at Holme 1799.

Repairs, Moreby Farm 1830 H Preston Esq.

Jan 9 Labourer ¼ of a day pileing bricks 6d
22 Robt and labourer 1 day each whitening Pidgeon Cote 5s 6d
21 got 5 stones of hair at 2s 6d per stone
28 Self ½ day doing Pump Grate stone 1s 9d
14 **got 1 cask of Cement or 5 bushels £1 8s**
March 5 Self and labourer 1 day each setting Foldyard trophs and jobing by the pipe and in Newton House at Kelfield 6d
Got ½ a stone of hair to Kelfield, Mr Bell's 1s 3d
12, 13 & 15 Self & Robt ½ day each, James & Geo. 1 day each
Father and jobing ¾ of a day each and a labourer 1 day taking tiles and laths of old Barn and digging foundations of the new barn etc 15s 4 ½ d
March 18, 19, 20, 21, 22 Father and labourer 4 ½ days each and John 5 ½ days and Lister 1 ½ days taking down old barn and dressing bricks £1 18 7 ½
24 James & Robt & Father and John and Labourer ¾ day each dressing bricks at the old Barn 10s 9d

August 25 & 28 two labourers 1 ½ days each dressing bricks and taking up part of old barn foundations 6s 9d.
July 14 got 5 stones of hair at 2s 6d per st. 12s 6d
16 James and Robt ¼ of a day each stopping Rotten holes and other little jobs etc at Moreby 1s 7 ½ d

1830 Work done at Richd Harris House and other places etc

April 8 & 10 Robt 2 days at whitewashing and jobing 7s
12, 13, 14, 15, 16, 17 Self 3 days Robt 6 days, James and Geo. 4 days each and Labourer 2 days plaistering in R Harris house and setting Range & Oven & Furnace and Scraping the walls and whitewashing and building a Rabbit House, and pointing the Chimney top and pointing house ridge & jobbing £2 19s 5d
19, 20, 21, 22, 23, 24 Self ¾ of a day, Robt 1 day, James 5 days, Lister 5 ¾ days, Labourer 5 ¾ days all at Mt Harris house, Paving and whitewashing the Game keeper house and taking down the old Cowhouse and Stable and dressing bricks & jobbing £2 18s 9 ½ d
Ditto 23 got a Hard Sinkstone 3 ft 6 in by 2 ft 10s 6d
26, 27, 28, 29, 30 & May ist. Self 2 days, James & Lister and Labourer 6 days each, Robt & Geo, 4 days each, building Pheasant House and Paving & dressing bricks etc £4 8s 11d
May 3, 4. James I day and Lister 2 days, Geo, ½ day, Labourer 1 day, taking up the Stable and Cowhouse foundations and paving and dressing bricks etc 14s 9d
May 5 Self, James, Lister & Robt & Geo. & Labourer, all of us ½ day each Paving and digging Stable foundations and doing gable ends of Pheasant House etc 9s 9d
7, 8 Self 1 ¼ days, Robt and Labourer ½ day each plaistering Pheasant House and laying on Copeing stone and whitening the house 7s 11d
June 15, 16, 17,18 James 2 days and J, Hoop 3 days and Labourer, Labourer 2 days laying Cloves towards Mr Etty's and digging Barn foundation and mending Mr Etty's Pigcote walls 18s 11d
29 & 30 two labourers 1 day each and Jo. Hoop 2 days taking down barn walls and dressing bricks 9s.
July 19, 20 James and Hoop and Labourer 1 ¼ days each taking out Granary windows and putting in some larger ones,and mending Boyler house floor etc 10s 3 ½ d
August 17 James & Hoop and Labourer ½ day each digging Barn foundation and dressing bricks etc 4s 2d
18 Three labourers ½ day each dressing bricks 3s 4d
25 **James and Labourer ½ a day each ramming barn end and Self beating down Stable ground etc** 3s 3d

SCAMPSTON ESTATE. (SCAMPSTON)

SCAMPSTON01

Account for the building of the Bridge within the Park, 1760-1761, extrapolated from Account Book No.3. Agent: Francis Armstrong. Scampston Hall Library.

1760

May 5th My charges at Ebberston about stone for the bridge 0-0-6
May 12th Gave the Ebberston masons to drink 0-1-0
July 13th For taking up 50 load of Knapton stone, bracing the pitt and leading 4-6-4
July 15th Paid Geo. Wilson for mason and brick work 17-8-10
July 19th Paid Rd. Metcalfe. John Brewster, John Baker, Wm. Huntley and Tho. Carr for getting up and leading 100 load of Ebberston stone and leading it to Scampston at 2s a load for the stone, 4s a load for leading.
July 24th Paid Braithwait in part for making 126,000 bricks on Scampston Common at 5s per thousand. For straw to cover the above bricks 1-10-0
August 22nd John Parkin for sawing and squaring wood for platform and centers of the new bridge 2-3-4
August 30th Braithwait for 126,000 bricks made on Scampston Common 24-16-0
October 4th Wilson for mason and brickwork in part 32-0-0
October 10th Pd Rd. Metcalfe and Tho. Carr for getting up 102 loads of Ebberston stone at 2s and 4s per load leading 30-12-0
October 23rd **To Geo. Mook for leading lime and brick** 3-3-6
December 10th Rd Metcalfe and Company for 61 load of Allerston stone at 2s a load and Wm Eddon and Company for leading them at 4s 18-6-0

1761
January 10th **Mr Percival Luccock for lime for the bridge** 15-0-0 *(this will be Malton oolite)*.
Geo. Wilson mason and brickwork at the new bridge 49-1-9
April 21st Metcalfe & Carr for Allerston stone for new bridge 11-3-1. Eddon for leading same 11-16-0
May 4th Rd. Bulmer ye Blacksmith for sharpening tools for the masons at the new bridge 3-4-4
Geo Wilson for mason work at the new bridge 29-12-6
August 24th To Wm. Thompson of Rudston for 11 dozen of rubbers 1-13-0
October 19th Paid Mr Bowness for 6 dozen of rubbers.
October 9th Paid Geo. Wilson for mason work at the new bridge 25-14-0
October 31st **Luccock for lime in full** 7-2-0

1762

April 16th Paid Geo. Wilson in full for mason and bricklaying work to 29th March 1762 43-9-0.

(Work appears to go on through the winters of 1761 and 1762, with autumn deliveries of lime. Lime from Malton a fat lime, at most very feebly hydraulic).

Francis Nicholson. Scampston road bridge c1790. Backside faced with brick. Image: Scampston Estate.

WEST SUSSEX RECORD OFFICE.

PHA/1630 (WSRO01)

The Rebuilding of Goodwood House

The total cost of the building was £556 18s. 6d which may be allocated to--

	£ s. d.
Bricklayer and mason	202 14 0
Carpenter and sawyer, including carriage	189 11 11

Tiler 27 5 2

Plasterer 37 12 9

Plumber and glazier 37 14 8

Ironmonger 56 0 0

Fireplaces 6 0 0

556 -18 - 6

A transcription of PHA/1630 follows:-

A Computation of the new buildinge at Goodwood August the 9th 1616

(NOTE A rod of masonry is 16½ x 16½ or 272¼ square feet; a rod of brickwork is the same if it is of a standard thickness of 1½ bricks. A rod of brickwork equals 306 cubic feet.)

The buildinge is in length 76 and in bredth 24 foote, wch is in greate measure 12 roddes and two foote.

The height of the Seller is 7 foote, the thicknes 2 foote 8 inches the whole wall cometh to 84 roddes 14 foote at 5s the rodde. xxjli iiijs vjd

The height of the seconde story from ye topp of the Seller to the boordinge of ye third storie is 13 foote wch maketh of wall at the same girte of 12 roddes 2 foote cometh 157 roddes halfe one foote and qer at 5s the rodde xxxixli viijs

The Porch is in greate measure 27 foote, in height 15 foote and halfe, in thicknes 20 inches, wch is in the whole 25 roddes at 4s 2d cometh to vli iiijs ijd

The Buttery is in gerte measure 27 foote in height 17 foote and halfe and in thicknes 15 inches wch cometh to 28 roddes and ½ at 3s jd the rodde iiijli vjs iiijd

The stayer case is in girte measure 27 foote and halfe in height to the boordinge of the second story 15 foote & ½, in thicknes 17 inches wch is in the whole 25 roddes at 3s vjd the rodde, cometh to iiijli vijs vjd

The water table aboute the howse cometh to 188 foote, at 4d the foote iijli ijs viijd

The makinge of three Doores in the Seller and eight in the second storrie all of brick turned wth arch at 5s the case lvs

The Hall Chymney mantle and an other arch for the Dresser at 5s the peece xs

The makinge of 7 bricke wyndowes of 7 foote and halfe high and 5 foote wyde wth two halfe wyndows of the same measure in the second storrie every window conteyninge 36 foote and halfe, beinge in the whole 288 foote at 6d the foote vijli iiijs

Three windowes in the stayer case conteyninge 53 foote at 6d the foote xxvjs vjd

Two wyndowes in the porch Conteyninge 29 foote at 6d the foote xiiijs vjd

The fowre wyndowes in the buttery conteyninge 78 foote at 8d the foote xxxixs

The five wyndowes in the Seller Cont: 76 foote at vjd the foote xxxviijs

The Cornish *[ie. cornice]* of fowre wyndowes in the Buttery Cont. 24 foote and halfe at 4d the foote viijs ijd

The cornish over eight windowes in the seconde storrie Cont 66 foote and halfe at 4d the foote xxijs ijd

The two wyndowes in the Porch Cont of Cornishe 11 foote and 9 inches at 4d iijs xjd

The Cornish over three windowes in the stayer case beinge the first storrie Cont 22 foote at 4d the foote vijs iiijd

The Cornish over the fowre Doores in the second story and Porch Cont 49 foote at iiijd the foote xiiijs viijd

Carpenter woorke

The first floore over the Seller beinge 72 foote longe and 20 broade for fellinge, squarinnge, sawinge, framinge and raisinge at ijs iiijd the foote beinge of that measure 92 foote wch cometh unto xli xvs viijd

The seconde flower [ie. Floor] being the same measure and woorke xli xvs viijd

The fellinge and the flower over the Butterie beinge 24 foote at 2s 4d the foote lvjs

The fellinge, squaringe, sawinge, framinge and raisinge the flowre in the Porch being 14 foote at 2s iiijd the foote xxxijs iiijd

wch hee Demandeth p[er] bill in the same tyme by him Disbursed xxvli xixs ixd

Som[m]e of his accompt both togither Cometh to ljli xixs vd

More worke to be done to finish the Chardgs of Goodwood house

In walinge of the Masons worke

From the boordinge of the second storie or flowre to the settinge on the roofe is 14 foote high and the girte measure 12 roddes 2 foote wch maketh in the whole 169 roddes and halfe, 3 foote and three inches at vs the rodde xlijli vijs vjd

The staier case riseth from the boordinge of the seconde flowre to the settinge on of the roofe 14 foote, in girte measure 27 wch is 23 roddes and a halfe 3 foote 3 inches cometh to iiijli vjd

The three gable ends sett foorth in the foreside of the buildinge, and two gable ends in the end of the buildings each conteyninge 11 roddes and halfe beinge in the whole 57½ roddes of 20 inches thicke at iiijs the rodde xjli xixs vijd

The gable head of the Porch cont: 3 roddes and halfe at 2s 6d viijs ixd

The gable end of the staiere case beinge in bredth 17 foote and the rafter 14 foote in length wch is sixe roddes at 3s vjd the rodde beinge but 17 inches thicke xxjs

The rowlinge crest of the 5 gable ends is about 174 foote at 4 the foote cometh to lviijs

The Corbell table under them five gable ends beinge 125 foot at 4d the foote xljs iiijd

(i.e. corbel-table or, perhaps more likely, corbie-steps--those attractive stepped gables introduced from the Low Countries in the late 15th century.)

for 19 foote of Corbell table under the gable end of the porch at 4s [recte 4d] the foote vjs iiijd

for thirtee foote of rowlinge crest for 3 gable end for the Porch at 4d xs

The 5 windows in the gable ends of 19 foote in a windowe and six more in the staer case and west end, of the same measure at vjd the foote iiijli xvs

For nine greate windowes in the third storry of 36 foote and halfe beinge in the whole 328 foote viijli iiijs iijd

The Cornish of 20 windowes beinge in 115 foote at 4d the foote xxxviijs iiijd

The rowlinge crest of the staiere case 32 foote, and corbet table 28 foote at 4d the foote xxs

The gable end of the butterie about 3 roddes wth a rowlinge crest xxijs

The makinge of 15 vinneals [ie. finials] to the worke at 3s the peece xlvs

For makinge three shaftes vjli

For layinge 16 squares of Horsam stones uppon the west side of the buildinge at 5s 2d the square and tylinge 25 squares at 3s 6d the square viijli xs ijd

For makinge three Doore cases at 5s the peece xvs

For three mantles Jalmes [ie. jambs] and foote paces for them three Chymnes at 40s the peece wth carriage hither vjli

For plasteringe the Hall wale beinge 156 yeardes at 6d the yeard iijli xviijs

For plasteringe the buttery beinge in all 25 yeardes at vjd the yeard xijs vjd

For plasteringe 46 yeardes of the staier case the topp and all iijli xiijs

For plasteringe the porch about 34 yeards at vjd the yeard xvijs

For plasteringe the lower storrie over head of all the buildinge beinge 160 yeardes at 10d the yeard vjli xiijs iiijd

For plasteringe the same proportion over head in the second storrie vjli xiijs iiijd

For plasteringe the uppermost storrie wch may be used for a gallerie beinge vij foote and halfe high 72 foote longe and 15 foote wyde wthin the Ashler and at the windowes in the gable ends 22 foote wyde, beinge in all 262 yeards xli xviijs iiijd

For plasteringe 14 yeards and halfe of wale at the end of the same buildinge at vjd the yeard vijs iijd

For settinge upp the olde waynscott and peecinge it to serve the roomes xvli

For fellinge squaringe sawinge framinge and raisinge the third flower beinge 92 foote at ijs iiijd the foote xli xvs viijd

For 25000 of tyles at 15s the 1000 xviijli xvs

For fellinge, squaringe, sawinge, framinge and raisinge the roofes of the same buildinge being 100 foote, the three gable ends 51 foot at 3s 8d the foote xxvijli xiiijs iiijd

For fellinge, hewinge squaringe framinge and raisinge the roofes of the porch, staier case and buttery beinge in all xiiijli vjs

The staier case fellinge, squaringe, framinge and layinge viijli

For makinge two p[ar]tic[i]ons in the Hall and two in the seconde story iiijli iiijs

For fellinge and hewinge 5 loades of tymber at Pettworth to boord the lower storie at Goodwood at xviijd vijs vjd

For sawinge 1900 of them boordes at ijs the 100 foote xxxviijs

For carryinge them five loades at vs xxvs

For layinge them at ijs vjd the 100 foote xxxixs

For fellinge and hewinge 10 loades of tymbr at Pettworth for to make boordes for the second storie at Goodwood at xviijd the loade xvs

For sawinge 3800 of them boordes at ijs the hundred iijli xvjs

For carryinge them tenne loades at 5s 1s

For layinge 2900 of them boordes at ijs vjd the hundred iiijli

For the boordes and boordinge the flowre over the butterie xs

For xv Doores wth their lockes boltes hookes and hinges at xs the peece vijli xs

For fellinge and hewinge two loades of Tymber for them Doores at 18d the loade iijs

For sawinge them 700 of boordes at ijs the hundred xiiijs

For carryinge it to Goodwood xs

For 14000 of nayles at 5s the 1000 iijli xs

For the glasse of 19 transomed windowes each cont: 26 foote at 6d the foote xijli viijs

For glasinge the old glasse in the litle windowes in the upper story iiijli

For 34 greate Casments at vjs viijd ye peece xjli vjs viijd

For two gutters and two pipes for the porch, one gutter betweene the butterie and Pantrie, and one gutter bettweene the staier case and the old buildinge cont in the whole about 57 foote at xli

For three Doores in the seller, two staires, the pavinge of the porch, the buttery and the Panterie wth the staier case vli xs

For 60 tunnes of Tymber Felled for the flowres and roofes at xjs the tunne xxxiijli

For the Iron worke about the windowes and barres since the ijth of August xlvli

Thirtee thousand of brickes more at 10s the 1000 xvli

For plasteringe 96 yeardes of Partition omitted in the lodgings at iiijli

The Goodwood property was acquired by the 1st Duke of Richmond in 1695 (nos. E784-790) and the old house--the subject of the above accounts--was used by him and his successors as a hunting lodge until it was rebuilt in its present form by James Wyatt for the 3rd Duke between 1780 and 1800. It was the 3rd Duke who developed the Goodwood property from about 1100 acres to something to the order of 17000 acres.

ADD MS 30 155 (WSRO02)

Salisbury Court, owner Mr Grainger.

1763 Mr Granger of Salisbury Court to Edward Cole.

May 30 To bricklayer and 2 labourers
1 day to chimney 7s
to 8 hods mortar; 225 grey stocks

May 31 mending the tyling, 1 bricklayer and labourer 1 day each 5s
To 6 hods of mortar and 1 hod of lime and hair
To 25 grey stocks; 25 plain tyles and carriage of rubble.

Jasper Orchard, bricklayer.

ADD MS 30 753 (WSRO03)

Mr Grainger to Wm Gibbs, Plumber.

April 23rd 1733 Work to take up the old lead and carry it home
30th Work to take up old lead trough
May 2nd for 0:2:16 of Mill'd Lead for watertabling

11th for 1:2:23 of Mill'd lead for a gutter
for half a yard of Socket pipe
for 4 pound of Soder
for 12 iron wallhooks
for a rainwater Cistern head
for 6 feet of Rainwater Pipe
work 3 men and nails
16th for 9 pound and a half of Mill'd lead
21st for 17 pounds and a half of ditto for a tiling
work and nails
22nd work to hang the last pipe and dress the old cove
for 6 iron wallhooks
26 for 4 sashweights
June 13 – 8 ditto
July 9 work to lay some new lead and to carry home the old
For 0:2:4 of mill'd lead to lay in the yard
For 2 ironwallhooks
10th for 2 feet 6 inches of rainwater pipe in ye Yard
for 2 ironwallhooks and work to put it up
for change of one foot 6 inches of pipe in ye street
for sodering two joynts to ditto
17th for 2:0:20 of cast lead to lay on the Cove
for work 2 men
18th for 8 sashweights…
31st for 3 pound of Soder for the old cistern
for a brass cock and setting in

Plaisterer's Work done for Mr Grainger by John Whitehurst

1733
May 22 To 1 bundle of lath 0:1:3
½ pound nailes 0:0:9
5 hods of lime and haire 0:3:9
29th plaisterer 1 day 0:3:0
labour ¼ day 0:0:6 ½
4 hods lime and haire 0:3:0
laths and nailes 0:1:4
30th plaisterer ½ day 0:1:6
boy, ditto 0:0:9
10 hods of lime and haire 0:7:6
8th June lath and nailes 0:0:6
2 plaisterers 1 day each 0:6:0
1 turn & ½ of white and size 0:6:0
2 plaisterers 1 day each
size cullers and varnish 0:5:0
plaisterers ½ day 0:1:6

21	3 bundle of laths 0:3:9
	1 thousd & ½ of nailes 0:2:3
28	15 hods of lime and haire 0:11:3
	plaisterer 1 day 0:3:0
29	2 plaisterers 1 day each 0:6:0
30	5 hods of lime and haire 0:3:9
	2 plaisterers 1 day each 0:6:0
2nd July	6 hods of lime and haire 0:4:6
	2 plaisterers 1 day each 0:6:0
	2 bundle ½ of laths 0:3:1 ½
to 18th	1 thousd of nailes
	3 hods of lyme and haire 0:2:3

Bogg house and yard –
6 hods of lyme & haire….

ADD MS 30 754 (WSRO04)

November the 21st 1737

Measured the Bricklayers work at your house at North End, in Fulham Parish a second time, Mr Hall being present and show'd the work.

For Plain Tyling 22 ½ squares and 4 feet
For old pantyling 17 sq and 43 feet
For new pan Tiling the house, office and washouse 2 ½ sq and 7 feet
For 4 rods and ? feet of Brickwork

Sir, I have measured this work and will stand by it. Except day works, as for white washing and stopping, Mr Hall did not insist on a second measurement, but is willing to let it pass, tho' my amount is less than his in that affair. I shall have Mr Taylors account ready by Saturday next and will be that day at Home. Francis Hutchinson, Fulham November 22nd 1737.

Work done at Mr Grainger's Farms by John Longly, Thatcher, 1739

Upon a house and Hogs Sty at Dawkers, thatching 352 foot at 2s 6d per square

At Vaughons, 381 foot upon house and hogsty
At Rowland Barn 1340 foot
At Vinals Barn 518 foot
At Vinals Hovel 945 foot

For work done 1750

At Vinals Barn 1024 foot
At Vinals Wainehouse 983 foot
At Vinals Hovel 983 foot…

For 300 spars
For halfe a hundred of Withs
For lathing 6546 foot at 2s per square

March 22 1736/7

For putting in the door case in the street
For a bricklayer & labourer 1 day
Four hods of morter; 1 hod of lime & hair

29
for new crowning of the Well & mending the brickwork of the Other House
for 2 bricklayers and labourers 1 day
for 10 hods of morter; 100 bricks

April 1 1737
The levelling the yard and cleaning the rubbish from the Garden Wall, a labourer 3 days…

For 7 hods of morter and 2 hods of lime & hair…

For setting over the coarse patches with fine stuff.

ADD MS 30 754 (WSRO05)

Articles of Agreement Between Mr Granger & William Woodstock & Richard Hall, Bricklayers, for Bricklayer's work to be don in Building six houses at Hammersmith: vizt

The said six houses to be built with walls in proportion as follows:
The foundation walls in front and rear to be two bricks thick up to ye first floor, from thence to ye garrett floor, 1 brick & half thick; ye Party Walls to be one brick & half thick to ye first floor & all ye way upwards to ye roof, one brick thick. The Front of ye roof to be tiled with plain tiles, ye rear and bogghouses to be tiled with pantiles at ye following prices: All of ye brickwork in and about ye houses to be don at ye rate of five pound fifteen shillings per Rodd; plain tileing at twenty five shillings per Square; pantileing at nineteen shillings per square; for lath plaster and whiten at eight pence half penny per yard; renderin & whiten at threepence halfpenny per yard.

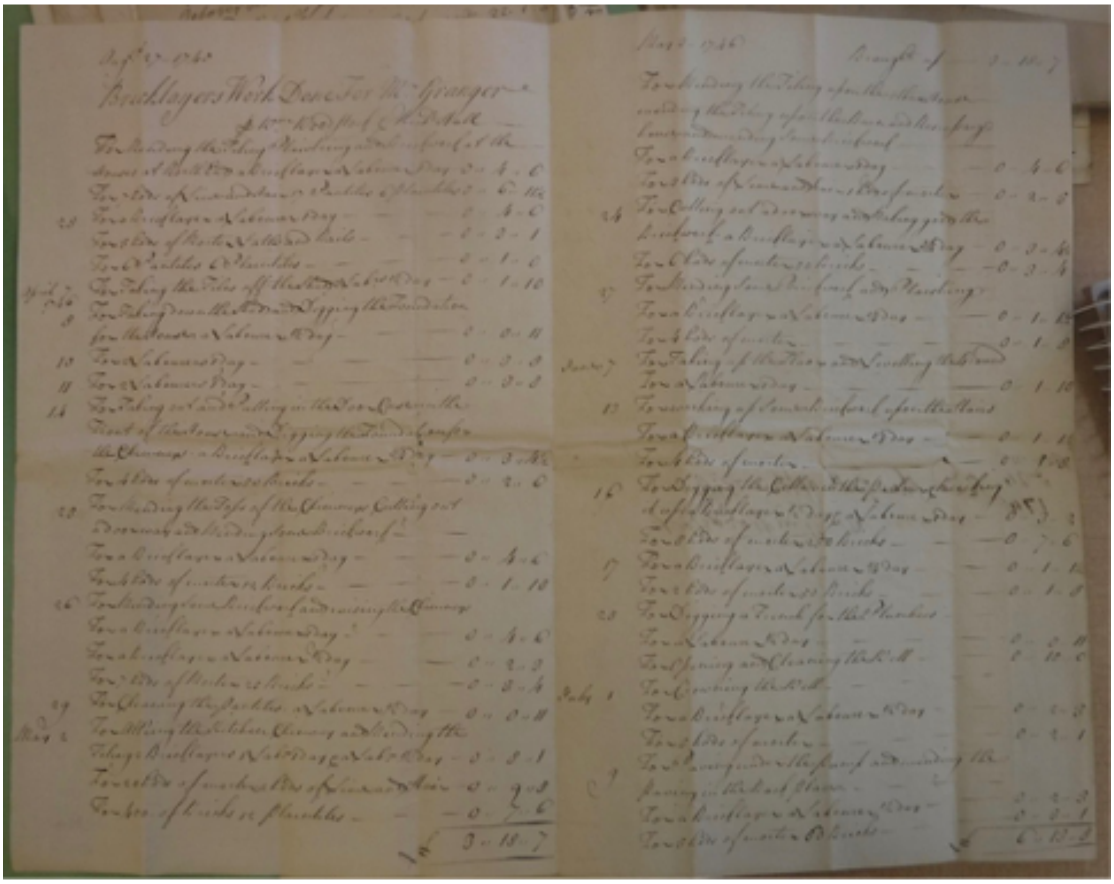
The said bricklayers to allow for all ye old materials as they are standing at 25 shillings per rodd for ye brickwork; 8s per square for plaintiling and 7s 6d per square for pantileing & to pull all down, dig ye foundations, cellars, well & Bogg houses & clear ye premises etc.

To which agreement ye partys aforesaid have sett their hands this 15 of May 1728.

Articles of Agreement between Mr Granger & Mr Jos Swafford, Carpenter for building six new houses at Hammersmith in manner following:

Said six houses to be built as per plan with a celler, two rooms & a garrett over ye same.
The height of the celler 6 foot clear
From ye first floor to ye underside of ye 2nd, 7 foot clear
From ye second floor to ye underside of ye garrett, 7 foot 4 inches clear.
To inclose a clossett with deale framing in each room adjoining to ye chimly & likewise under ye stayers on ye first floor with a shelf in each to inclose ye landing place on ye second and garrett floor with deale framing; to put a two light window frame 4 by 9 inches sqd in ye front & rear of each room, one in ye front of each garrett & a small light against ye stayercase of each house & one two light window frame of oak with a shutter of oak before ye same, to each celler to putt window shutters to ye front windows on ye first floor, to putt doorcaseing front and rear of each house with oak sills 6 by 4 ½ inches, ye doors of whole deale, glewed, lodged and battened with ¾ round; to erect bogg houses at ye lower end of ye Garden of each house, quartered and weatherboarded with a seat and floor compleat. To make a six foot fence between each house with five foot oak pales and a plank under ye same with oak posts and rails.

The girders of all ye houses to be 7 by 8 inches square; joyce 6 by 2 ½. All ye floors to be laid with yellow whole deales without sapp & likewise all ye stayers. Except ye Garretts & there to use ye boords of ye Old building so farr as (these) are sound & good & likewise ye timber of ye old building to be used in ye said six houses being sound and proportionable. To put a chimly piece and shelf to each chimly & hinges to all inside doors with hinges and fastenings to all outside window shutters; hinges and a bolt to each back door, and a good lock and hinges to each outward door & to cover ye well with 2 inch oak plank; to inclose ye pump & to make a communication from each yard to ye said pump. All ye aforesaid works to be completely finished in a workmanlike manner for ye sum of one hundred thirty six pounds.


Bricklayers Work Done For Mr Granger

Masons work done for Mr Granger at his house at Hammersmith by John Devall 1746

To 239: 0 feet sup new Purbeck paving
To 49:4 sup Portland chimney pieces
To 61:8 super, veined marble chimney pieces
To 76: 10 sup Rigate hearths and covings
To 30 iron cramps
To a pair of new Portland stone plinths to front doorcase
Paid carriage of 3 loads of stone to Hammersmith.

Weekly Time Book Commencing November 1810 Earl Poulett Estate, Hinton St George, Somerset; John Poulett, 4th Earl.

Masons, carpenters, plasterers daily activities.
Occasional Bills pasted to pages –

1811 The Right Honble Earl Poulett to Mr Vickery

June 28 To Drawing Stone and Burning 214 hundreds of Lime at 5 ½s

1812 A Bill for the Rt Hon'ble Earl Pulett by Saml Woodland

March 7th For burning 125 hogsheads of Lime at Strains Hill at 5s per hogshead

May 9th to burning 342 hogsheads of Lime at 5s per hogshead

July 17th 1812 Samuel Woodland – to repairing the Lime Kiln at Surrain Hill

Sept 5th To burning 170 hogsheads of Lime at 5s per hogshead.

Excerpt from main account: masons

May 8th 1812
Building walls to new stove room
Building chimney, Billiard Room…
Carting materials to church
Making Mortar (4 different batches).

January 13 1813 the Rt Honble Earl Poulett to Samuel Woodland
For burning 256 hogsheads of Lime by order of Mr Tewsley
For burning 4 ditto by order of Mr James
For burning 39 ditto by order of Mr Irish
Repairs to the Lime Kiln

December 24th 1813

For burning 121 hogsheads of Lime at Horcombe at 5d per hogshead, Isaac James

Nov 1813 To burning 356 ½ hogsheads Lime at 5d

Bill to Poulett from Thomas Andrews 1814

To 1844 feet of Capt Haydon's House Front & 2 ends,
Cleaning Walls, Raking Joints, Colouring Joints & Drawing Joints with White Lead at 2d per foot (work done in July)

Ditto from Isaac James June 3rd 1814

To burning 60 hundreds of Lime at 5d
To Ridding away

EAST SUSSEX ARCHIVES (ESA).

ACC 8648/3/25/5 (ESA01)

1737 & 1738 An account of the expences of the buildings at Hole Farm & of repairing all other of the buildings and fences.

The new Oasthouse cost as appears by the account £63
The enlarging the Hole Farm House…£130

In all – with extra works - £200-17-10

For building the Parlour chimney 1-11-6
For building the Brewhouse Chimney & oven 1-0-0
Repairing the Little House near Sadlescombe Bridge 11-3-0
Timber and carriage about £58-11-0

An account of the expence of building the Oasthouse at Hole Farm 1736
Paid the Sawyer's bill 6-8-4
Paid the Carpenter's bill 10-6-0
Paid the Mason's bill 6-1-9
Paid for deales and carriage 3-3-6
Paid for nails, hooks & rides 2-14-3
Paid for bricks and tiles 8-17-0
Paid for 5 load of Lime 3-0-0
Paid for a Bushel of Tarris 0-5-0
Paid for carrying Loam & sand
Paid for drawing Timber 1-19-0
For 13 tun of timber also 19-10-0
Allowed for the Rearing 0-15-0
Memorandum
The work of the Oasthouse was put out by my Father at the prices as under: The Carpenter 2/10 day, the Sawyers had 3/10 & no breaking nor kirff & halves allowed; the Mason had 2/6 for tiling in mortar and 2/10 (?) a yard for rough cast, walling and lathing.

An Account of the expence of enlarging the dwelling house at Hole Farm in the year 1737 as follows:
Paid the Carpenter's bill 24-8-0
More for cleaving of Laths 1-5-6
Paid the Mason's bill 14-3-8
Paid the Smith's bill for nails 6-10-0
Paid for Bricks and Tiles 31-5-10
Paid for 8 Load of Lime 5-2-0
Paid for hair for the walls 1-10-0
Paid for Deals for the Flowers 4-10-10
Paid for locks & nails about 0-19-0

Paid the Glazier's bill 0-3-16
Paid for carriage of Loam & Sand 6-2-6
Paid for drawing Timber 2-14-0
Allowed for the Rearing 0-1-0
For 18 tun of Timber 27-0-0
£130

Note: the Carpenter's work 9/- per square & take the timber upon the stem
& the oak flower boards at the same price
& the Deal flower at 5/- per square, joined down & door cases 8/- each; plain door & case 5/- & window lights at 15d.

The Prices of the Masons Work was as followeth, viz
For Tiling in mortar 3/- per square
For weather tiling 4/- per square
For 14 inch wall 10/6 per square
For 9 inch wall 6/- per square
For lath & plaister wall & ceiling 3d per yard
For brick pavement 3d per yard
For brick ditto, brick on edge 4d per yard
For building the Parlour chimney 1-11-6
For building the Brewhouse Chimney & Oven 0-1-0.

The Expence of Repairing of the Little House near Sedlescomb Bridge as follows, viz

The Carpenter's bill & nails etc 3-11-8
The Mason's bill 2-3-6
The Smith's bill & for more nails 1-1-0
Paid for Straw 9 square at 3/6 1-11-6
Paid the Thatcher's bill 1-10-2
Paid for bricks and carriage about 1-5-2

Note. The number of bricks contained in the several sorts is near the following estimate, viz
1800 bricks in 100 foot of 14 inch wall
1200 bricks in 100 foot of 9 inch wall
600 bricks in 100 foot of 4 ½ inch wall
300 bricks in 100 foot of single pavement

Note. Mr Wm Moon's account of the Carpenter's work to enlarge his house was as under:

For framing 8/6 per square & to take very good timber upon the stem
For laying deal flowers at 6/6 per square
For making doors & door cases 6/-

An account of money expended on Hole Farm, Field Farm, Whitedown & the Little House near Sedlescomb Bridge, begun in April 1776

The Carpenter 14-17-6
6 bushels Morter 0-4-6
20 fence poles 0-5-0
Geneva & sundry articles 0-8-6
Lime 1-2-9
Lath cleaving 0-9-1 ½
Repairing the Bridge 0-9-0
Baying the River 0-4-6
Driving a peg 0-1-0
Mending the hedges where timber was felled & stakes 0-5-0
100 fence poles 1-9-2
20 ditto ditto 0-5-0
lath cleaving 0-16-4
55 fence poles at 4d 0-18-4
25 more at 3 ½ d 0-7-3 ½
the Thatcher for mending etc 0-4-1 ½
5 bushels Hair 0-5-0
mending where timber was felled 0-3-0.

Mr Hyland's bill for nails 0-6-10 ½
The Thatcher & rope yard 0-1-3
The Pump Maker 0-2-8
The Mason's bill 11-13-0
The Blacksmith's bill 3-12-0
Lath cleaveing 0-7-7
A hasph & 2 staples 0-0-6
The Thatcher & rope yarn 0-2-0
Lath cleaveing 0-7-4
12 fence poles at 4d 0-4-0
23 fence poles at 3d 0-5-9
the Carpenter 31-10-0
118 per Slabs at 2/ 11-16-0
162 posts at 7d 4-14-6
the Carpenter 2-12-0
the Thatcher for mending 0-3-0
rope yarn 0-3-1
rope yarn 0-2-8
Mr Hyland for lath nails 0-2-2
The Thatcher for mending 0-4-6
The Carpenter 26-17-0
The Mason 7-7-6

The Blacksmith 0-15-0
Tiles & Bricks 21-15-0

Rope yarn 0-0-10 ½
Thatching the back part of the House near Sedlescomb Bridge 0-10-0
Mending the same 0-0-6
The Carpenter's Boy for his Box 0-1-0
20 Board Slabs 0-10-0

April 21st 1777
The Carpenter's bill 8-16-0
Paid the Thatcher 0-16-0
Paid T Chrisford for Straw 1-5-0
For 50 poles at 4d 0-16-8
2 locks 0-4-6
the Mason 0-1-0
the Blacksmith 0-8-6
5 bushels Hair 0-5-0

Jan 7th 1778
Paid for rope yarn 0-10-2
Paid Mr Hyland for nails 0-5-3
Paid for Tins for the Frame 0-11-0
Paid the Carpenter 3-9-7
Paid the Blacksmith 0-3-10
Paid the Thatcher 3-17-6

March 1st 1779
Paid the Carpenter 0-2-11
I cut 124 trees for the above repairs,
9 or 10 cut since for new work.

1782 June
Thatching Breda Lodge, 11 ½ square at 3/
Thatching Cottage 5 square 0-15-0
24 nails and rope yarn 0-8-11

An account of the expence of building my House in 1779 and all adjoining.

March 1779 Going to Sedlescomb with Mr Wood to put it out 2-5-7 ½

June
Going to Sedlescomb with Mr Wood 1-5-7

June 18 paid the Carpenter 88-0-0
Paid the Mason 61-0-0

June 21st Paid the Mason 50-0-0

Nov 23rd Give the Men 0-2-6

Jan 18 1780
Paid the Carpenter 89-7-0
Paid same 3-5-10
Paid the Mason 111-0-0
Paid to same 0-12-0
Paid the Blacksmith 2-12-2

Jan 22nd
Traveling expences 0-15-8
A lock for Front Door 0-5-6

March 23rd Paid Mr Wood 5-5-0
Nov 25 Paid the Carpenter 22-14-0
Paid for nails etc 1-17-5 ½
Paid Mr Wood for 1179 feet of Oak Board at 16/- per hundred 9-8-8

Jan 12 1781
Paid the Mason 14-15-0
Paid for Bricks & Tiles 14-4-10
Paid for digging a well 3-10-0
Paid the Pump Maker 3-8-3
Paid the Blacksmith 2-18-0

Jan 9th
Masonry & Painting 5-6-0
Ironmonger's bill 0-10-0
A carpenter's bill 0-3-6
A blacksmith's bill 1-3-0
Bricks 0-2-6

Mar 20
1 iron back 1-3-0
carriage 0-2-0

the value of the trees I cut not included.

ACC 6077/22/11 (ESA02)

STANMER PARK. New buildings for Henry Pelham, MP for Sussex after 1722.

1722 An account of the carriages of Sandstone, Horsham Stone, Timber etc from Kenwards to Stanmer at 18 (?) per carriage. To Ditcheling, Keymer & Plumton. Best tolls at 12d per carriage; for Henry Pelham Esq 50 foot per carriage. Stone & 100 foot per carriage, Timber: Viz

in the year 1722
Sept 19 Henry Pelham Esqr's Team to Stanmer with sandstone
22 sandstone
24 sandstone
26 sandstone
28 Purbeck paveing stone

Oct 2
Purbeck paveing stone
3 sandstone.
5 sandstone.
6 sandstone
8,10, 12, 15, 18. 20, 22, 24, 30. Nov 20, 23; Dec 3. Sandstone and more occasionally Purbeck paving.
Dec 22 a load of Wainscot
March 26 1723 a load of Timber to turn arches on

Abstract of all the Workmen's, Artifcer's and tradesmen's bills which were concerned & imployed in the several Buildings & other Works done at Stanmer in Sussex for the use of Henry & Tho: Pelham Esqrs from the year 1721 to 1728 inclusively, shewing the nature, quantity, carriage & value of all the materials used in the said buildings, together with all manner of Workmanship performed by the said Workmen, under the direction of Mr Nicolas Du Bois, surveyor to his Majesty's Buildings, the whole distinguished under the following Heads, viz

1. the main House
2. The offices, viz the Kitchin, Bake-house & scullery; the distill room; the Steward's Hall & closets; the Servants Hall; the Butler's room or Panetry; the dairy & larders; the wash-house & laundry over; the brewhouse & malt granary; five stables for above 30 horses, with several harness rooms, stair cases, hay lofts & lodging rooms over; four Coach-houses & lodging rooms over; a large granary over the Gateway to the Stable yard; the wood house, charcoal house, sea coal houses; the Hen house, chicken coop, Dogg Kennel, Forge-house & four houses of offices.

The out-works, viz the removing a large bank of chalk; levelling the Bowling Green & garden; making all the slopes & Terrasses etc; turfing them; digging the Canal & sloping the bank of it; levelling & pitching the middle court on the back from the house; all the Coach-way in the great Court, all the Brewhouse yard & stable yard & all the avenues to the House; repairing the new Roofing the Pidgeon house; making a long shed in the Brewhouseyard with severall Partitions in the same; building a house in the Wilderness for the Gardiner to put in his tools, feeds etc; building a brick & flint wall between the great court & the garden; another brick wall between the Bowling green & the middle court in the Back-front of the house & another between the said middle court & the

Brewhouse yard & between the Brewhouse yard & the stable yard. The flint wall round the hay-rick yard & all along the lane from the stable to the Church yard & from the said church yard to the gates & under the strait & circular Pallisades; repairing the Porch of the Church; the roof & the walls of the said church & the Pew of the family in the said church; making and fixing severall swing gates & doors in the road & church yard walls & all the work round the Dung Hole in the stable yard; making & fixing 30 Portland stone shidds (?) on both side of the Coach Way in the great court; making & setting a stone curb & dwarf wall under the iron gate & rail at one end of the terrass walk before the house & all the said Ironwork; three large Portland stone Pedestals & six bricks & stone peers to the two outgates & at the head of the Pond' the outgates, strait & circular Pallisades; the Portland stone steps & paving from the great court to the Terrass walk, before the front of the house & all the stone steps on the Bowling green & slopes; the stone capping & steps & the Purbeck paving in the middle court & in the passages going to the two necessary houses; & a large stone horse block & steps to the same by the Brewhouse yard gate; severall drying & leaping posts etc
Farm-house, stable, cart-house, granary, out walls & pitching about the said farm house & Parish well. The work done in the Parish well; the water-engin; the reservoir; the elm & lead pipes; the fire-engin; the pump in the Brewhouse yard. The kitchin garden walls, the Peers & gate & doors, the long shed, the Bason, pond, sluice & drains etc.

Quantity of Materials (costs not included here, generally. Also where used)

982,950 Bricks – Cost £865-13-9; Carriage £315-19-9 ¼
160,612 Plain Tyles £126-9-7
35,600 old tyles
6479 Hollow tyles
1000 Dutch glazed pantyles
2200 common pantyles
71,000 Dutch Clinkers
751 loads of flints
317 ditto from the old house
5 loads of boulders
1235 loads of sea sand
339 loads of Land sand
12 loads of Loome £0-6-0 carriage £1-10-0
44 loads of gravel
114 loads of Clay £4-5-0 carriage £28-17-6
110 loads of small chalk
1111 1/8 loads of Lyme £480-4-3 Carriage 29-1-3/4
19 ¼ bushels of Tarriss £3-15-5
1770 bushels of Cow hair £59-0-0 carriage £10-13-0
118 tons by ft cube of Portland stone £234-19-4 ½ carriage £25-11-10 ½
10 loads of sandstone £5-0-0 car £7-0-0
315 loads of old sandstone from limefield £157-10-0 car £283-9-10 ¼

4802 ¼ foot of Purbeck paving £80-4-4 ½ car £11-4-0
250 foot of old ditto from Limefield
290 ¼ ft of old ditto rubb'd from the old house £7-5-0
124 ½ ft running of Purbeck stone steps
34 loads 25 foot of Healing stones from Limefield valued £15-8-2

100 loads of Healing stone from the old house
462 ft of Rygate stone
150 loads 6 ft cube of oak timber £356-10-7 car £69-16-2
65 loads of old ditto partly from Limefield, partly from the old hose
370 loads 41 ½ ft cube of Firr timber £629-12-4 ¾ car £123-4-10
39 ft cube of Beech timber
1 load 27 ft cube of Elm timber
261 yards 4 ft of Elm pipes £30-8-10 ¼
3 wainscot logs
1366 ft sq of oak planks
16445 ½ ft of oak boards £216-10-8 ¾
455 deal planks £71-6-0
8m-8l-147gr deal boards
1218 bundles of oal laths £88-10-8 car £2-17-1
142 bundles of stone healing laths
130ft running of Eave laths
25 bushels of tyle pins
1 bushel of stone healing pins
50 firrs
14 load of ledgers & putluggs
362 ½ lb of cords & ropes
4 ladders
3 grinding stones
a large beam & scales
2 tons-17-2-16 of iron & steel
9 (hw) of old iron
25 tones -2-2-0 of lead in pigs & sheets £452-17-1 car £8-9-0

6 ton –1-0-0 of old lead valued
0-5-0-0 of solder
250 lbs of whitening & 21 barrels of Lamp Black
1415 ft sq of crown glass
25 ft sq of venus glass
906 ft sq of Castle glass
733 ft sq of old glass
52 ¼ lbs of glue & 24 gallons of Tarr
6 ½ of tallow candles
32 brass locks
144 iron & stock locks & staples
139 latches
34 pairs of dovetailed door hinges

210 pairs of common door & shutter hinges
2 slidding bolts & latches
47 bolts & staples
8 doz of harness rings
9 drop knobbs
5 pieces of sash line
136 dozen of wood screws
0-20-2-24 of nails, rivets etc
229 ft sq of black wire
4 ft sq of brass wire & pins
293 yards of old wainscot
4 old marble chimney pieces
2 pairs of harnesses & horse waces

Workmanship (broken down by building)

Diggers & Levellers
Masons (£653-16-4)
Bricklayers (£367-8-5 ¼)
Carpenters & Turner (£507-16-10)
Joyners & carver (£482-8-4 ¾)
Sawers (£18-0-8 ½)
Plumbers 86-17-7 ¾
Glazier
Blacksmiths
Plasterers £205-4-5
Painters 144-6-2 ¼
Engine Makers

Total of workmanship £2756-13-5 ¾
Total of the Materials £3866-13-11
Measurer £38-8-0
Clerk of the Works £80-0-0
Surveyor’s Fees £398-10-0
Surveyor’s Fees £398-10-0
His travelling charges £29-14-6

August 1771
Memdm relative to the stone that may be had in Kenwards of the same kind as the front of Stanmer

Part of an old wall of a Barn that has been taken down many years, about 28 ft long & 4 ½ ft high, and would produce stone enough to case about 126 square feet of front work – Expence of taking down and sorting the stone, abt £0-10-0; carriage of about 4 ton of stone to Stanmer in the rough £2-6-0

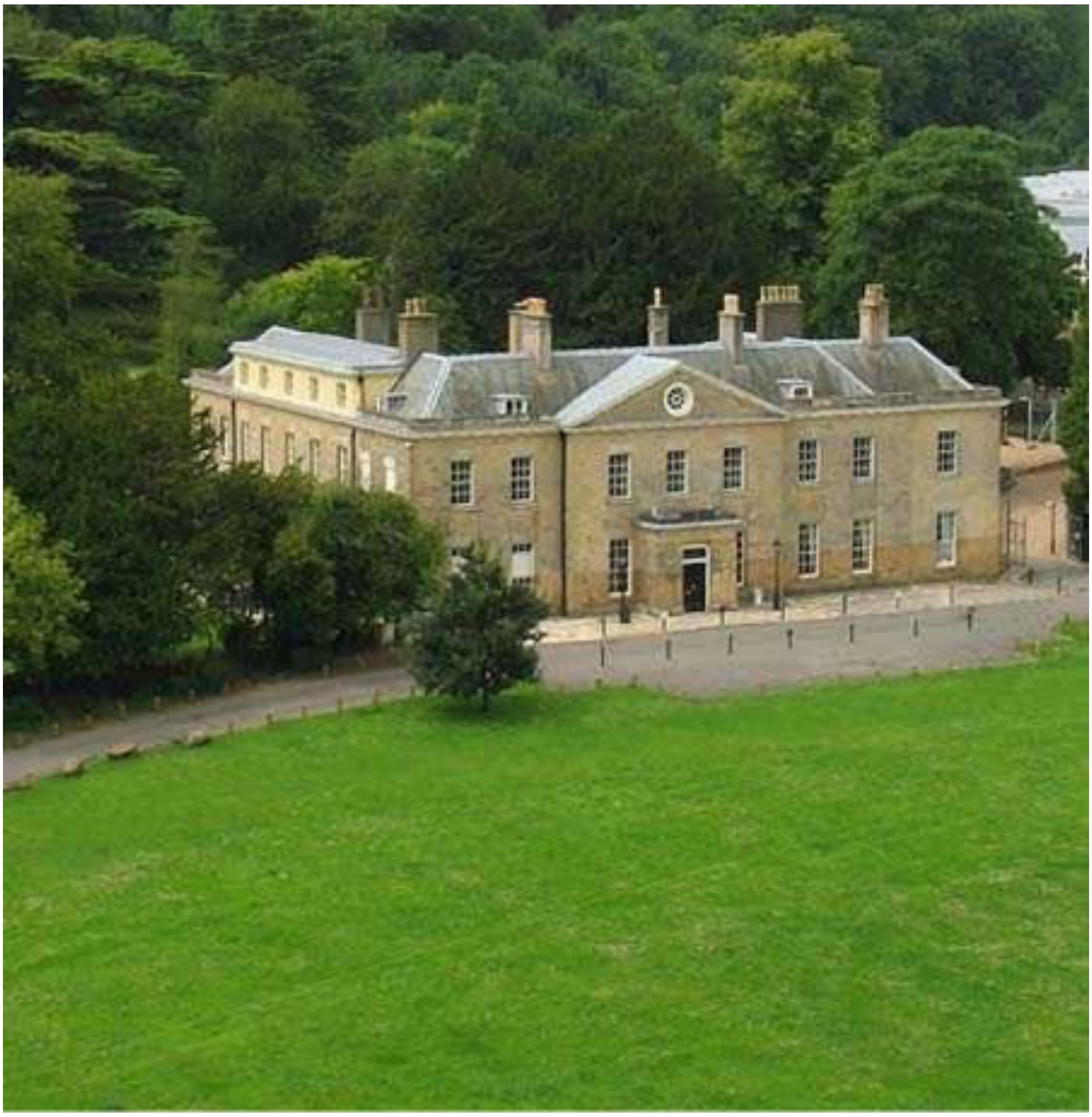
The wall of a courtyard before the house, 70 ft in circumference & 6 ft high might be taken down, is good stone and would afford enough to case about 400 square feet – expence of taking down this wall and sorting the stone etc abt £2. Carriage of about 12 ton of enough stone to Stanmer £5-8-0

NB If this wall is taken down, another fence must be put up in its place to defend the house, and might be done with Timber – expence of putting up a Timber fence before the house instead of this wall, timber included £3-12-0

An old Malthouse now used as an Oast house has a casing of stone with inside the brickwork abt 30 ft in length and 6ft high which if taken down would afford abt 100 ft – expence of taking down this building to get at the stone and working it, abt £6…carriage abt £2-5-0

NB This old building is quite ruinous, and if not taken down will soon want considerable repairs. If it be taken down a new oast house must be built to which it would be right to add a room to store the slops in, or to be used occasionally as a Granary, such a convenience being much wanted. – Expence of building a new Oast house & granary compleat, exclusive of the old materials would be abt £30. The expence of repairing the old one would be abt £20…

If the two first articles would afford stone enough for the purpose, it would be well not to disturb the Malthouse, but before any of this stone is taken down it would be necessary for a workman to take the exact size and length of every corner at Stanmer that is intended to be added, that it may be known whether or not, or what part of this stone will answer the purpose. The size of these corners seems to run from 6 to 10 inches. The stone is supposed to be from the quarry at Scareman's Hill, alias Seame's Hill, which is nearest to Stanmer by 2 or 3 miles…



FRE 8828 (ESA03)

SAPCOTE 1801 Repairs & Building of new houses. (Sapcote is a village in SW Leicestershire)

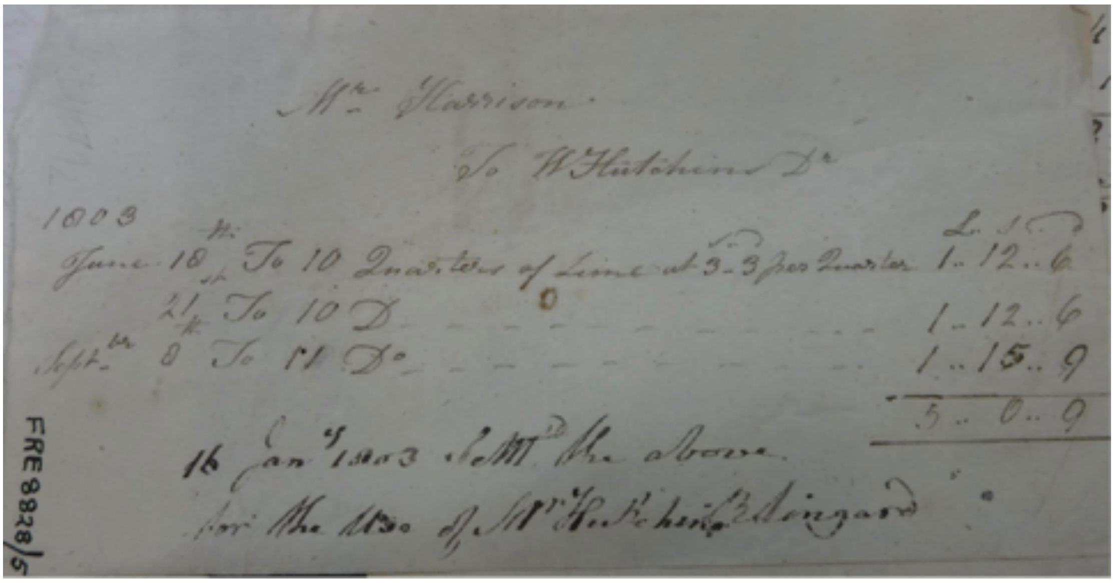
Money laid out at Sapcote in the year 1801 in Buildings, Repairs etc etc etc by order of J. Frewen Turner Esquire

1801
Jas Ellis 117 days work at 2s per day 11-14-0
Francis, Michl & Richd Hunt for wood and work
Edmd Clarke & Mr Shiner for Ale 16-18-6
G Nixon for wood and work…
Wm Cotton, the remaining part of his bill for building the Granary
Carriage of bricks, Lime, wood, etc
Jn Messenger for fetching Board from Pailton
Pd Mr Walker and Mr Smith of Hinckley and Miss Smith of Sapcote for Nails, Locks, Joints etc
Pd for 21 ash poles and 50 bunches of heart lath…
Six loads and part of a load for Straw
Six loads of stubble
(various workers)
Paid Welton for sawing boards etc…
61 quarters of Lime…
William Ellis for work taking down the Kiln
Thomas Clark for stones…
7 ½ Strike of Hair 11s 6d Two scuttles
Wm Cotton & his labourer for work in taking down the Kiln, Laying the foundation, cleaning bricks etc
34 pounds of Tar Ropeing
Paid for repairing the Kiln Pump…
Mr Towle for bricks, as per bill
Mr Craddock for Deals
Mr Cort for 50 bunches of Reeds
(various payments for work)
Mr Brown of Thorpe for Board & Squares…

Rec'd of Mr Burroughs for Bricks and Lime

1802
Wm Cotton for building Friendly Court…
Jno Bray for an Oak window frame
Sawyers allowances & Ale at Wood cart, brick carts…
Wm Harrison for carrying Bricks, Lime, Wood etc…
Paid for 22 quarters of Lime
Ricd Hunt for cleaving 9 bunches of lath
Thos Messnger for drawing wood & earth…

Paid for Hair and carriage from Hinckley
Paid for straw and stubble for the 2 new houses and Hunt's Houses
Wm Cotton for building 2 houses in the Lane
For glass for 2 houses and Elm boards as her bill
…for elm boards
Mr Harris for Deal…

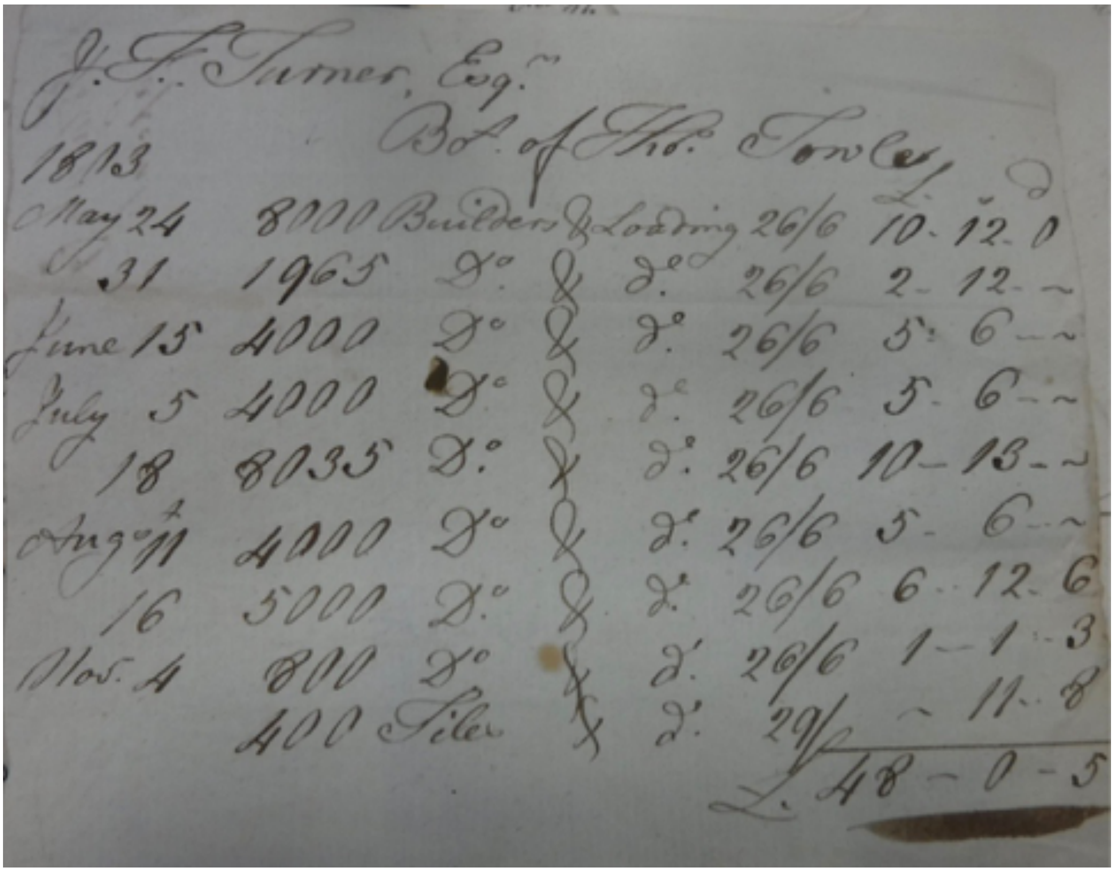

Mr Harrison

To W Hutchins Dr

		L s d
1803		
June 18th	To 10 Quarters of Lime at 3-3 per Quarter	1..12..6
21st	To 10 Do	1..12..6
Septbr 8	To 11 Do	1..15..9
		5..0..9

16 Jany 1803 Settd the above
for the Use of Mr Hutchins [illegible]

FRE 8828/5


J. F. Turner, Esq.

Bot. of Thos. Towley

					L
1813					
May 24	8000	Builders	& Loading	26/6	10-12-0
31	1965	Do	& do	26/6	2-12-~
June 15	4000	Do	& do	26/6	5-6-~
July 5	4000	Do	& do	26/6	5-6-~
18	8035	Do	& do	26/6	10-13-~
Augt 11	4000	Do	& do	26/6	5-6-~
16	5000	Do	& do	26/6	6-12-6
Nov 4	800	Do	& do	26/6	1-1-3
	400	Tiles	& do	29/	~-11-8
					L 48-0-5

Estimate of Repair (no date) 165-6-9
44 feet of ? (Sell?) at 6d 5 by 6
2270 feet of joist 2 ½ by 5 at 2 1/2D
28 feet of Plats to Out let at 6d
56 feet of Principal rafter 4 in by 7 at 6d
12 post 96 feet, 21 by 8 at 6d
1288 feet of rafter 2 ½ by 4 at 2d
1808 feet of Punchion & brace 2 ½ by 4 at 2d
1276 feet of ash lath quarter at 2d
70 feet of Coller at 2d
1 Mantle piece
board to lay Back Chamber floor
board to lay Garretts

ACC 6077/15/26 (ESA04)

Tidebrook Church & Parsonage1850s

A Tank to be constructed in the Yard at Tidebrook Parsonage – circular, 8 ft in diameter and 12ft deep in the clear – to be built of 9 in brickwork laid in Cement, grouted with Cement every course and entirely rendered with Cement when completed. The top to be domed over in the same manner with the same materials, leaving a Man-hole which is to be filled with a York stone cover to remove – provide and fix iron ring to same for purpose of lifting. Lay 4 in pipe from Tank to Drain, to take off surplus water – also stench trap to be provided and fixed so as to prevent any offensive smell from tainting water in the Tank, and provision must be made to prevent overflow or surplus water from returning into the tank in case there should be any sloppage in the drain. Also provide and fix 1 ¼ in stout lead pipe from the tank to the back kitchen, the same being fitted with stop cock, so that the water can be pumped into the back kitchen, either from the well or tank, at pleasure.

BRN/15, 16 & 17 Mason's daybooks (ESA05)

BRN/15

The masons in question were what would now be termed Monumental Masons, cutting and fixing mainly headstones and memorials, more occasionally steps and paving and chimney pieces, more occasionally repairing porticos, building the odd wall.

1847-48 Headstones, slabs fixed; paving. Regular entry for 'casks of cement' at 14s a cask (11s for contents, 3s for cask).

Examples:

‘Edgar Blaker Esq. Repair stone step and drain in front of house, Winchurst. 5 hrs and 4hrs. 1 quart cement.‘

‘Rev E Venables. A Portland stone grave cross to plan as per estimate £6 10s. 106 letters engraved; 207 more in verse £1 19s’

To Geo: Cheesman & son. For 8 casks of cement; 5 empties returned’ Also plaster.

‘Cement’ normally by the cask; plaster by the quart.

‘Cliffe Church. Fitting and fixing stone curb and iron fence at back of church…2 gallons cement; 1 quart Portland cement’.

BRN 16

Lots of cement; occasional Portland cement. Much more occasionally, ‘mortar’.

1850 ‘2 gallons Portland cement used by plasterers’.

For Sussex Archaeological Society.
Building walls and coping with concrete and making good upper room in west tower and laying brick paving and hearth….30 paving bricks; 3 gallon cement, 12 tiles. ‘**Thatching walls to prevent frost from destroying the new work’.**

WILTSHIRE AND SWINDON HISTORY CENTRE (W&SHC)

2057/A2/11 (W&SHC01)

Wilton House Weekly Building Account 1809-10. Extracts.

(Agent: Clement Bassant; Bricklayer: Thomas Talbot.

Nov 1809

Labourers 6 days digging foundation for Great Court walls and serving Mr Talbot; removing of ground from roots of trees and levelling the Great Courtyard and beating of clay etc

Dec 9th Talbot closing up doorway betwixt Chapel Gallery and the Reading Room.
Labourers digging of foundations for Court walls and driving piles etc; serving Talbot; sawing and facing stone.
Dec 30th Talbot at walls to support the Portland stone paving, North Hall

January 1810 Talbot following up stonemasons with bricks in North Hall; at dwarf walls under the stone floor in North Hall.

(indoor working or working outdoors preparing ground and materials – no building outdoors, apparently, during Dec and Jan except small-scale, where the work may be easily protected from the weather).

1461/928-940. (W&SHC02)

Goddards of Swindon.

Mainly comprises work books of mason/bricklayer carrying out repairs across properties in the ownership of the Goddard family, including the Goddard's Arms, which still remains.

A L Goddard Account Book with R Horsell.

1862

January. 38 feet run of **cement skirting** at 3d a foot at Mr Vincent's.

March. 1 ½ peck of cement and mortar. Lime whiting stable and wash-house at 4d per yard.
Repairing slating at Mason's Arms – man and apprentice ¼ day 0-1-6
Cement and mortar 0-2-0
45 yards of lath and plaster 2-5-0

May. Repairing slating in the cottages near the barn:
Man and apprentice ½ day 0-3-0
1 peck cement 0-1-6
mortar 0-1-0
colouring the front at Elleson's.

June. **Lime whiting outside of Mr Hall's house**, Westleat:
Man 1 day
Man 2 days
Boy ditto.
Lime wite 0-3-0
Colour 0-1-0

1864

Feb 2
Taking down stone chimney top of the house and fixing 2 new and repairing slating:
2 men 1 day 0-7-0

2 chimney tops 0-9-0
3 pecks cement 0-4-6

April.
Repairing and whiting the house stables etc at the Mews Farm:
3 men and boy 4-11-0
14 bushels of lime 0-7-0
76lb of plaster 0-9-6
2 (?) of whiting 0-9-4
2 firkins of size and coulours 0-6-6
laths, nails and hair 0-3-6

May 4
Repairing and whitening 2 cottages, Lower Town:
Man 4 days 0-14-6
3 pails of white and size 0-4-6
2 pails of coulour 0-4-0
12 lb of plaster 0-1-6

April 2nd
Work done at Beerhouse:
2 masons 1-18-0
150 bricks
2 loads of dirt 0-4-0
2 quarters of lime 0-8-0
Man 11 ½ hours (mixing) the same 0-4-7 ½

Wall at Quarry Cottages

2 masons 10 days 2-3-2
2 labourers 6 ¾ days 0-13-6
2 loads dirt 0-4-0
2 labourers 1 day each digging foundations.

May
Laying paving in garden by greenhouse:
2 masons 5 days 8 hours 1-3-2
Labourer 3 days 0-6-0
206 feet super of banked facing 5-11-7
mortar for same 0-6-0

Building closet at cottage:
2 loads dirt
1 ½ quarters lime

June
Repairing Hall

2 masons 11 days 9 hours 2-7-7 ½
labourers 10 days 8 hours 1-1-7
8 ½ quarters lime 1-14-0
6 loads dirt 0-12-0
3 loads ashes 0-6-0

1865

Feb 10
Repairing Mr Vincent's at Hiscocks, Newport Street and lime whiting:
Man and boy 1 ¼ days 0-6-6
Cement and mortar 0-2-0
Lime white and bricks 0-2-6
200 laths 0-3-6

March 3
Man and boy 2 days 0-9-0
2 pecks cement 0-4-6
2 bushels lime 0-1-0
hair and slates 0-3-0

9/28/61(W&SHC03)

Memorandum book, Maldon, Amphill, Bedfordshire 1693. pp 41-42
Values for Building.

Building.

Bricklayer

Brickwork, to find all, at a pole £6-0-0
The workmanship, a pole 1-4-0
Tileing, to find all, at a square 1-5-0
The workmanship, a square 0-3 ½-0
Seeling, to find all, at a yard 0-1-0
The workmanship a a yard 0-0-6
Rendring, to find all a yard 0-0-6
The workmanship, a yard 0-0-3

Roofeing, to find all, a square 1-10-0
The workmanship, a square 0-8-0

Carpinter

Flooring, to find all, a square 1-6-0
The workmanship a square 0-8-0

Boarding to find all, a square 1-8-0
The workmanship for strait joynts, a square 0-8-0
Ordinary workmanship, a square 0-5-0
Partitions, to find all, at a square 0-18-0
The workmanship, a square 0-8-0
Seeling joyce and ashlaring to find all, at a square 0-12-0
The workmanship, a square 0-6-0
Windows of Oake timber, 6 foot by 4 foot, to find all, at a square 0-12-0
The workmanship of a window 0-4-0
Ordinary Doorcases, to find all 0-8-0
The workmanship, each 0-4-0

Joyner

Norway Oake wainscoat, to find all, at a yard 0-7-0
Firr wainscoat, to find all, at a yard 0-4-6
Wainscoat Doors of firr 6 foot by 3 foot, projections on both
Sides, to find all 0-12-0
The workmanship of such a door 0-5-6

Plomer

Lead, cast into sheets, at a hundred 0-17-0
The workmanship of a hundred of lead 0-3-0
Sawder, a pound 0-0-10

Glazier

Square glasse, by the foot 0-0-7
Quarry glasse, by the foot 0-0-6

Mason

Masons work, paving free-stone by the foot 0-0-8 ½
Paving in black & white marble, by the foot 0-2-0
Stone steps, by the foot, to find stone 0-3-0

Smith

Casements, by the pound 0-0-8
Sadle barrs by the pound 0-0-6
Barrs of 3 quarries square for windows per pound 0-0-4
Smooth filed barrs for windows & doors, a pound 0-0-9
Joynts for shutters, large, a pair 0-0-8
Large joynts for great Doors, a pair 0-3-6

1369/4/40. (W&SHC04)

Bills etc between George Matchem Esq and various trades for work done at Plumley 1792.

Geo: Matchem Esq to James Emberley for work done at Plumley set by Estimate

1792
March 28 James Emberley 1 day **taking down old house**
For 3 men 3 days each.

May 5th James Emberley 2 days sorting Old Stuff
James Gatrell 6 ditto taking down old House
(three others 11 days total at same)

May 12th James Emberley 1 day
James Gatrell 4 days making Stools and Mortar Boards…

May19 1792 Paid for the House at Plumley

…Paid for cleaning brick
Paid for cleaning tile
Carting lime and sand
Paid for digging for water (?) and sand
To carting lime and sand
For a lode of poles from Poole
For a lode of lath and poles

May 22 to August 18

For 59700 of Common Bricks at £1-1-0 per thousand 62-13-9
For 7000 of Plain Tiles
For 1100 7 inch Pavors
For 1 dozen and half Hop Tiles
For 1300 Floore Bricke

Carried to Plumley

The Measurement of the Brickwork and Tileing at Plumley after deducting openings:

Brickwork 23 Rods, 1 Quarter and 17 feet
Tileing 24 Square, 1 quarter and 17 feet

Neal to Young for lime:

May 7 to 4 tun of lime 5-6-8

19 to 16 Hair 1-1-4
25 to 4 tun of lime 5-6-0
June 6 to 4 tun 10 hundred 6-0-0
10 to 4 tun lime 5-6-0
July 9 to 4 tun lime 5-6-0
August 27 to 3 tun 10 hundred 4-13-4
October 1 to 3 tun 10 hundred 4-13-4

37- 14-0

Carriage 14-3-0

G23/1/67 (W&SHC05)

Sarum, Ambrose Perry, agent. Building new Farmhouse at Laverstock, West Dorset.

An account of the charges necessary for repairing the house at Lastock (Laverstock). It is most proper to take off the stone from the roof and lay on theck (thatch), the roof being much decaid and is to weak for stone: first I will give an account of the cost of the materials wanting to perfect it:

There is wanting 40 loads of stone at 8s per load 6-0-0
There is also wanting 36 hogsetts of lime at 2s 6d per hogsett, the carriage of lime and stone included 04-0-0
There is wanting 8 hundred of read at £1 8s per hundred 11-04-00

There is wanting a hundred and a halfe of dealboards at £10 ?s per hundred carriage included 15-07-06
There is wanting 4 thousand of nails at 2s 6d per thousand 00-10-00
There is also wanting two thousand of flouring brads at 8s 4d per thousand 00-16-08
There is also wanting two thousand board nailes at 10s per thousand 01-00-00
There is also wanting 58 pound of ironwork as hooks and twest spike nailes and bolts at 4s per pound 00-18-08
There is wanting 6 thousand of nailes at 1s 8d per tho: 00-10-00
50-15-04

I hath not taken any notice of lafts and square timber, I suppose that will be had on the same estate labour.
I am come now to give an account of the cost of the 55 parch of masons work at 1s 8d per perch 04-11-08
Pointing and mending the old walls 01-04-00
21 square of carpenters work now framed in the roof and partition at 6s 6d per square 06-16-00
the stairs must be new and will come to 01-10-00
the mending the old roof 02-15-00
making doors and windows 01-04-00
10 square and a half of frowering (flooring? Lathing?) at 6s per square 03-11-06
the thecker's work 03-10-00
150 yards of sealing at 3d per yard 01-17-06
Sawing 1400 foot of square timber at 2s 8d per hundred 01-17-04
For making 3 thousand of lafts at 3s 4d per thousand 00-10-00
Fileing and thirt cutting timber 00-12-00
29-19-00
50-15-04
80-14-04

The farmer complaines of the badness of the barnes walls and it will cost five pounds to repair them 85-14-04

I have bought as much timber more as comes to 4-5-0
I have 2000 of bricks to pay for 2-0-0
I have 6 lode of ston to pay for 0-10-0
1 have 12 sacks of lime to pay for 1-5-0
and nex week must By som Bords & more Ston.
Am in debt for carige to ye farmer…
the weekly bills for labor will not look large. I have brought them to use Spar but Cannot bring them to mak use of moss.
I think to make use of heling ston. *Heling means roofing; Hellier. Roofer)* I do not like the tile.

Laverstock July 30 1720

The lathmaker made 2300 of laths…Paid Mr Poll for 6 lode of Ruf Ston…5 lode of ston. One lode of brick; one lode of lime…

Laverstock August 13 1720

…I desire you would let me have a Bill nex week for fifteen Pounds for I am in det for 2000 of Bricks and 32 sacks of Lime & 12 lode of ston and shall have in nex week 6 or 7 tun of heling ston wich must be paid for att the deliverie…

Costs.

Paid Richard Huchins for six hundred of Elm boards…10 lode of ston…one lode of Lime…

Laverstock September 24 1720

…the work is non likle to be complete in a short time. I supos the farmer hath been with your worship, what account he give I no'not. But I supos he makes the worst of Every thing…

Paid for helers more…paid for hair…nails, **lime & hair** will be the onely materials I shall want more of…I have had 4 lode of heling ston from Hamton Hill at six pens the hundred, I shall want no more….the Carpenters work will be complete in 12 or 14 days time…

(date illegible) 1720

…here is nothing but the helers work as I no of that can hinder. The wether have been very bad for such work…otherwise I should finish before….altho' I have don many things beyond your worship's orders, for which I beg your pardon, the farmer is still Grumbeling & sais the house is never the better, only kept dry. Therefore I hope your worship for better satisfaction will send somebody down to see the work…

Costs for heling stone, hew'd stone, brick and lime.

The weekly accounts of the workmen & materials at Leverstok Farm. **Began the 5th of July 1720**

Will Cran *IIIII 5 day 0-7-6 for 3 lode of walling ston
Robt Cran *IIIII 5 day 0-7-6 for one lode of timber and one lode of brick
William Jarvis **III* 3 day 0-4-6 Paid for one Pees of timber
Henry Clark ****I* 1 day 0-1-6 paid for 1000 of 4 nails

July ye 11, the second week. Spent at Bimister with workmen 0-1-2; hors & carriage to Bridport 0-1-6…

Thomas Canterby **IIII 4 day 0-6-0 paid the Lathmaker…
Will Canterby **IIII 4 day Paid Mr Pall for 6 lode of Ruf ston & 2 lode of hewed ston 0-14-0…
Danil Ston II**** 0-3-0 for 5 lode of ston 0-16-8; for one lode of Brick 0-8-0; for one lode of Lime, 10 sacks 0-5-0

July ye 13 the third week.

Will Cran, Robert Cran, John & Henry Clark; Will Jarvis; Thomas & John Canterby on site. Paid Mr Phelpis for timber 4-5-0

August 1…the 5 week.

Thomas & Will Canterby (7 days each); Will and Robt Cran; Wm Jarvis; John, Will and Danil Ston on site.

Paid Rd Huchins for six hundred of Elm board 3-12-0; bought at Bridport 500 nails 0-1-3…Paid the farmer for carriage- for ten lode of ston 1-13-4; for one lode of Bord 0-8-0; for one loade of Lime, 20 scaks 0-10-0
For to lode of Sand 0-4-0; for bringin the timber home 0-4-0; for the use of his hors 0-2-0

August 8 the sixth week.

Paid the Limeburner 1-10-0

Paid Brag for 2000 of Brick 2-0-0
Paid for Cres till (ridge tile) and Guter till (gutter) 0-9-0
Paid the ironmonger 1-12-0
Paid the Smith 0-6-1
Paid the Limeburner 3-2-6
Paid at Crashorn & Bimister for Haier 0-5-6
Paid for making Laths 0-2-10
I let the helers work by measure:
A eleven Pearch at 11s the Pearch 6-1-0
For Lathing & Paisting at 2 ½ d ye yard, 99 yards 1-0-7 ½
For Plaisting upon wall 39 yards, one penny ye yard 0-3-3
For work heling the oven, mending the porches & whiting the hous all over when it is proper 0-11-0.

(lime being burned as roofing and plastering proceeds)
The carriage of my Boxes home 0-8-8
My first Jorny down to Leverstok 4 days 0-18-0
Myself 19 weeks & 2 days -2-6 per day 14-10-0

My Boy 10 week & 3 days 02-12-6
Paid hors hyer for myself & a man the first time to Hampton Hill & charges 0-4-6
Paid one hors hyer to Bridport & one hors hyer to hamton 0-1-6

I had the misfortune to Breck one of my Ribs, being throwd of ye Coach. The charge of ye surgons at Dorchester and Bimester with a hors & boy from Dorchester to Leverstok 0-16-0

For building and hanging Stable Wall 0-7-0
For Read and Thacking 0-13-4
For work for the mason about the barn, stable and pig-stye 0-3-6…
For two sacks of lime and hair 0-6-0
For two Masons two days to plaister the Milk house & other places where wanting 0-5-4
For glazing the windows 0-4-6…
For lime and pointing the windows 0-2-6
For three days work for the Mason to plaister the Chimney and (?) the Underground gutter 0-3-6
For thecking the Carthouse all over 1-11-0
For thecking the pig-stye…0-16-8
For thecking the Stable 0-15-0
For thecking the barn the most part 2-5-0
For for thecking the Straw house all over 1-7-0…
For a Carpenter for making of gets and other repairs about the houses 18 days 1-1-0

Laid out for Plaistering the Milkhouse at Laverstock Farm

For 6 hundred of 3d nails 0-1-6
For 2 hundred of 6d nails 0-1-0
For gathering 7 hundred of brindles (? Brambles?) 0-0-7
For ? hundred of Sape Larts 0-0-6
For 2 sacks of Lyme 0-4-0
For one sack of hair 0-2-0
For 3 days work for one of the plaisterers at 14d 0-3-6
For 3 days work for the other plaisterer at 16d 0-4-0
0-17-1

(Lime is regularly delivered, but no sand is mentioned. The mortar is almost certainly being made with earth and subsoil from the site, with lime added (or without). Lime deliveries are generally for finish plastering and for pointing and for lime washing)

Layd out for that part of the Church of Stoke Abbott that belongs to Laverstock Farm to repair.

Pd for seaven Hogsheads of Lime 0-17-6
Pd for two hundred of Slat 0-3-0
Pd for the Carriage of the Slat 0-0-6
Pd for three hundred of 10d nailes 0-2-6
Pd for for hundred of 4d nailes 0-1-4
Pd for Six hundred of 6d nailes 0-3-0
Pd for one hundred of 4d nailes 0-0-4
Pd for five hundred of tiles 0-12-6

Pd the Carpenter fouer dayes 0-5-4
Pd the Helier ten dayes 0-15-0
Pd for Glazing the window 0-2-0
Pd for two hundred of Larts 0-4-0
Layd out in all 3- 18-6.

2667/22/1B/1 (W&SHC06)

Wardour Castle. 1698

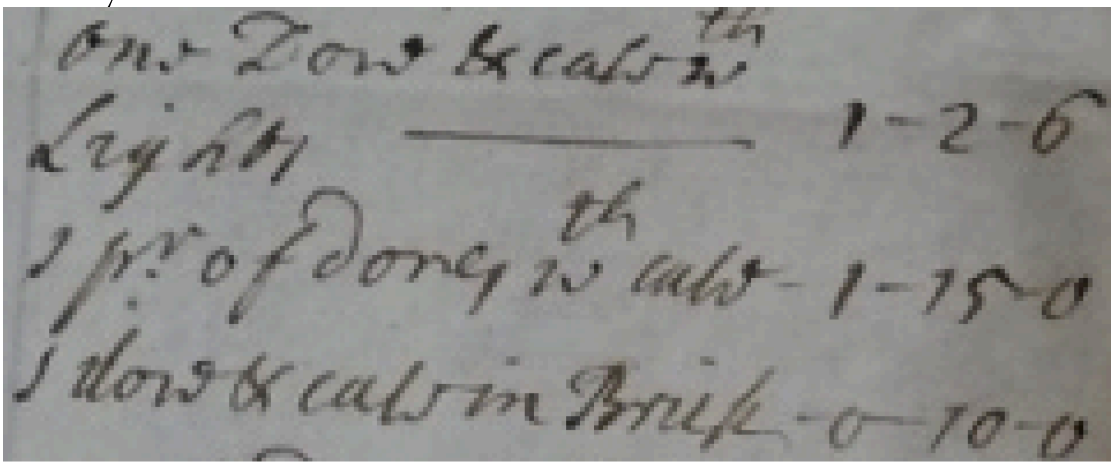
Rates for what is done by ye workman

	Per Sq	per yd	per foot
Flooring & Board per square	25	4-6	0-6
Ashlar and ceiling joists	.50	0-11 ¼	1 ¾
Partitions	.80	1-6	0-2
Naked flooring	1.75	3-2 ¼	0-4 ¼
Boarding	1.10	2-0 ¼	0-2 ¾
Grd flo. & board	1.20	2-6	0-3
Roofing	1.50	2-7 ½	0-3 ½
½ pace floor & bord	1.25	2-3	0-3
Naked Grinns (?)	2.5	4-6	0-6
Modill Cornice without			
Bed moulding per foot		12	4£
Ever Cornice of ye flatt		2-3	0-9
Lintolling at per foot			0-5
Window curb timber			
Timber of ye joyles		0-9	0-3
Girders and Bond timber per foot		1-1 ½	0-1 ½
Rayle & Balist		1-2-6	2-6
For Strings of 6 & 7 inches,			
Work & stuff		5-3	0-7
Strings 6 & 4 supra per ft		3-0-0	0-4
Architrave		4-6	0-6
Whole deal partitions		4-6	0-6
Skirting bord		0-9	0-3
Old wainscot in ye cellar			
Fitted up at 0-6d per yard		0-6	0-0 ¾
Ceiling & lath		0-9	0-3
Banc lathing		0-4	0-0 ½
Rendering		0-2 ½	0-0 ¼
New Purbeck laying		4-6	0-6
New Purbeck, not layd		2-7	0-3 ½
Polished Purbeck unlayd each		2-6	
Polished Purbeck wrought with			
An Astragal			3-4
Rough Purbeck unsett			1-4
Outside painting		0-5	0-0 ½
Quarries of glasse		3-9	0-5
Inside paint graining wainscot			
In ye parlour		0-10	0-1
In ye Garrett		0-10	0-1
Bolexion work in ye Garrett			

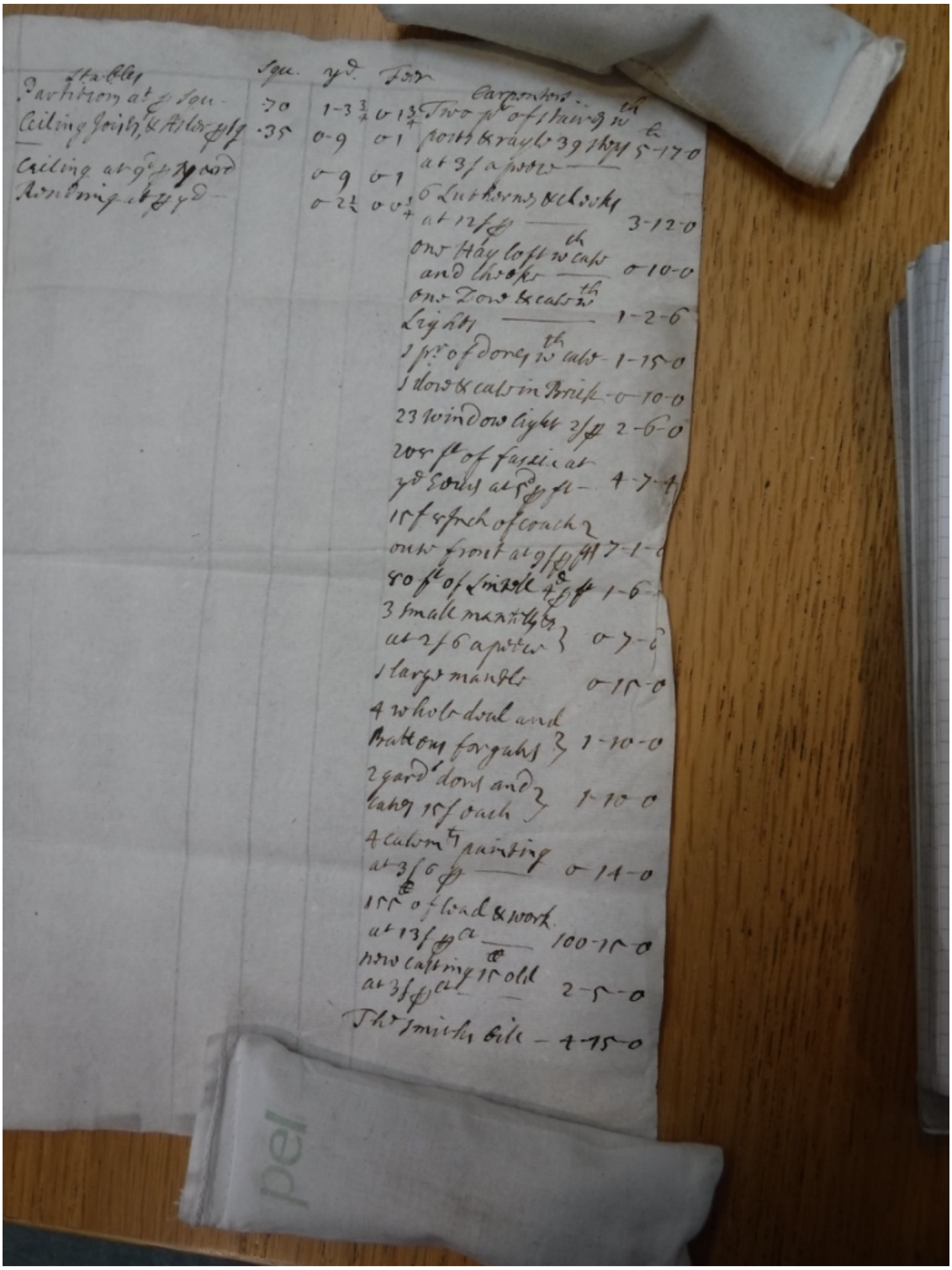
To ye Joyner		3-0	0-4
Plain deal wainscot		2-2	0-3
Bolexion work in ye parlor		3-4	0-4 ½
Plain deal wainscot		2-2	0-3
Reduced brickwork at 5.50 per Rod sq			0-4 ¾
Tyling per square	1-10	2-3	0-3
Paving in tyle	.80	1-6	0-2
…			
Roofing in ye stables	1.20	2-3	0-3

Carpenters

Two pairs of stairs with posts & rails 39 steps 5-17-0
6 Luthernes & cheeks (dormer windows) 3-12-0
one Hay loft…0-10-0


One Door & case with
Lights —— 1-2-6
1 pr of doors with case – 1-15-0
1 door & case in Brick – 0-10-0

23 window lights 2-6-0
208 feet of fascia 4-7-4


Stables | Squ. | yds | Tot | Carpenters
Partition at 4s 10s | ·70 | 1-3¾ | 0 1¾ | Two pr of stairs with
Ceiling Joists & Ashler | ·35 | 0-9 | 0 1 | posts & rayls 39 steps 5-17-0
Ceiling at 9d p yard | | 0-9 | 0 1 | at 3s a piece
Rendring at 4d | | 0-2½ | 0 0½ | 6 Luthorns & clocks at 12s p — 3-12-0
One Hay loft with case and hooks — 0-10-0
One Door & case with Lights — 1-2-6
1 pr of doors with case - 1-15-0
1 door & case in Brick - 0-10-0
23 window lights 2s p 2-6-0
3 small mantles at 2s 6 a piece 0-7-6
1 large mantle 0-15-0
4 whole deal and Battens for gates 1-10-0
2 gard doors and cases 15s each 1-10-0
4 casements painting at 3s 6 p 0-14-0
new casting 15 old at 3s p — 2-5-0
The Smiths bill — 4-15-0

The Woodhouse Charge at Warder 1698

The stone walling 1908.8
The ashler facing 1181-0

For 64 B of lime at 6d for every 30 ft solid 1-12-0
Carriage of 64 load of stone at 10d per load 2-13-4
Carriage of 64 load of sand at 8d 2-2-8

The Roof…the rafters being 15.4. Barnes Length 50 ft

For 20.5 tuns of Slatt stone at 10s per tun 10-5-0
Helliers laying and finding ?) for 1541 ft 3-04-4 ¼
For 41 bush of Lime at 6d 1-0-6
For 472 fower foot Lath 5 inch distance 0-9-0
For 6180 Nayles at 2/6 per thousd 0-15-3
The carpenters wages for roofing per square 6-4-0
For carriage of 20 tun of Tyle stone 2-10-0

The Carkasse

To ye carpenters for setting ye timber & framing ye body, 2 sides being 101 feet in length , height 10 ft, thickness 1.7?? at 16 d per square 2-6-0
To 3.434 foot at 16d per square as I suppose
To ye Sawyer for 1895 feet at 2/6 2-7-6
The value of 15 tun of rough timber 2-7-6

Stone Slatt…at Warder for porch, viz at 15 ft square superficiall or 225 ft

Raising 3 tun…
Laying and finding pinns…
2 sack or 6 bush Lime
Lath 120 4 ½ ft lath, 5 in. dist.
Lath nails

Lath Plaistering etc 116ft

10 bush Slackt lime at 2d per *(this would most likely be slaked to a dry hydrate, with water added to make a thick paste (putty) before mixing of the plaster. It will likely be for finish coats – see quicklime deliveries above and below)*
200 of lath
3 ¼ bush hair at 6d
400 of 3d nayls
750 Tyles 3 ½ gage
nailing and laying a square 0-3-0
6 ¼ bush lime at 4d per
a load of sand
a bundle lath (=100)
5d nails

Note: **30 ft solid or a mason's perche at Warder is a load in carriage and requires a Bush of Lime.**
Roofing 25 square for ye whole building.
Require of sand: timber 22 tun and 10ft att 5s 6d per Tun 62-5-4

The flooring with Summers and joysts 2928 ft requires 29 Tun and 36ft of sand.
Timber at 5s 6d per tun 83-12-0
Boards for 2980 ft at 20s per hundred 29-16-0
Carpenters waiges for Roofing 25 square at 5s 6d per square 4-7-6
Ditto for flooring 29 square at 2s 6d 3-12-6
Ditto for laying, joynting and plaining 29 square att 2s 6d without nails 3-12-6

Stone Slatt covering, pinning, **finding Lime and Lath**, raiseing, edging ye stone at 2s per square ye whole being 20 Square 20-0-0

Masons work for making ye wall of ye dayrye and kitchin, being 100 perch at 2s, agreed for 2ft thick, 15 ft super 10-0-0
For 150 Loade of Stone at 5s 37-10-0
For 444 Bush of Lime to answer 3000ft solid at 6d per Bush for ye wall 11-2-¾
Sand for ye same wall 1-4-4

Carriage not valued.

The Charge of the Banketing house at Warder in 1687

To Barrett Mason 15-0-0
To Sharp Carpenter 13-0-0
To Will: Skiner Joyner for 2 sash windows 2-19-0
To Leonard Gray for glasing them 1-4-0
To him for Glasing the other windows 1-14-6
To Rich: Ransome for Casements 3-17-6
For 106 dele boards 9-0-0
For elme boards for ye Stairs, 320 foot 1-18-06
For 77 Sacks of Lime at 2s 4d 8-19-8
For Cleaving 6300 Lathe at 4d per 100 1.0.0
Glew etc 0-1-1
Nailes for ye Stairs and floores 1-18-4
Barrs for ye windows etc 3-18-0
To Ed: Maine plummer, for casting and laying the Lead 8-10-0
He was allowed …for wast in casting.
To Waterman, free-mason for 18ft at 12d & 232 ft at 5d 6-14-0
Haire for ye mason

Agreed with Sharp for framing a Roof 37 ft wide, 98 ft long being 3625 ft or 36 ¼ square at 8s 6d per.
To him for framing a floore 25 ft broad 93 ft long at 4s 2d per square, being 1953 or 19 ½ square

Making a Cornish under the Eves.

Agreed with Thomas Fray, Hellier, for slateing the Roof being 37 ft one way, 98 ft the other, in all 3625 ft at 9d per perch, each being 35ft square, so that the whole amounts to 16 perch.

For plaistering upon lath the Ceiling of both Stables and whiting 1928 ft at 3d per yd square that is 214 yds
For whiting & plastering one cote upon the Walls, washing & sizing at 3d per yard 3479 ft in all, 386 yds square of both stables.

For falling and squaring 454 ft of timber for the summers, principles & lathing at 2d per 50 ft
For falling and squaring 250 ft more at 2d per 50 ft for boards…
For sawing 1960 ft of board at 2s 6d per cent
For sawing 235 ft of joysts, 175 ft of rafter,
Side-pieces 622 ft. principles 505, roof-beams 218, wallplates 305 in all…

Agreed with Barret, Mason to face ashler-way 2249 ft superficial at 3d per ft
To him for laying 5528 ft cube at ½ d per foot.
Sacks of lime for 5868 ft cube, 65 for stone-work; for 3625 ft square for tyling, 32 sacks; for 1928 ft square for ceiling, 8 ½ sacks, in all 105.

For framing the roof…
For framing the floore
For laying the boards
Making a Cornish under the eaves…

To the Hellier for slaiting…
To him for plastering the Ceiling
For whiting & plaistering on the wall
For falling & squaring timber 454 ft
For falling & squaring 250 ft more
Value of 250 ft for boards at 6d per foot
Value of the 454 ft of timber at 6d per foot
For sawing the boards
For sawing other members as joysts, rafters etc
Value of these members being 672 ¾ ft
For 105 ½ sacks of lime at 2s 6d per sack
To the mason for 2249 ft superficial at 1d per foot, hewing
To him for laying 5528 foot cube at ½ d per foot
To him for pitching 1302 foot in the grate Stable at 3d per yard
For making two chimneys at 1s 5d
For glazing 204 ft at 6d
For bringing the stone in place
For 6 stone windows molded at 6d per foot
For 2 doores at 3d per foot
For carriage and picking the stones to pitch
3 penny nailes for Ceiling, 25 thousand in all
for splitting 100 bundles of lath at 4d per
for about 40 bushells of haire for lime at 4d per
For sawing 626 ft of planks for the little Stable & the sawing of the sleepers about 370 ft

(another page saying the same)

To **Barret** ye mason for 15 days making the gutter under the stables at 3s 4d a day 1-0-0
To him for 42 days hewing & laying stones under the Bale-posts, forming the windows and making a doore-place betweene the Stables at 3s 4d a day 2-16-0
To him for 2 days placeing in timber for to lath behind the racks 0-2-8
To him for faceing ashler-way 2249 foot at 3d per ft superficial 9-7-4
To him for building the wall 5528 ft cube at ½ d per ft 11-10-4
To him for 2 chimneys by the greate 0-10-0
To him for carrying of stone from the castle for the Stable by the greate 5-0-0
To him & his men pitching & plaistring the little stable, 42 ½ days at 1s 4d per day 2-15-4
To him for raising the back wall of the stables & the breaches there 1-0-0

To **Sharpe** the Carpenter for setting up the racks and mangers, bale-posts, planking, making a staire-case, laying the floores, making doors in & over the Stable himself at 1s 6d per day, his men 1s 4d 27-8-8
To him for framing the Stable roofe 36 sq 15-7-8
For framing the floore 4-1-3
Laying & jointing the floore 2-5-6

Making a Cornish, by the greate 2-0-0

To **Tho: Frey**, heilier for new tyle to cover 6 perch at 15 ft square the perch at Wardour at 1s 10d the perch at the quarry 9-0-0
To him for slateing the stable 16 perch 7-4-0
To him for 4 perch over-measure at 9s 1-16-0
To him for plaistring upon lath 488 yds at 3d per yd 6-2-0

111-6-9

To him for plaistring upon wall 188 yd 0-35-8
To him for a perch more of tyling 0-9-0
To him for 2 load of paviers 0-14-0
To him for 1 day lathing 0-1-4

To John Waterman, free-stone Mason, 192 ft window at 6d 4-16-0
To him for 64 ft doore stone for the Stable at 12d 3-4-0
For 10 necks and bowles at 2s 6d a piece 1-5-0
For 94 ft crest with 8 windows, 2 doores at 49 ft all at 6d 3-11-6

Lime 98 sacks, brought home each sack 3s, some at 2s 6d & some at 2-4d per sack for the stonework 10-18-9
For 100 sacks more for tyleing and plaistring at 2s 6d & 2s 4d 12-14-4
For 4 sacks more at 2s 1 ½ d per sack for the stonework 0-9-0

To **Jo Abbot** and Joseph Glass, **Sawers** for 111 days at 2s 4d per 15-6-2
To **Ranson,** Locksmith at Shaftsbury for 6 casements 136lb at 8d per 4-10-08
For locks and hinges etc 1-17-10
For mending a lock & new bolts 1-9-0
For iron barrs for the windows at 3 ½ d per lb, 376 lb 5-9-8
For staples, rings, cramps etc 3-15-5

For 2 locks 0-2-2
For lath nailes 40000 at 3s 8d per 1000 3-6-8
For greate nailes 3-15-0
For 100 Deale boards at Limmington at 30d carryage from thence being 24 miles at #1 10s 5-13-4
For 20 boards more bought at Salisbury 1-0-0
For 4 days carryage of Tyle & pannier at 5s 1-0-0
For 121 days Carryage of Tyle, timber, sand & pitching stone for all the building at 5s 30-5-0
For cleaving 20000 lath at 4d per 100 1-6-8
For 239 ft of glaseing at 5d per 4-19-7

122-15-9

For laying the floore in the groome's chamber 0-9-8
For priming the doores, Cornish etc 4-0-0

For haire for the Mason 100ft at 4d 1-13-4
For labourers clearing rubbige 207 days at 9d per day in the garden 7-15-3

Sum total of the stables is £248-0-9

Memorandum of what sawed and squared timber is to be provided for the building of the Stables

Boards……………………….300
Plank timber………………......230
Summers……………………..275
Principles…………………….137
Lath timber……………………60

To be brought from Ansty

Tyle, about 40 load
Timber about 20

EAST RIDING ARCHIVES (ERA) Beverley.

DDHV 22/95 (ERA01)

Account for building garden wall, Langton

Tho: Norcliffe Esq to Geo: Willoughby *(bricklayer and brickmaker in Malton/Norton)* for building the garden wall at Langton by admeasurement in the year 1812. **Mr Willoughby doing the leading and finding all materials** except part bricks.

To brick and stone wall on north side of garden…a part built with Mr Willoughby's bricks and a part with Mr Norcliffe's.

The whole length 355 ft by 11 feet 2 inches…

To digging foundations…to building ditto with stone…

To turning one large arch (gateway) 7s 6d
2 small ditto (doors) 5s

Total £287-17-1

DDGR 30/13 (ERA02)

Grimston Family Archive.

Account, building unknown:

To three hundred of brick 0-3-0
To 6 bushils of lime 0-2-6
To Macener and his man each 2 days 0-6-0
To one iron anker weight 7 pound 0-2-2 ½
To 40 yards of wall at 1s 2d per yard 2-6-8
To 1 stone 10 pounds of spikes 0-8-0
To half a hundred of double cellfits 1-1-2
To 100 of twelvepenny nails 0-0-8
To 2 thousand of lat nails 0-4-0
To 7 ½ hundred of thach at 6 shillings per hundred 2-5-0
To thacher 10 days 6-6-0

DDPY 27/2 (ERA03)

Huggate Enclosure Award 1767

P13

Provided also, and it is hereby enacted, by the Authority aforesaid, that the said Commissioners and their Successors…shall and may, and they are hereby authorized and required to lay out, assign or allot such Part or Parts of the said Fields, Pastures, Lands or Grounds so intended to be inclosed, as they shall think most fit and proper for **common Quarries and common <u>Mortar</u> Pits, for erecting, making or repairing the Buildings, Walls or Fences** to be made in or upon the said antient inclosed Lands, or in or upon the said Allotments, and also for common watering places for Cattle.

WARWICKSHIRE COUNTY RECORD OFFICE (WCRO)

CR 734/6 (WCRO01)

Building specifications 1863.

Specification for the erection of 16 houses etc in the Tallisford and Parkes Street, Warwick for Mr Ayres Esq on part of the site of the King's Head Inn, stables, etc. *(These buildings now demolished)*.

Contractor: Mr Green.

(works to be done to the contract and specification with all extras or omissions to be valued as they arise).

Take down existing buildings, clean and sort materials for **re-use** as appropriate.

Owner to retain: 2 circular windows in stable, two racks and 3 stable doors and frames; grate and chimney piece and 2 windows in room over stable; fixtures and windows in saddle room and tiles on garden side of the old buildings.

Remainder for contractors use. He will value these.

Excavation. Foundations to be dug to a firm bottom; cellar dug down to 7 feet.

Bricklayer.

Sound stocks laid to English bond to height and thickness in drawings.

Cellar wall 14 inches to shop front.

"The front of the buildings to be picked stocks of uniform colour with gauged arches to doors and windows set with a **neat putty joint.** The mortar to consist of **one part blue lias lime to two parts sharp sand thoroughly incorporated and used fresh,** the courses to be properly flushed up."

(Blue lias the local lime. Hydraulicity varied significantly between beds, with thick, low beds the most hydraulic. Upper beds of little to no hydraulicity (Holmes, pers comm)

The walls to have at least 2 courses of footings. 2 courses of old slates **bedded in cement,** cross-jointed, to be laid over the whole surface of the walls one course above floor level to prevent damp arising.

Blue Staffordshire quarries to the floors…

The chimney tops to be finished in a plain and substantial manner, **the 3 top courses to be laid in cement.**

The walls through the roof and boundary walls to have proper coping set in cement.

Slater and Plasterer.

Bangor countess slates; gables square-filletted with cement.

Lath, lay 2 coats, set and whiten the whole of the ceilings.
Render 2 coats and set the walls (except wash-houses and closets, which are to be twice whitened); cement angle beading and cement skirting.

Carpenter.

Wood to be Dantzic or Regan memel fir…

Glass: Newcastle crown glass.

Quantities, Parke St.

Bricklayer
1350 superficial yards of 9″ brickwork
Bath stone window cills
York stone hearths and backs
Blue and red Staffordshire quarries

928 supeficial yards of render, float and set to walls
462 s. yards of lath, render, float and set, ceilings.

27 bluestone chimney pieces

Ridge tiles, copings etc.

CR 1291/318-319 (WCRO02)

Malvern Hall 1785 (Malvern Hall, Solihull)


(Constable)

John Soane for Henry Grizhold Lewis Esq.

Account of time.

1784

May 15. Taking down old garden wall and digging foundation

1785 May 10. Disbursements

177: 800 of old brick.
Made new at kiln 306: 300.
Others 67,000

Stone.

Stone from Mr Tatnall of Warwick.

321:9 of stone from Bikton for stair and fruit steps.
Stone from Hillsborough for the front and portico 405:6 @ 6d: 10-2-9

To 1238 Quarteres of lime and loading 191-3-0
Ditto lime from Birmingham 13-4-7.

June 1784

A/c of mason's work (excerpts)
To Hill 6 days squaring and loading stone at Merridon.

Taking down ballister and working string; taking down stone; sawing stone for gardin wall; **sawing old stone**; cutting out stone of old front; taking down old stone casing; fresh working old cills to front; working and setting strings to the wing.

To Hill 7 days working Cornish and string (7 more setting same; 15 days by Robert Hick; another 11 days by others); Hill working Cornish to wing; 2 ½ days taking out old string; 4 days **reworking old string**; William Twelves, **6 days taking down and working old Cornish; (more of the same).**

Blocking courses renewed; window cills renewed.

Oct 30 Taking down scaffolding from hereon with cills and string fixed.

(work complete by winter; then indoor working, then back outside in March)

November – internal works – stone for stairs (from Bilston); paving and chimney pieces.

March. Hill 6 days to portico and ballusters; ongoong work to both; plinths to court; portico steps.

Rosin and beeswax.

1784 Bricklaying Account.

Bricking up, partition walls, chimneys; bricking up windows; making good old brickwork.

Building scaffold for pediment; bricking up pediment and taking up chimney top; pargeting old chimneys; cutting away brickwork and making good. Laying of drains.

(Drawings of trusses and timber of partition walls).

Plasterer A/C 1784

Thomas Frazer, Sampson and Beckett 6 days ¾ lathing and plastering.

Lathing new south wing, Stephenton and Jones.

Frazer modelling of blocks (quoins?)

Cornish

Malvern Hall. Account of materials used in the addition

23,650 old brick
4,300 ft of old partition
11,000 old brick from yard and old staircase partition
45,800 old brick
9000 old brick from old court wall
3600 from old cellar, more from other parts

Lime delivered by Wm Baston to the garden wall.

1784 May-September

Between 5 and 48 quarters at a time, totalling 203 quarters
For loading 31-9-0.

June 17 1784

Mathis, 46 loads of sand
Asbury – 177 loads of sand to house
26 to the (brick) kiln
Asbury – to drawing sand and turves to the brick kiln
26 loads of sand to same
6 load of sand to the house
many more loads of sand

Lime delivered to the house

1784 – **May-October 798 quarters. Delivered every day or two throughout.**

Lime from Wm Boston 1784 Oct – Dec: 325 quarters.

Lime from Mr Wall, Birmingham. July – November 1784
13 quarters at 4s 6d. Neat weight 4 tons-13-1. 57 quartersof lime.

1785 Lime from Mr Boston. 50 quarters.

Coal to brick kiln from Bromfield, Birmingham. 136 tons

Much oak scantling; deal – yellow and white deal.

Harbone, Carpenter.

Making and fixing sash windows (along with all else).

Roof – green Westmoreland and welch countess slates.

30 foot (and more) of mason's cramps.

WEST YORKSHIRE ARCHIVES, LEEDS (WYAL)

WYL/678 acc 3810 (WYAL01)

Building a dwelling house and schoolhouse at Headingley 1783-1805

(no lime in this account, Earth and sand.)

Stonework or walling at 1s per rood
Slating and pointing at 3 ½ d per yard
Chimney pieces at 3s each
Stone steps for the chamber stairs at 4d per foot.

Dwelling house – 18 feet long by 20 broad with a chamber above.

Schoolhouse to be 27 feet long by 20 broad.

The said Harrison and Walker to find all materials in wood and iron doors, window shutters, boults, bars, hinges, nails, crook locks, laches and catches, boards and all other materials in wood and ironwork and sufficient honest workmanship for 16-0-0.

Dimensions of the timber:

3 baulks, two in the schoolhouse, one in the dwelling house, each 10 by 6; 2ribs each side 4 ½ by 6 1/2 ; principals 10 by 3 ½ ; spars 3 ½ by 3; joice 4 by 3. All to be good, sound red deal. The pitch to be 5 feet; the floor to be laid with good red deal of an inch thick.

Mr Kirk, leading:

1782 To leading stones 1 day
to leading 3 load of wood
to 3 days, one horse cart leading earth

March
To leading stones
To leading sand and stone
To fetching timber from Leeds and paying turnpike
Stones – more leading; more sand.
One day leading brick, sand and stones
One day leading slate
Leading flags, slate and rigging

Joseph Kirk account 1784

To leading stones
To leading 3 load of wood
To 3 days, one horse cart leading earth
Stones, sand
To paying Wilson for **removing clay**

1783 stones, timber, sand.

January 1st 1784

Paid Benjamin Harrison for meat and drink at the raising 0-9-0
Paid Hartley for him and son one day carrying or filling earth
1 horse and cart for laths, nails and brads
paid for a wattering pan
slate, rigging, flags.

May 25th Paid Robinson for lime 1-1-0
For lead and paint
For 4 quarts of oil and a bladder.

Paid for wheeling earth and carrying out stones and rubbish and levelling the floors for flagging.

WYL/13/71/1-5 (WYAL02)

Sheriff Hutton Park.

Contracts for building and making bricks 1627-36.

Agreement between James Cooke and Wm Pears of Hawton, brickmakers for 150,000 bricks formerly made there or at Sheriff Hutton.

For the sum of ¾ for every thousand at the digging of the clay…**Brickmaking to begin in March next or sooner if weather permits**. Sir Arthur (Ingram) to provide straw, wood and coles found needful and necessary.

7 August 1623
Work at Temple Newsome.

John Wilton of Rippon, bricklayer.

Addition to south side of kitchen 4s 10d the rood and to be paid upon measure every storeye, wall 2 foot and ½ a foot in breadth.

Also, brick wall on backside of the house for an orchard at said house at TN, 70 yards long, 42 yards broad and 3 yards high at 3/- a rood.

1636

Contract with Robert Fisher of York, brickmaker and Christopher Walton of Whitkirke, brickmaker.

200,000 bricks at 3s 4d the 1000, good, hard, well-burned, merchantable bricks of the assize lately made at TN.

71/6 early 17thC.

400,000 brickes to be made this summer at 4s 6d per 1000. To be had for digging and turning 12d per 1000; 4d and 4d for first turning and 4d second turning; 2s a 1000 for mouldinge, to be had weekly as they are made and 12d a 1000 when they are.

WYL100/SH/G/2 (WYAL03)

Account for building, Sheriff Hutton Park Estate 1617 (*Elyston is on Teesside)*

Paid for loading of 22 lodes of lyme from Elyston to Sutton at 4s 6d a lode 4-19-00

Loading 10 lodes of lyme from Elyston 2-05-0
For loading of sand and brykes for 8 days
To labourers for cutting wood for the brick kylnes

WYL100/PO/8/IV/97 (WYAL04)

The account of the charges of an Allome house built by Christopher Thorneton at Selbye Hagge (*Selby Hagg is part of Saltburn, Teesside*). *(Mortar appears to be sand and lime)*.

Carpentars

Paid to George Newsum and his men for 4 dayes tacking downe the owld lodge and other work as his note doth appeare

Bryck hewers

Pd to George Burke for 5 days at 17d a daye
Pd to John Selbie for 5 days at 16d a daye
Pd to Peter Thompson 5 days at 7d a daye

Pd to Thomas Cobe Labourer 3/6…

Carpentars worke

pd for leading of sand and brycks for 4 dayes for 12d a daye

pd for leading of 22 lodes of lyme from Elyston to ? Sutton at 4s 6d a lode…

(a lot of iron bars paid for)

pd for leading ten lodes of lyme from Elyston to ? Sutton
pd for leading of sand and brycks for 8 dayes
pd to four labourers for cutting wood for the brick kilns

(payments to brick hewers.)
pd to labourer for 6 dayes carrying earthe at 7d a daye…

pd to George Newsum and his men for hewing of timber and other worke in the parke…

pd for leading of sand and brick
pd for leading of 19 lodes of lyme from Elyston
pd to Eylliam Dalton for two lodes of deals and powles…
pd for leading sand and brycks
pd for fellinge & posting of the tymber trees at 2s a tree
pd to Wylliam Watles for a newe carte

(payments to brick hewers)

pd for leading of brick and sand
pd for leading of deales and powles to ? Sutton from York
pd for 4 lode of free stones
…pd Thomas Wyldon for a trunkle bede & tabyls in the Lodge

paid to Mr Muswell and Wylliam ?, brycklayars for 6 rood of wall at 4s a roode

(more of same)
pd more to him for the Cymney and ovens mackinge….
(many more roodes of brickwork….

Pd for leadinge of 21 lodes of lyme from Elyston
Pd for leading of sand

(more payments to brick makers, more sand and brick, payments for sawing timber and riving wood)

(Provenance of much timber from towns around) payments to brick hewers, 9 lodes of lyme

roofing timbers – spars, long powles…

12 July pd James Radlay for 8 lodes of lyme, 16 sackes to a lode at 13d a sacke…(more lime)…

lyme from Elyston…

paid to James Radlay for 6 lodes of lyme
4 lodes more
64 sackes at 8d
32 sackes at 13d a sacke
32 sackes at 13d
80 sackes at 8d

(more of all the same activities)

Lyme from James Radley 17th Awgust 1617

The 18th Awgust 6 lodes
The 23rd Awgust 6 lodes
The 30th Awgust 6 lodes

Bricklayers on the Chimney.

Wm Dodson, Bricklayer, his Bill for work done for the right honble the Earl of Holland att his house att Kensington, vizt Ano 1639 *(no sand, apparently. Lime and earth? Or lime putty bedding and lime and hair plastering only? Most walls would be wainscotted)*

In the new addition of building

Att iiij brick in thickness 23 rodds at xj £ the rodd £258-18-03
Att iij bricke 1/2 in thickness 20 rodds at £9 the rodd £194 – 18- 04
Att ij brick in thickness 9 rodds at £6 the rodd £54 – 17- 01
Att i brick and a half in thickness 2 rodds 9 foote at iiij £ the rodd

New tyling 17 square
Great (?) Cornish over the heads of the windows 348 feete at iijs the foote £52-04-00
Architrave about the windows 772 feete att 12d the foot 38-12-00
In the mouldinge of the stooths of the windows 250 feete 08-07-04

Lathed and laid with lyme and haire in the ceilings and partitions 824 yards at 10d the yard
Rendered upon brick walls 271 yards at 4d the yard 004-10-04
For digging and making the foundation 008-00-00

Sum is £741-09-06

New Stable vizt

Att 3 bricks in thickness 39 rodds and 58 foote £323-09-07
Att 2 bricks ½ in thickness 57 rodds ¼ and 24 foote £401-07-00
Att 2 bricks in thickness 49 rodds ¼ £283-03-09
Of 1 brick ½ in thickness 18 rodds ¼ and 14 foot 077-14-11
Shaftes of chimneys 30 at xxx s the shaft 45-00-00
Great Cornish within and without the Stables 746 foote at 9d the foote
Architraves about the arches and windows 2054 foot 068-09-04
New Tyling 178 squares at xx s 178-05-00
Old tyling 12 square ¾ at xi s the square
Lathed and laid with lyme and haire in the ceilinge and partitions 3553 yards at x d the yard 148-00-10
Rendered on brick walls 1068 yards at iiij the yard
In the great draine in the Stable yard
In the small drayne 13 rodds ½
For digging the Cellar 009-00-00
For levelling the halfe of the stable and the north end of the building
For digging and making the foundations of the stable and wash houses
For making iij bricke mantles in the wash houses at 13s 4d the piece
For making and finishing 18 arched brick mantles…

New brick wall in the garden:

Att iij brick ½ in thickness 5 rodds ¼ at £9 the rodd
At 2 bricks in thickness 15 rodds ½ and 10 foote at £6 11s the rodd
Att 1 brick ½ in thickness 26 rodds ½ and 45 foot at £4 6 s the rodd
Lathed and laid with lyme and haire in the Armoury and new staircase 796 yards at x d the yard
Rendered in the new staircase and stable lodgings 345 yards at iiij d the yard
In the stable court 6 rodds of small drayne from the new cistern into the vault
For digging two cisterns
In the cisterne att I brick in length…and for making the center
Tarras for the cisterne
For a bricklayer 3 daies to lay the cisterne with clinkers
For setting the two ? in the wash house
For making a drayne from the wash-house to the sink
(for pinning back doorcases)…
for diging 8 rodds of foundation from the stable to the garden wall
for stuff and hewing amd making of two pairs of brick arches in the garden

for diging the foundation of the first garden wall being 60 rodds at 2s the rodd

The Masons bill for work done for the right honble the Earle of Holland att his house att Kensington 1638-1639

Viij Portland hook stones with centres(?) to them in the new building at 4s 6d
8 Portland hooke stones with 2 greate doores in the stable
6 Portland hooke stones att the north end of the stable
for iij fork stones for the doores
for xi ring stones in the stables
8 stones in the stable for ? hookes to hang harnis on
for 10 hooke stones in the south end of the stables
for v hook stones for the doors
for 5 portland hearths 3 foot long, 2 foot broad and 9 inches thicke at 16s the piece
for 2 plinthes of Portland 2 foot long and 18 inches broad

Masons bill for work etc at his Lordship's house in Kensington

Mainly chimney pieces – marble and black marble – and flagging of hearths.

IMPORTED BACKGROUND MATERIAL

The Alum Company[edit]

Serving as collector for dyewood and starch duties in 1607-08, Ingram investigated revenues from the English alum refinery (for use in cloth dyeing processes) then being established in Yorkshire. In 1607 Sir Thomas Chaloner,[17] Sir David Foulis, Sir John Bourchier and Lord Sheffield in partnership obtained a 31-year monopoly based upon the Chaloner estates at Guisborough and Redcar. The concession was leased to London merchants who made substantial losses, despite the use of expert workmen from Germany.[18] As their investments failed, on Ingram's advice the Lord Treasurer Salisbury bought out the patent in 1609, and upon Ingram's favourable report[19] a new lease was issued, the dues of which however soon became onerous to the farmers of the industry.[20]

In November 1609 Ingram entered parliament as representative for Stafford, presumably under Salisbury's patronage in connection with the Great Contract.[21] He served on several committees for bills touching his own knowledge and interest, and that of his patrons, who by their continuing support taught him the advantage of a parliamentary career.[22] As he became over-engaged in land transactions doubts over his liquidity emerged, but confidence in his credit-worthiness was restored by means of a declaration signed by the Earl of Salisbury, the Earl of Northampton and the Lord Chancellor. At this time he was operating from premises in Fenchurch Street.[23]

By 1612 the Alum Company was failing, and went into insolvency shortly before the death of Lord Treasurer Salisbury.[24] Following various proposals Ingram, with Walter Cope and Robert Johnson, persuaded the Lords Commissioners to grant them control as contractors under a new adjustment, and in 1613, as the works passed into the King's hands, they became managers for the Crown, and claimed to have invested large sums of their own money.[25] In March 1613 Ingram obtained by purchase the position of Secretary and Keeper of the Signet of the Council in the North, a position he held until

1633, his elder brother Dr William Ingram serving as his Deputy until his death in 1623.[26] This post was acquired for £5,200 from Sir Robert Carey, governor to Prince Charles.[27] For his residence he entirely remodelled two large houses including the ruined former Archbishop's palace in York between 1616 and 1623.[28] He received the honour of knighthood on 9 July 1613, and his brother in 1617.[29]

Alum[edit]

In 1615 Ingram received the grant of Sheriff Hutton Park, in the Forest of Galtres, and over the next years built the New Lodge there as his country residence.[37] Ingram, Johnson, Martin Freman and George Lowe in partnership became the new farmers of the alum works upon more favourable terms.[38] The ill reputation which had seen him driven from court still pursued him, however, and a commission was set up to report into claims of fraudulent dealings. Lowe complained he had been drawn into the partnership unscrupulously, and in 1618 a scandal broke as it was proved that the Lord Treasurer, the Earl of Suffolk, who was on trial in the Court of Star Chamber for various offences, had engaged in corrupt transactions with Ingram.[39] Ingram however escaped severe punishment and continued his close involvement, gaining sole lease in 1621.[40] Though his management probably brought him little profit or popularity with his employees, he doubled the productivity of the works and built up an export trade, setting the direction for the continuation of the industry.[41]

In Yorkshire Ingram found for patron and associate Thomas Wentworth, Custos rotulorum for Yorkshire. Ingram was High Sheriff of Yorkshire in 1619-20, and was returned M.P. for Appleby, Westmorland for the parliament of 1620–1. Letters from late 1620 show him in Wentworth's interest for re-election as Knight of the Shire, and the hospitality of his house requisitioned for that purpose.[42] In the following year his son and heir Arthur was knighted, and in 1622 Ingram made his purchase (for £12,000) of the neglected mansion of Temple Newsam, near Leeds, from Ludovic Stewart, 2nd Duke of Lennox, with its prestigious royal associations as the birthplace of the King's father, and commenced a 12-year rebuilding project there.[43] His brother Sir William died at York in 1623.[44]

The York Corporation, with expressions of appreciation for his goodwill towards them, enlisted his help in resolving differences with Hull over lead and corn, which were brought to a successful conclusion in 1623 through the offices of Lionel Cranfield, now Earl of Middlesex and Lord High Treasurer. Ingram was rewarded with the freedom of York, exempt from duty in municipal office.[45] Wentworth, meanwhile, had been forced to give up his London position as Receiver of crown lands and return to Yorkshire.[46] In February 1624 Ingram became MP for York.[47] Having failed to support his friend Cranfield's opposition to a Spanish War, instead advocating practical measures dependent upon the royal intention, he was then drawn into, and contributed significantly towards, proceedings for Cranfield's impeachment over land transactions from which he himself had benefited at Cranfield's expense.[48]

Wheels were already in motion to unclamp his hold on the alum monopoly. Sir John Bourchier, who in 1622 was released from all crown debts relating to it since 1611, made a formal proposal to amalgamate the alum and soap businesses, with compensation to Ingram, but then neutralized Ingram's interest by bringing charges against him for misappropriation of funds and breach of contract. Ingram was arrested and taken to London in October 1624. Such was the evidence presented to the resulting Exchequer Commission that Ingram was obliged to surrender the business in February 1625. However, through his favour with the King, and the larger processes surrounding the Statute of Monopolies of May 1624, he escaped from the affair very lightly.[49]

Following the King's death in March 1625 and the accession of King Charles, he was returned as MP for the city in the next three parliaments, in 1625, 1625–6, and 1627–8.

Wikipedia (accessed 27.11.2017)

GLOUCESTERSHIRE ARCHIVES (GA)

Badminton Muniments

QJ3/11 (GA01)

General Abstract of Repairs 1740.

Bricklayer	80-3-4
Carpenter	189-1-3
Mason	76-5-8 ¾
Plumber	20-23-4
Plaisterer	23-70-14
Painter	45-1-8 ¾
Smith	97-9-4
Carver	66-13-5
Glazier	10-17-4
Paviour	25-13-10
Painter	9-3-5 ¼
Varnisher	3-12-0

698-0-4

Measured Bill Of Bricklayer work
Reduced and gaged work in red stocks; common brickwork.

Domes in Mrs Walker's garden;
Reduced brickwork
61 feet superficial of 'flatt stock brick paving in **Tarras'** at 8d the foot.

May 1740

Received 7000 old bricks.

A bricklayer and labourer, a day terracing ye wall in Mrs Walker's garden. **5 hods of tarras** to ditto;

Paid for ye carriage of 2 loads of **coal ashes** to raising ye wine vault;

Bricklayer and labourer a day cutting down ye brickwork for ye door case for ye ale cellar and making good and pinning in ye windows. 1 hod of mortar and 1 of bricks;

Bricklayer and labourer, a day making a ses pool and drain to ye landry. 9 hods of mortar and 6 hods of bricks;

Taking down arch and making good the brickwork. 3 hods of stock bricks, 9 hods of place bricks and 9 hods of mortar;

Bricklayer and three labourers a day each making a scaffold and mending the chimney. 7 hods of mortar, 6 of bricks, 2 of pargetting;

(more chimney stack work) 4 hods of lime and hair, 3 of mortar, 2 of bricks, 50 plaintyles and laths;

pointing with mortar;

(most jobs with 'mortar')

Bricklayer and labourer, a day mending ye tyling over ye laundry and coach house and stables. 16 pantyles. 8 ridge tyles, 3 hods of lime and hair, 2 of mortar, 1 of bricks;

Mending and tyling in ye house. 2 hods of mortar, 50 slates and 4 ridge tyles;

Mending tyling over coach house and stables, two bricklayers and one labourer a day each. 2 hods of lime and hair, 3 ridge tyles and 12 pantyles (lime sheeting?);

Bricklayer and labourer a day, ditto and turning a new arch in the kitchen. 2 hods of mortar, 1 of bricks, 16 red stocks.
Masons Account.

(Marble, Portland and Purbeck, as well as local stone).

261 feet of Bremen stone **laid in Tarras (copings);**
186 feet of same laid in mortar;

17 ft 6 in of old marble paving in Tarras to front door.

Day Bill:

Mason cleansing the door case, pointing coping on back front, making good paving in Butler's room and cleansing the kitchen chimney-piece and fastening the key-stones.

Coping the garden wall. 1 hod of tarras.

Plaisterer's Account

163 ¼ yards of rendering;
57 ½ yards of common lath and plaister;
975 yards of ditto to wash, stop and white.

107 ft of cornice enriched
136 ft similarly.

Repairing stucco inside.

Lime and hair.

Painter.

(all plaster surfaces painted; chimney pieces, too).

Paviour's account.

1000 Flanders brick; lots of gravel and 'pebbles'. Several tonnes of 'raggs'.

(no sand or lime mentioned, lest pebbles be small lump lime)

QVI/1 (GA02)

Agreement 16th of Charles between Lorde Coventrie and Matthew Browne of St Martins-in-the-Field to build a new house at Croome Dabifort, Worcestershire.

Matthew Browne shall substantiallie and workmanlike build and erect all the brickwork of said house, finishing by mid-summer day 1641.

The outward walls of said house shall be ? and artificially done with grinded or hewen bricks laid in rowes and **with white joints**

First floor painted.

GBR K1/15 (GA03)

Building account, St Bartholemew's Hospital 1569

16th Dec

Plaster bordes and timber
4 barrels of lyme
2 loades of sand
2 loads of stone

28th January

2 loodes of stone
2 loodes of stone
3 barrels of lyme
2 barrowes

3rd February

2 barrels of lyme
barres for new windows
2 loads of sand

11th February

700 borde nayles
more barrels of lyme
10 spykes
200 lathnayle

more of the same.

D1799 A102 (GA04)

Dyrham Park (Dereham)

1692 Mr Blathwayt account

May 9	12 sacks of lime
17	13 sacks of lime
June 18	12
July 29	12
Aug 30	14
Oct 3	7
Oct 7	7
Nov 14	14

Thomas Tilly, his account for Lime sent to Dirham Hous

May ye 9th 1692   14 sackes

May ye 17	14 sackes
May ye 30th	12 sackes
June 18	14 sackes
July 5	14 sackes
July 29	12 sackes
Aug 15	13 sackes
Sept 13	14 sackes
Oct 21	13 sackes

Herefordshire Archives and Record Centre (HARC)

P92/1/i-xix LC 9160 (HARC01)

Building of new house and garden, Langarran, Herefordshire, 1724.

A Particular of the Articles of Agreement between Mrs Mary Clarke of Treribble in the Parish of Langarran in the County of Hereford and Mr John Harguess, Mason of the parish of St Martins in the City of Hereford, for Building an House at Treribble aforesaid.

The Front 32 ft high, 43 ft long Chissel Work with a bold water table and 2 facies at 4d per ft. The door and 14 windows to be deducted. And no turn in measuring the sides of the windows or the sloapes of the water tableand facies. The Cornices to be laid by the Day.

The Back front and two Ends good Range Work with a large Rustick Water-table, the Door and 8 Windows to be Measured in. The Arches over the Window to be Chisel Stoned, the thickness of the two walls at each end to be deducted. 1s 8d per perch, 16ft 6 inches to the perch. The Back front Doorcase to be made by the Day.

Underground stonework 1s per perch. The 3 Arches brickwork Measured in the inside with their Spangles Given in 1s per perch.

The Partition Brick Walls with their Doors Measured in 8d per perch.

Two Stacks of Chimnies, 6 (turnes?) in one, and 3 in the other, Stonework to the Square above that Brickwork and finished with a bold Cornice, which if colour'd, oyl, Cramps and Lead to be paid for, so 14 stools for the front.

One Guinea given in Earnest Feb: 11. 1724. When this Particular aforesaid was Agreed to, by and between the abovesaid Parties, whose names are underwritten.

Forest Quine stones Rustick

2 Quines long 1ft 10" and in depth

8 ditto

the height of this floor: 11ft 10″

1 Quine 1ft 10″ long and in depth
8 ditto

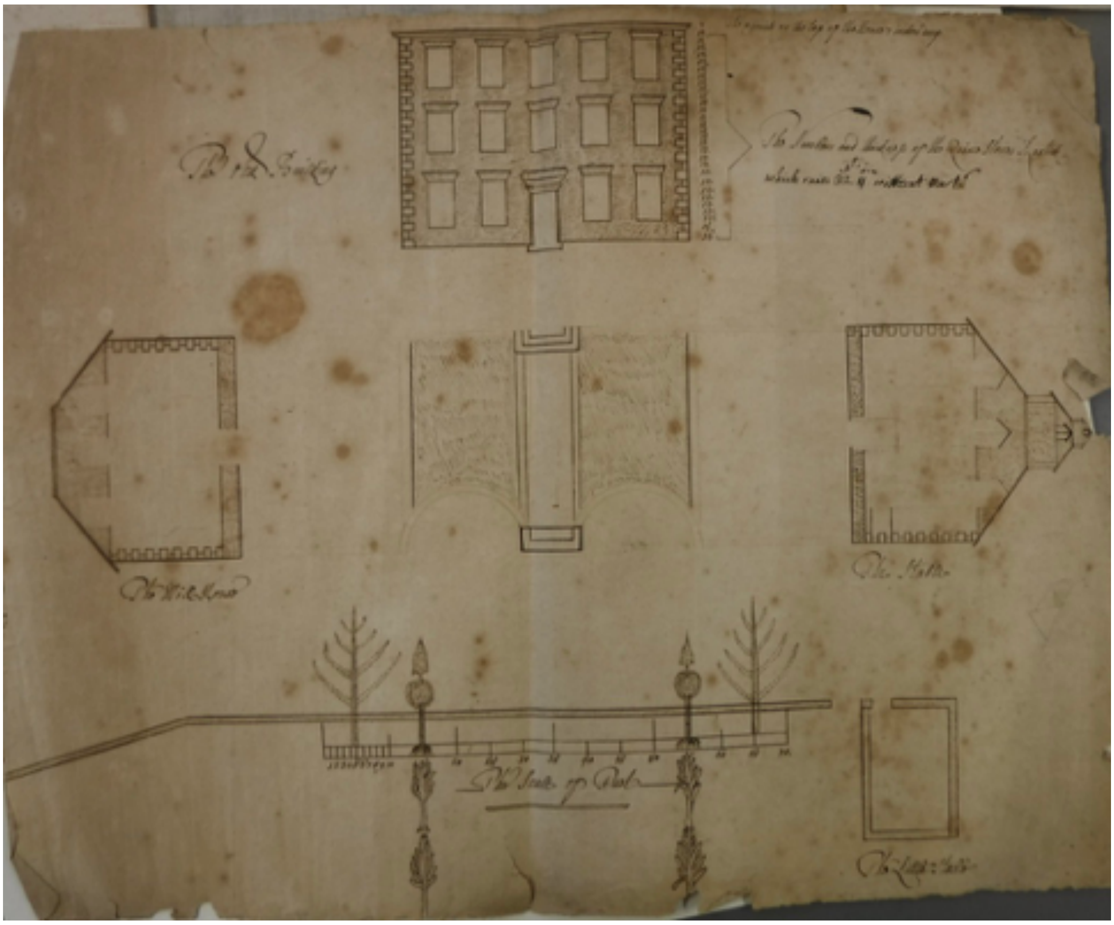
short by 2″ of the 2^{nd} floor height 10′ 01

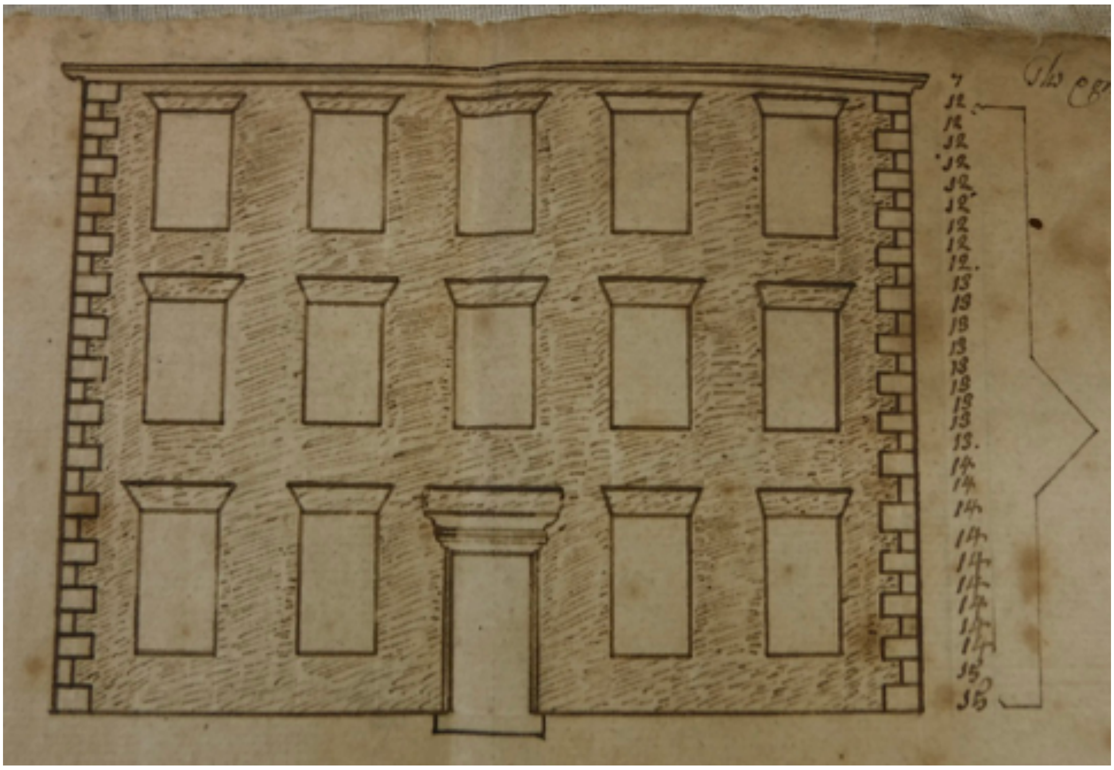
1 Quine 1ft 10 in long and in depth
9 ditto

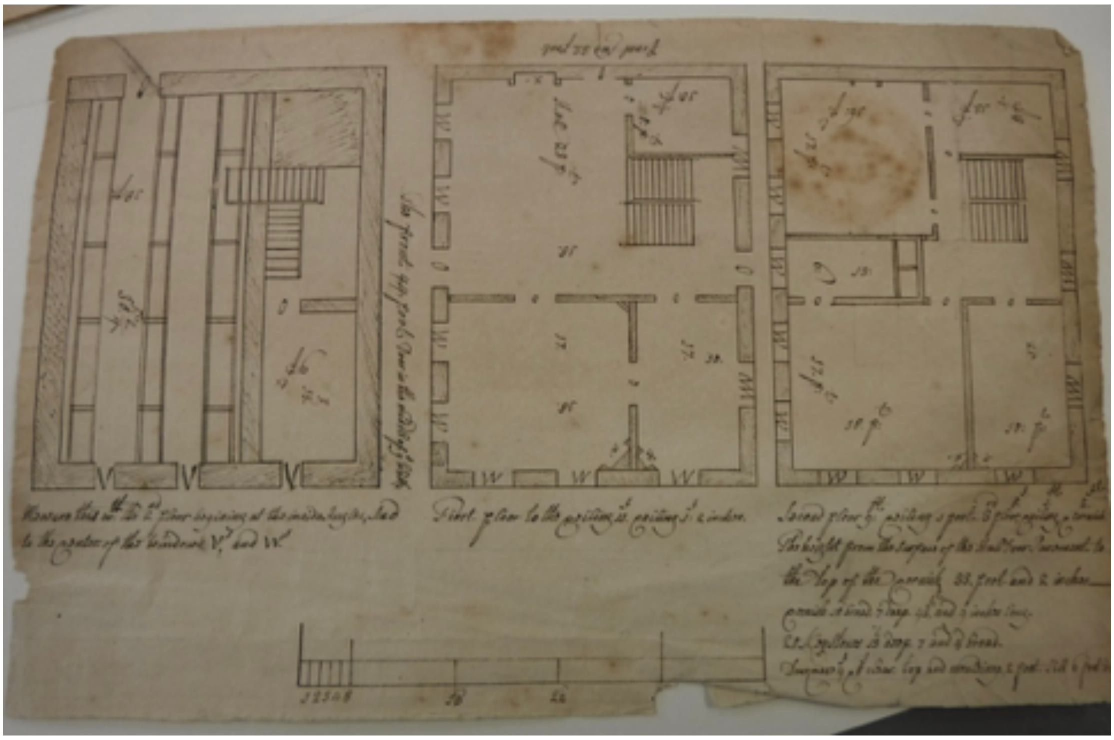
the 3^{rd} floors height 10′ 01″

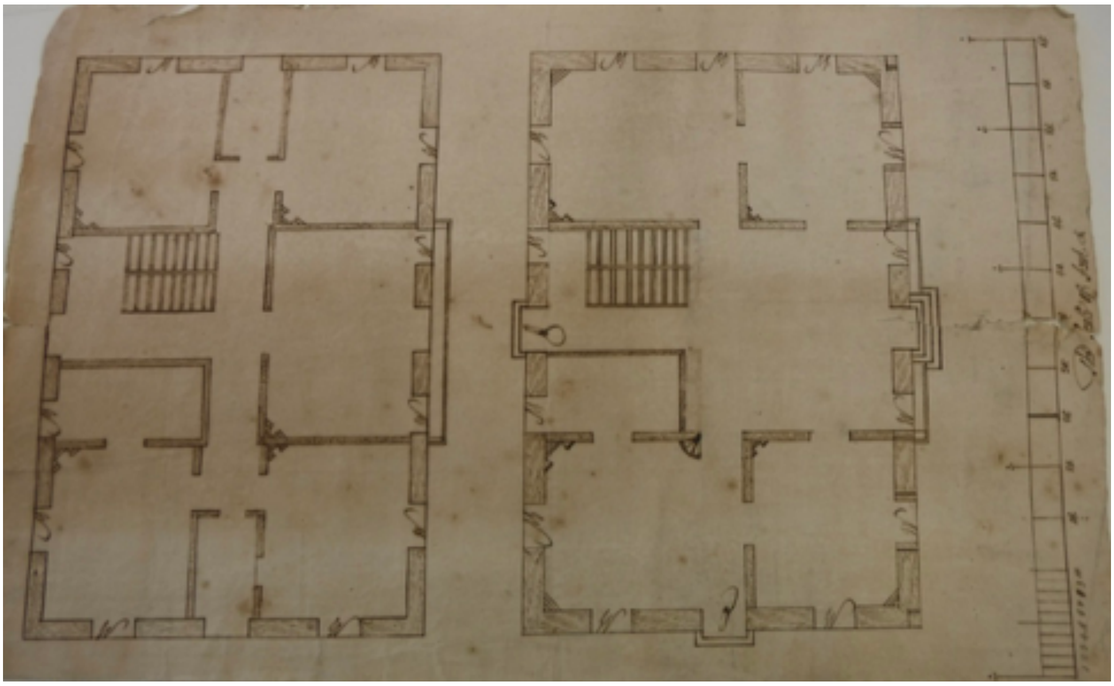
The Cornish in depth 7″

The whole height 32 ft 6 in.





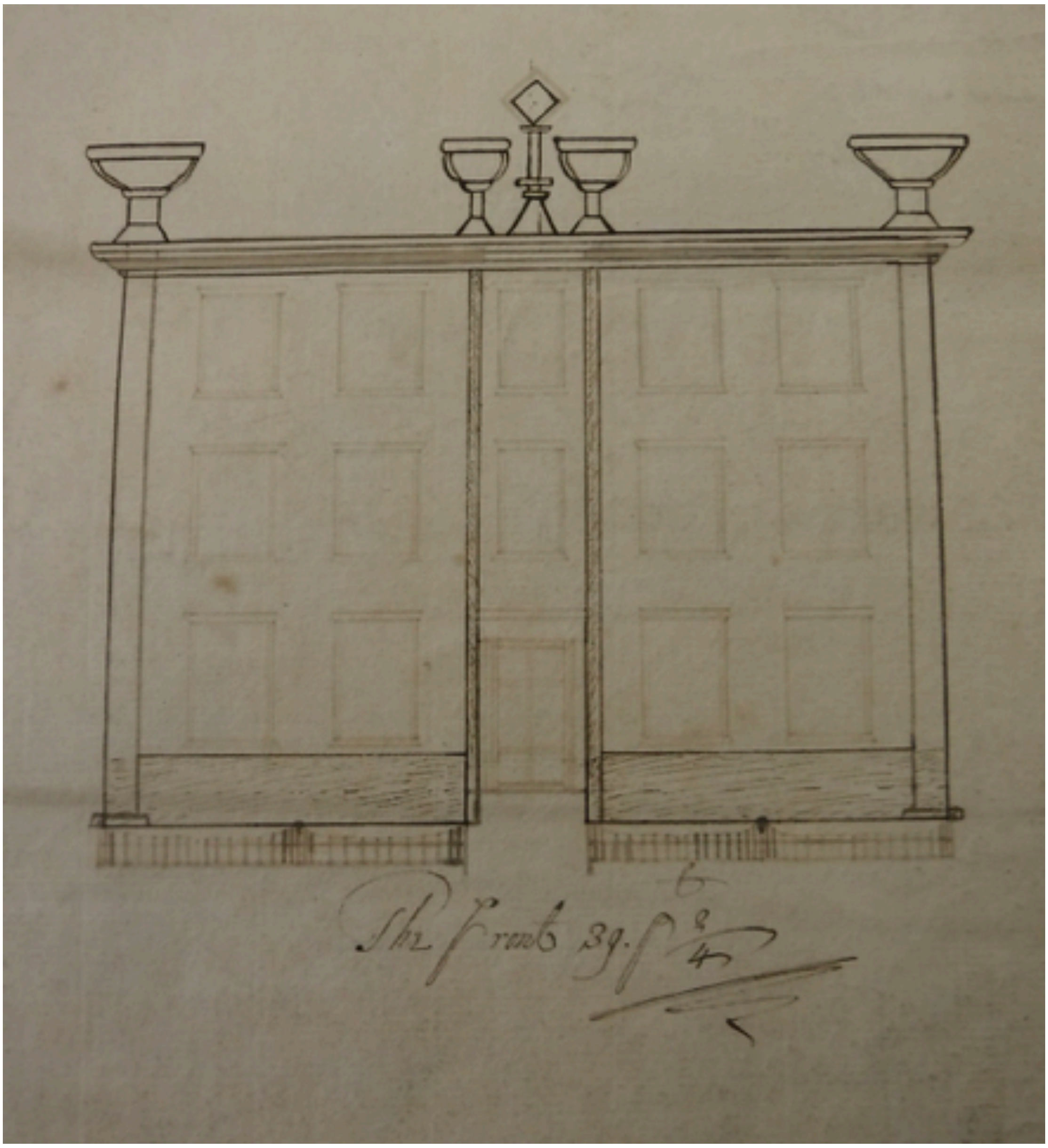


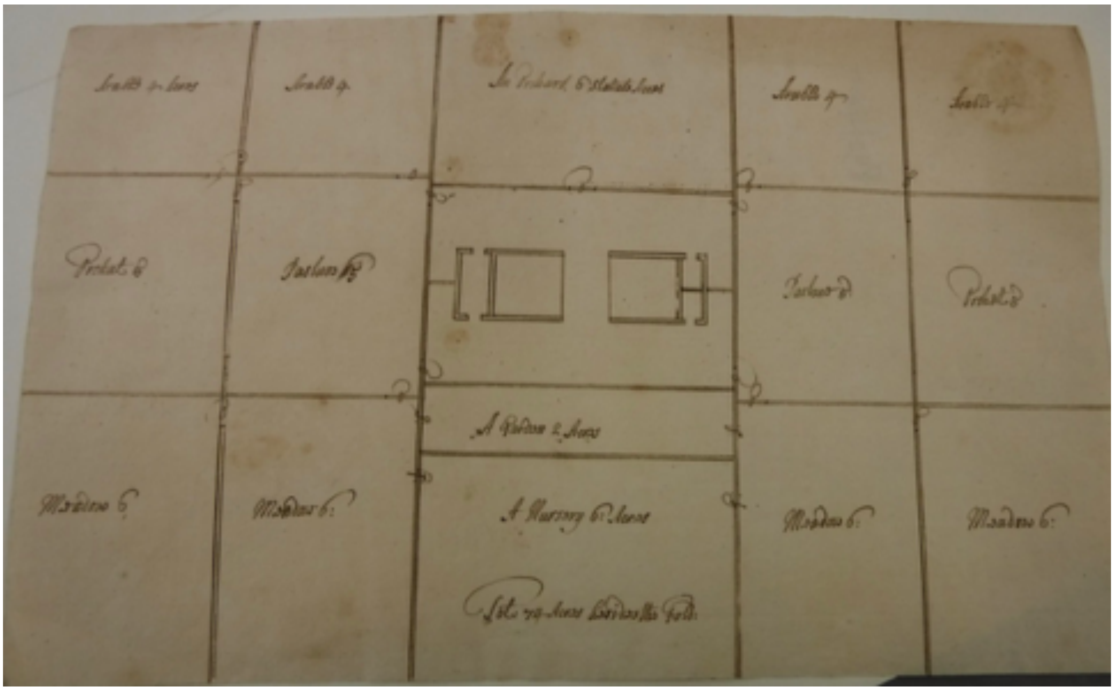


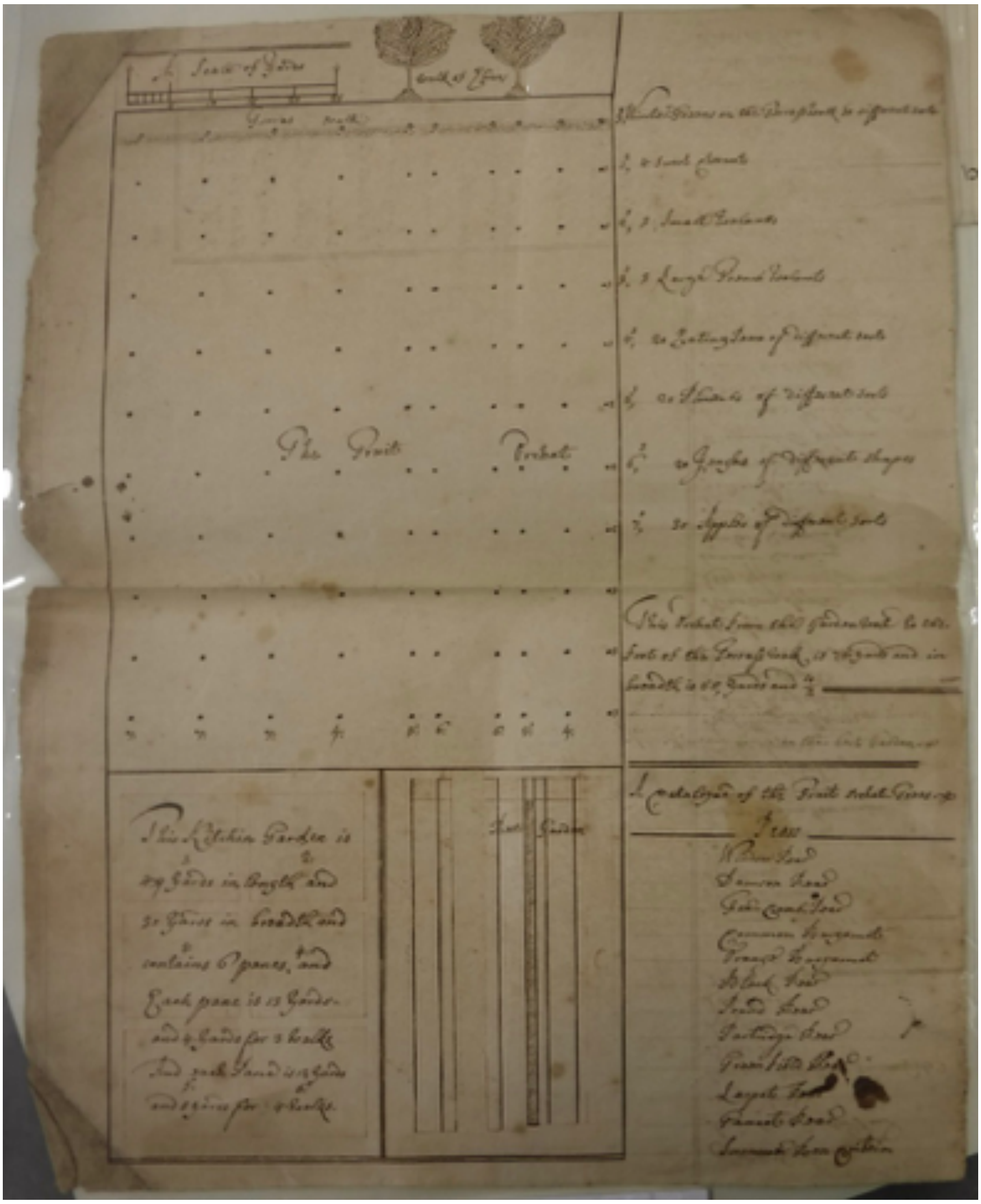
1724 Particular of Expenses in building the House, Treryble

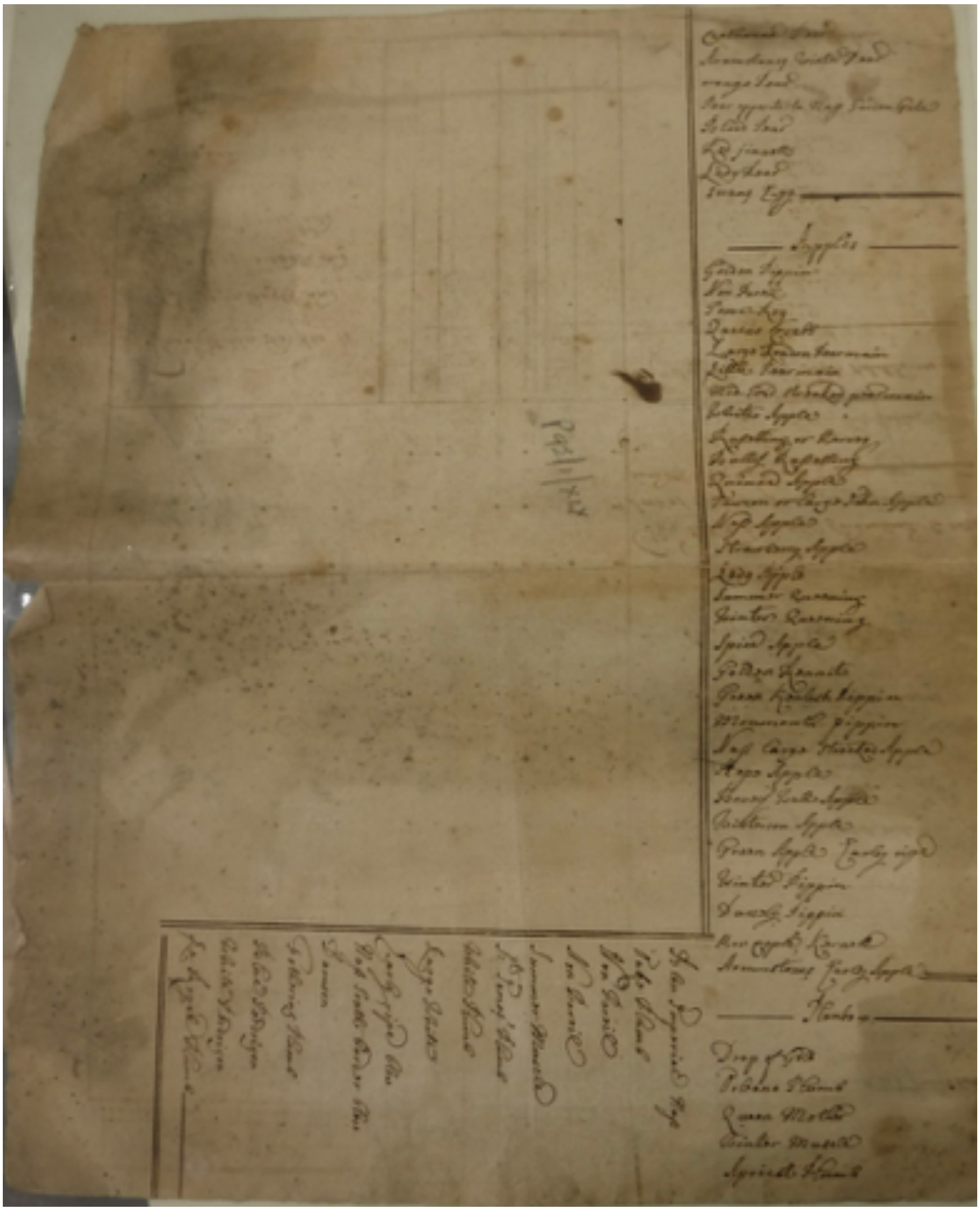
Digging Stone 12-0-0
Clamp of Brick 14-0-0
Brick and Mason Work 56-1-4
Sawing by Floyd, Powell and Prichard 28-10-6
Plummer Work and Glazing 40-8-0
Tyles and Tyling 8-11-0
Ceiling and Rendring 10-14-4
Chimmnie Pieces 11-1-0
Stair Case 20-0-0
Prichard forest stone work 21-0-0
Lime 7-10-0
Boards bought at Bristol etc 14-5-0
Pavements and laying them 21-6-0
Hair, glue, laths, oyl and colours 19-7-0
Nails, Locks and Hinges 43-10-6
Felling and Squaring Timber 5-5-0
Rulward (?) Work in Brick, Steps, Peers etc 24-10-0
Carpenter Work as agreed for by Measure 50-12-4

£400-04-0


The Front


A Nursery 6 Acres





Apples
Golden Pippin
Summer Queening
Winter Queening
Spiced Apple
Winter Pippin

J56/IV/2 (HARC 02)

Moccas Court


(image Philip Pankhurst)

Dec 21 1776

Thomas for 1920 feet Boards
For brickmaking;
For ridding limestone;
Williams for turning clay for 400,000 bricks
Nelson for rising stone
Philips 179 pieces of timber, 55 ton 20
Carver on account
Kingdon on account
Mr Keck for Bath stone

(mainly household accounts and wages, with building materials and labour interspersed).

Bills

June 1773

Bill for lime 3-7-6
Bill for brick 2-9-8
Thatching in Paddock

1775
July Faggots for brick at Mornington
August 19 burning 52,162 bricks
Sept 3 G Evans-Williams bill for repairs at Mornington

Ditto for sawing 3929 ft
Thatching

Oct Williams, 40,000 bricks
Yeates, Waggoner 42-16-0
Nov 30,000 bricks

1776

Jan 5 To Hawkins for 6 dozen lime coal 4-16-0
May 7 to Tully for lime 2-2-0

(July 5 At Hereford Races
Lodging 8-10-0
Horses 2-15-7
Subscription 21-0-0)

J56/IV/3 (HARC 03)

Account book, March 1777-Dec 1785

(Regular entry – so many 'quarters watching')

Lots of paving

Repairs and new builds:

1782 Thatching
April 22 Bevan beast-house 137-16-0
1784 Jan 5 Bevan new buildings 541-1-3
1785 January
Bevan new building 68-19-3 ½
Cyder Mill 13-15-9
Repairing Lime Kiln 1-15-6

R93 8351 (HARC04)

An account of the charge of building an Isle and repairing and beautifying Canfrome (Canon Frome) Church, begun February 2 1716/17.

Feb 2 1716
Hays for falling, squaring and cutting 4 trees.
For sawing 505 feet
For sawing 484 feet
Sawing 1596 feet for wanscott

Hays is to do ye roof of ye Isle and Church

For watering ye boards
July 26 Hays sawing for scaffold and centre of vault…
Sinking vault, sawing and making centre

Child, mason and men 24 days

Aug 25 4 load of lime 05-00-00
Labourers 00-03-00

Aug 30 Walcroft for Tiles
Sept 15 4 load of lime
For moss, 11 bags 00-02-09
Sept 20 Hays altering centre and pulling down old timber.
(payments to joiner)
Oct 3 Bricklayers 03-08-06
31 days diet 00-10-04 (regular entry alongside payments to workers)
Oct 4 3 loads of lime
Oct 6 Tiling
Apperly for raising 9 load of stone

Oct 11 Hays sawing for joiners
Glass for ye sashes
Oct 31 Apperly in full for tiling
800 ½ of heart lath

New building timber 13 tun
Wainscot timber, 4 tun
18,000 brick

Nov 13 Apperly in full of ceiling
2400 of sap lath, ceiling

December. Hays sawing for Belfrie
Paving
Hays for the Porch

1718 Jan 28
Apperly for paving and plaistering and whiting ye Chancel
Hays for squaring and sawing plank for ye steeple

May 1719
Ja: Smith for 2 loads of paving from Stamford (total paving 212 feet).

1720 Fisher for painting and gilding ye font
Nov. Godfrey for 2 pieces of marble put in the piers of ye Isle and for carriage of 'em from Gloster 2-13-0.

Began building the tower at Canfrome Church 20th April 1730.

Hays pulling down ye wood steeple
16 barrels of lime
8 waggon load made him 126 barrels 06-06-0

July 11 new timber in the tower
32,000 bricks
80 brick tiles
Carriage brick, timber and lime 5-0-0

R93/11874 (HARC05)

Bills, Mr Risnal to John Chamberlain

Sept 4 1839
To 1 load of lime 1-5-0
Sept 12 to 1 load of lime
13th to 2 loads of lime 2-10-0
Settled Dec 12 1839

Sept 2nd 1840
To 480 pillar bricks
And 800 smelt bricks
At 36/- per thousand

Sept 21 1840
Mr Hooper to Daniel Baker for sawing 3410 feet in Ellem at 3s per hundred 5-2-3 ½
Ditto 410 feet in oak at 4s per hundred
Ditto 24 posts at 1s per pece
21 posts at 9d per pece.

Mr Rymall Pig-sty

March 30 1840
To Saml Yarrington 1 rod 27 feet of brickwork
26 yards of brick on edge floor
2 square and 8 feet of tiling
17 feet lineal of brick gutter
41 feet lineal of pointing on tiling

Reverend John Hopton to Richard Badham, Sawyer
To sawing 5123 feet in oak, elm and poplar at 3/- per hundred.

Bransford District Oct 1839
4 loads brick and tile
Turnpike to Canon Froome
4 loads of lime 0-5-4
6 loads of stone 0-9-0
stone plinths and steps

Aug 22 1839

14 feet of tooled forest stone 1 ft wide and 2 in thick
4 tooled gray Aveley stone, 1′ 10″ x 1′ 2″ by 9 1/2″
44 feet x 2″ barn flooring
2 masons 1 ¾ days fixing forest stone to barn and gray Avely plinths repair, and floor etc.

R93/9363 (HARC06)

Collins and Cullis, Builders, Timber, Tile and Stone Yard, Tewkesbury to John Hopton Esq, Canon Frome Court 1872-3.

To building Billiard Room etc as per contract 539-0-0
To stone cornice to eaves over bedrooms
Marble chimney piece in Billiard Room 15-15-0
Pitch pine floor in Billiard Room, secreted nailed.

Kitchen…making good plastering and colouring

Larder
To stripping roof, re-slating, boarding and **felting** same…
Taking up old floor, relaying same with blue Bedford stone on 6″ of **concrete**, repairing plastering, new skirtings and colouring walls…
2 Cwt of plaster; ½ cask of cement
400 3′ 6″ plastering lath and half…
108 ft blue stone paving on 6″ of concrete…

passage floor near Entrance…taking up old stone floor, excavating soil and relaying with blue Bedford stone paving on 6″ concrete…
87 feet run cement skirting.

Back passage from kitchen to yard…
To altering drains, constructing grease-trap, etc…
1 cask of cement

Old attic
100 3′ 6″ plastering lath and half
28 lbs plaster
2 buckets of whitewash

Old Bedrooms

To taking down old ceiling, making good joists, relathing and plastering ceiling, securing cornice and making good walls.
Plasterers 133 hours 4-8-8
Carpenters 25 hours
Labourers 90 hours
10 Cwt of plaster
1850 3 foot plastering lath and half
3000 1″ cut lath nails
1 peck of Parian cement 2s 6d

New Bedrooms

To furring out, running cornice to both sides and soffit of tie beams
133 feet supr lathing, roughing in and running cornice complete
600 3feet plastering lath
7 lbs lath nails

cellar drains…1/2 bushel cement.

Third Landing…one 'Jennings' Patent Housemaid's Sink with hot and cold water-cocks.

To making scaffold and fixing coat of arms in panel over archway in gable end, to stable yard. Labour and cement….

1 Painswick stone chimney piece.

AF57/4/5. (HARC07)

July 31 1800

Bridge built on the Bole.
Stone 11 loads;
Lime 1 load.

AAI/7 (HARC08)

Letton Parish Church, Churchwardens' Accounts 1769-1887.

1788-89

For lath;
Glaziers bill
Tho: Downes for stone;

Tho: Morgan for powles;
A quarter of tile;
For walling the tile;
For four scaffelling cords;
For three bushels of haire;
For moss;
For lime 4-0-0

1790

For making a bridge and improving the way over Letton Common.

300 pales
700 brick
10 bushels lyme
4 tun stone.

1804

Paid Jonas Preece 8 days on the Tower
Paid ditto for 29 days on the Church
To moss, hair, shreds *(lath)* and nails
For 12 bushels of lime
To a load of tile

BRI16/1 (HARC09)

An account of money disbursed by my Lord Scudamore and paid by the hands of Rd Marke the Elder towards the re-edifying of the church at Dore, beginning April 1633.

Quarrying for tile
7000 of tile at 5s the thousand –
more, totalling 36,000 tiles.

Mason David Adams for making the tower and 2 buttresses.

Tiler paid for
Piling of tile, hewing and holing, raking down tile off church and tiling again.

Making the lime kiln
Apr 13 Paid John Price and Rd Parry for making
April 13 paid same for making of lime

July paid new Limemaker for 8 days at 12d
Paid his two men 9 days apiece.

(Between April 13 and Sept 14, 205 man days 'making lime' (burning lime). 42 ½ man days spent digging stone for the lime-burners and many days 'drawing stone to the kiln' between May 11 and October 20.

Lime bought in, July-Sept: 75 seams; 40 barrels
Oct 5 40 barrels
26th 28 barrels
March 22 18 barrels
May 11 12 barrels
June 29 39 barrels
Aug 23 29 barrels
Nov 27 14 barrels.

Cleaving wood for lime burners: 162 man days between April 3 and Sept 14.

Also lots of lath cleaving: 13,900 laths.

Digging of paving but also paving bought in.

Aug 30: 16 bushels of hair ('heare').

B43/29 (HARC10)

1740. Thing Hill, Hereford.

Labourers digging ye foundations, raising of stones and levelling ye ground.

To Anthony Lawrence for raising and halling stone, clay and timber.

Nov 62 loads of stone
Feb 26 9 loads of clay
27th 5 load of stone and raising;
8 load of clay.

March 3
7 loads of stone
4th 22 loads of clay; 2 load of scaffold poles
5th 24 loads of stone and clay; a load of poles
6th 9 loads of stone and clay
7th 15 more
9th 15 more
10th 18 loads of stone
11th 19 loads of stone and clay
one load of lath, 5? Of heart and 3 ? of sap (inch probably)
12th 20 load of stone and clay

13th 44 loads of same
14th 48 loads of stone and clay
16th 9 of same
17th 8 loads of stone.

Similar through 1741:

April 22 to May 29: 340 loads of 'stone and clay'; 243 loads of stone; sap and heart lath; poles; load of tiles.

May 30 – August 21: 384 loads of stone; 28 loads of tiles; 189 loads of stone and clay; 6 hundred of paving; 18 loads of sand (after June 19).

(Also 1741):
1 load of crests (ridge- tiles).
To halling 56 tuns and 3 foot of timber from Cowhorn's Wood;
For moss for ye tyles
For more moss
To 14 tuns timber
11 ½ of large lath for ye barn
3 ditto, 1 ½ of sap lath
oak board.

AA 61/37 (HARC11)

Specification of Artificers Works Requisite in erecting and completely finishing a Vicarage House and Stable…at Leinwardine…in the County of Hereford for the Rev Edw Green. (LATER 19THC)

Mason and Bricklayer

All the walls coloured stone colour upon drawings to be built with approved stone of the district as rubble masonry laid random in mortar well flushed up, that no vacuities be left. All the fronts to be neatly arris pointed at the completion of the work with a pale blue mortar.

No one portion of walling to be carried up more than 3 ft above any other…during the progress of the work with through stones…**the upper 4 courses of chimney stacks to be set in Portland cement.**

All the brick and stone walling to be built in mortar composed of fresh burnt lime and sharp clean sand in the proportion of 2 to 1. The lime to be kept under cover to prevent weather until slacking.

…The rainwater tank to be built in mortar with 9″ brickwork…to be puddled round sides and bottom with 12″ clay, rammed …to be lined round inside with 2 courses of old plain brick tile in Portland cement….

Tiler

All the roofs to be covered with Broseley tiles, each tile to show not more than 4″ **and to be bedded on a daub of hair mortar**…**The ridges to be covered with glazed ridge tiles, bedded in hair lime mortar and jointed in Portland cement…(hip and valley tiles similarly)…**

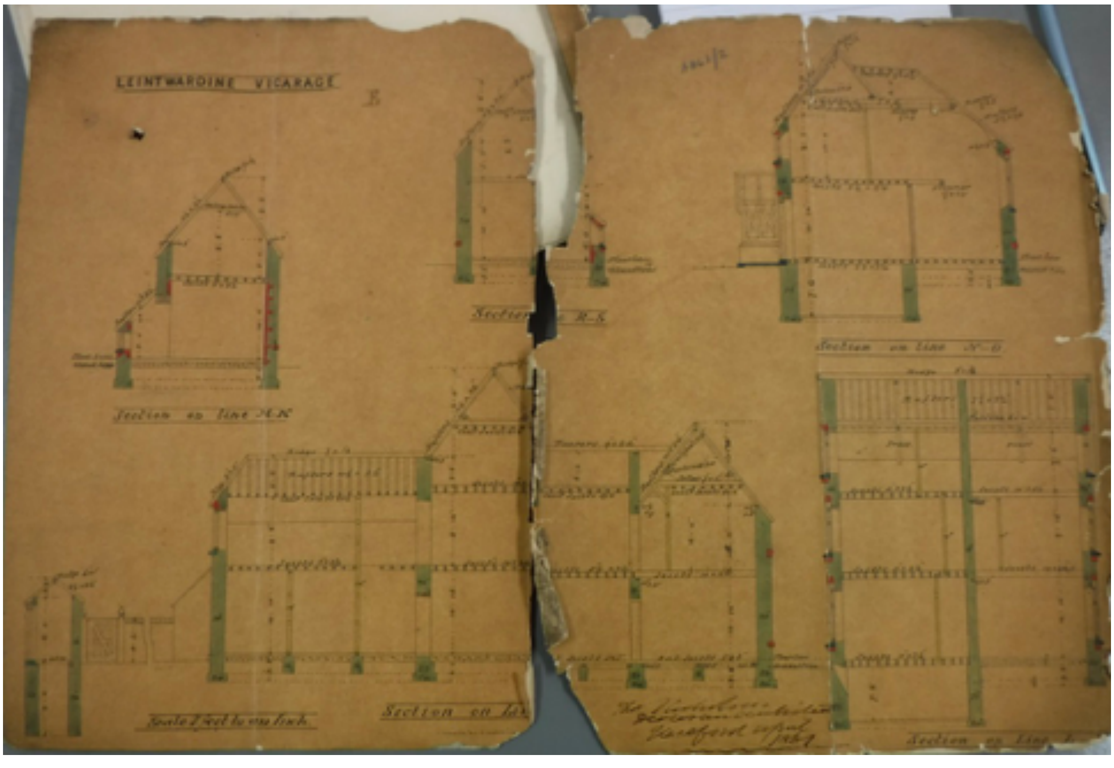
Plasterer

The dining and drawing rooms, study, hall and staircase to have walls 3 coat render float and set and ceilings and partitions (the same). All other walls to be 2 coat lath plaster and set. Ceilings of cellars, stable, cowhouse, coach house and harness room to be 2 coat lath plaister and set.

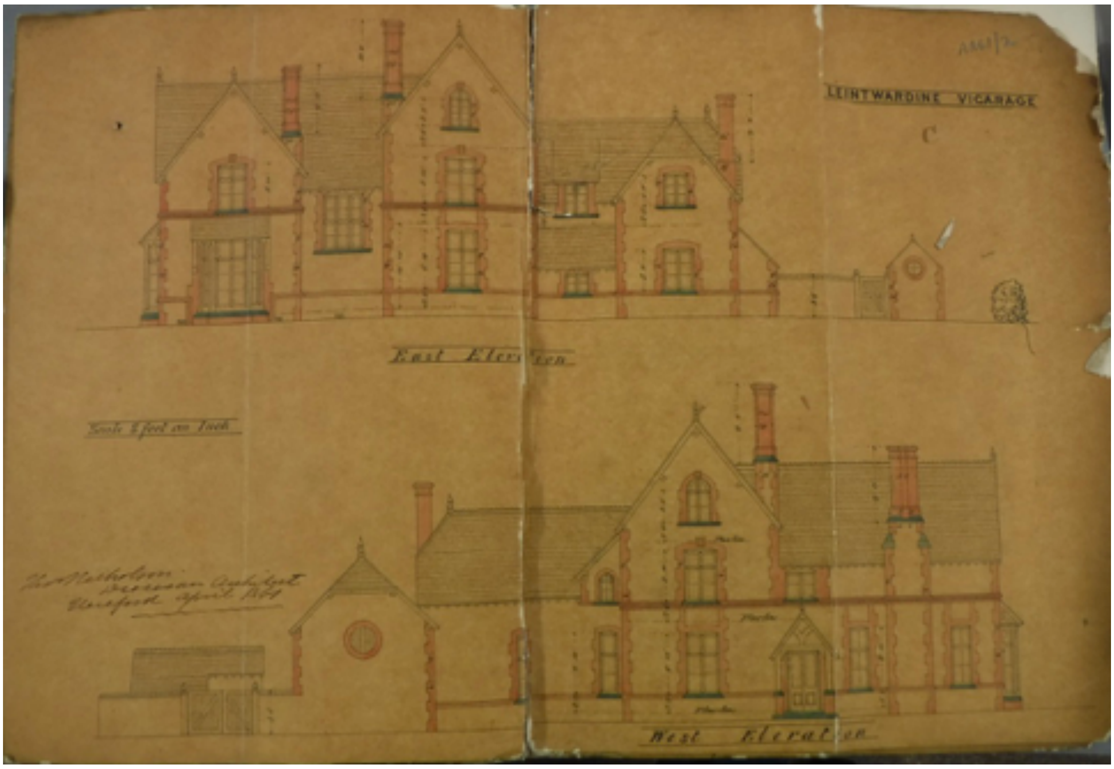
All the ceilings to be twice whitened and the walls prepared with size for papering.

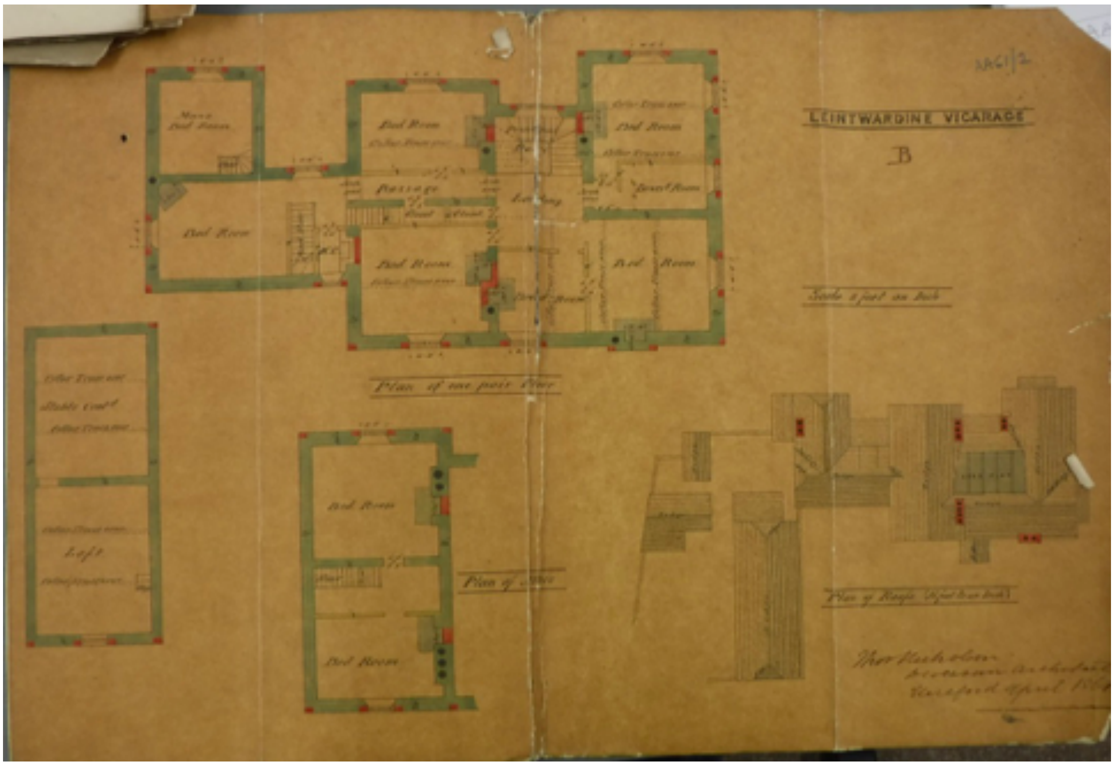
Twice limewhite all walls, struck or worked fair for limewhiting.

All plaistered rooms having tile floors to have Portland cement flush skirting 8″ high.




LEINTWARDINE VICARAGE
D
Elevation on line AB
Scale 8 feet an Inch
Elevation


LEINTWARDINE VICARAGE
C
East Elevation
Scale 8 feet an Inch
West Elevation



NORTH YORKSHIRE COUNTY COUNCIL RECORDS OFFICE (NYCCRO).

Cront 526 (NYCCRO01)

From accounts of the County Treasurer 1780-1791

York Castle

1780 Payments on account to Messrs Prince and Wilkinson for building in the Castle Yard. (Regular until 1782 – 5 payments of £93-2-6).

Nov 25 Paid same, 'the North Riding proportion of the balance due to them for erecting the new buildings in the Castle yard £108-12-11.

1783 April 22. Paid same for work done at the Castle £61 – 0- 7.

Paid Mr Carr for his trouble in designing and conducting the building in the Castle Yard £15-10-5

1791 Aug 25 Paid Mr Carr for business done at York Castle £13-6-11 ½

Cront 733-755.

Medieval building accounts, mainly Bedale.

Cront 748 (NYCCRO02)

Summary of contract for building at Wynyard, Stockton, County Durham. 31st January 1415. Source DCRO D/LO/F 322.

This indenture between Thomas de Langton of Wynyard and Thomas Rose, Vicar of Merrington on the one part and John Todd, wright, Robert Todde of Lanchester and Nicholas Hayforth of Durham on the other, witnesses that John Todde has undertaken to make anew, well and sufficiently, with sawing and all manor of work and things to wright-craft pertaining, except timber and carriage of it, and ironwork, a cross-chamber to the hall of Thomas de Langton at Wynyard with **6 couple of posts, each couple being from the other 11 feet, with an entry underneath to the kitchen, with an entry closet athwart, in the middle of the said chamber above and two privies to the said chamber…which chamber be sufficiently set in ground-sills ('sole trees'), wattled and daubed ('rabet and dight') in all parts to be plastered…ready for theaking by August 1st next.**
Payment of £6 by instalments.

Nun Stainton 1392.

Lease by monks of Durham to the Prioress of Nun Monkton of the whole of their estates at Nun Stainton for 200 years of one messuage and two bovates of land (24 acres). The Prioress and Convent (shall maintain etc all buildings)…- one house called Le Firehouse, containing five coples of syles and two gavelforkes; one small house…containing three coples of syles and two gavelforkes. (from Surtees Society Vol 58 p167).

Cront 749 (NYCCRO03) Delaps around Northallerton c1450

The hearth-house of **John Copsy** needs rybbes and walplats for four rowmes, one pair of crippils, 40 tignis (rafters) and 400 lattes with clav (nails) to the value of one carpenter for 6 days found by the Lord.

Cront 753 From ZBA/11/8/1/3 (NYCCRO04)

Mich 1426-27. Repair of tenements. Bedale.

8 cart-loads of stone from the Park of Bedale to tenement of John Watson in Ayscogh 4/-
3 cartloads of wattlyng to same 1/6
Stipends of 2 carpenters carrying stone and clay for the same for 1 day 2/4

6 cartloads of timber for repair of house of John Clay 2/6
1 cartload of spars from Frithbylund to the same
1 cartload of stone
600 sclatestane from quarry of Hernby *(Hornby, Bedale)* to manor of Bedale at 9/- per 1000 6/3
4 cartloads of lime from Cracall to the Manor 2/8
2 cartloads of sand for the same 3/-
stipend of the carter carrying 10 quarters of lime of Burton on Yhore to Bedale 2/6
2 cartloads of clay for the Lord's house once of John Caterik in Emgate 6d
3 cartloads of old timber from the tithe grange of Ayscogh to the Manor of Bedale
2 cartloads of old timber from the tenement of Wm Walker to the Manor
2 cartloads of spars and watlyng from the Park for the repair of the tenement of Thomas Rudd in Burrell.
2 cartloads of timber for the Manor Gate from the wood
Stipend of John del Cote tiling (tegen) on the Grange, 9 days at 8d
Bread and ale for raising the house of John Watson in Ayscogh…
2 cartloads of clay for daubing (riggat) a grange.

5 cartloads of clay for repairing a wall within a tenement 1/3
carriage of lime by a hired woman 2d
4 cartloads of straw brought from the Rectory to the tenement 8d
2 cartloads of straw to the tenement of John Watson.

ZBA/11/8/1/4. (NYCCRO05)

Michaelmas 1429-30

Repair of the tenement of Thomas Vale
Stipend of John Thirn for cartload of timber for the buildings of one house of Thomas Gale, erected anew 19/-
Stipend of Simon Wade for the carpentry of the same…in gross 100/-
Sawing of 'tubularum' and timber 20/-
Stipend for carrying stones for walling, clay and sand 17/10
1000 laths bought for the same 10/5
4000 lathnayles bought for the same 6s
400 medilspykyngs 20d
iron bought for making chains, crokes, hasps and staples ¾
12 quarters of lime (calceto) 10/8
stones bought for roofing same house 21/6. Carriage 14/10
bread and ale at the raising 2/6
total; £11 – 14 – 5.

ZBA 11/8/1/6 (NYCCRO06)

Michaelmas 1431 – 32

Repairs
Symon Ward the carpentry of a tenement lately in the tenure of Thomas Chandelier 21/4
To Thomas Felett and his mate for carriage of timber of the same 2/8
Thomas Harpour for daubing walls 11/9
Stone bought for roofing of the same, of which 9/6 for carriage.
Laths bought for same 5/10
10 quarters of lime bought for same at 9/4 for 7 quarters and 3/- for 3 quarters and for carriage.
4000 brodes 5/2
iron of Laurence Spicer for John Hamsthwayte for crokys, chains and nails 2/5
Bread, ale and cheese at the raising ¼
Roofing.
Total 116/5 ½

(lime for finish coats over earth plasters, possibly also for addition to daub)

ZBA 11/8/1/7 (NYCCRO07)

Michaelmas 1432-33

John Pygot for walling le Yatehouse of the Manor 10d
Thomas Harpur hewing and 'stauryng' the same 4/-
6 cartloads of earth for the same 18d
1 quarter of lime (calcet) 8/-
3 cartloads of sand
Schlatstanes bought at Langthorne for roofing the same manor 6/-
Carriage of the same by two mule-drivers 2/2
To Thomas Schlater for roofing 3 roods of a chamber called Dungron and another called Yatehouse 15/-
Same for mending great chamber on east side 4/-
Paid for carriage of baysestanes for the grange in the tenement of John Chalenor 10d
2 cartloads of wood for the same for wattling and daubing the same 12d.

ZBA 11/8/1/8 (NYCCRO08)

Mich 1433-34

Carriage of 19 cartloads of stone for the grange of John Hampthwayte 4/9
Carriage of 11 cartloads of earth and clay to the same 2/9

ZBA 11/8/1/10 (NYCCRO09)

Mich 1442-43

Excerpts.

To Wm Godale, carpenter. For making anew a small house in the said messuage
To the same for soleing (soland) lez Stothis et postis within the said house
Collecting several stones called baystonis and carrying
Cutting stoups and carriage from the Lord's wood to said house
Digging and laying in the cart **7 cartloads of clay** with carriage from le stonecannse to said messuage
To Robert Morland hired for 'peyntyng and betyng 7 rood in said capital house
3 quarters of burnt lime at 16d per quarter
2 cartloads of sand.

To Cole and Clapham, labourers, hired for mending walls of (John Burrel) in places
Carrying 2 cartloads of clay from le stonecannse to said house
Carrying 5 cartloads of sand
6 quarters of lime.

John Punderson hired for making anew one wall of a house within the manor called le Carthous
1 quarter burnt lime for same
1 cartload of sand.

To John Hamswayt hired to cut and carry from the wood to (Wm Coltonn) house one cartload of 'dowbynstawris'
To Thomas Clapham constructing and daubing the wall of said house
To John Cartere of Harnby for 2600 slatstonis for roofing said house
…**To Wm Symondeson for 7 quarters of burnt lime for the said walls**
To John Hamswey carrying lime from Ffrtheby to said house
To same for digging, laying and carrying 13 cartloads of calay for said house
To same for 3 cartloads of sand.

To John Hamsweyt for cutting and carting 1 cartload of underwood to said grange (of Robert Medilton) for walling the same
To same for digging 3 cartloads of clay for said grange
To Thomas Clapham for mending and daubing walls and for roofing the same.
Thatching.

2 cartloads of timber from the Lord's wood for the messuage of Wm Smyth.
John Hamsweyt for 4 cartloads of clay for the same

…one sieve for sifting burnt lime

one vessel called a 'bolle'

ZBA 11/8/1/11 (NYCCRO10)

Mich 1443-44

To Robert Morton, Parson, for 60 threaves of rye straw for roofing of a capital house in the tenure of Wm Smyth at 2d a thrave
To Margaret Hoddeson for drawing said straw for roofing
To John Hamsweyt for 6 cartloads of stone from the field of Brell to said house
To same for digging 12 cartloads of clay from the stonycawnsey for same
2000 lathnayle
3 cartloads of underwood called wattelyng from the Lord's wood
7 cartloads of clay and carriage from Crynggilgate to the house
To Richard Durrell and Rob Medilton for 60 thraves of barley straw for roofing
To John Webster for 20 thraves of wheat straw.

ZBA 11/8/1/19 (NYCCRO11)

1454-55

To Simon Bynkes, carpenter, for one pair of mylletrendles bought for the water mill
To Wm Smyth for a new loop of iron bought for the mill
To John Lofthous for planks bought for part of the millwheel called lez almes mending
To Thomas Herryson for one piece of timber called walplate lying on the wall of the mill, defective, with carriage from the Lord's mill
To Wm Slater of Exylby for roofing the mill house in various places with burnt lime and le slatestones and mending the roofing of the Town Hall
Thomas Cole for mending the wall of the mill in places with clay.

ZBA 13/4/5 (NYCCRO12)

Bedale 1755-1769

Account of cash laid out for Mr Peirse about Tindall House (April 1755 – January 1756.

Jonathan Sowler making bricks (44,000) in the Park 15-10-0
Thomas Thompson for mason work 22-2-3
Hodgson for digging sand hole
Mr Theakston for lime 6-10-0
William Horner for lime 4-17-0
A treekle hogshead for the brickyard…
For a hair sive…

For a fine sive.

Richmond House 9/12/1755

Thomas Thompson agreed to do all the plastering at following prices: all that is lathed and plastered with three coats at 2 ½ d per yard and all the rest at 1 ½ d per yard.

ZBA 19/2/4/46 (NYCCRO13)

Thomas Thompson for work by day.

Jan 12 Myself 3 days putting up the chimney stones and laying two hearths
Jan 16 Myself 2 days walling in the cellar
Feb 3 Myself one day and half latting the cellar chamber floor
Ditto George Walton 1 ½ days
March 2 for a hearth stone
Myself half a day dressing and laying it
Paid for two scuttels
For lime to finish the kitchen
Feb 16 Myself laying the passage floor 1 day
Feb 20 Myself 5 days laying the plaister floor and making the stuff ready
Ditto George Walton 6 days
Ditto Wm Walton 3 ½ days
Ditto my son 3 days

(all indoor work during winter)

March 27 Myself 2 days making the steps
Ditto Wm Walton ½ day
Wm Walton 5 ½ days carrying rubbish out of stables and brewhouse
Wm Walton 5 days at sandhole and filling the chart
April 3 Wm Walton making lime and diging the foundation for the little house 1 day
April 6 Myself at Little House 1 day
Ditto my son 1 day
Ditto George Walton ½ day
April 14 George Walton at the house 1 day
Wm Achison 1 day
For 1 yard of rigen to George Scott.

PR/BPT/6/1 (NYCCRO14)

Specification and estimates re building of vicarage 1861-63
Bishop Thornton Parsonage, John A Cory, Architect, Carlile.

Mason's work

Walls
All the walls to be externally of coursed rubble with an inner lining of brick, leaving a space of 1 ½ inches clear, the outer wall to be throughed once in every yard….

Slater's work

Best Welsh slates, each slate with 2 copper nails…**to be well pointed with hair and lime.**
Provide an earthenware or stone ridging bedded in lime and pointed with cement

Plasterer's work

Lath and plaster 3 coats all the ceilings of the house, boys' bedroom, coach house and stable and whiten the same
Lath and plaster the stoothed partition on the upper floor 3 coats
Run bead and flush **Portland cement skirtings** in the lobby entrance, staircase, lower WC, kitchen and scullery.
Plaster with Portland cement the jambs and breasts of all the upper windows and of the kitchen windows and the jambs of the larder pantry and scullery windows.
Lime white 2 coats the stable, washhouse and cellars, run cornices in dining and drawing rooms.

ZAZ/ 75 and 76 (item 8813 onwards), NYCCRO15)

Marske Hall.

1609-1624 Accounts for work on Dovecote, Brewhouse, Hall etc.

1622 June 21

9 stone wyndowes, 3 feet high, 3 lights apiece.
2000 slate
1000 latts
3000 latt prods
20 yards of water-table
5 roods of wall 26s 8d per roode
burning ye lyme kyllne 50s
24 quarters of coles
rypping of wall stone at quarrie
rydding of rubbage off ould wall
leading ye lyme
leading sand
lead gutter
leading of wall stones.

August 1622 Computation for ye Brewhouse. It must be 20 yards long…and lofted.

Rypping and leading stones
Walling 29s per rood
Rydding walls and earth
3000 slate
leading slate
for slating
40 payre of spares 5 yds long sett in ye wall-plates
wall-plates and rybbs
1000 and a half of latts
latt prod 4000
lyme kyllne

August 17 1622 *(mason burning lime as well as building)*

March 2 Thomas Stott for ye kyllne
April 12 Thomas Stott for ye kyllne
May 25 Stott for walling in part
June 8 Stott for walling in part
June 15 Stott for ye kyllne
June 17 Stott for walling in part
June 28 Stott for the same
August 3 Thomas Stott for slating in part.

A Computation of the Dovecoate

To be 7 yards square and 7 yards high, cometh to 4 roodes.

Ye leading of ye stones
Ye building
Ye woodwork
4 stone wyndowes
6 water tables
406 slates
206 latts
106 nales.

Thomas Stott 6 dayes leading lyme and stones, man and horse. 6d man and 6d horse a day.

Januarie 6 1619. A Rate of ye Dovecoate

A lyme pytt betwixt 9 and 10 (yards?) at ye boddom, 4 yardes highe and proportionable as they shall be directed by Christopher Orton and well fylled.
£3 for burning and making ye pytt.
60 loade of coals with some wood
wall 30s per rood
£3 of wood worke
slating 14s

Rydd grounde and walles
Payment to masons in July

Slates brought from Richmond.

Payment to masons, August
Agreed for leading all ye lyme 15s

June 27 1625

Agreement between Timothie Hutton of Marske and Peter Crossbie, Gardiner…viz ye said Peter shall ? ye grounds of ye garden abovesayd within and without ye walls…to make fower quarters therein according to ye proportion of 1 quarter already drawne on ye four-wast syde of ye said garden with flower allies as they are already sett forth and the sayd Peter shall make an Arbor on ye north syde…from ye east to ye west end as far on ye west as ye orchard done now standeth.

ZDV (NYCCRO16)

Newburgh Estates Accounts and Wages Books 1851-1939

Thomas Fox, lead mason. Payments for all masons (which include 2 and then 3 of his sons) made to him; all paid on a day-rate, which is the same winter and summer. James Fox ultimately takes over from his father. There is little difference between the nature of the work in winter and summer – indicating that lime work was being done all year round. In one year only, payments are made in January and February for shovelling snow (and for little else). Mortar is made typically the day before use – for plastering as well as building. Or else, all mortar is made before works of longer duration begin, and during these works. It is typically made up in the 'Lime House'.

1851

June 24 Paveing at Newburgh
29 Repairing the Park wall

1852
January 10 1 day at Oulston well
February 2 1 day at Lazenby oven
4 1 day at Park wall
6 1 day at the little hothouse
11 1 day with the bellhangers
19 1 day fixing the spout in the yard
20 fixing grate stonework
March 13 1 day whitewashing
15, 16, 17 at the Lime House
18 on 7 days working on the Park wall

Christopher and James Fox appear.

April 17 C Fox slacking lime; James Fox working stones
19 Building sawmill – 4 men through April, May and June

July 2 2 men making lime
July 16 numerous days at Oulston Lodge; also working on the Mill Wash.

August 28 **2 men 1 day making lime**
31 whitewashing at Newburgh

September 23 **Robt Simeson 1 day making lime**
27 1 day setting oven
28 3 men 1 day plastering Granery
29 chimney and foundations
30 several days, 7 men pulling down house, four of them Thomas's sons, this the main job through October and into November.

December 2 3 men latting and plastering Gass House
4 1 day lime
18 1 day whitewashing
1 day lime.
Working on Gass House through December.

1853
January 6 men at the Park wall
24 onwards and into February 4 men working on **Harrison New House** – George Taylor, Christopher and Thomas Fox, Richard Lovell. 3s a day is masons rate. Christopher Fox (presumably apprentice) 1s 6d. Lovell 2s.

March 21 onwards and well into April, James Fox and Geo: Taylor at Harrison new house; then, from April 25 and through May at the Tanyard.

June 15 Pulling down cottages in Coxwold.

September 5 men in Park quarry and building cottages in Coxwold.
Work on Yearsley Chapel

October, working a lot on the Gas House and still on Coxwold cottages.
November – same. Still on the cottages in December.

December 26 on cottages and still in January, February, March and April. No work on Christmas day or New Year's day.
May 12 At Mr Scott's and Thornton Hill.

September 25 Newburgh stables, 4 men till October 2.

October and November, a lot at Angram Hall.

1869.

James Fox now head mason, earning 3s 6d a day; others on 2s 9d.

July 3 leeding bricks to Bog Hall
Leeding sand from Yearsley
July 17 leeding tiles from the Brickyard

Working on the Gas House.

September 1 ½ day at the soft water tank, Bog Hall
2 Wm Fox 1 day repairing and plastering tank with **cement.**

Park Wall repairs, paveing. I day at Coxwold quarry wall.

October 7 Thomas Scott digging foundations for garden wall at Bog Hall
23 walling beast trough at Bog Hall

1870

January – repairs to Coxwold quarry wall; other building repairs – Wm Salmon House, Coxwold; Lion Lodge; Wm Johnson house

February 1 day beam filling and whitewashing, Granary
19 1 day at pillars, new Park wall.

April 18 1 day coulering and repairs, south front of the house, 4 men.
20 painting and repairs, north front
4 Acres door, pillar and Park wall, Park House
29 1 day whitewashing loose boxes and pig-styes at Newburgh.

July 4 whitewashing cowsheds at Newburgh.
Bricks and tiles led from the Station.

November 1 day at Shandy Hall

1871

Jan 25 Francis Walker ½ day slaking lime
26 ½ day at the Cowhouse
30 ½ day at sunk fence wall
Feb 2 Mixing mottar for Mr Sowerby's
3 and 6, 2 men at Sowerby's House
Park wall repairs.

August 26 1 day coulering Hayton's House at Newburgh.

1872
January, at various buildings

April 24 **J Scott 1 day making plastering for Mr Priestman's**
26 C Fox 1 day at Priestman's
27 ditto. J Fox 1 day mixing mortar for gardens

May 7 J Scott 1 day making mortar for Watson's buildings
8 5 men at Watson's;
Wm Fox colouring at Mr Watson's
28 1 day pointing pillars t Newburgh

June 6 1 day at Watson's, Oulston, plastering granary. 3 men.

July 17 J Fox, 1 day repairing Mr Sowerby's ceiling and Lime House roof.

Nov 19 J Thompson 1 day pulling down and rebuilding stackyard wall with 3 others for 3 days.
Nov 26 pointing stackyard wall

December quarry wall repairs. Building repairs going on throughout December.

1873

January 1 – 8 Repairing farm buildings Newburgh. 3 men, fetching tiles.
20 pointing tiles at Cowsheds, Newburgh; other building repairs

Feb 17 Scott leeding lime
21 getting stones up for Mount House.

March 10 J Fox pointing at north front
Wm Fox hammering stones at Mount House
24 scraping stones to the front of the Hall; pointing the same.

July 4 whitening the house and pointing
8 whitening at Mr Dobson's
25 J Fox working stones for north front, Newburgh.
28-30 3 men repairing same

Sept 16 pointing the outbuildings
25 making mortar at Moorhouse
26 J Fox at Moorhouse repairing with 3 others.

October 16 – 18 J Fox 1 day hammering stones for Chapel with C and Wm Fox.
20 Wm Fox and 2 others digging foundation
21-30 4 men, Chapel wall.

31 until 24 November, all at Mount House, with occasional days thereafter.
Again Dec 1 – 6.

Then at New Mill 8 – 19 December
December 19 making mortar for slating
20 and 22 at Chapel.
23 putting coping on Chapel wall, 3 men.

More days at the Mill and at Mount House.

1874

Jan 9 J Fox latting and plastering with C Fox and J Scott.
12 J Scott getting sand
Wm Fox 1 day plastering
22 getting sand
23 J Scott making plastering
29 Wm Fox setting fireplaces
C Fox plastering with J Scott *(plaster 5 days old)*.
30 plastering
31 leeding slates from Station

Feb 3 plastering; J Scott at Newburgh making mortar
4 Wm Fox plastering
7 plastering

April plastering at Mount House

Similar patterns of working for next 7 years.

1879

Jan 6 5 men at quarry wall.

Cleaning drains; working generally at Pond Head

Jan 23 making plaster at Pond Head
  28 whitewashing in farm yard buildings

February – repairing various walls

March. Still largely at Pond Head and still into April, although less intensely.

1880

Jan 15 4 men laying **cement floor** at the Hunt House

March 13 Plastering staircase at Hunt House
  25 finishing plastering at same

April 16 Laying cement road near the office, Newburgh

Sept 7 Removing ridge in the Lime House

Oct 26 pointing old stable 4 men

1881

March 30 **J Scott 1 day making mortar at Newburgh for Winter Cottage**
  31 3 or 4 men at Winter Cottage for 6 days; more days through April and into May

Jan 1 Wm Fox shovelling snow, with the other masons; still doing this on 29th.
(1881 was one of the coldest winters on record, with maximum temperatures in York of -7.8C and down to -21C. This the only winter in the accounts when the masons did not carry on working as usual, with indoor work being done only if it was there to do).

Dec 1881-Feb 27, intense activity at Mr Easton's/Oulston Lodge

March 25 mixing mortar for Mr Berry's buildings

Jan 1882 brick oven in hall
Pulling kitchen fireplace down
Pointing bedroom fireplaces; other inside jobs around hall, but also in May.

ZKZ/3/2/1/6 (NYCCRO17)

Nunnington.

Papers re Stone Bridge

1691 Letter to Ronald Grahame Esq

…If you please to order the getting up and rough hewing of stones at the quarry to be ready at May Day for leading, the work may be done this summer.

An Account of the Charge of Nunnington Stone Bridge built in the year 1673

To John Wilkinson, free mason £85
6 trees out of plankwood
From Wiggington 35 trees 14:15:06
Richard Marshall at our time 15:6:8 and at another time 11:17:2 for carpentry work about the said bridge
To Edon for 4 chalder of coals bought to burne 25 chalder more lime
For 25 chalder of lime for the stone bridge at 2s 4d a chalder over and above the lime above-mentioned.

Alternative version:

Paid by lime which Grahame had in his Lime House which was delivered out for the use of the said bridge 40 chalder
For burning the said (extra) 25 chalder, the fellows got stones out of the barne wall.

For gathering pebbles to pave the bridge with.

ZPB (M) 1-47 (NYCCRO18)

Fitzwilliam Estate, Malton archive

Specification of the manner and executing of the different works proposed to be done in the repairing the Hunters Hall, Old Malton. Architect John Gibson 1841.

Masons Work

The contractor to repaire the window sills and architraves on the front of the house in the proper manner according to the same order as at present, shall take down to the same order as at present shall take down and rebuild the crack part of the back wall , repair the chimney tops and take off the old tiles of house and kitchen and retile and sheet them *(lime sheeting over lath)*, on the backside, shall point up all cracks etc in the walls **with good mortar**, cover the ridges with good ridge stones and the front end side of each end of house with 13″ water-tabling and corbles in a proper manner , shall lay the floor of kitchen and entrance hall with good tooled flags, well squared and jointed in good dry sand, the back kitchen floor to be laid with the old flags got from the present kitchen floor, and the dairy with good common brick, good flag thresholds to all doors, sett all Ranges with fire bricks in the proper manner…

Slaters

The slater will slate the front of the house and back kitchen with good duchess Welch slate laid on good common fir laths, united with two copper nails to each slate; and **pointed with good lime and hair.**

Plasterers

Will plaster the ceilings of low rooms and chambers with good three coat plaster, on good stoute laths, three coat plaster on walls of low rooms and chambers, two coat ceiling of kitchen with good two coat plaster on walls, will lath all lintels and quirk all beads.

ZPB III 8/9 (NYCCRO19)

"Estimate of the Expense of Raising the Talbot Inn at Malton, belonging to the Right Hon'ble Earl Fitzwilliam and Tenanted by Mr Husband [Thomas Husband had taken on the lease, from Ann Smith in 1807]. Valued April 1808.

Chiselled ashlar masonry stone, and all materials included Hammer-dressed outside walling Five inch partition walling Chimney flues
Outside chimney shafts Outside hammer-dressed arches

Thresholds and window sills. Working and resetting the old cornice with part new 3-coat ceilings. Plaistering the walls for paper

Carpenter work: Reframing the roof with additional new timber; Framing up the floor and straightening the timber floors; Ceiling joists1 1/2″ boarded floors; Hip and rolls; Astragal moulded sashes and frames; 2 inch ogee and beads1/2″ window casings 1 1/2 ″; rebated door casings 1 1/2″ ; double-framed doors; Torus moulded scanting; Ten chimney pieces; Glass in the sashes; Slating the roof with the best Westmoreland Slate and all materials included; Locks, bolts, sash cords, pulley weights, iron work for the roof, etc
NB in estimating the above work no leading is considered and the old lead when taken off and recast will cover all the hip ridges, chimney, gutters etc. The old slate ridging, coping , dormant windows, doors boarded floors, mouldings, etc etc will amply repay the expense of £788 19 - 6

Taking down the old roof, walls etc ready for rebuilding, also for altering the best stairs and the centre window in the street front."
P Atkinson

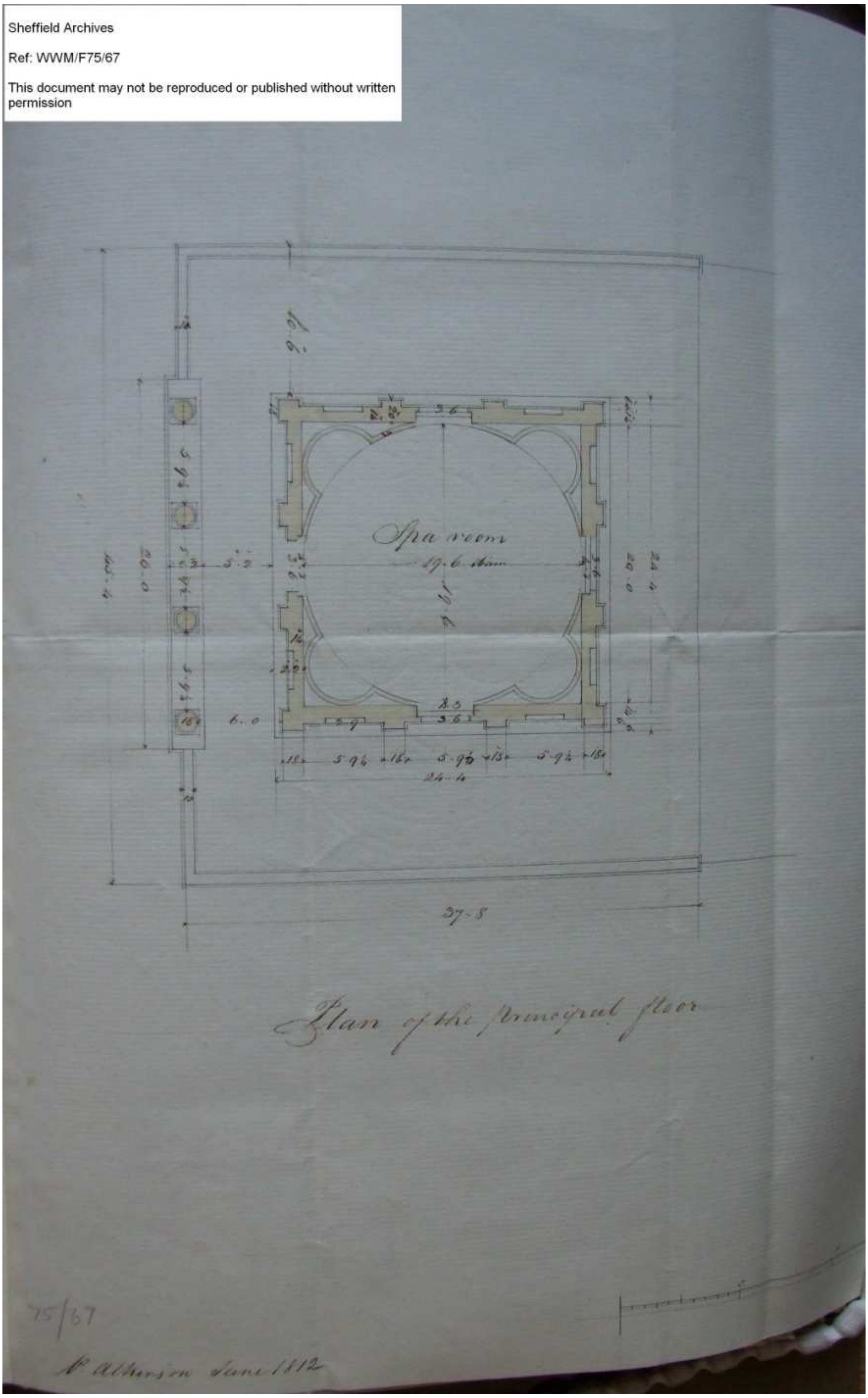
The bundle also contains a letter to Malton Agent from a roofer in York, Thomas Rayson, an excerpt from which reinforces the involvement of Atkinson:
"seeing in Mr Atkinson's office Plans for the additions and alterations to the Talbot Inn, Malton..."

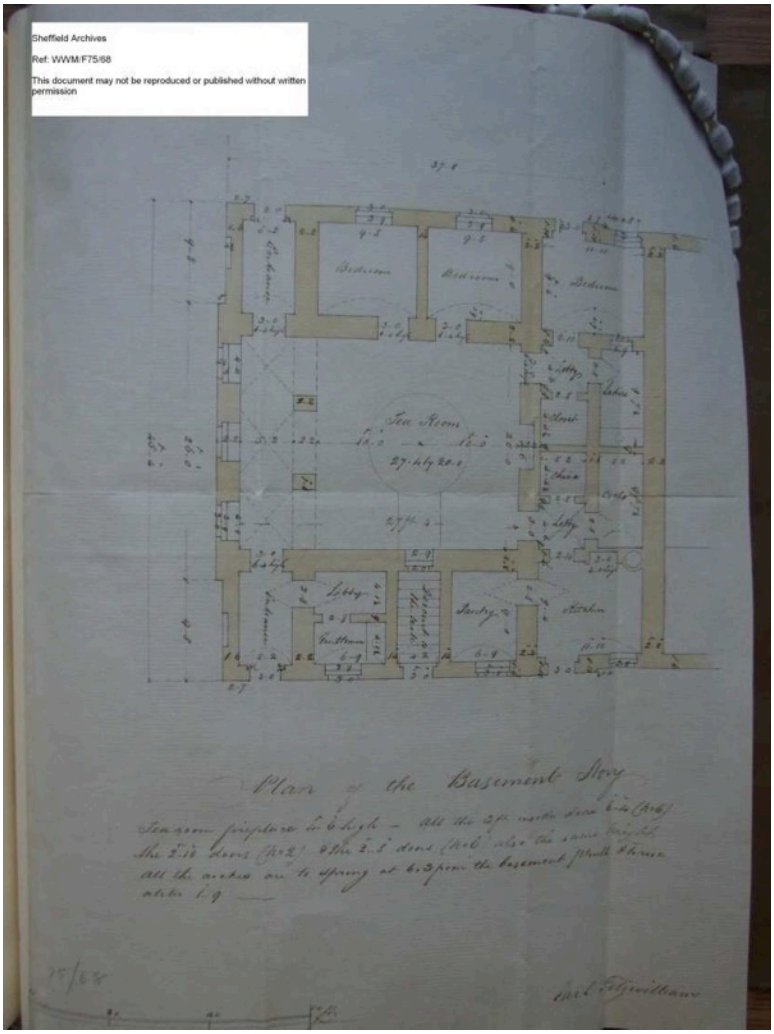
Letter from Atkinson to Malton Agent: "York, August 15th 1808.

Inclosed you will find the plans for the alterations at the Talbot Inn, Malton, together with a plan of the roof timbers,etc, laid down in the ?? which I trust John Craven will fully comprehend, as I have taken all the pains in my power to render it as intelligent as possible – but should he require any further assistance, I will ride over any day this week to Malton...." P Atkinson
Another, York, September 24th 1808:
" I am extremely sorry I was so unfortunate as to pass you on the road yesterday on my return from Malton...Earl Fitzwilliam having ordered that a water closet should be fixed in the small room at the end of the chamber passage, near the room named the Rockingham, I found upon enquiry that the plumber at Malton has not been accustomed to such work and, as the utility of a water closet solely depends upon their being properly fixed, if it meets your approbation I think it would be advisable to send Messrs Crofts from this place to fix it – but I shall wait upon your reply before I announce it to him.
I was glad to find the workmen had forwarded the building so well. Mr Exley must write to Rayson the slater when the roof will be ready for them.
Peter Atkinson"

York, September 29th 1808: "Dear Sir,
The sketch on the other side is for the alteration of the Talbot staircase and passage. The new part is coloured yellow and I have dotted the line of the passage wall. The bar will be considerably improved by going under the half? Of the stair and I shall get nine feet clear headway under the stairs to the best rooms which will make quite handsome – the wall which divides the vestibule and staircase I have taken away altogether as it only supports the landing floor which may be framed into a beam. I have written this in pencil that it might be scrubbed out to another way for your letter to Lord Fitzwilliam.
P. Atkinson to Samuel Copperthwaite, Agent.

Atkinson's Spa building drawings, 1812.


Spa room
19.6 diam
Plan of the principal floor
75/67
P Atkinson June 1812



In 1818, Atkinson and Phillips prepared a 'General Statement of the Workmen's Accounts as measured and valued in April 1818' by themselves.
These accounts included works to Howe Farm (£67), The Lodge (£345), House in Low Street (now Castle Dykes, then a stonemason's house and yard, built by George Willoughby); 3 tenements in Wheelgate, as well as more stables 'at the hotel' (Talbot) .

This document is signed, the works having been 'measured, valued and examined by Atkinson and Phillips, Architects, York April 22nd 1818. The works themselves were all executed in 1817.

THORNTON ESTATE ARCHIVE (TEA), Thornton-le-Dale, North Yorkshire. Private, now at NYCCRO but as yet uncatalogued.

TEA01

From Account Book 1733-34

To Wm Grey for leeding 181 load of stones from Appleton Comon to Normanby at 2s per load - £18 18s
To Idem for leeding **86 load of mortar *(earth mortar)*** at 3 ½ d per load - £1 5s 1d
To Idem for leeding 10 load of Thatch – 5s
To Idem for leeding 1 load of bricks from Kirbyovercarr – 4s
To Ld Blomberg for 650 bricks – 9s
To Wm Westday for cleaning the rubbish out of the new house – 4s 2d
To 1 load of Oake wood to make a Helme for Wm Grey - £1 8s
To Wm Grey for damage done in his ground by building the house - £1
To Wm Grey for leeding 1 load of Chimney Stones from Pickering – 4s
To Buckett for Wm Grey well – 1s 2d
To James Sparling for 1 threave Straw – 1s
To Ellin Hind for ale the workmen when they built Grey House – 1s 2d

TEA02 Thornton - High Paper Mill

This appears at the end of the Thornton Estate account book for 1733-1734. High Paper Mill remains, as a farm, towards the head of the dale through which Thornton Beck flows and just below Dalby Forest. This account is notable for the volumes of imported building materials used – particularly softwoods from the European continent and – surprisingly, perhaps, pantiles from Holland. The earlier building will have been thatched.

The Charge of Rebuilding High Paper Mill in 1734 viz

£ S d
To Bryan Fenwick for an Axletree containing 73 foot when it was brought,
It was afterwards reduced to 48 foot
5 0 0

To Wm Storr for leeding it from Helmsley to Thornton at 3 ½ d per foot
0 14 0

To Richd Foorde for cutting down six large oakes at Welburn
0 10 0

To Wm Storr for leeding them at 3 ½ d per foot 188 foot
2 14 2 ½

To John Hill Esq for 6 oakes containing 188 foot at 12d got at Welburn
9 8 0

To Richard Beilby's bill for nails
5 11 0

To Henry Wilkinson for 120 deales
5 12 6

To leeding them 12s allowances & tole 12d
0 13 0

To Mr Olbie's bill for 8000 Holland Tyles
22 6 0

To fraight of ditto from Holland; to carriage of ditto from Scarbro
4 16 0

To tole & allowance for ditto
0 8 0

To John Gilbank for 108 foot of riging (ridge) stones at 6d per foot
2 14 0

To Saml Woodhouse for 35 stone and 5 pound of Lead at 2s 4d per stone
4 2 4

To idem (same) for 85 ½ foot of Leaded Glass at 5d per foot
1 5 7 ½

To mending old glass
0 1 4

To Wm Keay for 16 foot of riging stone at 6d per foot
0 3 0

Richd Birdsall bill for Ironwork
3 17 0

To Richard Marshall for leeding 71 load of stones, 13 load of Flaggs,

1 load Tyles, 2 load stones from Ebberston, Deales & Thatch
2 13 7

(side note: see P 136 – on which page of the a/c book, more detail:
'to Richard marshall for leeding 71 load of stones to Pa: Mill; to 13 load of flags to ditto; to 2 load of stones from Ebberston to ditto; to old Thatch leeding from ditto; to 1 load tyles from Scarbro to ditto; to 2 load Deals from Thornton to ditto...)

To Roger Coates for leeding stone
0 4 8
Thomas Marshall for leeding stones and wood
0 12 6

To Robert Gilbank for 87 load of stones at 4d & 13 load of Flaggs at 12d
2 3 0

To John Baines bill for Wood & Workmanship
73 11 8

To Richard Rogers for Millwork
21 0 0

To 2 Plates for mortars

To Wm Skelton for 8 threave Straw and leeding it
0 5 8

To Wm Robinson of Kirby for 170 smale Oakes for the roof
22 10 0

To Wm Storr and others for leeding the sd wood there being 21 tunn of it
7 0 0

To Henry Wilkinson for 21 Deals
5 17 6

To leeding them 12s toll & allowance 12d
0 13 0

To Mr Gott's bill for deales and poles
5 4 6

To leeding 'em
0 12 0

To toll, loading & allowance for the Draughts
0 1 0

To Wm Allason for going to buy the Deales etc
0 1 6

To ale for workmen at several times
1 0 0

Mason work
13 2 10

Labourers work
8 7 9

Joyner work done at the house
2 4 11

(Lime is not mentioned – perhaps because supplied by Estate; earth will have been sourced on or close to the site)

TEA03

Scalby Manor Rebuilding 1733-1738

John Hill of Thornton acquired the Honour of Pickering and Manor of Scalby lease in 1733 from Mary Hart, widow of Robert. This document shows that he immediately set about assessing the condition of this Estate, which he found to be very poor in the case of Scalby, at least, and sought to quickly address its improvement. These few documents alone show that this was a major undertaking – and show equally that it is one that Robert Hart had clearly been content to ignore. A spate of enclosures in and around Scalby, as well as in Wykeham, Brompton, Allerston and Ebberston illustrate that the Hills sought to improve generally and, of course, to enhance in the long run, their income from the Estate.
As shown in building accounts, the masons involved – Robert Gillbank to some extent, but mainly James Joyner – were from Thornton Dale; likewise William Allison, the joiner. Thatch was the main roofing material and was mainly of Straw, but some Ling was also used. Pantiles were brought from Scarborough, into which they had likely been imported from Holland. On one house, 'Cornish stones' were used – these almost certainly being Delabole slates for the roof. Stone was sourced locally, as may be expected, as well as mortar. The masons not only laid up the stone, but also tiled the roofs and plastered the interiors, the carpenter sawing necessary roofing battens and riving lath on site. Deales were typically brought from Scarborough, indicating their importation from the Baltic. Heavy structural timbers were of oak and were locally sourced, as detailed in these accounts. Thatching was always done by a Thatcher, with straw often

supplied by the tenant whose house was being repaired or rebuilt. One tenant, at least, supplied and mixed the lime mortar for the masons, indicating, perhaps, the presence of a lime-kiln on his land and a part-time occupation as lime-burner.
Come 1772, Captain John Hill was seeking permission of the Crown to convert many of these same houses into barns and stables, whilst building new houses in response to the enclosure of the commons of Scalby Manor. **(HE/DL/104).**

To his Grace John, Duke of Rutland, Chancellor of his Majesty'd Dutchey of Lancaster etc
The humble Petition of John Hill Esq
Sheweth
That his late Majesty King William the third of Glorious Memory by Indenture of Lease under the seal of his Dutchey of Lancaster, bearing date the 18th May in the ninth year of his reign, did demise unto Abell Tassin D'Allonne Esq, the Castle and Mannor of Pickering and the Mannor of Scalby with the appurtenances and divers other lands, tenements, messuages, farms, houses, edifices, barns, stables and other things therein particularly mentioned...to hold for the term of 99 years from the death of Catherine late Queen Dowager parcel of whose Jointure the same were...and in which said Lease there is a covenant that the lessor, his executors and assigns shall from and after the expiration of the said late Queen Dowager's terms sufficiently repair and uphold the Houses, Buildings etc and leave them so repaired at the end of the said term taking from time to time sufficient Houseboot and Timber growing in the Woods and Lands of the premises by assignment of the Surveyor Generall, together with the Hedgeboot, Ploughboot, Fireboot and Cartboot, without delivery, doing no waste and to be dispended upon the premises. That the premises are now by Mesne Assignments vested in your Petition and many of the Houses and Buildings there now in your petitioner's possession are very much out of repair, which repairs your petitioner is willing to make, having sufficient Houseboot and Timber assigned him for that purpose, the particulars of which and of Timber necessary for the same and hereunto annexed.
Your Petitioner therefore humbly prays your Grace to issue your Warrant to the Surveyor of the Woods for the North Parts of his said Dutchey and such others as to your grace shall seem meet to View and Survey the premises and what Timber will be necessary for such reparations, and to assign the same in such manner as your Grace shall think fit.

Tenants Names at Scalby	**Houses Down**	**Houses in bad repair**	**money to be laid out in Timber for rebuilding Or repairing the sd Houses**
Wm Coulson A house on the Green		1	10: 00: 00
Wm Smith A barn & Cowhouse		1	12: 00: 00
Robt Read, 2 houses,			

2 barns & outhouse		2	14: 10: 00
Robert Outhert, house			
Barn & outhouse		1	00: 10: 00
Joseph Linsley, house & barn	1		10: 00: 00
Ditto, house & barn, lately burnt	1		18: 00: 00
John Atty, house		1	00: 05: 00
Mathew White, house, barn			
& stable		1	12: 00: 00
Samuel Hodgson, barn		1	10: 00: 00
Robert Vasey, house & barn	barn	1	15: 00: 00
Edward Storme, house & barn		1	10: 00: 00
Wm Hollis, house	1		20: 00: 00
Wm Pattison, house & barn	barn	1	19: 00: 00
Richd Vaugh, house & barn		1	05: 10:00
John York, house & shop		1	05: 00: 00
Francis Ash, house, barn & outhouse		1	10: 00: 00
Ditto, another		1	15: 00: 00
John Leasy, house & kiln	kiln	1	15: 00: 00
	3	16	194: 15: 00

Tenants names at Newby

Thomas Megson, house & barn			
Mathew Goodhill, house & barn		1	04: 00: 00
Wm Keld, house & barn	1		10: 00: 00
John Harrison, house		1	07: 00: 00
Wm Jefferson, house & barn		1	00: 10: 08
	1	3	21: 10: 08

Tenants names at Burniston

Thos Thornton, house & barn		1	08: 00: 00
Wm Washling, house & barn	1		10: 00: 00
Richd Richardson, house & barn		1	03: 10: 00
Thos Wade, house & barn		1	12: 00: 00
Richd Atkinson, house & barn		1	02: 00: 00
John Roades, house & barn		1	10: 00: 00
	1	5	45: 10: 00

Cloughton

Rd Tissaman, house & barn		1	03: 10: 0
Thos Wilson, house & barn	1		16: 00: 00
John Leadley, house & barn		1	15: 00: 00
Robert Gamble, house & barn		1	03: 00:00
John Mathews, house & barn		1	08: 00: 00
.....Westlaby, spinster, house		1	01: 17: 06
Stephen Walker, house & barn		1	16: 00: 00
John Sunley, house & barn	1		07: 00: 00
John Hird sen, house & barn		1	02: 00: 00

John Mathews sen, house & barn		1	03: 00: 00
Robert Leadley, house & barn		1	03: 00: 00
Edward Mathews, house & barn		1	01: 00: 00
Samuel Wainman, house		1	02: 02: 00
	2	11	81: 09: 06

Langdon

Richd Smalewood, house & hayhouse		1	20: 00: 00
Robert Pennoe, house		1	07: 00: 00
Robert Milner & John Kelds, Beast house and barn	2		20: 00: 00
Thos Keld & Wm Keld, 2 houses And barns down	2		30: 00: 00
John Cross, house		1	12: 10: 00
Thos Berryman, house	1		16: 00: 00
Thos keld jun, house	1		20: 00: 00
Robert Baker, house		1	10: 00: 00
	6	4	135: 10: 00

Timber necessary to Rebuild & Repair 18 messuages in Scalby will cost at a moderate computation		194: 15: 00
ditto for 5 messuages in Newby		21: 10: 08
ditto for 6 messuages in Burniston		45: 10: 00
ditto for 13 messuages in Cloughton		81: 09: 06
ditto for 10 messuages in Langdon		135: 10: 00
	Total:	478: 15: 02

Rutland duly ‘impowers’ Oswald Mosley Esq, Surveyor of his Majesty’s Woods within the North Parts of his said Dutchey, Hugh Cholmley, Wm Osbaleston, John Burdett, Timothy Ottbie Esquires, and John Baines, Gent, two or more, to survey the state and condition of the said houses and buildings distinctly, and to compute what, and how much Timber will be necessary for the repairing and making good the same severally, and when, where, and in what places such Timber, growing and being within the said Mannors, may be best and most conveniently cut and taken for such repairs, due regard being had to the preservation of the young Timber Trees and Saplings and the rest of the Woods and Springs of Wood within the same. And thereupon to certfye the same unto me, with (their) opinion what may be fit to be done in the premises...

“We have surveyed the same distinctly and find that within the mannor of Scalby, Vizt in Scalby, Newby, Burniston and Cloughton, there are thirty-nine messuages in bad repair and five messuages quite down, and in the Manor of Pickering, vizt at Langdon, there are four messuages in bad repair and seven messuages quite down. But we, Hugh Cholmley, William Osbaldeston and Timothy Otbie, upon our own judgement not being able to ascertain to your grace the quantity of timber necessary for the repairing of the same, have taken to our assistance **John Wilson and William Allanson, able and experienced Carpenters and Builders** whom we directed to survey each house and building severally and to certify the same to us, having also desired Mr John Baines, one of the persons named with us in your Grace's letter, who is experienced in Building and in Timber to accompany them in the said survey, in pursuance whereof the said John Wilson and William Allanson, being accompanied by me, John Baines, have surveyed the sate and condition of all the houses and buildings distinctly and have also estimated the quantity of timber necessary for repairing each house and building severally. The Estimate & survey...is hereto annexed...and by it we find that the quantity of timber necessary...is 419 tun; we have also viewed the woods within the said Mannors and do compute that in certain places called Dalby Haggs and Cloughton Wyke , 419 tun may be conveniently cut and taken for repairing and rebuilding the said premises....

And as the Rebuilding and repairing the said houses, being fifty five in number will require a great space of time and cannot be performed at once, we further propose....that as many of the trees as shall upon admeasurement be found to contain such a quantity of timber as is necessary to enable the said John Hill Esq to repair and rebuild the said Houses... may by your Grace's Warrant be assigned, mark'd and set out in the respective places beforementioned with power for the said John Hill Esq to take down the said Timber or any part thereof from time to time as he shall think necessary and convenient...on condition that the said timber shall be used and expended in and upon the rebuilding and repairing the said premises only and not otherwise.

The Survey:

Houses & Outhouses Out of repair	timber necessary for repairs

Scalby

1. one messuage in the possession of William Coulston, in bad repair 15	fifteen tun
2. one messuage in the possession of William Smith, In bad repair 9	nine tun
3. two messuages, two barns and outhouses, all In very bad repair, in the possession of Robt Read 12	twelve tun
4. one messuage in the possession of John Linsley, Great part of it down 4	four tun
5. one other messuage in the possession of the said John Linsley, lately burnt 10	ten tun

6. one message in the possession of Mathew White,
in very bad repair seven tun
7
7. one message in the possession of Samuel Hoghson,
In bad repair twelve tun
12

8. one message in the possession of Robert Vasey,
In bad repair fifteen tun
15

9. one messauge in the possession of Edward Storme,
Great part of it down, barn to be built four tun
4

10. one message in the possession of William Hollis, quite down seven tun
7

11. one message in the possession of Richard Vaugh,
Great part of it down twelve tun
12

12. one message & shop late in the possession of John Yorke,
Now of Robert Megson, in bad repair two tun
2

13. one message in the possession of Francis Ash,
In bad repair twelve tun
12

14. one other message in the possession of the said
Francis Ash, in bad repair eight tun
8

15. one message & kiln in the possession of John Leasey,
In very bad repair, the kiln and great part of the outhousing
being down to be built and repaired eighteen
tun 18

Newby

1. one message in the possession of Mathew Goodhill,
In bad repair, and the barn down five tun
5

2. one message in the possession of Thomas Megson,
In bad repair seven tun
7

3. one message in the possession of William
Keld in bad repair & a barn down seven tun
7

4. one message in the possession of John Harrison,
The outhouses thereunto belonging are in bad repair seven
tun 7

5. one message in the possession of William Jefferson,
In bad repair three tun
3

Burniston

1 one message in the possession of Thomas Thornton,
In bad repair and the barn thereto belonging quite down five
tun 5

2. William Washling, one message and barn thereto belonging
In bad repair four tun
4

3. one message in the possession of Richard Richardson,
In bad repair six tun
6

4. one message in the possession of Thomas Wade, in very bad repair two
tun 2

5. one message in the possession of Nicholas Atkinson, in very bad repair two
tun 2

6. one message in the possession of John Roades, in very bad repair seven
tun 7

7. one messauge in the possession of Jane Peirson in bad repair six
tun 6

8. one message in the possession of Richard Hoghson, now of
John Jackson, in bad repair seven
tun 7

9. one message in the possession of George Fox, in bad repair, and
The barn thereto belonging, quite down six
tun 6

Cloughton

1 one message late in the possession of Richard Tissaman, now of
John Hodgson, in bad repair three
tun 3

2. one message in the possession of Thomas Wilson, in bad repair five
tun 5

3. one messuage in the possession of John Leadley, in bad repair
seven tun 7

4. one messuage in the possession of Robert Gamble, in bad repair two
tun 2

5. one messuage in the possession of ......Weslaby, Spinster, now of
John Brown, in bad repair five
tun 5

6. one messuage late in the possession of Stephen Walker, now of
Thomas Baker in bad repair four
tun 4

7. one messuage in the possession of John Sunley, in bad repair
eight tun 8

8. one messuage in the possession of John Hird sen, in bad repair
thirteen tun 13

9. one messuage in the possession of John Mathews sen, in bad repair
twelve tun 12

10. one messuage in the possession of Robert Leadley, in bad repair
three tun 3

11. one messuage in the possession of Edward Mathews, in bad repair
eight tun 8

12. one messuage in the possession of Samuel Wainman in so bad repair
That it must be entirely rebuilt, and a new barn five
tun 5

13. one messuage in the possession of Thomas Tranmer, in bad repair
six tun 6

14. one messuage in the possession of John Pickering, in bad repair
four tun 4

15. one messuage in the possession of John Mathews jun, in bad repair
twelve tun 12

Langdon

1 one messuage in the possession of Richard Smalewood, in bad repair
three tun 3

2. one messuage in the possession of Robert Pennoe, in bad repair
seven tun 7

3 & 4 two messuages in the possession of Robert Milner & John Keld,
Quite down twenty-five
tun 25

5 & 6 two messuages in the possession of Thomas Keld & Wm Keld,
Quite down sixteen
tun 16

7 & 8 one messuage in the possession of John Cross & Thomas Berryman,
Quite down and another in bad repair twenty
tun 20

9. one messuage in the possession of Thomas Keld jun, quite down
eight tun 8

10. one messuage in the possession of Thomas Eskdale, quite down
fifteen tun 15

11. one messuage in the possession of Robert Baker, in bad repair
five tun 5

One Hay House in the possession of Richard Smalewood, in bad repair
two tun 2

Abstract Messuages, Timber for Repairs

In Scalby	15	147 tun
Newby	5	29 tun
Burniston	9	45 tun
Cloughton	15	97 tun
Langdon	11	101 tun
Total	55	419 tun

Hugh Cholmley John Baines
Wm Osbaldeston Wm Allinson
Tim Otbie John Wilson

Whereas His Majestie by his Commission bearing date 11th December 1734 and under the seal of the Duchy of Lancaster hath authorized and impowered Oswald Mosley Esq, Surveyor of the Woods within the North part of the Dutchy of Lancaster, Hugh Cholmley, William Osbaldeston, Timothy Otbie Esquires and John Baines Gentleman or any two or more of them, to set out and mark such and so many Timber Trees Growing and being in Dalby Haggs & Cloughton Wyke (having due regard to the Preservation of the Young Timber Trees and Saplings and the Rest of the Woods there) as will in the whole amount to four hundred and nineteen Tunns of Timber fit and necessary for the repairs of Thirty nine Messuages in his said Majesty's mannor of Scalby (to wit) in Scalby, Newby, Burniston & Cloughton, now out of repair and the rebuilding of five Messuages there now quite down; and also for the repair in his Majesty's Mannor of Pickering (to wit) four Messuages in Langdon now out of repair and for rebuilding seven there now quite down,

We the said Hugh Cholmley and John Baines, at the request of John Hill Esq, Assignee of a Lease of the said Mannor of Pickering and Scalby, for the purposes aforesaid, have set out and markt in Cloughton Wyke 253 Timber Trees which by admeasurement upon a survey contains 50 Tons of Timber, and we do hereby authorize and Impower you the said John Hill by yourself or agent to fell & cut down the said 253 timber trees to be used in such repairs and rebuilding only and not Elsewhere.

7th May 1735, Cholmley & Baines.

Followed by a list of houses as above – rebuilt or repaired.

Then another authorisation as above:

"We the said Hugh Cholmley, William Osbaldeston and Tomothy Atbie at the request of John Hill...have set out and markt in Dalby Haggs 750 Timber Trees...(containing by admeasurement) 369 Tunns (for exclusive use in the abovesaid repairs).

Trees were marked with John Hill's initial letter.

1738 – note that all repairs are complete.

Final report by the Commissioners when the term of their commission ended 1734, observing that not all repairs completed, but trees marked, felled and allocated.

Building/repair Accounts HE/DL/JR/295d (TEA04)

Paid out in 1735 for Repairs etc	£117-8-6
Charges about the wood this year (viz)	
To Allison for cutting down etc	1-10-3
For leeding wood this year	2-7-0
To Mr Wooller for marking etc	1-11-6
S Tatlay expences	0-4-6
Charges about the wood to be deducted out of this year's repairs	5-13-3
remains to be charged as for repairs	£111-15-3

Abstract of Mr Fairsides accounts relating to repairs in 1734

To repairs of Wm Pattison house, as appears note dated 8 December 1734	17-5-5
To Widow Storme for building an oven	0-10-0
To repairs of Wm Keld's house	5-15-3 ½
To repairs of John Harrison house	0-13-1 ½
To repairs of John Sunley house	1-7-7
Mr Fairside layd out in repairs in 1734	25-11-5
Samuel Tetlay laid out in repairs as appears by a particular account in 1735	117-08-6
The totall charge of repairs in the Manner of Scalby	142-19-11

A particular account of the charge of repairs to several dwelling houses, barns and beasthouses in Newby, Scalby, Burniston and Cloughton as hereafter mentioned viz

No.1
At Newby 0 Keld's Barn

Whole
charge
To James Joyner and Robert Gillbank each 3 days at Wm Keld's barn wall
at 16d per day 00-08-00
To labourers 3 days serving them at 10d 00-02-06
00-13-03
To Wm Allison (Joyner) 1 day 18d, his man 1 day 15d 00-02-09

No.2
At Newby, John Harrison Dwelling House

To Wm Bentley & Robert Barker each 3 days walling an end wall at 18d 00-08-00
To a labourer 3 days serving them at 12d 00-03-00
To Wm Allison (joyner), his man 2 days at 15d 00-02-06
00-17-06
To Widow Harrison for leeding stones & mortar 00-04-00

No.3
At Scalby, a house, barn and beasthouse, late John Lasey's now
William Sleightholme's

To James Joyner (Mason) for building 41 rood of wall at 3 shillings per rood 06-03-00
To James Joyner for pulling down the old walls and making ground work 00-02-00
To Wm Allison for slitting laths, sawing spars and all manner of
Carpenter work at the roof of seven Roomsteads and half accounting
5 yards to every roomstead at 15s per roomstead 05-12-06
To Wm Sleightholme and Others for 278 Threave of Straw for Thatch 10-06-03
½
To George Carr for 33 days Thatching at 16d 02-04-00
To Watering and Pulling 278 Threave Straw 01-14-06
To Richard Beswick for 12 ½ foot of Glass 00-05-02
To Wm Pattison bill for Iron work 00-14-03
To Idem for ale for Draught 01-03-03
To Rd Hird & Tho: Leadley for leeding wood 02-07-08 29
½ -12- 9 ½

No.4
Burniston – Nicholas Atkinson barn or beasthouse

To James Joyner for building 11 ½ rood of wall at 3 shillings per rood 01-14-06
To William Allison for slitting laths, sawing spars and doing all manner of
Carpenter work and setting the roof upon two Roomsteads and half at 13s 01-17-06
To Obediah Ridsdale for 46 Load of Stones at 4d per Load 00-15-04
6-13-04
To Tho: Langdale, Thos: Leadley & Christopher Harrison for leeding
44 load of stones at 8d per load 01-09-04
To Robt Leadley bill for Ironwork 00-08-08
To John Sunley 6 days thatching at 16d 00-08-00

No.5
Burniston – Tho: Wade Barn end wall
To James Joyner for building 3 ½ rood of wall at 3 shillings per rood 00-10-06
To the said James Joyner for making the groundwork and pulling down old wall 00-01-06
To Idem for 2 days at the Battlement of his house 00-02-08

No.6
Burniston – William Wasling Beasthouse
To James Joyner for 1 day walling at 16d 00-01-04
To Wm Allison for slitting laths & spars and doing all manner of work and setting the roof upon two roomsteads at 10s per roomstead, part of the roof being set up before Allison began 01-00-00
01-01-04

No.7
Cloughton – John Leadley, a new barn
To James Joyner for building 19 rood and half of wall at 3 shillings 02-18-06
To the said James Joyner for making ground work 00-02-06
To William Allison for slitting laths and sawing spars and doing all manner of Carpenter work and setting the roof upon 3 roomsteads and half 02-12-06 06-14-00
To William Read 13 days Thatching 00-13-00
To Robt Leadley bill for Ironwork 00-07-06

No.8
Todd's House repair'd and now let to John Mathews Junr at 20s p ann
To James Joyner for building 7 roods of wall at 3 shillings per rood 01-01-00
To Idem for mending the Chimney 00-00-06
To Idem for him and his men 4 days at 16d 00-05-04
To Wm Allison (joyner) 4 days at 18d 00-06-00
To his man 4 days at 15d 00-05-00
To Richd Hodghson for 30 threave of Straw at 9d 01-02-06
To Wm Read 7 days Thatching at 12d 00-07-00
04-14-06
To John Leadley for Wm Read's Table for 8 days 00-04-00
To Wm Richardson for 7 days serving the Thatcher at 10d p day 00-05-10
To Idem 4 days watering and pulling Thatch at 10d p day 00-03-04
To Richd Hodghson for leeding stones and mortar 00-02-00
To Richard Beswick for 25 ½ foot of Glass 00-10-08
To James Joyner man 1 day plastering 00-01-04

No.9
At Cloughton, John Sunley House and Barn repaired
To James Joyner for building 9 roods of wall at 3 shillings p rood 01-07-00
To Idem for pulling down the old wall and making groundwork 00-03-00
To Idem for 1 days work at Chimney 00-01-04
To William Allison 4 days at 18d 00-06-00
To his man 4 days at 15d 00-05-00
To Richard Hodghson for 10 Threave of Straw 00-07-06 02-09-10

No.10
At Cloughton, Richard Hodghson before barn repaired
To James Joyner for his men 4 days walling 00-05-04
To Wm Allison 1 day setting up a pair of Centers 18d; his man 1 day 15d 00-02-09 00-08-01

No.11
At Cloughton, Richard Harrison House repaired
To Wm Allison 1 day putting up a Ridging tree 18d 00-01-06
To Thomas Baker at ditto 00-02-08

No.12
At Cloughton, Wm Man's Barn repaired for the use of Rd Hird
To James Joyner for building 8 rood of wall at 3s p rood 01-04-00
To Idem for pulling down old wall and making groundwork 00-02-00
To Wm Allison 2 days mending ye roof 00-03-00
To his man 3 days at ditto at 15d 00-03-09 1-13-10 ½
Paid for 500 lath nailes 00-01-01 ½

No.13
At Cloughton, a New House 49 foot long and 15 foot wide built for
Samuel Wayneman near Hagbran Beck
To James Joyner for building 41 roods of wall at 3 shillings p rood 06-03-00
To Idem for making and setting on 3 Chimney Toppes containing
102 foot at 4d per foot 01-14-00
To Idem for 49 foot of Cornish Stones at 3d 00-12-03
To Idem for getting up stones for 41 roods of wall at 2s 6d per rood 05-02-06
To Idem and his men 42 days tyling, pointing the tyles and walls and
Plaistering the walls and stoothings at 16d per day 02-16-00
To James Marshall, John Atkinson & John Waynman 29 days making
Mortar and serving masons at 12d 01-09-00
To James Joyner for 20 bushills of Lyme 00-10-04

To Idem 1 day at Scarbrough to Load Tyles 00-01-04
To Idem for a Chimney in the End Wall 00-08-00 44-16-10
To Wm Pattison bill for Iron work 01-00-00
To Samuel Waynman bill for Ale 00-08-00
To Rd Beswick bill for 63 ½ foot of Glass at 5d 01-06-05
To Tho: Leadley and Tho: Langdale for leeding Stones for 39 rood of wall at 3s p rood 05-17-00
to Idem for 1 load & ½ of Deales, i load of Tyles & 1 load of Lyme from Scarbrough 01-04-06
To Idem for leeding 15 load of stones 7s 6d & 5 load of sand 7s 6d 00-15-00
To Idem for leeding Boards and wood from Cloughton 00-01-00
To Rd Hird, Rd Harrison & Henry Allison for leeding 3 load of Tyles from Scarbrough 01-01-00
To Mr Gott's bill for Tyles etc 05-14-00
To Wm Allison bill for joyner work 08-13-06

Expences about the Wood etc
To Wm Allison 7 days assisting the Draughts to get the wood out of the Bank at 18d 00-10-06
To his man 7 days at ditto at 15d 00-08-09
To Wm Allison 4 days at felling wood 00-06-00
To his man 7 days at ditto at 13d 00-05-00
To William 1 day at Scarbrough about Deales & Tyles 00-01-06
To Idem for tole of 9 draughts at Scarbrough for tyles, deales, etc 00-01-06

To Tho: Leadley & Tho: Langdales for 9 days leeding wood out of the Bank 02-05-00
To Idem for pt of 2 days at ditto 00-02-00
To Thomas Plummer bill for joints 00-03-06
To Mr Thorpe of Hull his bill for nailes etc 05-03-00
To Samuel Tetlays Expences at Cloughton with Mr Cholmley & John Bayes about the wood 02-02-02
To Mr Wooler for marking and measuring 253 Oake Trees in Cloughton Wyke 01-11-06
To Samuel Tetlay Expences at Cloughton with George Jackson about the Bark of the said 253 trees at 2 several tymes 00-02-06
To 6 Scaffold Ropes 00-01-06
To Mr Gott's bill for Deales etc 05-10-11

16-14-04
Total of all the disbursements about the repairs at Scalby etc by Samuel Tetlay: **£117-08-06**

An Account of all the Repairs at Scalby, Langdon etc in 1736.

The Charge of Rebuilding a House abd Barn for John Cross at Langdon
To Wm Allison bill for joyner work 14-06-06
To Wm Pattison bill for Iron Work 01-08-04
To the Glaiser bill for 52 ½ foot of Glass 01-01-10 ½
To Wm Abram for 30 bushills of Lyme 00-12-06
To Wm Gott bill for 60 duble Deals 04-00-00
To Robt Salton for 4 days serving Masons 00-04-00

To John Cross bill for Lyme, Locks etc 00-12-10
To John Storr for carrying the Rubbish away and making a Drain behind the house 00-14-10

To James Joyner Mason, his bill for walling etc 12-19-04
£35-19-4 ½

The Charge of a New House for Robert Salton at Langdon
To Wm Allison bill for joyner work 06-05-03
To Wm Abram bill for leeding stones, wood, ling for Thatch, etc 04-19-7
To Wm Gott's bill for 40 duble Deals 02-13-04
To Wm Pattison bill for Iron Work 00-05-00
To Wm Estill for ...Threave of Ling 01-01-00
To the Thatcher 11 days at 18d 00-16-06
To the Glaiser bill for 37 ½ foot of Glass 00-15-07 ½
To Robert Salton bill for Labourer work 01-16-10
To James Joyner Hill bill for mason work 08-05-06
£26-18-2 ½

The Charge of building two dwelling houses at Cloughton for John Mathews and Thomas Tranmer
To Wm Allison joyner, his bill 13-12-09
To Tho: Langdale bill for leeding stones etc 02-07-04
To bills for Iron Work 01-17-04
To Glaiser bill for 51 foot of Glass at 5d 01-01-05
To 46 bushills of Lyme 00-15-06
To Tho: Leadley bill for leeding stones etc 01-04-06
To Rd Hodghson bill for ditto 00-05-10
To Christer Harrison bill for ditto 00-04-06
To Tho: Plummer bill for lings etc 00-03-04
To Wm Gott's bill for Deals etc 03-12-05
To allowances in Drink for the Draughts 00-03-06
To joiners 4 days at Tranmer old house at 16d 00-05-00
To James Joyner bill for Mason work 16-16-04
To Obediah Ridsdale for 1000 Tyles 02-10-00
£44-19-03

The Charge of Repairing Widow Todd House in Cloughton, now Mary Wright's
To Mortar leeding 00-01-06
To Glaiser work 00-02-01
To joyner work 00-02-10
To James Joyner for mason work 00-07-10
£00-15-03

The Charge of some smale repairs at Rd Harrison Barn
To Wm Allison for joyner work 00-04-00
To James Joyner for mason work 00-07-04

£00-11-04

To Wm Allison for some smale jobs at Wm Coulson's of Cloughton, Wm Keld's of Newby and 1 day at Scarbrough 00-06-09

£00-06-09

To Rd Hird for repairing a barn that belonged to Wm Man 03-19-00

£03-19-00

The Charge of repairing James Hargraves House at Cloughton
To Wm Allison for joyner work 01-00-09
To bill for Ironwork 00-04-00
To John Langdale for leeding stones etc 00-18-14
To Glaiser bill 00-04-02
To Thatcher 14 days at 18d p day 01-01-09
To Francis Hodghson for Straw for thatch 02-11-04

£08-17-10

The Charge of Repairing John Jackson House at Burniston for David Chapman
To Wm Allison for Carpenter work 00-05-08
To Thatcher 1 day 18d 00-01-06
To Glaiser bill 00-01-00 ½
To bill for ironwork 00-04-02
To David Chapman for Thatch and Thatching the whole house 01-01-00
To David Chapman for serving Masons 00-02-00
To James Joyner for Mason work 01-11-00
£03-06-04 ½

The Charge of Repairing Rd Richardson Barn at Burniston for Henry Pierson
To 21 load of Stones at 4d per load 00-07-00
To Henry Pierson for leeding stones etc 01-00-09
To Thatch and Thatching 00-03-02
To Carpenter work 00-05-08
To Iron Work 00-02-06
To James Joyner for Mason work 02-07-08
£04-06-09

The Charge of Building a Barn for Francis Ash at Scalby
To Wm Allison for Carpenter work 01-17-06
To Tho: Harrison bill for leeding stones & for Straw 00-09-07
To Wm Abram for leeding load of Ling 01-10-06
To the Thatcher 11 days at 18d 00-16-06
To a labourer 11 days serving him 00-09-02
To Iron work 00-11-06
To Carpenter work at Fr: Ash dwelling house 00-06-00
To James Joyner for mason work 03-15-04
£11-01-01

To Wm Allison for several smale jobs of Carpenter work done at

Mathew White's in Scalby
£00-05-08

To Mr Newton of Hull, his bill for nails for all the buildings
£03-00-04

Disbursements relating to Cutting down Timber and Leeding to all the Houses which were Rebuilt and Repaired in 1736
To Wm Allison bill for cutting down 90 smale Oakes in Langdon Side for John Cross and Robert Salton Houses 04-07-04
To Wm Allison for felling and cutting out 213 smale Oakes in Cloughton Wyke for Repairs of the Houses in Cloughton, Scalby etc at 3d per tree 02-13-03

To Rd Hodghson, Thomas Leadley, Christopher Harrison, John Langdale, John Waynman & Rd Hird for leeding 35 Tunn of Timber from Cloughton Wyke to Cloughton, Burniston and Scalby at 6s 10d p Tunn 11-19-02
£18-
19-09

The Charge of Stallaging Brompton Fair (viz)
To Wm Leafe bill for the stallaging, Brompton Fair, 40s 02-00-00
To James Laycock for all the Tressles, Benches, Poles and Deals which he used in Stallaging Brompton Fair and were delivering to Robert Dobson in November 1736 as appears by an account thereof 07-00-00
£09-
00-00

Total of all the accounts: £170-13-08 ½

Charges abt wood included in the acct above (viz)
To Wm Allison for cutting down 213 smale trees at 3d a piece 02-13-03
To Leadley & others for leeding the said trees 11-19-02

To be deducted out of the summe charged for repairs 14-12-5

Remains to be charged to acct for repairs etc £156-1-3 ½

(TEA05) A Particular account of Money layd out in repairs in 1737 in the Manor of Pickering and Scalby as follows, viz

The Butcher Shops in Pickering

To John Baines bill for wood and Carpenter work 02-15-00
To John Halder walling 1 day at 15d Labourer 10d and 1 load of Stones 5d 00-02-06
To Wm Read 7 days thatching 7s, labourer 7 days serving him 4s 8d 00-11-08
To Wm Hick for Watering and pulling 29 ½ Threave of Straw at 1 ½ d per threave 00-03-7 ½
to Rd Pennock and William Marshall for leeding Straw to and from the waterside 00-01-06
to Richd Harding for 29 ½ threave of straw at 10d per threave 01-04-02
to Francis Nicholson for leeding stones and mortar 00-01-06
£04-19-11 ½

Cloughton, a dwelling house built there for Christopher Conyers
To James Joyner bill for mason & labourer done at said house 04-01-02
To Christopher Conyers bill for leeding stones etc to the sd house 01-09-08
To William Allison bill for Carpenter work done at sd house 03-11-03
£09-02-01

A House built for John Sunley
To James Joyner for Mason work 01-19-04
To Wm Allison bill for Carpenter work done at said house 03-02-09
£05-02-01

Thomas Vasie Barn Repaired
To James Joyner bill for Mason work done at sd barn 00-06-06
To Wm Allison for Carpenter work 00-01-02
£00-07-08

The Charge of Repairing Robert Leadley Barn, John Mathews Senr late tenant
To James Joyner for Mason work 00-16-00
To Carpenter work 00-02-04
£00-18-04

The Charge of Repairing Peter Stonehouse Dwelling House
To James Joyner bill for Mason work 00-07-03
To Wm Allison bill for Carpenter work 01-10-03
£01-17-06

The Charge of Repairing John Leadley Beasthouse
To James Joyner bill for Mason work done at sd Barn 01-00-00

The Charge of Repairing William Richardson Dwelling House
To James Joyner bill for Mason work 00-04-10

The Charge of building a barn for Tho: Wilson
To James Joyner bill for Mason work 01-19-06
To Wm Allison for Carpenter work 00-19-00
£02-18-06

The Charge of building a Beasthouse for John Waynman
To James Joyner bill for Mason work 01-04-02
To Wm Allison for Carpenter work 00-19-00
£02-03-02

The Charge of Repairing Robert Leadley, Blacksmith, his Beasthouse
To James Joyner bill for Mason work 00-11-00
To Wm Allison for Carpenter work 00-04-06
£00-15-06

Burniston Repairs

The Charge of building a Barn for John Rhoades
To James Joyner bill for mason work 01-10-06
To Wm Allison bill for Carpenter work 02-09-00
£03-19-06

The Charge of repairing Jane Pierson Barn
To James Joyner for mason work 00-03-04
To Wm Allison for Carpenter work 00-01-02
£00-04-06

The Charge of Repairing William Washling Beasthouse
To James Joyner for mason work at said Barn £00-11-08

Scalby Repairs

The Charge of repairing Thomas Grey House
To James Joyner bill for mason work 01-06-00
To Wm Allison for Carpenter work 00-16-03
£02-02-03

The Charge of repairing Robert Outheart Barn, late John Linsley
To James Joyner for mason work 01-01-02
To Wm Allison for Carpenter work 00-02-04
£01-03-06

The Charge of repairing a barn for Wm Smith, Rbt Read late tenant
To James Joyner 00-04-00
To Wm Allison 00-05-04
£00-09-04

To William Allison for Carpenter work done at William Coulsons Beasthouse £00-15-00

Newby Repairs

Wm Keld Barn
To James Joyner for mason work at said barn 01-04-02
To Wm Allison for Carpenter work done at said Barn 00-03-00
£01-07-02

Repairs of Paterick Johnson Dwelling House
To James Joyner for mason work 01-07-00
To Wm Allison for Carpenter work done at said house 00-09-04
£01-16-04

To the Glaiser bill for work done at severall houses as appears by his bill 02-02-04

To Wm Leaf bill for Deales etc	03-13-03
To Wm Pattison bill for Ironwork	00-10-06
To Robert Henderson bill for nailes	03-05-06
	£09-11-07
To Wm Allison 2 days at Scarbro buying Deales, nailes etc	00-03-00
To John Waynman for Damage done in his Ground by leeding wood through it	03-00-00

Total of repairs in 1737: £55-05-01 ½

Scalby Repairs in 1738

In 1738 Disburst for the repairs of the severall premises below mentioned in the Manor of Scalby etc

Scalby

To Mathew White for repairs of his Beasthouse at Scalby	00-06-06
To Tho: Harrison for repairing Smith Garth wall	00-03-00
To Idem for Deales for Doors to Thomas Dickinson house	00-03-06
To mason work at said house	00-07-04
To Carpenter work at ditto	00-03-00
To mason work at Wm Smith house, late Robt Read's	01-19-00
To Carpenter work at sd house	00-06-00
To mason work at John York house	01-01-08
To Carpenter work at said house	00-08-00
To 22 load of stones to said house	00-07-04
To Crooks and nailes for ditto	00-01-04

Burniston

To Hen: Pierson for repairs of his house, late Richardson's	01-06-04
To mason work at Jane Pierson barn and chimney	00-19-06
To Carpenter work at ditto	00-10-06

Cloughton

To Richard Harrison for repairing his Wainhouse	00-10-00
To Richd Hird for repairing his Wainhouse	00-10-00

Landon

To Wm Allison for Propping Richard Smalwood house	00-01-06

Cloughton

To mason work at Geo: Harrison house	00-13-00
To Carpenter work at ditto	00-04-06

Totall of Repairs: £10-02-00

There is then a summary account covering the years 1734.35,36 & 37.

This includes an account for the cost of wood in 1735 & 1736:

Charges about cutting down and leeding 253 Oake trees from Hagbran Wyke to Cloughton etc in 1735 & 1736

To Wm Allison for cutting down the said trees	04-03-06
To Leadley and others for leeding the said wood	14-06-02
To Mr Wooller and Baines for marking and measuring wood	11-11-00
To Samuel Tetlay expences about measuring the wood, selling the Bark, etc	00-04-06
To Mr Wooller and John Baines expences at Cloughton and other places during the time they were marking the wood	01-05-00
to Samuel Waynman for damage done in his Ground by leeding the wood through it	03-00-00
Total charge about wood	£34-10-02
Received of George Jackson for Bark of said wood	£20-00-00
Disburst more than recived in relation to the wood	£14-10-02

To the Right Honourable Lord Hyde, Chancellor of his Majesty's Duchy and County Palatine of Lancaster, **the Humble Petition of John Hill of Thornton in the County of York, Esquire.**

That his late Majesty King William the Third, by Indenture of Lease under the Duchy Seal ...(on) 18th May 1697 granted unto Abel Tassin D'Allone Esquire the Manor and Lodrship of Pickering...with all rents and Demesne Lands to the said Manor and Lordship belonging, and also the Manor and Lordship of Scalby...with all the rights members and appurtenances whatsoever, To hold the same in reversion (to commence on the Death of Catherine the then Queen Dowager, which happened in December 1705) for ninety-nine years at the yearly rent of £10, in which lease there is contained the following covenant, vizt:
"That he the said Abel Tassin D'Allone, his executors, administrators and assigns shall and will at his and their own proper Costs and Charges from and after the expiration or other sooner determination of the Estate and Interest of the Trustees of the said Cathering...in the premises and those claiming under then from time to time, when need shall require **well and sufficiently repair, uphold, sustain, scour, cleanse, maintain and amend as well all the Houses, Buildings, Walls and Coverings, as also all the Hedges, Ditches, Mounds, Fences, Shores, Bankes and Inclosures of and belonging to the aforesaid premises hereby Demised, with all necessary Reparations and amendments whatsoever,** and the said premises so well and sufficiently repaired, maintained and amended at the end...of the said Grant or Lease hereby made leave void and yield up; He, the said Abel Tassin D'Allone...from time to time **having and taking competent and sufficient House-Boot and Timber growing in the Woods and Lands of the premises by the appointment of the Surveyor General of his Majesty, his heirs and successors for the time being and Hedge Boot, Plowboot, Fireboot and Cartboot in and upon the premises growing,** without delivery doing therein no waste of Destruction; the same to be dispended and used in and upon the premises hereby leased and not elsewhere."

That the said Leasehold premises were afterwards assigned to John Hill Esquire, your petitioner's late Uncle, deceased and by virtue of the Limitation of his will, your petitioner is now in possession of the premises as Tenant for Life therein.

That within the Manor of Scalby there are a great number of small Cottages and dwelling houses being parcel of the premises comprised in the said Lease many of which are in want of repair.

That his Majesty's Lands in the said Manor of Scalby consist chiefly of unenclosed arable lands lying dispersed in the Common Fields but by an Act passed in the last session of Parliament, the said Common fields, and also the Wastes of the said Manor, are intended to be Inclosed, and a great progress hath already been made therein, and your petitioner finds it will be necessary , and he therefore proposes to build, several new farm Houses on the Crown's Allotments (which he is impowered to do by the said Act) **and to convert some of the present Cottages into other Farmhouses for the better improvement of the premises.**

That by means of the Inclosure and new Building, many of such small Cottages and dwelling houses will become useless and will in no respect answer the expense of keeping in repair as dwelling houses but may be converted into Barns and Stables and other convenient outbuildings for the use of the adjoining Farm Houses belonging to his Majesty.

(Hill asks that a survey be carried out by the Duchy), **that a proper quantity of rough timber may be assigned to your petitioner for repairing such of the said houses as are necessary to be kept up...and that your petitioner may be at liberty to convert such as shall be found improper to be continued as dwelling houses into necessary Barns, Stables and other Buildings for the use of the Farm-houses thereto adjoining.**
(Hyde instructs the same, writing in margin of the petition).

DONCASTER ARCHIVES (DS)

DD DC/HI/2/1 (DS01)

OULSTON HALL BUILDING ACCOUNTS 1794-96

1794
Plaister from Cusworth
Stones from Park Wood
Stone from Brodsworth, John Beal's quarry
Blocks of stone…

(more of same)

Plaister from Cusworth

November 1794

1 ½ tun white plaister

1 ½ tun common mortar

December 3 tuns common plaister

Jan 1795 4 ½ tuns common plaister in three 1 ½ tun deliveries. 9 more tuns.

March 1795 1 ½ tuns common plaister
April 1795 1 ½ tuns common plaister

May 1795 3 tuns common plaister

June 4 ½ tuns of same
July 1 ½ tuns of white plaister
August 3 ½ tuns of common plaister
1 of white plaister

1796
April – 4 ½ tuns of common plaister; ½ tun of white

(Lots more stone from Brodsworth)

1794 Carpenters and Masons accounts.

June 2 kilns of lime
July 2 kilns of lime
July 26 great kiln of lime 12s
12 coal baskets

August 2 small kiln of lime 7s
15 load wall stones
20 load throughs
(lots of joinery, mainly)

August 30 small kiln of lime
Sept 13 great kiln of lime

(timber, inc 90 feet of mahogany; 'looking after sawyers').

Oct 4 2 kilns of lime burning 19s
Oct 25 great kiln of lime
Sept lead for roofs, windows, sash weights, sky light, cistern flashing
Dec 13 Blue slate; 5 bunches of laths
1795

Jan 3 Hanson burning lime for plaister 7s
Jan 10 carriage for plaister nails from Sheffield
Jonathan Hanson burning small kiln of lime 7s

March – larger lime kiln burning 12s
March 14 Wm Robinson jobs for plaisters, making gantries etc 7/6
Ditto jobs for white lime for plaisters and expences 1-8-4
Hanson kiln of lime burning

March load of red sand and a bar
April 18 bar for plaister (darby?)
April limeburning and plaistering

May 2 lime burning
May 16 smaller lime kiln burning 7s

Mr Conway for sand and allowances for lime etc 2/6

May 30 larger kiln.
Birkenshaw leading coals

June 13 Richard Lawson leading coals for lime 16/4

July 18 still plaistering
Larger kiln burn

Aug 22 Hanson larger kiln burning
Sept 26 leading coals

Oct 10 smaller kiln
Stone still being sawn.

Oct 17 lime burning and stone sawing.

Nov 14 smaller kiln.
Nov 20 Halliday plaister upon account £10

Dec 11 larger kiln burn

May 6 smaller kiln
May 27 larger kiln
Birkenshaw leading coals
June 24 small lime kiln burning
Loads of gravel from Doncaster
July small lime kiln.
{blank pages).

May 18 From Mr Chambers, Warmsworth – waggon load of lime
Oct 13 From ditto 1 chaldron of lime
Oct 12 same

Baths from Thorne

30 bunches of laths from Mr Robinson of Doncaster

Jan – June 9 450 bundles of lath from Ellerson of Thorn

1796 account of Wm Holliday £30

Wm Holiday account – received on account of different limes £131.

NORTHAMPTONSHIRE ARCHIVES (NA) Northamptonshire Archives

Fitzwilliam Misc Vol 432 (NA01)

The Booke of Moneye Laid out about the Building and Repairing of the House. 1579

To the plasterer for a daies worke

For iiij strike of lime at ij d the strike *(a strike was a measure of dry volume – usually half a bushel)*.
To a mason for mending the chimney in the great chamber
For iiij strike of heare
ij bundles of lath…
lime iij fooder at ij s ij d…
to Foster the Mason for a daies worke
to hod man
to his labourer…
to the carpenter for ij daies work at xd the day
to the dauber for work at vj d the day…
for the splitting of a tree into boorde…
to the thacker for ij dayes work finding himself…
for a lode of stone…
to the slater for his daies work & his boyes

1581

…for x toone of stone….
To the Slaters charged by the roode…
For lime not the carriage thereof…
For vij bundles of lath…
For riving of lath
The charges of victuals in my absence for the carters that brought me some stone, timber and slate…
For iiij lode of plaister at vi d

For the thacker at x d a day…
For digging of earth & daubing iiij
For a fooder & demi of lime at 1j s ii d the fooder…
Digging of stone…
Forty & five lode of timber

1582
…for brick beside mine….
To the plaisterer for plaistering of xiiij roodes demi & viij yards at vj s the roode…
For digging the foundation of the wall
To the masons….
For sand…
For xiiij fooder of lime…
For ij T & demi of reede for plaistering at iij s T and the charges for bringing it home

1583

to ij masons and one server for iij dayes work and to iij masons and one server for iij dayes…

1584

(Much ironmongery and door and window furniture)

To the paints for whiting…
To the painters for their woorke in whitinge sundye Chambers…

Lime xxj
…heare vj stone
sand iiij lode…
to ceilinge reede…
for wainscot & clapboard…

a fother of lime…

1588

…to a labourer for daubing
for mending the chomneys…
for carrying stone and sand

1587
for a lode of thack
for vj foother of lime
for daubing and whiting of broken places about the house…

for thack rope and charges in thacking…
bred and beare for carters

1588

payments to carpenters, masons

to the lime man for xxx fother of lime at xxij d the fother

(*a 'fother' or, in this case 'fooder', a variation of 'fodder', itself a dialect variation of 'fother' is equivalent to 19.5 hundredweight of material).*

Fitzwilliam Misc Vol 50. (NA02)

Building of new stable 1674

Accompt of what Money paid to severall men for the carridges and other materials for the Building of a new stable at the Bull in Setchy (*Setchey in Norfolk).*

May 15 (to two men) a daies work to take ye stone out…at ye Brewhouse yard at ?? Bridge
May 20 to ye same men for pulling down a wall at ye Bridge
June 2 paid for loading 3 carts at Mr Goodings of Lynn with spars and deales
June 5 paid Rich Kempe for 12 load of Clay digging in Runton (Runcton, near Lynn and Setchey).

June 11 paid for loading 4 carts with timber
June 15 paid Alcock for 6 chalder of lime at 10s per chalder
Paid Francis Lamkin the mason
Paid Mr Pepper in full for 65 loads of stone
Paid Robert Sill in full for carting worke
Paid Francis Lamkin more in part of his work at ye Stable
Paid James Everall for carting stone, sand, clay & 3 loads of timber from Lynn
Paid smith for spikens for the rofe of ye stable
Paid for one hundred of nailes
Paid Francis Lamkin more in part of ye same worke
August 4 paid Bonhall for 8 chalder of lime…
Paid Thacker in part for sufficiently laying a coate of Read upon ye new stable
To Wm Rogers for 4000 & a halfe of brick
To Wm Rogers for 10 dozen of rush rope
To ironwork

September 4 Paid Mr Case of Stow Bridge for 2000 of Brick
Sept 5 Paid James Everall more for carting
Paid for 2 load of Thack to Rofe the stable with
Paid for 30 loads of sand

13 payment in full for the thacking the stable
24 paid Francis Lamkin Mason for one daies work of himself and 5 men more at the Bull wall
29 paid the carpinder in part
October 4 paid more for thack
6 paid more for 5 dozen of rush rope
9 paid for carrying and fetching of Mr Dickenson's ladder…
(timber and deale)
19 paid Kemp for levelling the Barn floore
24 paid for 1000 & ½ of nailes for paleing worke
28 paid Nicolas Love, Carpinder more for worke
Nov 6 paid Mr Spencely for 6500 of Read
14 paid Kelke for two chalder of Lime
16 paid Rogers of Magdalen for 500 of Brick
17 paid Love, Carpinder in full
paid Setchly smith for hooks and hinges for the windows
paid Lamken in full

1675 General accounts

October 10 paid Tho: Handly Mason for worke at Tho: Wilsons House
Paid for brick for the same worke
Paid for a load of clay for the same worke
Paid for a load of sand for the same worke

(many entries concerning repairs to the river bank).

March 6 paid Wm Rogers for 3000 of Brick for ye house late Shales in Tilney
21 paid Gurton for **2 load of Clay carrying for Sam: Barker's house in Westwinch…**
August 9th paid Wm Grasby the Mortarman for 6 daies worke

1693

paid (Edwd Seyton) what he paid John Sutton in full for digging mortar for himself and ye other men…
paid Goodman Shaw for 4 loades of Sutton stone Coins
paid Seyton and he paid Bradery wife for digging Mortar by the Loade- 33 loads
(*earth mortars)*

September 24th 1694 Brought in from Goodman Pitts of Collyweston 3 loads of slate which one load by mistake was taken up at Allan Newsomes pitt of Easton. Received from Pitts the same time 13 bunches of 3 foot heart lath…

A Bill of work done for the Right Hon'ble the Lord Fitz Williams by Wm Dunston, his son: & Wm Marshall beginning August 20th 1694…

Wm Dunston 11 days at 14 d per day
3 days knocking
4 days burning at 12 d per day

his son 11 days at 5d per day
Wm Marshall 11 days at 5d per day…

Item 3 nights watching the Kill

September 6th -16th 1692. Paid him in full of all for himself & sonne, the Boy Marshall & for old Saunders & for small beare

Fitzwilliam Misc Vol 638 (NA04)

1842-43 Works to Milton Hall

Sawyer's account – part of

1842 Jan 1st (onwards) Kingston Wm 750 feet
Crick Wm 664 feet
8th Kingston Wm 1204 feet
Crick Wm 1000 ft
15th Kingston 800 ft
Crick 1077 feet
22nd Kingston 1399 feet
Crick 1082 feet
29th Kingston 1208 feet – 841 Park; 367 Milton
Crick 563 Park; 358 Milton – 921 feet
Feb 5th Kingston 1351 feet
Crick 957 feet
12th Kingston 249 feet Park
Crick 207 ft Park; 355 ft Milton
19th Kingston 444 Park; 444 Milton – 888 feet
Crick 642 feet Park
26th Kingston 939 feet
Crick 29 feet (1s)
March 5th Kingston 703 feet
Crick 217 feet
12th Kingston 18 cuts, 34 rips of deal
19th ditto 324 feet, 85 cuts of deal
26th 1000 ft 9 cuts
april 2nd 565 ft
16th ditto 747 feet
23rd ditto 34 cuts, 18 rips of deal
30 69 cuts of deal 333feet
May 7th 12 cuts of deal, 1091 feet

14th 4 cuts 19 rips
21st 34 cuts

(1 ½ pages more. Total cost £120. 10. 5 ½)

1843 Limekiln.

Wages of Richard Kingston and Luke Parker beginning 4th February until 23rd December totalling £27-14s at average £1-2s a week per man.

Fitzwilliam Misc Vol 96 (NA05)

1714 wages.

Wages paid on Saturday night at the Angel Coffee House.

Robt Smith 25 loads of Rubish at 4d; 10 loads of stone at 9d
Paid Francis Baxter in part for sand
Robt Arnold for freestone work
Paid the Ruff masons this week £4-6s…

May-June Deliveries of stone, sand and lime to the Angel

To 12th June
Paid John Draper for 10 loads of Mortar at 10d
Paid the freemasons in part this week
Paid the Ruffmasons in part
The bricklayers in part this week
Paid John Manningson 2 chaldron ½ of lime

To July 1st
Paid the Ruffmasons this week £10-10s
Paid the freemasons this week £4
Paid Robt Smith for Mortar & carriages £3-15-6
(Timber and carpenters wages)
paid Wm Dunton for throwing the water
paid the carpenter for making the gutter at the Coffee House
(lots of timber)

to the 4th July

toll for 3 teams at Deeping
Nicholas Church for 6 loades of Mortar
Paid for landing 14000 Bricks at the Market Side 4 men
Paid the bricklayers this week
Paid the Ruffmasons this week

Paid John Loving loading of stone 1 day at 16d
Old Holmes labourer 4 days at 12d…
Paid Shaw of Sutton for 1 load of Sutton (stone)

To 18th July – disbursements this week at Peterborough
Toll for 1 load of rotten stone
John Loving 1 day loading stone
The ruffmasons this week in part
The bricklayers this week
John Coy John Baxter throwing the water in the Lane…
Anthony Ward for removing 6 load of Lime from the Coffee House to the Angel

To 8th August
Paid for carriage of stone & mortar
The bricklayers this week
The ruffmasons this week
Mr Wilkinson of Ketton for stone
Paid for carrying of 14500 bricks from the Rudge to the Coffee House & Angel
Paid for carrying of 3 loads of Lime from the Coffee House to the Angel at 8d the load

To 29th August
….paid the carpenter for slotting a beam & hewing several others that came from Lynn
paid Anthony Ward for carrying 12 loads of Mud from Bongate for the Arches
paid Mr Westwood of Wisbech for bricks
paid for carrying of 4 loads of stone from the Coffee House to the Angel
paid Anthony Ward for carrying of 9 loads of timber from the Bishops Yard to the Angel

To September 5th
Paid the ruffmasons this week
Paid for carrying of 117 loads of stone from Mr Wallsoms
15 loads of brick from the water side
8 loads of stone from Mr Billings
55 loads of mortar from Mr Turners barns carried
3 loads of stone
8 loads of timber
robt Smith 30 loads of stone from Mr Wall's house
5 loads of brick from the water side
4 loads of stone
47 loads of mortar and carriage at 2s the load
paid for carriage of mortar and stone
(Labourers wages)..
paid for carrying Timber for the roofe of the Little Stable
lime 1 load at the Angel.

To the 24th October
Paid for 1 bushell & ½ shells & 2 bushells of Dust for the bricklayers to pave the Cellar Flowers

To 29th May 1715
…Gave to the workmen for making mortar 1 night
paid for making 4 trays to hold mortar…

to 3rd July
…Paid for 40 bunches of Sapp Lath at 6d
paid for 31 bunches of Heart lath at 9 ½ d
19 bundles of Sapp lath at 6d
9 bunches more…
paid for 3 scaffalling cords…
paid Daniel Sparkley for carrying 7 loads of bricks
1 load of dubble deals carrying
…Loading them of the Water

to 17th July
…Slaterer 4 days at 18d. the plaister betting (beating)…

To the 24th July
…paid for hooping a Tub to carry water in
making trussels for the Slater
for a load of lath carrying…
ale and meat for the Slaterer this week when laid the flower of plaister down

To the 21st August
…**paid for 1 Bushell & ½ of Shells for pointing
Smidy dust 5 bushell**

To the 11th September
…Paid for Ashes 4 Bushell and Color ½ bushel, the Slaterer

to the 25th September
…John Loving and Francis Baxter for sand…
Mr Turner for Mortar

ASL 443 (NA06)

Captain Senhouse Esq to Nathan Bull, Builder 1885

May 252 feet tiling lath.
July 6 10 hours felling larch trees and preparing the same (for bridge over the pond).

Estate of Capt Senhouse to Nathan Bull 1885-86. Mr Umfrey's House.

Dec 2 days propping
1 day horse carting
Jan. 1 hour getting lintel out
Feb. 4 hours making centre
4 quarters lime; 3 load of sand
2 bricklayers 10 hours each
ditto
2 labourers 10 hours each
2 bricklayers 5 hours each
800 bricks.

March. (bricklayers and labourers)
1200 bricks
(carpenters) (throughout March).

March 30th 9 quarters of lime
750 blue roofing tiles
31. 2 loads of sand carting

April bricklayers and labourers

6th 700 bricks; 3 loads sand
carpenters; deal board; 9ft poplar board
Rafters, nails, bundles of lath, bricklayers and labourers
1200 bricks; 4 quarters of lime

10th 4 loads lime
20th 500 bricks
5 quarters of lime
21st 20 bundles of ceiling lath
30 lbs lath nails
bricklayers and labourers
May 3rd
2 bricklayers
3 bushels hair
1 labourer
3 quarters of lime
4 load sand

4th 7lbs flooring brads
4 bushels cement
8th
400 bricks
2 loads sand
12th
2 carpenters, 2 bricklayers

6 bundles lath
labourers and brickies, carpenters
3 quarters of lime
27th 1300 slates
1640 of slating lath
bricklayers and labourers
600 bricks
22 bundles lath
June 8th
Building chimney and cleaning bricks. 350 bricks for same.
July 5th
2 bricklayers lathing attic
2 labourers the same & making mortar
6th 2 bricklayers plastering; 2 labourers
8th 2 bricklayers plastering parlour; 2 labourers
10th man and horse carting lime and sand
bricklayers plastering.

1885 Repairing Cottage
Bricklayer, labourer
400 of 9 inch squares
105 feet of ceiling joice
4 bundles of lath; 3lb of nails
2 bushels of plaster
mortar and cement and hair
whitening and size

Mr Williams's House

Bricklayers etc
Mortar and hair; mortar and cement.

Mr Webb's House

560 bricks; 1 load of sand
2 bricklayers 2 labourers
repairing ceiling of Webb's cottage
mortar and plaster
oak joists carting sand and bricks
2 gallons (?) plaster

Th 2444-2479 (NA07)

Accounts of James Fremeaux, merchant to the Levant, in the building of Kingsthorpe House, Northants, 1774.

James Fremeaux Esq. to John Johnson

(timber, sash windows, cords and associated ironmongery)
scaffolding cord
an iron skylight
a chimney piece sent March 1774
4 baggs of plaister, 6 picks (pecks) of Terras,
plates for the masons.

General ironmongery – mortice locks, etc

Dingley, I day cutting joice for Plaster floor

John Wilkins 4 ½ days to plasterers moulds

Bills:

James Freemeaux Esq to Wm Boswell to 104 load of stone at 1s 6d per load
To 6 loads of Lime stone at 1s 3d per load
To 21 load of stone at 2s 6d per load
To 60 feet of window sils (?) at 2d per foot
To 7 window heds
To 6 springers
To 3 top stones
To 172 feet of table at 4d per foot
To 29 feet of chimney hed at 4d per foot
To 109 load of molter at 9d per load

Received Oct 1775 in full of all demands.

1774 James Freemeaux to Wm Boswell
to 21 load of stone at 1s 6d per load
to 11 load of molter at 9d per load
to 2 colames
to 5 hearth stones, 24 feet
to 3 springers
to 32 feet of table at 4d per foot
to 8 days work working of paving
to 303 feet of coping at 8d per foot

received October 1775 in full

James Freemeaux to Wm Johnson 1775

To whitewashing, mason and labourer each a day: 9s 2d

To 25 pound of Witeing and a pound of Glue

To repairing of the Dovehouse, mason 12 days
15th July: to mason 12 days
to labourer 12 days
to a bushel of hair

23rd to work at the wall by the farmyard and other work
mason 12 days
labourer 13 days and a quarter
to a bushel of hair

august 5th to work at the Court walls and laying on the coping and other work.
Masons 12 days and a half
labourers 8 days and a quarter

to work at the Gate way up at the road and building the walls on each side…mason 18 days; labourer 3 days and 2 quarters
to ditto and other work, mason 13 days,
labourer 13 days and a half
to 8 load of stones to ditto
to 2 load of Pitt mortar to ditto
to 38 feet of coping to ditto

to work at the house and other work, masons 21 days and a half; labourer 13 days
to 2 load of stones to ditto
to 2 load of mortar to ditto
to a bushel of hair

1775 Mr Freemeaux Esq to Wm Whiting

May 8 to 5 quarters of lime at 3s 6d each
To leading
10 to 5 quarters ditto
13 to 5 quarters ditto

Cooper's account

To one new oak butter cover with white hoops
To one strong, new oak Mashing Vatt with strong new iron hoops…and cross barrs to the bottom of it to hold 480 gallons of liquor and mash 36 bushels of malt
To one large oak working Vatt for ale…to hold 310 of liquor
To one new oak working Vatt for small beer with new iron hoops etc…to work three hogsheads of small beer
To two new iron hoopt water buckets with feet

To two new oak carring (carrying) tubs with six new iron hoops upon each of 'em with new carring staves for both
To two new mashing rules to stir the mash with
To one new iron hoopt water Paile with foot for housemaid
To seasoning of the brewing vessels my man and self
To one new large had bowle for the Dairy
To one new wood tap with new iron work to it & for making it to fit to the Mashing Vatt
To one new large had bowle & a new oak brewing scoop
To two large new oak brewing scoops to hold the hopps with 3 foot wooden handles and hair bottoms with barrs
To heading and cleaning of four large casks

Th 3616 (NA08)

April 3rd 1847
Erection of a farmhouse and other buildings and works.

Masons work
Carpenters
Blacksmith
Ironmongery
Laths and cement
Lime and sand
Bricks (3 suppliers)
Stone (ditto)
Cement

SHEFFIELD ARCHIVES (SA)

SIS/3/7/2 (SA01)

Roberts & Cadman Builders, Sheffield.

1813
June 5 1 peck of hair
12 3 pecks of hair
15 3 pecks of hair
18 & 19 16 bunches of lath
Labourer ½ day leeding sand
28,29,30 32 bunches of lath

July 1813

45000 of nails
8 bunches of lath

labourer 1 day riddling sand
(more lath and hair)
Labourer 1 day riddling sand

July 24
Putty and plaister
30th whitewashing Mr Ingell's house
colouring best yellow
(whitewashing numerous rooms at same)

man 2 ½ days plastering cellar top and pantry
man 1 day plastering
labourer 1 ¼ days sowering and mixing up Barraw (?) lime
7 mitto (?) of same lime; hair.

August
½ peck of plaster
labourer 1 day riddling sand
hair
30th – 31st man and labourer 1 day each repairing stucco at outside and blank window
man ½ day pointing coping at top of building
1 peck of Barraw (?) lime
Labourer 1 day riddling sand
15 bunches of lath

(Barraw lime may be lime from Barrow-on Soar, Leicestershire, which was variably hydraulic, but could set underwater and much used beyond its region from the later 18thC. The works for which it is being explicitly used above are for works in the cellar, pointing of copings and exterior render repair)

September 4
4 men 1 day lathing and plastering the small tops under the Court House
20th Selfe and apprentice ¼ day each lathing and plastering
25th 1 board of stucco
labourer ½ day making up lime for jobbing (*could not be hydraulic*)
2 boards of putty and ½ peck of plaster.
SIS 2 (1-35) bills etc Roberts and Cadman Builders, Sheffield.

1813
29 loads of sand
to lime 15-4-6

1814
to ½ mett. of cement at new building
peck and ½ of ditto

Estimate for Plastering Work by Mr Holmes

Putty & plaster ceilings 7d per yard
Plain cornisis 6d per foot
Stair (?) walls 7d per yard
Three coat lime & hair at 4 1/2d and 4d per yard
Two coat lime & hair at 3 ½ d on laths per yard
Two coat lime & hair at 3d on walls per yard
Rough Casting at 3 1/2d per yard
Laths at 2s 3d per bunch
Nails at 9d per thousand
Hair at 3d per mett.

Bill for leading materials 1813

March 8 1 load lime
9th 1 load sand
16th 1 load stone
1 load sand
1 load lime
17th 2 loads sand
2 loads stone
2 loads rubbish
19th 1 load sand
1 load lime
20th 5000 bricks
22nd 1 load lime
2 loads sand
24th 5000 bricks
25th 1 load lime
2 loads stone
26th 1 load sand
2 loads stone
2000 bricks
29th 1000 bricks
1 load sand
1 load lime

April 2nd 1 day leading rubbish
3rd 1 day leading rubbish
6th 1 day leading stones
1 load lime
1 load sand
8th 1 day leading stone
9th 4000 bricks
1 load stone

10th 2 load sand
1000 bricks
12th 1 load lime
500 bricks
15th 1 load lime
2000 bricks
leading rubbish
17th 2 load sand
1000 bricks
leading rubbish
19th 2500 bricks
20th 1500 bricks
2000 bricks
21st 1 load lime
2000 bricks
23rd 2500 bricks
1 load lime
24th 2000 bricks
29th 4500 bricks
30th 1 load lime
1 load sand

May 2nd 2000 bricks
3rd 1300 bricks
200 arch bricks
May 5th 1 load lime
1 load sand
6th 5000 bricks
10th 1 load sand
1load lime
11th 2000 bricks
13th 1 load lime
2500 bricks
15th leading slate from Tinsley
17th 1 load lime
1000 bricks
19th 1 load sand
20th 2000 bricks
21st 1000 bricks
22nd 1 load sand
26th 1000 bricks
27th 1 load lime
1000 bricks

June 1st 1 load lime
1 load sand
3rd 1 load lime

4th 500 bricks
10th 1 load lime
15th 1 day leading sundries
19th 1 load Flags
2 load sand
21st 1 load lime
1000 bricks
22nd 1 load lime
1 load sand
23rd 19 yards paviours
25th 22 yards ditto
28th 1 load sand
30th 22 yards paviours

July 1st (says June, but in error) 1000 bricks
1 load sand
2 loads stone
3rd 1 load lime
loading stones and rubbish
6th 1500 bricks
1 load sand
9th 22 yards paviours
14th 1 load lime
1500 bricks
16 1 load lime
1 load sand
21st 300 bricks
1 load stones
30th 23 yards paviours
August 5th 23 yards paviours
Leading rubbish
7th 1 load stones
500 bricks
11th 1 load lime
1 load sand
12th 23 yards paviours
13th 1 load stone steps
20th 2 loads sand
25th 1 load lime
1 load sand
27th 3 loads sand
September 4th 3 load sand
6th 1 load sand
13th 1 load lime
3 loads rubbish

(these sequences clearly indicate that the mortars are being made and used immediately for brick-laying)

Account of plastering by John Holmes for Messrs Roberts & Cadman, 20th October 1813

Putty & Plaster Ceilings – (all at 7d per yard)

In front lodging room 24.16 yards
In parlor under ditto

In Counting House
In Shew Room
In Stair Case
In Out Passage
In Water Place

Stucco Walls
In the above Rooms 390 yds at 7d
Stucco found for above rooms 390 at 1 ½ d

Putty & Plaster Cornices in ditto 306 ¾ at 6d (per foot)
1 cornice in the old passage 23′6″
Plain soffits (measure and a half) 66 at 5d
Beads to ditto 89 at 3 ½ d
1 extra narrow soffit 15 2/3 at 3d
3 broad soffits (sq measure) 90 at 4d
beads to ditto 38 at 3 ½ d
1 pann'd soffit (sq measure) 19 at ½ d
2 double architraves 25 at 6d
single quirks cutting 776 feet at ¾ d
circular frame moldings 58 at 4d
mouldings in staircase 176 ½ at 4d
straight beads 7 ½ at 2 ½ d

Lime & Hair Ceilings

In two warehouse chambers 85.13
In Stove Room 41.25
In Privy & Passage 4.19
In Timekeeper's Room 9.26
(All at 3 ½ d)

Walls

In the above rooms 390.39 at 3d

Cielings (sic) etc

In Packing Room 37.81 at 3 ½ d
Extra lathing to partitions etc 90 at 1 ½ d

Rough Casting the Out Walls 659.97 at 3 ½ d
Double Quirks cutting 32 ft at 1 ¼ d

1813. Holmes bill for works at Mr Ingell's.

Passage leading from Mr Roberts limewashing
Man ½ day & a labourer ¼ day repairing at Mr Ingels
½ peck of Roman Ciment & 1 board of lime & hair

1814

8 stone of Rhoe (or Rhoo) plaister & bakeing and sifting (gypsum?)
man & labourer 1 day each plaistering stove & jobbing
6 barrows of lime & hair.
Man & apprentice ¼ day each jobbing in Mr Ingel's house

2 boards of (coarse?) lime & hair
1 ditto of fine & ½ peck of plaister
2 passage tops whiting
6 passage sides colouring pink

WWM A 225 (SA02)

Wentworth Woodhouse Muniments. 1754

Charges of Lime Kilns etc upon Kilnhurst Wharf. 1755

To cash paid by Mr Evans

May 21 to 2 loads of Hay for the Houses at Kilnhurst
To M. William Paine, a stack of Hay for ditto £14

June 1 To Thomas Bottomley, Baring Lime-stone at Hooton Quarry, 18 days at 10d
Breaking Knottingley Lime-stone 2 days at 1s per foot
Making Lime-kiln eyes 4 days at ditto.

(Payments to Bottomley and to John Metcalfe on account, June, July, August, September).

(*Kilnhurst Wharf is part of Mexborough. A cutting leads from the River (Aire?) to the Wharf. Hooton Roberts, site of limestone quarries, is to the immediate east of the wharf and former limekilns. The stone would be magnesian limestone, very similar to that at Knottingley, but exact composition is unknown).*

Charges of Buildings upon Kilnhurst Wharfe, 1755

To cash paid by Mr Evans 73-16-5 ½
May 28 To Messrs Samuel and Aaron Walker, a Hearth Grate for Kilnhurst
June 3 To Edward Firth, Building a Smithy Chimney and walling a Saw pit 5 days
To ditto, a Trough working
June 12 To Joseph Cooper for slating, tiling and Mossing the House at Kilnhurst
August 17 To Edward Firth for Materials and Work for the new Fence Wall
September 4 To Joseph Bingley, for leading stones to the Fence Wall
To ditto 3 loads of sand
To ditto 3 loads of Stones.

Charges of the Grand Stand upon Knavesmire 1755

To cash paid by Mr Evans 79-4-11
May 21 To Mr John Cook, an Anvil to sharpen the Masons Tools on, 83lb
To Mr Matthew Charlton, 3 days leading stone at 5s per day
May 22 To William Wilson 10 days ditto at 4s
To Samuel Turner 2 days ditto at 5s
To John Roebuck 1 day ditto at 4s
To Jonathan Hobson 20 loads ditto at 6d per load
May 29 To the farmers of the River Don, Lock Dues of 14 ton of Stone £1 8s
June I To three weeks wages to the Stone Getters at Hooton Quarry to 31 May 1755
June 3rd To Edward Firth, one days work
21st To three weeks wages to the Stone Getters from 31 May to 21 June
July 12th to ditto to 12 July
to Daniel Biches for a rope mending
September 11th To Edward Firth, three days Labourers Wages scapling Stones

Stones scapling for the Grand Stand

June 3rd To Edward Firth for scapling 1127 feet of stone at 1d per foot
July 3rd To ditto for ditto 1644 ft at ditto
August 17th to ditto for ditto 281 ½ ft at ditto
September 11th to ditto for ditto 234 ft at ditto
To ditto for scapling 58 ft of pavement at 3d per foot

Detailed Building Account, Rockingham Mausoleum 1785-87.

(details stone volumes and from which source quarries. Most of it in feet, not simply loads – stone likely dressed at quarries, for most part.)

April 29th 1786 to Kilnhurst for sand

First delivery of lime, November 10th 1786: Paid William Malpass for 36 Chaldrons of Lime to the Mausoleum at 10/6 per. Leading of stone had begun 11th November 1785. Scaffolding began to arrive same day as lime.

May 30th 1787 Paid John Woodcock for Lime to the Mausoleum:

June 8th 1786: 1 chaldron
9th 9 chaldron
17th 8 chal
20th 6
27th 5 chaldron
July 12th 1 chaldron
August 12th 2
October 16th 2
17th 1
December 26th 10 chaldron.

January 15th 1787 Paid Samuel Walker and Geo: Clarke for Freight and dues of a bundle of Tarpoling from Hull to Rotherham for the Mausoleum.

1787 January a lot of ashlar stone brought to site, as well as 28 tons of River Dun sand. Ashlar stone deliveries resume March and April.

1786 Paid William Malpass £16-5-0 for freight of stone from Donnaby Quarry and for Lime to the Mausoleum.
Jan 17th one boat of Dun sand (otherwise stone)

November 24th 1786 1 chaldrons 2 pecks (?) of Lime and carriage
25th 1.2 more
29th 1.2 more
December 1st 1 chaldron more

18th July 1787 Paid Richard Naylor for freight and dues of 30 scaffold poles from Hull to Cinder Bridge
August 16 Paid Thomas Carnelly for carriage of Lead from Derbyshire.

Lots and lots of stone.
July 15th Paid Mr Charles Snow for 2 chaldrons Lime from Greasboro
16th Paid John Cooper for tiling and pointing carvers (? Lodge?) at Mausoleum.

June 9th 4 tons of deal poles
July 19th 3 tons of deal poles

July 24 Paid Charles Hobsonand Masons £20 for building shed for Carvers . 14 roods of brick in length walling at 2/6
4 yards of chimney pipes
1 grate setting

Thomas Waterworth is the stonecarver – paid £466-8-10 August 12 1788
Very detailed account of his works.

20th September 1788 Samuel Sykes and Charles Hobson paid £1061-19-10 'for the Masons work done at the Mausoleum, measured 'to top of square basement on Sept 17th 1787. Followed by detailed breakdown of their works.
10 Masons still at work on site in December 1788 (typically 24 days) and in January 1789 (typically 20 days). Also in February (typically 24 days) and March 1789. (No pause for winter, therefore).

By August 1789 plumbers on site of Mausoleum Lodge, casting and laying lead; sash windows being installed. September, whitewashing. Payments for miscellaneous ironwork, such as bannisters, gates etc.

Attention turns to Octagon Lodge: 9 roods 1 yard brick in breadth wall at Octagon Lodge at 20d, 15s 3d
17 feet stone chimney top at 8d
8 yards 1 foot chimney pipe at 12d
1406 feet of stone wall, cornice and plinth cleaning, setting and backing at 3d per foot;
42 11" circular steps to Octagon Lodge.
35 feet solid foundation to circular steps at 2d per foot
Paid Thomas Denton £6-0-11 ½ for plastering the Mausoleum Octagn Lodge:
66 yds 1 ft roof & ceiling plastering at 6d per yard
31 yds plaster floor laying at 9d
172 yds 4 ft walls plastering 3 coats at 4 ½ d per yard

August 19 1791

Thomas Waterford paid £128-1-6 for more carving and gilding the inscription – very detailed again.
Oct 25 Henderson and Crabtree paid £62-11-0 for plasterwork at the Mausoleum. Detailed descriptive account.

British Library (BL)

Knoop D & Jones G P (1936) Building Accounts of Bolsover Castle 1612 - 1613. (BL1)

Ars Quator Coronatorum Vol XLIX Part i.

A very detailed account of labour and materials expended in the rebuilding of Bolsover Castle to designs by Smythson. Below, the lime-related elements mainly. These would indicate that lime was burned in a kiln built on site for the purpose, fired by coal. Also, that lime was dry-slaked – probably by the lime-burners – sieved and mixed with the sand immediately, the coarse stuff being screened and banked for later tempering immediately prior to use. Works continued throughout the winter, with lime being burned, slaked and mixed to a mortar, but that most winter works were to the vaults. During the winter months, earlier and ongoing work was covered (wall tops) with thatch and/or bracken to prevent water ingress and subsequent frost damage. A notable number of labourers, particularly those associated with the lime burning and the serving of mortars to the stone-layers, were women, as well as boys, although they were paid less than the male labourers. Lime burning and mortar making goes on alongside stone quarrying, dressing and laying throughout, the kiln built as the first stone was being quarried and dressed at the quarry.

23 January – 6th February 1612

Workmen at the making of the lime kiln;
Labourers at the lime kiln

6th – 20th February

Workmen at the lime kiln and scappling of arch stone;
Carriage of clay and limestone getting (*the kiln likely built with clay mortar);*
23 loads of clay to the lime kiln, 60 loads of limestone.

6th – 20th March 1613

Masons and layers at the lime kiln and scappling;
Carpenters making hods;
Wilson, 1 day setting of the lime kiln, 6 women helping him at the same*);*
Labourers carrying earth from the foundation and sand to the lime kiln *(sand is regularly delivered to the lime kiln, indicating the mixing of quicklime straight from the kiln with this sand – initially dry-slaked and sieved, but probably mixed hot and then the mortar 'harled', a regular operation, often in association with sifting of the lime; sometimes the entry is lime harled, at other times mortar is harled. Miriam Webster dictionary gives this definition: 'dialectal, British* **:** *to*

drag, scrape, or pull (an object) usually along the ground' indicating that harling in this context is the mixing and beating of lime and sand, otherwise larrying the lime and sand or lime alone to fully mix for either coarse stuff or just before use. One reference to 'harling up lime' suggests it may be banking of the lime and/or mortar);
Carriage of limestone, coals for the lime kiln;
Breaking of limestone;
(Freemasons are now working in the quarries in earnest and 'layers' are at work on site).

20th March – 3rd April

Payments to the lime burner and women both at the lime kiln and at the foundation;
Limestone getting and breaking – 90 loads;
Carriage of limestone and coals to the lime kiln – 27 loads of stone, 9 loads of coal, 1 load of wood for the lime kiln.

2nd – 17th April

To the Limeburner and women at the kiln;
Labourers at serving the layers and harling of lime (48 man days);
4 labourers at drawing of water for lime (38 man days);
Boys at sifting of lime (28 boy days).

17th – 30th April

(Freemasons, layers at work; carpenters erecting scaffolding and centres);
Limeburner at the kiln (15 days);
Labourers at serving the layers at the foundation (55 man days);
Labourers at tempering of mortar and sifting and harling of lime (47 man days);
Sifting sand and slecking of lime (21 ½ man days);
5 labourers at drawing and carrying water;
6 women at the lime kiln;
Getting and breaking stone for the kiln;
Carriage of limestone and sand from the More;
Coals for the lime kiln.

30th April – 15th May

(Masons and layers at foundation walls of the castle);
The Limeburner and 6 women at the kiln;
2 labourers at drawing of water;
Labourers at sifting and harling and tempering of lime for the work (53 ½ man days);
60 loads of limestone got and broken;
Coals for the lime kiln;
Paid the colliers for 15 loads of coals for the lime kiln;

Carriage of sand (7 loads).

15th – 29th May

Labourers at sifting and harling of lime;
Drawing and carrying of water;
Serving the layers; women carrying sand;
Limeburner and 6 women at the kiln;
Limestone getting and breaking.

29th May – 12th June

(Freemasons at both quarry and castle; layers);
Limeburner and 6 women at kiln;
2 labourers at sifting of lime and harling of mortar (48 man days);
Labourers serving of the layers of the walls of the foundation;
Boys serving layers;
Limestone getting and breaking and one sieve for lime.

12th – 26th June

(Masons now above foundation level, pillar bases fixed);
Freemasons and layers at walls;
Labourers tempering mortar;
Labourers drawing and bearing water; sifting and harling mortar;
Labourers serving layers;
Limeburner and boys carrying sand;
Getting of sand and limestone.

26th June – 10th July

(Masons, layers and scaffolders on site);
Labourers tempering mortar and harling lime;
Labourers drawing water;
Labourers serving masons and layers;
Boys serving layers;
The Limeburner and women at serving the layers with filling stone and carrying of sand to the lime kiln;
Getting and breaking of limestone and sand;
Carriage of limestone, getting sand;
Coals for the limekiln and carriage.

10th – 24th July

Labourers at harling and sifting of lime;
Labourers serving layers;

The lime man and women at serving of the layers with filling stone and carrying sand to the lime kiln.

24th July – 7th August

Boards for making hods, scaffolding and centres;
Labourers at harling and sifting of lime and carrying water;
Labourers serving layers and getting of filling stone and sand;
Women carrying filling stone and sand.

7th – 21st August

Labourers carrying water and harling of lime;
Labourers serving layers;
Women serving of layers and carriage of sand from the old wall

(Women paid between 3s 4d and 3s 8d; male labourers 5s 6d a day; boys 3s 8d but as low on occasion as 10d for one of the crew).

Limestone breaking;
Coals for the lime kiln all winter, 10 loads; boards for hods and trowes.

21st August – 4th September 1613

At carrying water and and slecking and harling lime;
Serving layers and freemasons;
Lime burner and women serving layers;
Coals for the kiln, 10 loads.

4th – 18th September

(Building on-going)

Labourers serving layers;
Boys serving layers;
Women at the lime kiln and sand carrying;
Breaking limestone;
Stacking 100 loads of stone.

18th September – 2nd October

(Masons in quarries, carving and dressing rough stone);
Layers still on site;
Serving of layers and harling of lime;
Coals for the kiln; limestone breaking.

2nd – 16th October

Labourers sifting and harling up of lime;
Labourers serving layers;
The Thatcher covering the walls of the house;
Labourers and women at getting of bracken for the cover of the walls;
Limestone for the kiln; coals for the kiln.

16th October – 6th November

(Works focused on more locations more protected from the weather, but continuing at reduced pace and volume)

Layers at the vaulting of the great beer cellar;
Labourers serving layers and making of mortar (average of 6 hours each, 14 men);
Getting of bracken and thatching of walls;
Coal and limestone.

1st – 14th November

Layers at the wall;
Work done for the cover of the walls (thatcher 5 days, his labourer 5 days; 5 women getting of bracken for the thatcher);
Labourers at the foundation and making of mortar;
Breaking limestone; coals for the kiln.

14th – 27th November

Layers at the building;
Labourers serving lime to workmen;
Bracken for cover of walls;
Coals for the kiln, 10 load.

27th November – 11th December

(Freemasons still at quarry; work on vaults of larder and cellar);
Work about the cover of the walls and centres;
Labourers serving layers and making mortar;
Labourers at the lime kiln and at sand and filling stone getting;
(A lot of quarrying; taking down of old castle wall);
Stone and sand sorted for the work;
Hurdles for scaffolding, 6 dozen;
Carriage of stone for vaults;
Coal for the kiln.

11th – 25th December 1613

(Freemasons at quarry – finishing capital of the pillar of the larder, springer of pillar, 28 feet of water table, 66 feet of 'window stuff' in Freestone);
Workmen at the vaults;
Labourers serving of layers of the vaults;
Women at getting bracken and carrying sand;
Smythson's charges – 10 meals and for his horse *(These are regular)*.

25th December – 15th January 1613

(Fewer workers generally – still in quarries, scappling stone; masons and layers at vaults and centres - 5 and 6 man days)
making mortars for vaults;
Women carrying and sorting sand and stone;
(Gathering other materials, such as wall fill);
The lime kiln set;
Coals for the kiln.

15th – 29th January 1613

(Much as above);
Paid James Wilson for 6 days at setting of lime kiln; paid Rode's wife and 6 more of their fellows for 10 days a piece at filling of the lime kiln and getting away of rubbish;
Carrying water, harling and sifting lime; carrying of sand;
Breaking limestone.

29th January – 12th February 1613

(Stone working);
Harling and sifting of lime;
Lime kiln setting and drawing;
Sifting of lime;

(Saw-pits built).

12th – 26th February 1613

Layers at the old house;
Serving of layers and harling of lime;
Sorting of sand and wall stone;
The lime kiln setting and drawing, Wilson and 7 women;
Harling of lime; sifting of lime.

26th February – 12th March 1613

Lots of wall stone scappled;
Layers at larder and cellar of old house;

(Sawyers very active; carpenters also);
Labourers serving layers at old house;
9 labourers at harling of lime and sorting of stone;
Sifting harling and lime.

Plymouth and West Devon Records Office. (P&WDRO)

Building account of Edystone Lighthouse 1756.

Cash paid Colin Campbell for the Bass by Mr Weston £273
Cash paid Pearson the Smith for Mooring Chains on Acct
Cash paid Hen: Bird, Shipbuilder on acct…
Mr Smeaton in full to 22 May last £120
Cash paid Wilson, Smith for Mooring Chains on acct…
Cash paid Pepwell, Anchor Smith…
Henry Bird in full £70 17s
Cash paid Ropemaker for Cables
Cash paid Campbell, Ship Chandler
Cash paid Edwin, Cooper
Cash paid Matthews, Plumber
Cash paid Owen & Son, Oilmen…
Cash paid Josh Bird, Sailmaker
Cash paid for pilotage of the Bass to the Downs
Cash paid John Nichols, Rigger…
Cash to Mr Smeaton for work on the Model for the use of Mr Jessop (assistant/Clerk of Works) of Smeaton £47 5s
Cash paid Bryant for oars…
Cash paid Captain Luggar in full
Cash paid Wilson, Smith for 5 fathom chains…
Parsons for Plaister of Paris £9
Crowley for 3 saws
Cash paid James Crawford of Rotterdam for 3 (?) of Terras £3…
Cash paid Wilcox for 2 Moons…

No.1
Mr Smeaton's Disbursements as by the Vouchers and Accounts sent up by him from Plymouth £1789 3s
Mr Smeaton's Expences from London to Plymouth £10 12s

By wages paid before the commencement of the works on ye Rock
Wm Hancock Shipwright on Account
Michael Nichols Timber Merchant
Wm Hancock Shipwright in full
Wm Harris Sailmaker in full
Richd Bickford, Smith, in full
John Jeffery Ropemaker, ditto

No.2

Wm Hancock Shipwright for the use of his Sloop for 44 days £6 12s…
Peter Randell Carpenter….

No.3
…Mr Smeaton on account £50
Peter Randell Carpenter …fencing & building at Mill Bay per agreement £50

No.4
…Josias Jessop for his attendance on the works £47-10-6…
Mr Smeaton on account £50

No.5
Wm Hancock in full for a Long Boat
John Crier, Capt of the Susannah for freight of 30 tons Portland Stone £12
Jacob Thorne Capt of the Industry ditto £19 -17-9
Willm Wilson Capt of the Vineyard ditto £17-7-9…

No.6

John Mosshead Merchant for Pozzellaine £20…
Mr Smeaton on acct £50

No.7
Treleaven & Son on account of Moorstone £20-2
Nicholas Millar Capt of Thomas & Sarah for 16 ton Portland Stone
Wm Wilson Capt of the Vineyardfor 49 tons 4 feet of ditto
Peter Randell Carpenter £82-16-6
Josias Jessop for attendance on the works…
Wm Smart for freight of 16 ton of Moorstone

No.8
Wm Smart for freight of 17 ton 2 ft of Moorstone
Matthew Box, Moorstone man on account…

No.9

April 12th **John Winter of Watchet on account of Lime £42**
Jos: Reynold Capt of the Cross Oak for 74 tons 13 ft 6″ of Portland Stone
33-14-5
Wm Wilson Capt of the Vineyard for 43 tons 12ft of Portland Stone £19-13-9
Matt: Box, Moorstone man on account.

No.10

John Croad for Dutch bills

Waltham Savory for 300 trenails…
John Winter for Lime by Capt Hawkins's Receipt £41-7s

No.11

Wm Smart for freight of 30 tons of Moorstone £6 13s
Wm Wilson for freight of 20 tons 1 ½ ft of Portland Stone £9-0-9…

…No.13 (May)

Richard Deeble Cooper
Wm Wilson for freight of 50 tons 1 ft of Portland Stone
A Kerman for freight of 70 tons 3ft 6″ of Portland Stone
Martin for freight of 31 tons 5ft of Portland stone
Wm Thorne for freight of 26 tons 11 ft 6″ of Portland stone
Winchelsea a year's rent for loft and cellar…
Mr Smeaton on account £50

No. 14 (August & September)

Box on account for Moorstone…
Wm Wilson for freight of 50 tons 6ft of Portland stone…

No.15

Henry Holt in full
James Parsons
Richard Deeble
John Bayly
Richard Heddon
Elias Dunsterville
Richard Bickford
Michael Nichols
P Furze
S Elliott
John Jeffery
Rd Bridges
John Mudge
John Palmer
Wm Hancock
Wm Harris
Peter Randell Carpenter on account
(?) Cockey in full
Wm & Phil Cookworthy
John Lewis in full
Josias Jessop for attendance on Shore
Mr Smeaton on Account £35

Running Total £6116-1-4

…No 17

Josias Jessop for attendance on the works
By Capt Rd Miller for freight of 30 tons of Portland stone…

By Wm Wilson for 12 Fathom Chain
By Mr Smeaton on account £40…
Due to Mr Tucker for Portland stone. Mr Wston having accounted per Bill £412-16-0
To Thornton for a Box for a Model.

234/35 (P&WDRO02)

Plympton Grammar School 1663-71

This is mainly a labour account, with some accounting of materials used, particularly stone and lime, both of which were consumed in some quantity. Labour was paid by day-rate. No reference to earth or sand (although sand is delivered when plastering is underway. Earth may well be being sourced on site. There is no mention of carts, but multiplr payments for men and horses, suggesting that materials were brought in by pack-horse.

Paid for nayles to amend the slate
Paid…for a tubb
23 May 1664 30 bushels of lyme
25 May 6 bushels of lyme
26 May 30 bushels of lyme
27 May 36 bushels of lyme…

2nd June 30 bushels of lyme…
8th June 21 bushels of lyme

10th June 21 bushels of lyme
13th June 9 bushels
14 June 15 bushels
16 June 15 bushels
17th June 39 bushels
22nd June 36 bushels
23 June 24 bushels
25 June 24 bushels

Thomas Gimblett in full of all the lyme brought hitherto0 being 453 bushels..
(no mention of earth or sand at this point)…

paid for a plate & nayles for a barrow…
1st July 30 bushels of lyme
(payments to masons, as above).
9 July 30 bushels of lyme…
10 August 1665 36 bushels of lyme
11th 18 bushels of lyme
masons payments..
9 May 1665 30 bushels of lyme
10th 30 bushels of lyme
11th 30 bushels of lyme
13 May 15 bushels of lyme

…Paid for carrying timber & stones…
3 July 7 bushels of lyme
8th 10 bushels of lyme
10th 20 bushels of lyme…
paid for ten boatload of stones from ? to Crabtree
26 July 10 bushesls of lyme
27th 10 bushels of lyme
29th 10 bushels of lyme…
paid for moorstone…
paid for two tunnes @ 16 foote of tymber & for carrying thereof…
Paid Thomas Gimblett in full for sixtie bushels of lyme by him lately delivered…

1st Sept 1667 Paid Walter Greene for quenching of 40 bushels of lyme and for takeing of stone…
2 Nov 1667 paid for 40 bushels of lyme and for carryage thereof from Plymouth
(payments to plaisterers, including Walter Greene, who had earlier quenched 40 bushels of lime)…
Paid for 3500 of lathes att 8s per 1000
Paid for 12500 lath nayles at 14d per 1000…
Paid for great nayles
Paid for 40 lbs wool at 2d the lb
Paid for 12 bushels of haire at 10d the bushel
Paid for 20 threaves of reed at 1 ½ d the threave…

Paid for 25 lbs of wool
Paid for one bushel of haire…
Paid for two bushels of haire
Paid for 12lb of woole…
Paid for half a hundred of laths
Paid for 500 of lath nayles
28 Dec 1667 paid Thomas Gimblett for 3 horses & one man one day to fetch stones for the wall
paid him for 5 horses and 2 men two dayes
paid him for 6 horses and two men two dayes…
21 March 1667 paid John Weale in full for making of the wall
paid Thomas Gimblett for 12 sackes of lyme ashes & carryage
9 January 1667 paid…for 27 bushels of lyme
22 August 1668 paid for Copeing stones
29th August 1668
Plasterers wages
Paid Daniel Turpin for quenching of the lyme
5 September 1668 paid Phillip Walter for 19 ½ bushels of haire whereof 2 ½ bushels was white haire *(white hair would be for lime finish coats; ordinary hair for previous coats, suggesting 2 or 3 coat lime plastering, perhaps).*
Paid for 6 bushels of lyme and carryage thereof from Plymouth
Paid for carrying the stones for covering of the walls
Paid for a man and horse two dayes carrying the stones from the street
Paid for carrying of the rubble from the streete…
Paid for hewing the stones att the quarry
7 Nov paid for 6 bushels of lyme
20 March 1668 paid James Brookeing for 2 days to quenching 50 bushels of lyme
Plasterers wages. *(lime is clearly being slaked and used – probably slaked, sieved and mixed to a mortar)….*
17 May 1669 paid for 2900 of lathes
Plasterers wages
…paid for five pounds of white haire
28 May paid Thomas Gimblett for 30 bushels of lyme
5 June 1669 paid for 3000 of 3d nayles
paid for 9000 lathe nayles
paid for 2100 lathes
paid for 30 bushels of hair
paid to put deale boards in the windows…
13 Aug 1669 paid for 9 bushels of lyme
plasterers wages…
18 Aug paid for 12 bushels of haire…
paid for 50 bradds
paid for 200 lathes
paid for 1000 lath nayles
paid for 6 bushels of lime

paid for 38 foot of tymber from Woolaton, paid for the carryage thereof to Plympton
paid (one man) to chuse the tymber…

3 Dec 1670 paid for 3 ½ days to hew the paveing stones at the quarry
paid for one day to make the gutter 3 ½ days more)
10 Dec paid 2 ½ days to make a wall against the garden (5 days more).
Paid for 12 ½ days & two horses to fetch paviers (7 more days of this)
25 March 11 days (man and two horses) to fetch paving stones for the schole at Plympton
Paid John Weale in full for paving the scole, being 1337 foote at 1d per foote
Paid John Lyde in full for the stones for paving the schole being 1337 foote & for 37 foote of pavers to lay over the gutter in the…garden.

13 May 1671 paid Thomas Gimblett for 30 bushels of lyme
pd him for fetching of 20 sackes of sand *(first mention of sand)*….
18 June paid for 4 ½ bushels of lyme & 5 sackes of sand..
7 Sept paid for 6 bushels of lyme & three sackes of sande
paid to John Hill for bringing of two thousand of healing stones from quarry to the free school *(lime and sand being used in the roofing works, therefore)*.
Paid John Lyde for 2000 of healeing stones

Dorset History Centre (DHS)

D/BOC/889/19/42 (DHS01)

Creech Grange, Isle of Purbeck 1738-40

Accounts of the Building and Alterations to the House by Denis Bond Esq 1738-1740.

Building About the Stable 1738

Faggots for the brick and lime kills

Lime Kill
Wm Frost labour
Timber from Mr Wild
Ditto from Mr Major
Flakes
Making the brick kill £28-25s
Frost
Helping the timber up
Cress (Crest – ridges)
P Corbin Stonework
Falner building the wall
Glazier
Lock
Hellier
Landing of timber
Mr Speck for 10 loads Healing stone.

Building about the House 1738

(excerpts)
Mr Withy painting etc
Timber from Mr Drax
Paid Mr Clavell for paint..

Paid Mr Speck for 19 loads of Healing stone and carriage of part…
Nineham part tiling over the Hall & the Staircase
Pd Roger & Wm Frost for serving of Masons
P Falkner about the little Hall, great Hall & Chimnies
P Sqibb & Tubb for tending
Gawdwin for building & carriage
Bascomb for tending
110 Bushells of Lime £2-5s
Faggots to cover the Kill
3 doz & ½ of Crest
March 1st drawing stone for the Lime Kill 6d
For digging of sand
Mortimer faggoting for the Lime Kill, 3000
Faggots to cover Peter Corbin's Shed
800 for Brick Kill
Drawing stone for the lime Kill
April 20th Faggots for the lime kill
1300 Brush faggots for the Brick Kill
April 24th Carriage of Deal from Pool
27th 1100 furze faggots for Brick Kill.
1739
April 27 Burning the Lime Kill £1 2s
30th J Webber for Stonework

May 1 paid Mr Wbber for 92 yards of Sail Cloth, 14 breadths (likely for covering the works and/or the roof)
2nd 500 faggots for the Brick Kill
700 for the Lime Kill
Pd Edward Cox
8th The Brick Maker £3 3s
9th Withy & Boy 8 weeks 4 days about the rooms over the Hall
4 jemmies for doors, 2 locks, 100 beads
12th Taking down the Walls
16th Paid the Brick Maker
18th Pd Peter Corbin (mason) £10 10s
19th Flakes (perhaps wood shavings for deafening between floors, or roof)
25th Brick maker £1 1s
W Brown pulling down and carrying away the rubbish…
Pd Russell for 1500 of furze faggotts for Lime Kill
Mortimer for 1400 faggotts for the lime kill
Opening ye pit at Lutton
June 5 Gover for 1060 Furze Faggotts…
8th Labour about the Foundation 8s 10d
9th to the Brickmaker £3-3s
To Webber for stone from Lutton
Roger Frost carrying away the rubbish
Mortimer 600 furze faggotts for the lime kill & to cover the parlour floor
18 Godwin for carriage & attendance
21st Rope for drawing up stone in the Building
22nd Roger Frost's Bill
Will Frost 2 days about the Brick kill
11 days with the plow carrying away rubble
Mortimer furze faggotts for lime kill
To Withy
Timber from Mr Wild £9
To Peter Corbin £10 10s
Pd farmer Reeks for carrying a pot of lime to Grange (limewash?)
2 days carrying stone from Tincham
2 days carrying stone from Windspit
T Webber 2 days about the lime kill
July 22nd Working the Stone £1-4s
Ferry for carriage from Wareham
Pd Sam Cox for stone for lime kill
Drawing stone for Ashler
3 doz & i/2 of Cress
for use of a crane
Pd I Seaman his acct of labour about the Building £1-4-9
28th Pd Nineham (for same) £4-4s
August 4th Pd farmer Smith for carriage £30-2-5
For 40 boards from Seward
Pd Mr Speck for Helling Stone £10-18-6

…9th Burning a Kill of Lime £1-5s
Drawing stone at Bradle & Lutton …
11th Carriage of stone from Windspit £10-12-6…
13th I Man furze faggotts for the lime Kill…
15th Sam faggotting for lime kill
21st stone for Water table £1-1-7 1/2 …
25th Labour about the building…
29th 6 Doz: of Cress…
Sept. 7th Peter Corbin in part £42
10th Webber for pitchers & fitting stone for the front
13th pd for board from Seward
14th for Rope
Bringing Timber from Pool
20th Labour about the building…
Oct 5th Varnish
(payments to men about the building)…
Oct 26 Pd Mortimer for 240 faggotts to cover the Brick Kiln
I Webber towards working the Ashler £1 1s
27th Pd Solomon for plaistring £2 2s
Nov. labourers
Nov 1st rubbing of stone 14s 4d
10th Mr Hitch for painting
R Frost rubbing of Brick
Pd Webber towards burning a Kill of Lime 5s
23rd Frost helping Hancock 5 days 4s 2d
Man's girl 7 days 1s 6d
27th pd the Brick makers 10s
Dec 18th pd Mr Clavil for paint £2 1s
Pd Cartwright for 3 Chimny pieces £5-19-3…
Jan 6th pd farmer Reeks for carriage of Stone
8th pd Corbin £17…
14th pd Glazier…

1740
April 1st for cutting 2000 furze faggotts
For cutting 100 ditto
4th J Webber towards the Lime Kill…
pd Mr Jordan the Plummer the remainder of his Bill…
12th Mortimer 1000 faggotts for the Lime Kill
Will Frost serving Mason
21st pd for carriage of Deal from Pool…
Webber burning the Kill £1
May 3rd Stone for Lime
5th carriage of Boards from Weymouth £1 1s
10th pd Godbee the Carver £1 1s
21st pd Evans the Bricklayer 5s
24th Godbee £2 2s…

June 6th Brickmaker £1 12s
Foggotts for the Lime Kill…
21st Godbee £1 1s…
July 5th Foggotts for the Lime Kill…
12th pd Wm Webber towards the Stone for paving the Walk…
17th pd Webber for burning a kiln of Lime…
24th pd for 3 doz: of Cress…
28th J Seaman pulling down the Court Walls, tending Walter
Roger Frost digging Stone at Lutton, Sand etc for the Building
J Seaman Jnr 500 faggotts for the kill
One day emptying the Kill 1s…
August 8th pd Cox for drawing Stone for the men's room
9th Lawrence the Plaisterer £2 2s
Wm Frost labour about the Building 12s
Helliers about the Barn £1 15s 6d
Load of helling stone & carriage …
J Seaman tending the Building…
Pd Peter Corbin the Balance of his Account £29-14s
August 14th 4 lb Glew
15th Tubb drawing stone at Lutton…
16th 10 doz of Cress…
23rd Cox & son drawing stone at Lutton
J Seaman jnr ditto…
Pd Nineham for 2 load of helling stone
S Mortimer faggotting
P Corbin about the Kitchin Door Case & windows £1 7s
3 doz Cress
R Tubb faggotting …
T Man faggotting …
Pd Webber for stone…
Rubbing stones
Webber for burning lime
October 14th Webber for healing stone & paviour…
27th Pd Symmonds for Hair & Oil…
Nov pd Speck for Laths
8th pd John Seaman for serving Mason & drawing stone for the Kill
11th pd for Rope Yarn
Dec 26th pd Webber for paviour
Pd Ferry for carriage
Pd T Man for making furze faggotts
Jan 8th Pd Chincton for stones

1741 April 7th
for carriage of 9 load of paviour
pd Webber in full for 900 ft of paviour, having paid him 30s before £7 4s…
23rd Robt Tubb rubbing stone
pd Chamberlayne making the Backs & Hearths of the Chimneys…

Roger Frost 4 days about the Building 4s
May 7th Will Frost grinding colours…
16th Chamberlayne for new making the Chimney over the Hall 9s 8d
23rd Pd Mr Sargent for 4 oz Prussian Blue 12s
9 brushes
1 quart of Varnish & Bottle
1 pint ditto…
26th pd Cox for drawing stone for a limekill
27th Tachel making 1300 furze faggotts
pd Russell for 600 ditto
30th pd Webber 19 days this day included for 200 of stone…
May 30th pd Solomon for 7 days & ½ plaistring till this day 18s 9d
Jack tending & making Mortar 15 days 15s
Pd Roger Frost tending Masons, sawing etc …

(Total Cost of build to this point: £1106-4-4)…

August 10th 1741 pd Symmond's bill for hair £1-8-6
Pd Webber towards the fountain
Pd him for burning the lime kill…
Sept 5th pd T Man for faggotts for the lime kill…
Pd the Helliers 14s
Pd Wm Frost for cleaning brick
Pd Peter Corbin for work £1-4-6
Drawing stone for the lime kill…
Maugir for mahogany posts & fir poles
Pd Chamberlaine at several times for mending the garden wall £2-8-8

1741 Oct 23
pd Mr Cartwright £10
pd Marsh the Upholsterer's Bill £3-7-0
pd Strickland for carriage of stone to the lime kill
pd for a pail us'd by the Masons during the Building 2s…
pd the Glazier at Blandford his bill £2-18-0…
pd Coursefield the Smith £20-0-0
pd for 2 sieves & a Tubb 5s

(Remainder of the book comprises general household accounts, including occasional building repairs and materials – eg 'carriage of Terras' (trass) and occasional lime burning:)

pd Webber drawing stone and chalk
burning the kiln and clearing…

'about the East & West wall of the Garden at Grange…Stucco of the Front (at Lutton)

Also- Granary Built at Muston 1754

Mason £8-14-6
Brick & Tyle £12-1-6
Brown for Deal £18-1-2
Carpenter 12-0-0
Smith 2-10-0
Carriage £9-0-0

£62-7-2

D-MHM/8871/A (DHS02)

Sadborow House Building Account 24 May 1773 – 23 December 1775

(*Sadborow House is in Thorncombe, Chard, Somerset).*

To Cash Paid at Sadborow for Jon: Bragg Esq On Account to New House.

24 May To cash for Couch & Expences from London
29th To ditto to Expences at Chard after Stone
to Brandy to labr for Well
to horse to Hamhill & expences…
July to hors & expences to Hamhill
To paper to coppy Drawing etc
14th To cash upon first stone to New House £10 6s
to hors to Lime & expences (Lyme Regis)
to men on bord of ship…
Staples & Rope to fasten timber
To a labourer on bord of ship
To horse and expences to Hamhill
To paper
August To horse to Stape & Lime & expences
To a Pale for Mason

To loading to load of lime at Upton
To Horse to Hamhill & expences
To horse to Lime & expences
To wire sieve for Mason
14th September To cash to loading 2 load of Lime at Uplime
to turnpike 7 tons to Lime
to turnpike 3 tons to Hamhill
to turnpike one for Water Sand…
to files for Mason
turnpike 3 times to Hamhill…
to turnpike once to Hamhill with 5 horses…
to turnpike 9 times to Hamhill…
to loading Lime at Uplime (*Uplime is upon the same Lower Lias formation as Lyme Regis, but also had seams of relatively pure cretaceous limestone*)
to 1 lb of Candles to Stable
to 1 ditto of candles to New House…
to expences of Lime & a quire of paper
to turnpike 3 times to Hamhill
to Beer to labourer of Lime pitt
(ongoing trips to Ham Hill…)
to mending cellar & candles to Stable (regular purchases of candles for the stable and new house)…
to 7 baskets…
2 brooms
to loading Culm at Bridport…
to expences to Lyme after coal and Culm
to loading Culm at Bridport…
to 7 baskets for Builders & 2 for Limekiln £6…
to loading culm at Bridport
to expences to Lyme for Culm (or Culin)
to a Peace (?) for Brick Maker
to ditto…
to loading Culm/Culin at Bridport
to 7 baskets…
to turnpike 3 times to Lyme after Culm/Culin
to delivery with Bark
to 2 shovls one for Stable & one for Limekiln
a man taking account of Culm/culin
wax and rosen for cemmen(t ?)…
to turnpike 3 times for Culm (*culm can mean 'the hollow jointed stem of a grass or sedge' (reed was used for thatching in the region); also (in US usage 'waste material from coal screenings or washings' – this may be coal ashes and suchlike for use as an aggregate in the foundations)*.
to beer for a man going to Hamhill…
to a chisel to cut grooves (grovs) for stone for lead
September to 9 lb of Glue
To 1 lb of candles to New House…

To turnpike to Lime
To 22 ft of iron hoops for Barrows
To turnpike to lyme for slat(e)…
To file for Mason
To brushes…
To 1 lb of Candles to New House
To 2 brooms…
To 1 lb of Candle to Stable…
To turnpike to Crewkerne & for hair…
To 16 lb of Candles to New House…
For expences to Lime (for lime)…
To expences of Lime for self…
1775
January
To Petch for paint pots
To expences for sand for sawing stone
To horse & expences to lime…
To coal ash for Slater…
To a man to help load Portland stone…
To expences after sand for sawing…
To expences to Lyme after Portland stone
To a man from Lyme to give account of Portland stone and expences…
Turnpike to Lyme after Slate…
For sharp tools to clean walls
To expence for leading slate
To pitch…
To carriage of a bag of plaster to Crewkerne…
To 1 lb of candles for work in cellar…
To coal ashes for Brewhouse £1…
To 2 sacks of charcoal.

1773 Labour Time.

19th June 386 days to labourers to Taking down old house (breakdown of same, including:)

to levelling ground
to cleaning brick, stone, etc
cleaning stone
24th July cleaning brick & digging foundations
31st July 6 days to lime kiln
to filling in ground to New House
landing Piling Deals, unloading Hamhill Stone etc
7th August to clearing stone & loading same
levelling ground
to moving slate, loading stone etc
to levelling ground

21st August 26 ½ days to filling in new rooms, loading stone and **making grout** levelling ground
41 days to filling room, clearing stone & brick. Loading same, sawing stone etc…
53 ½ days to taking down wall in garden, cleaning and making grout (more of same)…
33 ½ days to taking down wall, cleaning brick, sawing stone, making grout
October
To cleaning stone for Drain
To piling deals, sawing stone, making grout etc
14 days to digging drains & clearing stone
to sawing stone, making grout; turnpike for Lime kiln
to firs (?) to lime pitt (*timber to line pit?)*
…to taking down summerhouse
to taking down garden wall, cleaning brick etc
November 27th
16 days to filling in Drain etc
to thatcher covering wall
6 days to felling timber
4th December to thatcher at new building
to (his) boy
500 twigg
11 ½ days to cleaning brick, sorting stone
digging & filling drains
5 days to Stable
6 days to felling timber
7 ½ days to loading stone & filling drains
24th Dec 3 days to piling deals etc

1774
January
Felling timber, levelling ground (much more of both), filling drains
To thatcher to old house
February 19th
12 days to lime kiln
3 days to Stable
26th 4 days to gather & load stone for limekiln
10 days to gather stone & digging Lime Kiln
to righting scaffolding etc
March
4 days to lime kiln
6 days to lime kiln
to taking down wall & cleaning brick
10 days to cleaning and loading brick
to 8 days uncovering wall etc to new house
3 days to thatcher and his boy
6 days to repairing scaffolding etc

12 days to taking up paving stone etc
2 days to getting sand to brick kiln
8 days to making grout, sawing stone etc
10 days to cleaning & loading brick
7 days to making grout etc (more of this)
cleaning brick & stone (more of this)
May
16 ¾ days to serving stone, making grout etc (much more of this)
to taking up paving
levelling ground
July, Aug, Sept 6 days to sorting slate
Wheeling earth etc
(much) cleaning and loading stone
2 days to mending road about Limekiln…
4 days to lime kiln
(much levelling of ground)
9 days to levelling cellar etc
December
6 days to drawing brick kiln
to righting scaffold
to Thatcher & boy
to loading paving stone, cleaning and rubbing etc
1775
levelling ground, more drains,
digging of pond in field
to taking slate off old house (and then)
to thatcher and his boy
400 ½ twig
March
3 ½ days to lime kiln
23 ¾ to taking down old kitchin (20 ¾ days more)
8 days cleaving wood
6 days cleaving wood & landing firs
to cleaning stone for garden wall etc
to digging foundation to front steps
to cleaning stone for Court Wall
to digging foundation for same..
to taking down old house and to levelling ground
(many days taking down old house)
July
To help to load fuel for lime kiln
To clearing stone & to garden wall
To righting firs & loading same for lime kiln…
To cleaning windows

Account to Piece work to labour of Sadborow (excerpts)

To gathering 30 loads of stone at 3d

Bill of Materials

1773

August to Gay for lime £3-16
To paige for lime
To Norris
To Hadder for lime
(others for lime) to Petch, Johnston, Hoare, Gover.
To Tucker for lath
Regular significant payments for coal 1773-75

Payments to plasterer, painter & mason

To Edward Stainton
For burning 1616 hogsheads of lime at 6 ½ d £43-14-4
To Stainton for burning a Pitt of lime £2-15
…to Hallett for 76 load of Hamhill stone (20 more loads from others)

Account of Lime to New House at Sadborow

1773

Three pitts of lime to new house
165 hogsheads of lime to new house at 2d each
30 hogsheads to Stable
10 hogsheads of lime to former house

1774
330 hogsheads of lime burnt with culm to new house
373 hogsheads of lime to offices, burnt with culm
77 hogsheads of lime to Mr Walsh building, burnt with culm
33 hogsheads of lime to dressing to garden, burnt with culm
140 hogsheads to garden wall
466 ½ hogsheads of lime sold at 1s 9d per hogshead, burnt with culm
195 hogsheads of lime to Plasterers, burnt with culm
15 hogsheads of lime to plasterers from Uplyme
20 hogsheads of lime to Plasterers from Pitt
the rest of Pitt Lime was used to Garden, Stable & Brewhouse

Account of Materials to Plasterers at Sadborow

230 hogsheads or 46 Hundred of lime to New House & office
46 load of sand

120 bushels of hair
lath nails
25ft of 1 ½ inch Deal
22ft 1 inch Deal
nails
Time to Making Mortar Boards, trussels, rules, etc 5 days London Carpenter's time
To cutting mouldings, altering mouldings, making rules etc
28ft of glue & one hundred weight of Whitening
no. of laths used to New House & office 749 bundles.

Materials to Stable

37 bundles of lath
10 bushels of hair
2 ½ hundred of lime
4 load of sand
12500 3d nails
500 2d nails
us'd to repairing cealing 5 hods of fine stuff, 2 ½ days plasterer & labourer
Plasterer left 7 hods of Coarse stuff for Stable…

Account of New Brick us'd at Sadborow

33,350 brick used to New House
53,420 brick used to Offices
19,930 Brick used to Bastock Farme house
500 brick sold at 2s 6d per hundred

Mr Hill, Painter
3 gallons of linseed oyl
1 gallon of Turps
6 lb of dry white lead
7 lb of Spanish Brown

Account of Time to Jonathan Bragge Esq Waggon & Cart at Sadborow

500 days – to bringing materials to New House, Offices, Drains, Brick Kiln, Lime Kiln & fetching about New House
263 days to materials to former house, stable, garden.

Summary Account

Sundries 36-3-10
Labourers 154-2-2
Piece Work 110-11- ½

Country Carpenters 192-15-7 ½
Sawing 97-7-10 ½
Hamhill Masons 45-11-1
Stone & Timber carriage 131-9-11 ½
Water carriage 131-9-11 ½
Stone & Mason work 635-13-10
Bills of Materials 90-2-6
Brick, Coal & Slater 123-3-6
Plasterers, Painters & Mason 222-16-2
London Carpenters, Lime etc 223-6-5
2,424-10-5
Willis's Time 158-16-11 ½ 2,583-7-4 ½

D 754/B4 (DHS03)

Cheddington Church 1840

Architect's Specification

The whole of the church and chancel walls are to be built and set in the best Mortar and with stone as to the foundations well bonded and set and faced with Ham Stone in courses as good scabbled work (equal to the work in the east ends of the offices at Mr Tevelyan Cox's new house at Cheddington) and to be neatly pointed…the courses to be level round the building, the Buttress which are to be of Ham stone block being neatly and safely built and bonded to the said walls, which are to be two feet thick to the church and twenty-one inches thick to the Chancel and to the Gabels above the building….

Plastering.

The walls of the Chapel and Chancel (which are to be beam-filled with solid masonry as to the walls up to the underside of the rafter) to be pricked up and floated with two coats of Hair Mortar and stucco'd theron in a neat manner with a sharp sand and joints to imitate bonded wrought stone work in courses. The Chapel and Chancel to be plastered with three coates of hair mortar, first to the rafter up to an then to the ceiling joist and to be finished with white mortar. Quirks are to be cut to all the Quines of the window and door openings…

Mason.
The stonework contained in the different walls of the building shall be done with stone that is known to withstand the weather…The whole of the above work to be **laid in good beaten Mortar…compounded of good stone lime and sharp sand and mixed in the usual proportion…**

Agreement to build new church at Mosterton. Between William and Robert Sumerhayes, masons and Elias Dawe, mason. 1832.

To build the walls of Mosterton new chapel or church. They are to hew the stone at the Quarrys so neat as hands can make it and use it in the walls as nise lain as possabel can be done by man. The walls are to be carefully carried up right and level and **grouted every two feet and well filled in with small stones.** The said William and Robert Sumerhays shall have the stone, lime and sand delivered on the spot. **The lime and sand shall be mixed well into mortar within two days after been delivered .** They ar to find scaffold, ropes, buckets and all tools belonging to their trade. Elias Dawe will find all scaffold, wheel barrows and mortar boards. The said William and Robert…shall work and do £20 worth of work before they draw any money and then after that they may draw 12s per week for each man and 5s for boy…these above walls to be carried up and pointed down well fitting to receive the roof…If the said William and Robert do leave or neglect the work and go away drinking at any time, they shall allow E Dawe to take up 2s 6d each time in so doing….

PE/SML: IN 2/2/2 (DHS04)

Repairs and building new stable 1897.

Specification of work to be done in erection of a cow-stall etc at Bailie for the Revd J Cross, September 1897

…To put a bed of concrete composed of clean broken brick, stone or gravel & blue lias lime under new walls and floors
to build the new walls the height and width shown with hard, sound brick laid on mortar composed of blue lias lime & clean, sharp sand, the joints both internally and externally being struck fair as the work proceeds.
Lay damp course of slate bedded in cement.
To twice limewhiten the internal mud walls

To lay the floors of cowstall and meal house with hard brick laid in mortar on edge on concrete previously specified & grouted with Portland ceent

D-WLC/AE/19B (DHS05)

Bindon Abbey Estate, near Wool. The account relates to the building of St Mary's Chapel, adjacent Lulworth Castle and smaller works to the Castle itself, and to the parish church 1785

An account of Stonemasons, Bricklayers and Labourers Quarrying stone at Bindon Warren, taking down stone at Bindon Abby, with working Bindon and Warbarrow stone for the plinth & laying in the foundations and carrying up the inside walls.
Daywork.
James Buckland
Wm Appleby

Wm Corbin
John Vey and others

May 1st To unloading stone;
July To cutting holes through Cornices to let down lead pipes, letting in flashing and cleaning down the building
October 28th to putting up the vases in the niches and making foundations for steps…
1787 January to putting in the center brickwork under ye paving in the chapel, laying foundations to altar steps and backing them up & setting ye altar
February. To working and setting chimney pieces, the oval stones for the vault and writing inscriptions
Own time and expences to Portland to look out stone
Pd Mr Randall for beer for the men for unloading at West Lulworth
Pd Capt Schollar for freight of Portland stone
For 25 tons of Portland stone

An account of the Measurement of the Stonework of the Chapell

1150 feet of circular paving of Portland and black Marble
355 feet of straight course paving
116 ft run astragal
step plugging, setting and craning included
945 feet superficial straight mould cornices etc
450 feet super circular mouldings
464 feet super of circular plain rubbed work
3466 feet of straight tooled Ashler
2925-10 feet of circular tooled Ashler
2332-8 feet of backing of the Parapet
855-6 feet super plain rubbed work
46-5 feet run of small steps under gallery
900 cramps, plugs etc
2 hundred plaster
1 bushell Terras

1788 April for 83 feet super of black marble squares for the saloon floor
for 150 feet of white Purbeck stone for the squares
for 1 ½ bushels of Terras for the Gutter round the terrace
for 3 stone saws
for sieves for washing sand
for the 2 coats of arms including stone and carving

Thomas Weld Esq to Jos: Towsey
For money paid to bricklayers and labourers at the Chapel 102-8-9 ½
For the Measurement of ye Stonework of the Chapel, labour only with ye daywork done in ye Castle etc £835-0-6 ½
Capt Schollar's freights & for the Stone that was us'd as lay at ye Town's End etc

(included above)
for men's time & tradesmen bills to the repairing ye church £238-0-11
for marble and stone squares for ye saloon and masons time to different jobs in ye Castle & on ye Terrace £243-0-11

(DHS06)

29th April 1820 An account of expences of labour building a new wall at Whatcombe

27th May paid nine women 1 week each all but one day Picking Flints 11s 4d
paid for picking 13 loads of flints at 8d
paid for picking on Whatcombe Farm at 8d 37 loads…
(Ongoing flint picking)
paid for cutting 2000 furze
paid for 8 days digging stone at Milbourn

Carriage done for the new wall at Whatcombe
7 horses & 3 men carrying flints 1 day £1-11
8 loads of same
3000 bricks from kiln
3 loads of lime from ?
4 loads of stone from Milbourn
paid for cutting 7600 furzefaggotts
24th June 1820
ten loads of sand from Hitterton
(15 more)
eight loads of lime from Thorncombe at 10s per load
29 July
17 loads of sand from Shitterton
eight loads of lime from Thorncombe
two loads of bricks from Bere Kiln (2000)

paid Thorncombe Farm for rent of the Lime Kiln 4 times

paid Robt White 2 weeks 3 days attending the masons
paid George Lane for burning 1000 bushels of lime
paid Mr Joyce for carriage of lime
paid for cutting 2300 furze faggotts
paid Thorncombe farm for rent of the kiln for burning 1000 bushels of lime…
paid George Lackyer 5 ½ days digging at the Sand Pit…
(flint deliveries)
paid Thorncombe Farm for 10 loads of stone
paid the balance to John Cross for building the wall 24-16-5
paid Mrs Billett for 10000 Bricks

Total, Flint Wall 135 ½ Perch 1820

Masons 75-16-5
Labourers 20-14-0
10000 bricks 19-5-10
Lime 65-5-10
Carriage 62 loads of sand 49-7-0
Ditto 10 loads of brick 10-0-0
32 loads of lime 16-1-0
flints and stone 29-7-0
one new cart 8-3-1
harness 2-5-0 £296-11-8

D/BOH/E24 (DHS07)

Account of the building of almshouses, Sherborne, Dorset 1440-1444

Translated from the Latin by an unknown hand.

Quarry opened on a site leased from the Bishop of Salisbury.
Easter Week.
Mason 2 ½ days scabbling stone in quarry at 6s a day
2 men carrying stone 4 ½ d each
2 masons 6 days scabbling stone
2 men carrying and digging stone
Week 3
2 masons scabbling stone 6 days each
week 4
2 masons scabbling stone 4 days each
week 5 ditto 4 ½ days
week 6 ditto 3 days

week 7 ditto 6 days
(stone diggers' and carriers' hours mirror those of the masons throughout)
Whitsun week
Mason scabbling stones 2 ½ days
Trinity week 1 mason 5 days
(more weeks of the same)

Iron Goods (all made to order)
Pykes (picks)
Crowbar (crowe)
Iron wedges (wiggis) tempered with steel
Hods (scallops) for carrying stone
Sledgehammers (slegg)
Hand barrows (Berewys) to carry earth.

41 loads of stone carried and victuals (bread, meat, cheese)
payment of women serving three men loading stone and their food

Wood.
35 oaks in gross
carrying 31 loads of same, bread, ale and other victuals.
More oak gifted.

Account No.15 1440-41

31 loads of stone from quarry
2 men and 2 horses clearing a place next to the cemetery to put stone on.
Payments to masons and meat and fish
(cementarii – first use of the term: stonelayers. Latami, otherwise).
Loads of stone carried, masons paid
53 loads of stone bought at Hampden (Ham Hill)
(masons payments vary between 4d and 6d the day: cementarii – 6d a day
latimi 5 ½ d a day (but mostly 6d), labourers 4d a day).
Carting of 13 loads of stone and sand
1 load of sand
cartage of 15 loads of clay and sand
16 sacks of lime at 6d each
3 sacks of same
saw bought for sawing stone
2 sieves bought to sift sand
Osiers for the Lodge, straw for the same
36 hurdles (cladis) for the scaffolding
13 sacks of lime

Wood – oaks felled and lopped, wainscot bought
400 laths.

No.16 1441-42

Masons wages
Carriage of stone from Sherborne
10 loads of clay (argill)
14 sacks lime
Stone deliveries, masons and labourers wages
16 sacks lime
masons
8 sacks lime
14 sacks lime
5 loads of stone and sand
5 sacks of lime
masons
6 sacks lime
labourers wages
5 loads lime, masons and labourers
6 sacks lime
3 loads stone tiles
more stone
2 loads sand
1 load stone tiles
3 loads stones from Ham Hill
9 sacks lime
lots of stone, 3 sacks lime
freestone crests (ridges)
3 sacks lime.
Paid Robt Hulle, mason for making put-log holes for the scaffolding to help the tiler
Wm Symmes for a fireplace
5 sacks lime, masons, labourers
John Hooper for 3 loads of clay
Symmes for freestone crests
13 sacks lime at 7d
1100 stone tillers (total used)
8 loads of clay 2d a load
stone
14 sacks of lime
9 loads of clay
16 loads of stone
3 loads of clay at 3d
stone 3 carts
2 loads of clay
17 sacks of lime at 6d

1 cartload freestone from Hampden (more follows)
stone tiles

John Symmes for windows (eg window at east end of the Chapel)
Wm Helyer for pointing the house 20d
6 sacks of lime
12 loads of stone (much more follows)
1 load paving stones
1 sieve

Wood (excerpts)
200 ft of board sawing
5 boards called wenskottes
In splitting 600 laths at 4d per hundred
Sawing 300 ft of board at 18d the hundred (more later)
Tacknails
Victuals when 4 trusses raised
300 lbs of lead bought
Plumber for casting 4 sheets of lead
Nails
2 lbs wax and rosin
felling 8 elms
200 lbs of lead
plumber making leaden gutter of it
100 laths, hinges, straps etc
850 board nails (many already) 16d per hundred
300 tinned nails 2/4 per 100.

No.17 1442-43

Chapel consecrated
Masons, 6 sacks lime
9 loads clay
6 of stone (and more)
masons and labourers
5 sacks lime
7 sacks lime
1000 stone tiles
more stone, lime, clay and stone tiles
crests and tablement

More wood (similar to above)

2 cartloads straw, one seam of thatching-pins
thatcher 6 ½ days at 5d per day
1 man, 1 woman serving him.

No.18
Masons payments, mainly stone-layers, labourers serving them
53 quarters of lime 'bought at divers places for the work'

76 loads of clay and sand bought for the same
6 windows of freestone from Symmes (Norton)
2 more
10 loads of freestone
2 doz hurdles for scaffold.

Cost of tiling and stone for same
14 loads stone tiles
600 laths, 3000 lath nails, 200 board nails and hatchenails
2 loads paving stones.

DC-BTB/M/15 (DHS08)

Building of the Market House, Bridport 1593.

(*Earth is not mentioned, but lime is, in relatively small quantity. The mortar almost certainly of earth, possibly earth-lime)*.

Account of Henry Brohane (?)…collector for the buyldinge of the Market House and Scole House of Bridport…(and of the Gifte of freestone for the building from the right honourable Lady Cromton out of Chideock quarries, as follows

Item paid 3 carpenters for 4 days work
Item paid for drawing of stones
Item paid to Corbyn and Pullam for ?
Item paid Hardy for carriage of iij loads of stones from Chideock(?)
Item to John Hamborne for vij lode of stones carried from Chideock
Item to Corbyn for walling of the ?
Item to Corbyn and Skerry for vj dayes for drawing of stones..
Item to Prince for his horse hair(?)
Item for carriage of tymber
Item for viij hogsetts of lyme…
Item to the stone drawers
Item to Hamborne for vj lode of stones carrying from Chideock
Item to Hardy for vj lode of stones carrying from Chideock…
Item to ij persons for help
Item for help loding stone
Item to the stone drawers
Item for xiiij hogsheads of bere…
Item for mutton
Item for ij quarte of wyne (5 more quarts)
Item for a peck of wheat for cake
Item for a quarter of beef (and more beef)
Item for mutton…
Item for ij capons

Item for butter…
To Hardy for iij calves
To Hardy for half a mutton…
Item for mackerel
Item for butter…
Item for rope and candles
Item for baking of bread…

Hamilton Thompson A (?) The Building Accounts of Kirby Muxloe Castle 1480-1484. Transactions of Leicestershire Archaeological Society.

…W/c 23 Oct 1480

To Thomas Walker and John Claybroke for carriage…of 36 cart-loads of wood carried from le Fryth to le Breke hous, 7d per load.
To Thomas Jonson for dyging 43 cart-loads of sand, 1d per cart-load
To Roger Bowlott for carriage of the said cart-loads at 3d
To William Haselame for lowying (loading) of 59 loads of wode…
To Roger Bowlott and Richard Cookkis for carriage (of same)…for carriage of each cart-load from Baronparke to le Breke house
For 2 cart-loads of straw carried for le breke at 12d…
To Hugh Geffrey, workman there, at making the way for carts coming into le Waren mote with rough stones…
(Plentiful tree-clearing)

W/c 13th November 1480

Paid to John Claibroke and Robert Woode of Glenfield for dygyng and carriage of 16 cart-loads of stone at 6d a load
(16 cart-loads more)
(much more tree-clearing and 'working in the garden' or the 'le mote')…

W/c 18th December 1480
Carriage of stone. In primis paid to John Fletcher of Newtoon for carriage of 26 cart-loads from le Steward hey to Kerby
Item to Roger Bowlott and John Cater, 15 loads, le Waste to Kerby
To John Balle, William Walker, John Claybroke, Roger Tawell and Robert Woode, 53 loads at one time, 16 at another, from Stewarde hey to Kerby
(a further 77 loads)…
To John Burbrygh and Robert Deyn, 10 loads of Rough stones from Steward hey to Kerby.

Slaters.
Paid to Richard Godesalf, working on the hall and divers chambers within the place…*(this to the old house)*
To John Purce of Barough for 2 cart-loads of lime bought from him at Barough, at 21d. 3s 6d
For carriage of the said 2 loads of lime 2s 0d
(Barough is Barrow-on-Soar, which is on blue lias geology and produced a moderately hydraulic lime. When analysed by Smeaton in 1756, Barrow lime had 21% clay, Aberthaw lias lime 13% and Watchet lias lime 12%. Barrow is 13 miles from Kirby. In 1756, Smeaton analysed it thus: "That of Barrow in Leicestershire, of which we used considerable quantities in the Calder Navigation. I was never at the quarries, but having procured some of the unburnt stone, I found it had the appearance of blue Lyas, only somewhat of a more yellow tinge, and more of the slate kind, it ***burns to a buff coloured lime,*** *like that of Aberthaw and Watchet , and on dissolution affords nearly 1/14th (7.2%) of its original weight of blue clay, with a minute quantity of dirty grey sand, so I have no doubt of its being the true Lyas, though perhaps of a less perfect composition than that bordering the Bristol Channel. It contains more clay, can be carried further and remains longer without injury, but in the actual use thereof as mortar, it does not appear to me to acquire quite so firm and stony a hardness as the blue lias of Somersetshire.* ***It makes, however, excellent water mortar,*** *if properly treated…." The lime may have been chosen for its known strength and toughness over more local supplies, given the fortified nature of the building; it may have been routinely used in the neighbourhood).*

For 3 loads of sand carried at 3d
(Work in clearing and preparing the site and in the garden continue through the winter)

W/c 26th February
…Labourers – John Byngham, at laying the walls and the chamber within le moote upon le drawe Bryge 6 days at 4d….
for 1 barre of iron bought…to make a croo thereof for divers necessary purposes within the manor, and for dygyng stones 18d

W/c 5th March
Labourers Richard Bradefeld at laying le Sclattis of the chamber by the bridge in gross 3s 4d
Byngham for le dyging 28 lodes of rough stone

Byngham, working within the place at laying the walls of the chamber there

W/c 12th March
…Labourers, Haukyn, laying hosues and walls within the place…
W/c 19th March
Haukyn, in the manor, bringing together stones, plaster, and other necessaries…
(over 2000 loads of stone brought, largely from Steward Hey, but also from Barne Hills and Baron Hyll and Borune Hey, Typtre. Lesser amounts of 'rough stone').

Carriage of John Eles brick.
Thomas Raulyns for carriage of 10,000 bricks at 5d per 1000
Richard Colles 10,000 more
Thomas Colles 14,000
John Fawxe 4000
Launder and Haslam 1400 with my lord's wains
John Fawxe for delivering le Bryke from John Eles, 39,000 at 1d per thousand
Roger Boolot for carriage of 1500 at 6d
John Alen 2000 at 6d
John Parnell, 1 cartload le Bryke from John Elys.

Carriage of le Freston.
John Fletcher for carriage of 7 loads le freston from Aleton at 16d the load
Thomas Colles, 6 loads from Alton
The township of Thornton, for the expenses of 15 cart-loads of le freston carried from Alton to Kerby for love of my lord
The township of Bagworth, for the carriage of ten loads of freston as a reward.
(38 more loads of freestone from Alton)
Richard Barewell, for drawing freeston out of the pits 22d
26th March 1481
…Labourers Hawkyn, at laying walls and gathering together stone and plaster, 6 days at 4d.

2nd April…
Hauken, at laying walls and gathering together stones and sclates 5 days.
(Carpenters working on the Bridge).

16th April
John Wildwode making 4 whellebaros, 4 days
Haukyn, cleaning divers buildings and walls within the manor…

Purchase of lime
John Purce and John Lanne, 29 cartloads of lime at 3s 4d, each cartload 4 quarters
Purce and John Browne 17 loads
Lane and Purce 25 loads and then 17 loads
Purse and Browne 15 loads
Purse and Lane 30 loads
John Sawce and Thomas Alen 17 loads
Purce and Lanne 24 loads and 18 loads from Barough at 13d a quarter *(Barrow lime in smaller quantities than the other and significantly more expensive)*
Lanne and Brown 3 loads
Purce and Brown 30 loads from Barough
Lane and John Clyff 24 loads at 13d a quarter.

Purce 12 quarters at 7d
(Paid for a spade yron, a Shovell yron…)
Bowles bought for the masons and 2 syffez (sieves)…
Purce and Lane 10 loads (of lime) at 3s 4d
8 quarters of lime bought at Barough at 7d, carried with the wains
3 loads of hay bought at Desford
8 quarters of lime bought of Purce at 7d
(265 loads more).

23rd April.

Labourers. Hawkyn, cleaning le innercourt…
John Crose for dygyng 25 loads of stone on two occasions, at ½ d the load
Carriage Roger Bowlott, for carriage of le olde wode from innercourt to le outercourt…
Carpenters …scappling le poles et le shovels for Mastermason
Labourers Haukyn and Hudson, cleaning the walls and olde tymbre

7th May

Freemasons. Mastermason, surveyor over the stonemasons there 24 days at 8d
Patryk Hagare, apprentice 24 days at 6d
Robert Steynforth, freemason, per week in gross 3s 4d for 2 weeks
Rough-masons. William Taillour, William Wyso, John Paille, 5 days at 18d
Thomas Sandur 2 days at 6d
John Crose 3 days at 6d
Servants of the said masons. John Stedman and John Boolt, 5 days at 8d
Ralph Langton, servant of John Paille, 2 days at 4d
John Graunt, servant of John Crose, 3 days at 4d
Bryke layers. John Hornne, 6 days at 8d
Robert Smyth and Robert Tylere 6 days at 12d
John Smythley, William Thompson and Richard Mossye, serving the said breke leyers, 6 days at 12d
(continued digging of the moate)
Carriage of sand. Ralph Petche, for carriage of 18 lode of sand with dygyng at 2 ½ d the load
Roger Bollott, 29 lodes of sand with dygyng.
Purchases. 1 Coolle *(large tub),* 4 Barell'hedes for holding mortar (to put mortar in)…

May 14th

(payments to Freemasons and Rough masons, Labourers)…
Carpenters (3 men) 5 ½ days at le forge and squaring divers pieces of timber for boards to be made thereof for scaffolding…
John Dolee, for overseeing the said carpenters and markeing the said timber…
John Doylye, for surveying the said timber for cutting
John Doylye, for le marking divers pieces of timber at Loughtburgh parke…
Layers of Bryke, Horn 6 days at 8d
Smyth and Tyler, Troell men, 6 days at 12d
Smythley, Tomson and Mosye, 6 days at 12d
Carriage of sand. Ralph Petche 23 loads with dyging
Roger Boolot, 17 loads.

21st May. (Payments to masons, labourers and dykers in the moat)…

Carpenters – Thomas Wynwode making le Whillebarous and a Coorte (cart) for carriage of sand
28th May. (much as above)…
Bryke leyers in gross – Horne for leying 13,000 in gross at 18d…19s 6d…
Carriage of sand. Boolot and Petche, 38 loads

4th June

Freemasons. Steynforth 3s 4d

Rough masons 7 men at 3s 6d
Labourers of the said masons. 7 men at 2s 4d…
Carriage of sand. Boolot and Petche 13 loads each
Leyers of Bryke in gross. Horne for leying 9000 breke at 18d per 1000 in gross 13s 6d…
Dyging rough stone *John Tomson 4 loads*
(Similar the following week, minus payment to bricklayers).

18th June
Carpenters. Turner, 5 days at making trestles, trays *(hurdles),* ladders and other necessaries for scaffolding to be made therefrom…(others) squaring divers pieces of timber for boards…
(Freemasons, rough masons and servers)
Carriage of sand. Petche, 15 loads…Boolot 17 loads.
Bryke leyers. John Hornne, 21,400at 18d - 32s
Robert Burrell, 30,000 at 14d – 35s
Labourers at dyging stone. John Wryght, for dyging rough stone for my lord's wains, 10 loads at ½ d
Purchases. John Lokyere, pro 200 nails called fourpenny nail, for making le haukes for lime to put therein for the masons, at 4d a hundred….
Margaret Gregore, for hay bought for the horse of master masson
A bed for maitur mason, according to agreement in gross.
For one hors hyre from Kerby to Tattersalle for Robert Steynforth, riding to fetch maister masson. *Tattershall Castle, Lincolnshire, was built (officially) between 1430 and 1450. Was Steynforth master mason at both?).*

25th June
(3 freemasons; 7 rough masons; 8 mason tenders; 6 dykers)
Bryke leyers. 23,000 le bryke, price of leying et werching (working), 14d per 1000
(25 loads of sand)…
7 hopys bought for le barrelles for putting mortar therein.
Necessary expences. Margaret Whatson, for the fare of a horse from Kerby to Alton twice for the surveyor of the carriage of le freestone.
2nd July (as above)…
John Lather, for collecting le Roddys for making le herdyls for Scafuldyng…
Roger Alen, for le Shredring of the said Roddes
John Haywod for making Scafold hyrdulles
John Lather and Stephen Jefson, at torching (plastering/daubing) le forge, in gross 12d…
Berell, 20,000 bryke leyeng, ay 14d

(38 loads of sand).

9th July (much as above)
Sawyers John Mortymer and his fellow, sawing divers pieces of ash-wood for scafoldyng.
Bryke lyers. Byrell, 26,000 at 14d
Carriage of plaster. Bowlott, for carriage of le plaster within the place from le mote Syde to le Oxhouse syde
(61 loads of sand)
Slaters. Richard Goddishalfe, upon le forge 6 days at 6d…
Apprentice of Goddeshalfe 6 days at 5d
Dykers. Powell, at foundations in le Courte for walls and in le mote
Labourers. Jefson 4 ½ days at le forge Chympney…
John Wylwood, at making the wall within forge and for le torching of the said forge, 4 days at 5d…

16th July
(3 freemasons on site, 12 roughmasons, 2 mason tenders)
Brekeleyers in gross. Byrell and Cosyn 34,000 at 14d
Brekeleyers per diem. Robert Norfooke, Henry Cornell, 4 days at 20d
Servants of the said leyers. William Horne, Richard Mores, 6 days at 8d, Richard Outer, 4 days at 4d.
(8 dykers 'in the foundations'. 54 loads of sand)
Labourers. Thomas Gardiner's wife, for cleaning le Should (shed, lime house) lying full of le plaster, carried from Baron yend to le utter (outer) palle in gross…

23rd July.

(2 Freemasons; 6 roughmasons 'at the foundations'; 8 servers of same; 4 bricklayers paid by the day, 3 servers, 15,000 bricks laid; 48 loads of sand; 8 dykers at the foundation)
Purchases. 4 cart-loads of straw for covering le Shold made for le freemason and for putting freestone therein….
14 boolles bought for the masons, 2 syffez…..

(July and August, also September very similar, more scaffolding)
20th August. Sawyers – 3 ½ days at sawing le Waynscottes for moldes to be made therefrom….
Alan Smyth, for le Shappyng freemason axe and cheselles, in gross.
Purchases. John Lokyer, 100 iiij peny nail and 2 Waynescottes bought for moldes to be made therefrom for the masons.
(September – mason's lodge plastered and wooden windows (aspen) installed)
September – *Dykers*. Davy Jonson, 5 days, for making lime placez…
Jefson, for torching and florthyng (flooring) the chamber at the end of the Oxhous
Necessary expenses. For shappyng le freemasons axus.
W/c 24th September. (labour as usual)

Purchases. John Watson, 9 cart-loads of stubble…for covering le Towres and the new walls there.

1st October.
(4 freemasons, 6 roughmasons, 7 servers, 28,000 bricks laid, 72 loads of sand, sharpening of masons chisels and axes. Later in month 'for sharping 9 dosen axes')
(Similar work as the summer all through October, but changes after 29th).

W/c 29th October 1481
Freemasons. Lyle, Steyforth, Bardalf 6 days
Brekeleyers per diem. Norfolk, 2 days (bricklayers have otherwise ceased work)
Labourers (6 men) at covering the walls, 4 days.
Stephen Fletcher for digging 41 loads of sand.

November. Freemasons and labourers, a lot of wall-covering.
December, Freemasons and labourers.
W/c 10th December.
Carriage of le Freestone. John Fletcher…4 loads from Aleton
(29 loads more)…15 loads from Hale – 264 loads more.
(freemasons and labourers only through January)

W/c 4th February
(3 freemasons)
Carriage of le pybull. John Fletcher, John Alen for the carriage of 81 loads of le pibulles with gathering the said pibulles, at 3d the load, for making a path. (36 loads more the following week)
(freemasons and labourers, a few carpenters only through February and into March).

18th March.
(Rough masons (4) return)

W/c 25th March

Freemasons. 4.
Breke leyeres in gross. John Corbell, 36,000 breke at 18d, leying with hewyng.
(65 loads of sand)
2 Boletes, for drawing water for leyers le Breke
40 hyrdulles…pro scaffoldyng

W/c 1st April.

3 freemasons;
Brekeleyers in gross. Corbell 5000 Breke in gross with hewyng at 18d
Marc Maligoo, John Dale, Milhere Wattes, John Midulton, Staner Matlot, John Rankyn, 4 days at 3s 6d at leying anew le Basse Powrs…

Labourers. Filip, Hudson, Dodyng, Graunt, Boolt, 4 days serving the said Brekeleyers at laying the towers….
Purchases. John Lokyer for 4 heryng Barelles for putting mortar and water in…

Purchases of lime. (general account for previous year)
John Purce, John Lanne, John Browne, 13 loads, each of 4 quarters, at 10d the quarter, 3s 4d the load. 43s 4d.
(240 loads)
Purce, Lanne 17 loads on 17 June
Purce, Lanne 29 loads 6 July
Purce, Lanne 30 loads 20 July
Purce, Lanne 22 loads
Purce, Lanne 10 loads 3 August
Clyffe, Purce 14 loads 10 August
(43 more)
Lane, Purce, William Brown, 29 loads, 9 September
Purce, Lane, Clyff 22 loads
Purce, Lane, 24 loads from Barough
Purce, Thomas Brown 36 loads, 30 September
Lanne, Purce, Thomas Clyff 31 loads
Purce, Lanne, John Clyff, 30 loads, 19 Oct
Lane, Purce, 20 loads, 26 Oct

(This shows a steady flow of quicklime to the site, indicating prompt mixing and use, with sand also regularly delivered through the year).

22nd April.

(Usual suspects, minus rough masons)
900 loads of rough stone.

29th April

Freemasons. Cowper 6 days
Patrik Aker, Lyle, Steynforth, Bardallf 5 days
Breke leyers in gross. Corbell, 20,000 Breeke at 18d
Labourers. Fylyp, Hudson, William Smyth, Peyntour, William Nicholson, at laying walls at le yatte hous newly built…
Stephan Fletcher, for dyging sand, 30 loads at ½ d for mixing with lime. ('pro mixand cum calc')….
John Lokyer, 1 lb of wax and 2lb Rosen for syment to be made therefrom for le freemasons
(Roughmasons back in May, building the gatehouse, in May and June. Carpenters making joists and other structural timbers, as well as mullion and transom windows)….

2nd September…
(usual)
Carriage of thorns and brambles. Bowlott, for carriage of 5 loads of brambles and trouns from Gullet to Kerby for making a hedge round **le frameyng place**.
(During September, deliveries of freshly quarried ashlar stone)

21st October.

Brekeleyers in gross.
Corbell, 4000
Brekeleyers per diem. Peter Corbell, 2 days at 7d at le Coveryng the towers
Arnold Ruskyn, 6 days at 7d at Coveryng the towers (labourers carrying 'le Crapes and Breke for covering the towers, 6 days)….
Purchases. John Swanne, 2 cabulles and a rope for le Jenne (Ginny) for freemasons
2 pulleys for the said Jenne
Grease, for the wains and for Jennez and for sethyng the said pulles
A Cartwhell…for the said ferne (ginny) for le freemasons.

W/c 28th October

Carriage of timber for wages.
John Gybbes, 9 loads from Leicester
Robert Gamul, 25 loads from Leicester
John Cater, 10 loads from Leicester
John Fletcher of Newtone, 30 oaks from Bradegate parke
Richard Colles, 18 loads from Osse Baston woodez
Bowlott, 17 loads from Osbaston woddes
(More timber carried 'for love' – 67 loads).

W/c 4th November 1482

(7 freemasons)
Breke leyers and hewers. Corbell, at hewyng le Breke for fireplaces
Peter Corbell, Maligoo, John Dalle, Milner, Bruston, Ruddicowrt, 6 days at hewing, covering the towers….
Fylyp, Hudson, John Browne, William Shawe, William Thyrcaston, Thomas Doddyng, Stephen Jefson, 6 days at making a sawe pytt and carrying le Breke, lime and sand upon the towers for roofing….
Necessary costs. John Hatter for carriage of 41 cwt 12 lb of lead from the abbey to Northyatte in gross
Costs incurred by John Smythson, plumer, at weying 32 cwt and for weying the said 41 cwt 12 lb of lead….
***Carriage of sand.* Bowlot, 2 loads for mixing with lime for le freemasons**
(Into November, brick hewing but no laying; bricklayers 'roofing the towers').

9th December. (9 freemasons on site; 7 bricklayers, a few carpenters, 2 sawyers, 1 labourer. Much the same throughout December and into January, but just 3 bricklayers, hewing).

27th January.
Breke hewers. Corbell, at making le seynters for le vote over le yathouse
Peter Corbell, Bruston, 6 days at 10d, at the said senters.

3rd February…
Brekeleyers per diem. Corbell, upon le Voote.

10th February.
Leyers Breke per diem. Corbell, at leyng Breke upon le Wootte (vault) in le yatte howse. (no freemasons)….
Purchases. A sieve for syftyng and a Baston rope for tying senters.

17th February.
(8 freemasons, bricklayers (3) still on the gatehouse vault; 5 carpenters, 4 labourers, including 'Antone Docheman'…Many loads of freestone; many of roughstone. 100 assheler dug)
Payments for Burning Lime.
John Love of Barough, 1 March, at Leycester, anno 22 Edw IV 60s
Paid by the hand of John Grage, 20 April 60s
John Love at Kerby, 4 May 40s
John Love, by the hand of John Brown, 24 May, at Kerby 60s

Carriage of lime.
315 loads, 4 quarters per load, from Barough where source is mentioned.

(March, building back in full swing. A new brick kiln is built. Costs of this, including board of builders and of burning 28,000 bricks).
April. William Cowper, for hopyng le fern (lifting gear) colles and barelles.
April and May, usual trades minus rough masons. Works have reached parapet level. Lead purchased. Plumbers paid.

June. Oaks purchased, gifted and carried.
For a sieve for lime Riddelyng for Corbell.

(William Hastings, for whom the castle is being built was executed on 13th June. Work all but ceases the week following, with only 1 day worked).

Week after this, timber carried, bricks moved about. Masons have departed.

Bricklayers and stonemasons return W/c 8th September, but are different, apart from Lyle, freemason. Some new carpenters, also. Labourers are the same. Most payment now on day-rate. Towers covered (with thatch) for the winter in

October. Freemasons remain through the winter, as well as carpenters, making doors and windows.

19th April 1482
Carriage of sand. Bowlot, 2 loads of sand called flot sand, for mixing with lime for Water Tabulles leying.

(Freemasons and labourers and waynman through May and June)
21st June Haslam, with the wains on divers carriages with timber and lime (plaster) and other needful things….Bowlot, 5 loads of lime from Barowgh…7 loads of sand, 1 load freestone.

As winter closes in, various roofs are completed, with stone slates, thatch or lead.

Shropshire Archives. (ShA)

112/10/1 (ShA01)

Attingham Estate

Bricklayers Work done for Lord Berwick at his house in Portman Square, 1783
By Thomas Newbury

14 square, 66 ft super labour, mortar & laths to Plain Tyling;
9 sq 6 feet super ditto to Pan Tyling;
3182 ft super flatt joint pointing to arches, walls, parapet.
Ridge.

Bricklayers Day Accounts from Feb to April

Taking down kitchen range, cutting out doorways to Wine-cellar, opening and cleaning drains; setting kitchen range, mending tiling to Stable and House, altering chimney in Laundry.
Making cesspool and drain from wash-house through front Area. Erecting and Striking scaffold to windows in front, cutting away for and setting Broiling plate in kitchen, cutting out doorway and making good Brickwork to Water Closet. Setting stoves etc

87 days bricklayer
87 days labourer
400 bricks
105 Paving bricks
56 12 inch tyles
86 10 inch tyles
255 plain tyles
30 pan tyles

25 slates
14 load, 6 hods Mortar
1 load 15 hods lime & hair
4 ½ hods Pointing Mortar
Candles

From July to Oct 1783

Ripping tiling on dwelling, mending brickwork to Gables, taking up paving in Stable, pulling down chimnies in Stables, carrying up chimnies and gables, carrying up parapet walls. Erecting scaffold to Stable and Arca wall, turning arches from Arca wall to body of house; making a new chimney to room in Stable; laying foundation for Ground Joists in Housekeeper's room. Setting grates in hall Stable & double boiler in kitchen etc
105 days bricklayer
153 days labourer
15 ½ loads of Mortar
½ load of lime & hair
½ load of pargetting
3700 bricks
4 chimney potts
9 nights watching lead at Stables.

Clearing snow of the House at different times, cutting out doorway in Coach house; cleaning drains and cesspools in kitchen and scullery; laying down paving.

Bricklayer 4 days
Labourer 8 days
6 hods of mortar

Masons Work done for Lord Berwick at his House in Portman Square 1783, by John Devall.

5 ft 7 cube Portland Stone
17 ft 7 superf Plainwork to ditto
16 ft 2 super sunk & moulded work to ditto
69 ft 0 super Portland stone in mantles
79 ft 11 new Firestones
8ft 6 new Purbeck slab & hearth
48 ft 8 new Portland paving
20ft 5 new York paving
6ft 0 new Purbeck paving
487ft 9 old Paving jointed and Relaid
5ft 7 old Portland jaumbs reset
24ft 7 new 2 inch coping
7ft 6 new Purbeck step

24 mortice holes cut
a chimney black'd

Masons Day Account 1783
Feb 13th
Taking down and resetting old coping over front door, setting bearer under sink in kitchen, new facing old paving in Butler's pantry; rubbing & relaying paving to landings of best and back stairs; cleaning chimnies in Parlor, one pair and two pair. Fitting firestone to Broiling plate & sundry grates; taking up, repairing & relaying old paving in Hall; cleaning best & back stairs; cleaning & floating paving in Hall etc
26 ½ days Polishers & materials
29 days Mason
43 ½ days Labourer
17 hods of Mortar
13 coping cramps
10 chimney cramps
materials for cleaning stairs
a new Portland Bond-stone for back of Cornice

Slating…by John Westcott

8 sq 60 ft New double welch slating done on boards with strong clout nails, painted.

Slater's Day Account 1783
July 26 to Aug 2nd
Repairing slating on dwelling House. Taking of slating to new lead the flat round Skylight & making good to ditto.
Slater 17 days 4 hours
Labourer 8 days 6 hours
Ready-cutt Lady slates
1435 ready cut double Welch slates
486 clout nails, painted
8 hods Lime & Hair

Joiners Account…Ironmongers Account…

Plastering Work…by John Papworth

205 yds washing and stopping only
85 yds whiting to new work
115 ft supl plain whiting to moldings
425ft supl whiting to enriched Cornices
2325 yds wash & stop and white
218 yds washing colour of the sides of Hall Columns
206 yds Lime whiting

195 1/3 yds wash and stop to ornament ceilings
393 ydsrendering sett fair
71 yds lath and Plaister ditto
9 ½ yds lath and plaister floated
14 ft 9 supl ditto ceiling circular on the Plan
9 ¼ yds trowel'd stucco on brick
5 2/3 yds circular ditto on laths
6ft o supl circular plain facie
50 ft 9 run of plain molding 3" girt
16ft 6 run of circular ditto 2 ½" girt
9ft 10 run of circular ditto 1 ½" girt
36ft 0 run of Quirk
8ft 0 circular ditto
9ft 0 run of circular bead and double quirk
14 chimnies repaired and black'd

Plaisterers Day Account
Repairing plaistering on Basement Story; making good to the blank doors in passage; cutting down and making plaistering in rooms over Stable; repairing plaster floor in laundry; rendering and plaistering in wine cellar; making good round doors
Plaisterer 8 ¼ days
Labourer 2 ¼ days
Boy 6 ¾ days
9 ½ hods of fine stuff
1 hod of running stuff
23 ½ hods coarse stuff
14lb plaster
laths and nails

For the General Repair

July 19th. Erecting scaffold in Great Stairs; stopping cracks in…staircase; making good to the Cornice moldings & cutting down and making good in the Garrets, making good to Skylight; fixing up flowers & repairing …repairing stucco in Hall and Parlor; cutting down & making good the plaistering in Stables…
12 hods of fine stuff
42 hods running stuff
38 hods coarse stuff
13 (lbs?) plaster
putty
24 cast flowers for Staircase
laths & nails
6 loads materials Carted.

1784 January to July

making good Plaistering in the Stable & Coach-house & round the Skylight in Stable; making good plaistering in dwelling house.

Lord Berwick Esq for a Patent Water Closet at his House in Portman Square 1783, by Joseph Bramah

A patent Apparatus for a Water Closet….

A Stink trap with 1 ft of 4 ½ inch Pipe…1 Joint
A service box with cover @ flaunch solder'd on
9 ft of ¾ inch Pipe for the service
2ft inch Pipe to Valve in Cistern & 1 joint to ditto
3ft 4 ½ inch funnel Pipe
12lb of Solder for Box and funnel Pipe
soldering in Box fixing Stink trap, pipes, apparatus
an ½ inch Cock & Ball for Pump pipe that serves Water Closet Cistern
1 joint to ditto
altering & Repairing the Iron work of a force Pump painting and refixing ditto
a 3 ½ inch Plunger to ditto
sundry screws etc used in fixing ditto
repairing pump, putting a new sucker 1 day
a new sucker

1784 Cleaning out funnel pipes of Water Closet on groundfloor, taking up seat of old water Closet & repairing the Pipes.

322/8/311 (ShA02)

1798 Corbet family.

1798
17 April. Agreed with Thos: Madley for to build a new stable at 33 foot 6 inches long; 18 foot wide and 13 foot 6 inches high…for the sum of £9:9:0.

The slating is 96 yards at 7d
Plasting is 92 yds at 3d
Rending is 50 yd at 4d

P238/B/1/1 (ShA03)

Sambrook.

Book of Carriage of Materials for the New Church, Parsonage House, School & Schoolmaster's House, at Sambrook. (summary)

July 5 - 10 1855…54,950 bricks delivered; 45 loads of stone

July 10 – 14 4 loads of lime, valued at £1:12:4
1800 bricks; 133 loads of stone; 61 loads of sand; 5 barrels of water

July 14 – 21: 4 loads of lime; 14,500 bricks; 87 loads of stone; 10 barrels of water;

July 23 – 31: 1 load of lime; 2000 bricks; 119 loads of stone; 10 barrels of water;

August 1 – 15: 1 load of lime; 12,000 bricks; 144 loads of stone; 14 barrels of water;

August 15 – 27: 4 loads of lime; 8500 bricks; 82 loads of stone; 38 loads of sand; 9 barrels of water;

August 27 – September 12: 11,500 bricks; 83 loads of stone; 11 barrels of water;

Sept 12 – 21: 15,250 bricks; 24 loads of stone; 11 barrels of water;

Sept 22 - Oct 4: 3 ½ loads of lime; 23 loads of stone; 13 barrels water; 5 loads timber

Oct 4 – 31: 84 loads of stone; 3 loads timber; 6 barrels water;

Nov 6 – Dec 4: 87 loads stone; 3 loads timber;

Dec 6 – 18: many loads of 'tiles from station'; 14 loads sand; 5760 bricks\

Dec 10 1855- March 17 1856: 1 ½ loads lime; 174 loads of stone; 2 loads timber;

March 17 – 24 1856: 2 loads lime; 43 loads stone; 10 loads timber;

April 28 – May 26: 4 loads lime; 22 loads stone; 8 loads timber; 19 loads sand;

May 28 – June 14: 4 loads lime; 89 loads stone; 2 loads timber; 4000 tiles; 45 loads sand;

June 14 – 26: 2 loads lime; 35 loads stone; 3 loads timber; 12000 tiles;

June 26 – July 21: 63 loads stone; 9 loads timber; 2000 tiles;

July 23 – Aug 14: 3 loads lime; 22 loads stone; 6 loads timber; 6000 tiles; 8 loads sand;

Aug 14 – Sept 10: 1 load lime; 3 loads stone; 7 loads timber; 20 loads sand;

Sept 12 – Oct 1: 1 load lime; 89 ¼ loads stone;

Oct 1 – Nov 1: ½ load lime; 56 loads stone; 5 loads timber; 4000 tiles;

Nov 3 – Dec 3: 1 load lime; 3,150 bricks; 7 loads timber;

TOTALS: 114 tons 12 cwt lime; 129,930; 1488 loads stone; 77 loads timber; 28,000 tiles; 265 loads sand; 89 barrels of water.

9th- 18th Oct **1865**: 12 tons lime; 450 bricks; 52 loads stone; 16 loads of sand (45 previous total); 17 loads mortar (76); 6 barrels water;

Oct 19 – Nov 4th 1865: 10 tons lime; 17 loads sand; 42 loads mortar; 1 barrel water (37)

APPENDIX SIX

MALTON BUILDING ACCOUNTS FROM 18TH & 19TH CENTURIES. Previously published by the author at www.maltonbuildingsgroup,com

Documents referenced in this section are from NYCCRO ZPB(M) 7-107; ZPIII 9-6 and, concerning the Lodge, ZPB 8-10.

Malton Building Contracts

Contracts between the Fitzwilliam Estate and local craftsmen – especially masons and joiners – survive in the Fitzwilliam Archive held at NYCRO from the 1730s until the late 19thC. These show the evolution of the roles of these craftsmen (and, on occasion, craftswomen) and of working and class relationships.

In the earlier 18thC, small contracts appear in the 'Agent's Memo Book'. The terms are set out in the form of measured rates. There is a clear pool of masons locally who would seem to be working in a loosely co-operative environment – sometimes working as a group, other times, on smaller projects, in smaller groups. The use of measured rates illustrates a basic trust between the Estate and these craftsmen, who have all agreed upon a reasonable value for their work. During the later 18thC and earliest 19thC, most projects are executed in the name of a single 'lead' mason and a 'lead' joiner, who offer detailed estimates for a particular project. The masons, at least, accompany their estimates with scale drawings of the proposed building – most of which are identifiable today and remain. Occasionally, there is a formal contract between the Estate and the mason and joiner respectively, which contains a very detailed specification of materials. In two contracts for a major addition to the Fleece in Market Street, a provision is put into the contract that the work may be inspected during the work or at completion by an independent craftsman on behalf of the Estate. That such a proviso would be acceptable to the mason or joiner strongly indicates that an atmosphere of trust, mutual respect and co-operation still pervades the craftsmen of the town.

In 1802, Rogers, a mason, agrees to build a brick house in Old Maltongate, attaching an elevation of the same. This house remains, close to the traffic lights. It was to include 'pantiling and sheeting'.

Thomas Luccock quotes in 1803 to build a house in Newbiggin, to his own attached plan. Also in 1803, Exley provides an estimate and plan for building a house near Pye Pitts. In 1843, George Exley has a 'house, sheds and masons sheds with granary over' as well as a cottage, chamber cottage and garret in Wheelgate. This included a yard and probably a stone shop in Chapel Yard, which has since been demolished. The house was demolished to make way for the Yorkshire Bank building. Robert Exley has a a house, stone shed and shop in Swine Market, but shares same site with a number of others (perhaps employee masons), as well as with John Gibson, the architect, perhaps significantly.

Architects make their first appearance with Atkinson and Philips 1808-17, whose valuations of various works appear in the record, and they are signing off whilst not specifying these works. There remains a variety and fluid body of craftsmen working upon larger and smaller projects.

There is greater division of labour, however. Whereas teams of masons were responsible for a wide range of activities in the 1730s and 1740s – plastering and roofing, as well as building – the accounts from the early 19thC – for the building of the Talbot Hotel coach house and stables, for example – show that roofers and plasterers are becoming distinct from the masons, although the latter still lay either stone or brick. Parallel with this process – and particularly during the younger Copperthwaite's time as agent, in the mid-19thC, we see detailed specifications being issued for building work by the Agent, for an extension to the Blue Ball in 1860, for example, with the source of lime being specified for the first time – North Grimston Lime, in this case (ZPB (M) 7-71, NYCRO). Stone is to be from Appleton le Street. For the first time in these documents, we see a distinction made between the work of masons and bricklayers, as well as other demarcations between trades for the first time.

By 1878, when major repair and extension of the Lodge took place – and for which very detailed accounts survive, including accounts of painters, masons, heating suppliers, etc – John Gibson is the architect (he had been very busy in Malton from the 1840s onwards, designing very many buildings that survive today and offering up designs for many that were never built), and very much in control. The mason's day-books survive, with each hour of labour recorded, as well as the tasks upon which this labour was expended. Crucially, in this context, a list of competitive tenders by masons for these works also survives. The mason who got the work was Hodgson, who had also submitted the lowest tender.

In the space of 150 years, therefore, we witness in these documents, the dilution of the power of local craftsmen; the dilution of bonds of trust, and the arrival of an intermediary professional layer, as well as cost – the architect, and the subsequent introduction of competitive tendering as the accepted means of achieving 'best value' for the client, at the same time as disciplining the craftsman and diminishing his role in creating the townscape of which he is a part. Craftsmen are set against one another, rather than being encouraged to work in a common cause. The small contracts to measured rates of the 1730s were signed by all of the craftsmen concerned – each knew the rate and was paid the same. The quotations of 1878 are by one mason, who will carry the risk, but also the benefit of his quotation, and employ others to realise the works, paying each of them less than the value of the works they perform, creating an inevitably exploitative relationship between the craftsmen of the town and competition between the 'employer masons' within which context, they can only hope to gain competitive advantage over another by increasing the rate of exploitation of their fellows or by skimping on quality of materials or work. It has become the architect's (highly paid) job to prevent this – but which came first, the architect or the need for him?

The houses of masons who sign the 1730s and 1740s contracts may be some of them identified by cross-reference to the 1732 Terrier documents and 1730 Terrier Map, as well as to the Settrington painting of 1728. These were substantial properties – properties that are today occupied by professional, middle class residents. Gibson, who did most of the joinery at this time, leases several properties in Malton, and owns several more.; in 1808, George Willoughby built and occupied a house and stoneyard in Low Street – now known as Castle Dykes – before selling it to the Fitzwilliam Estate and leasing it thereafter (it having been built upon Estate-owned land). By the later 19thC, employer masons still occupy significant yards, but what of their employees?

Between 2005 -10, the modern-day Fitzwilliam Estate came close to achieving a situation akin to that which operated in the earlier 18thC, with a group of masons and craftsmen working co-operatively towards a common end, to commonly agreed standards using appropriate traditional materials, working as a fluid team, each paid individually by the Estate at rates appropriate to their experience and skill; none of them exploiting another, with no marking up of materials or labour. A culture of skills training and best practice was promoted within this context. The York House Project became the focus (and ultimately, perhaps, the litmus test) for this. In this way was created a committed, informed and reliable pool of craftsmen with a developed and ever-developing understanding of local craft practices and methods historically. After 2010, the Estate rejected this, in favour of competitive tendering once more, and with a deliberate policy of setting one mason against another; firm against firm, and of accepting the lowest tender, often submitted to ill-judged or insufficiently detailed surveys or specifications. Local knowledge became accidental and occasional in this scenario. Was this a quest for 'best value', 'best quality' or simply for class control?

Transcriptions.

Estimate, Repairs of Sagg's House.

"The mason work in repairing Mr Sagg's House:	£7	10s	
The materials including bricks, tiles, lime, hair, laths, nails stone ridging and leading (carriage):	£12	6s	
The mason work in building a back kitchen:	£2	16s	
The materials included, as above:	£5	15s	
The mason work in repairing Candle House:	£3	3s	6d
The materials for ditto:	£1	1s	6d
The mason work in repairing the stable:	£4	4s	
Materials:	£7	19s	

Sagg's garret windows-

Jackson, glazier:	£1	10s	11 ½ d
Exley, mason:		6s	10d
Luccocks for raff:		3s	10s

	£1	10s	11 ½ d

Christopher and John Luccock's Bill
for carpenter work and nails:

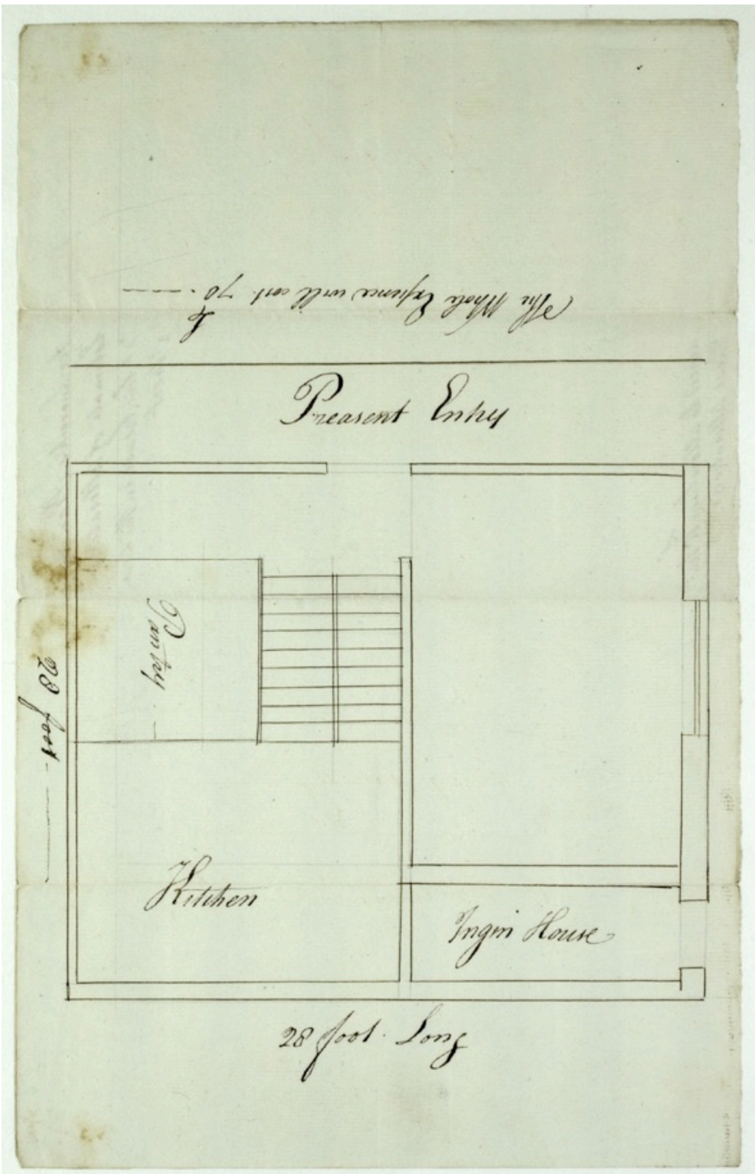
Chr Luccock	£1	3s	2d
John Luccock		3s	

Note on separate slip:

Mr Sagg's House: £28 - -
Mr Wilkinson's Stable: £7 - -
Candle House: £6 10 -

£41 10 -

Rutter for Candle House: £2 10s



The Lodge, October 24th 1784

" Account of money laid out in fitting up the Lodge at Malton now tenanted by Josiah Maynard Esq.

To Joseph Gaskin for raff, etc
Michael Atkinson and to Wood and Pattison for carpenters work
George Nicholson for painting
Ralph Mathers for glaziers work
John Jackson, ditto
To William Exley for mason's work (£117 – 4 – 5)
Andrew Race for leading (carriage, not leadwork)

Materials:

William Wright for hardware

Thomas Luccock, ditto
John Luccock, whitesmith work
Obborn for flooring boards
William Garanciers for lining the pew
William Normans for two marble chimney pieces (£21 – 11 – 9)

Labour, making a new garden:

Levelling, leading, rubbish and earth
Mr Kemp for pale fence
William Oliver, new pump

Total: £532 – 13 – 10 ½

(NYCRO ZPB III 8/10).

1789 Exley Estimate.

"To taking down and rebuilding Orchard Close Wall being 252 yards long and to be 4' 6" high.

To 54 rood of walling @ 5s 6d per rood:	£14	11s	
To 125 loads of stones @ 8d per load:	£4	3s	4d
To 125 loads of stones, loading 8d per load:	£4	3s	4d
	£23	3s	8d

In earlier contracts, masons were paid to a measured rate per 'rood'. As a measure of area, a 'rood' was a quarter of an acre, making clear that the rood being used in Malton to measure area of new walling was not this. As linear measure, a rood was between 16 ½ and 24 feet, depending upon local custom. This estimate offers the information necessary to work out was meant in Malton by the 'rood' – it was 7 square yards – which is to say 7 yards x 1 yard, using a linear measure within the norm for a linear rood multiplied by 1 yard to generate a commonly agreed area. This would have been for two sides of the wall, of course. Indexed to average earnings, Exley's 5 shillings and 6 pence per rood would equate to £366.00 today.

Summary excerpts – **Agreement with Christopher Luccock to take down building behind the Fleece and build new with cellar, 1788.**

Luccock, joiner, agrees to "in a good substantial and workmanlike manner and according to the best of his skill and judgment compleat and finish all the carpenter's, glazier's, blacksmith's and all other work necessary to be done there (except mason and plaistering work and painting)", finding all materials.

There follows a detailed specification of materials:

‘The two floors to be laid with good red, inch fir, the principal beams to be a foot square, the joists 6” x 3 ½”, the principal rafters, 12” x 3”, the ribs (purlins), 6” x 4”, the beams for the principals, 12” x 6”, the sparrs (rafters), 3” x 2 ½”, the ceiling joists, 4” x 2”, the pans (wall-plates), 6” x 3 ½”.

The low room to be 48’ in length by 16’ within, to be finished with a plinth and surbase and to have 5 sash windows 5’ 1” by 3’ 11” within, to be cased with wood and have a moulding round them inside and out, to be well glaized with the best brown glass with proper fastenings; to have 3 fireplaces finished with mouldings and a frieze and cornice to each. To have 2 six-panel doors made of inch and a half fir, with locks, bolts etc to each and a swing ceiling the width of the room made of 1 ½” fir finished with a plinth and surbase the same as the rooms, to hang on hinges and run on castors and to open and shut the width of 12’. The upper room to be finished with a plinth only and to have 4 sash windows 5’ 1” by 2’ 11” within...and to have wood lintons (lintels) over each...(and be) divided by two stoothings at the distance of 12’, the thickness of a brick on edge, to have two fireplaces (as above) and two four-panel doors made of 1 ¼” fir’ and to form a gallery and passage to link the new building with the old, with stairs within.

Luccock shall “clear off and lead away all the rubbish and such part of the old timber as are proper to be used by him or them in the said building”

There is an allowance for the Agent, if thought necessary, “for any experienced workman to be employed to inspect the said work either while the same is carrying on or after the same is finished” and that, if this is the case, the “sum of £70 shall not be paid until such person shall certify that the same is completely finished to the satisfaction of such workman in every particular according to the terms and dimensions (agreed here)”.

This is signed by Wm Hastings, Agent and Christopher Luccock, witnessed by Ralph Tindall.

A similar contract is drawn up with William Exley, mason, concerning the same building, dated 1788.

‘To complete mason and plaisterers work necessary at said building and cellar: £91 (£120,000 2010, using average earnings index), finding “all stone, brick and such other materials as are now in the old buildings (except timber, planks in boards, etc)”, using skill, judgment, etc to “make, erect, set-up and build or cause to be made, erected, set-up and built, one good substantial building of brick and stone” 48’ long by 16’ within, height 17 ½’ above the ground floor.

“The two side walls shall be of good, well-burnt brick well laid in good lime and sand of the thickness...: the front wall next the yard, a brick and a half in length; the back wall, a brick in length”. Two end walls of stone “the thickness of 21 inches”.

The whole was to be “covered with the best tyle and sheeted, the whole to be ridged and the end walls to be coped with stone and corbels.”

Exley will also, “ make and build three fireplaces in the ground floor of a proper size and lay down and finish the same with cleansed stone hearths and slips with proper chimneys to the same” and three other fireplaces in the upper floor, two finished with hearth and slips ‘same as below’.

“All the windows in the low room to have a straight arch of Woodhouse flags over each”

The upper storey was to be divided into three parts, stoothings of 'brick on edge plaister'd over and properly finished."

Exley was also to "sink, dig and make under the east end...one cellar with doorway and stone steps" 20' long, 14' wide and 6' deep, clear of ground floor joists.

He was to be paid "£91 of lawful British money" on 1st August next, if finished according to dimensions, etc and subject to the same possibility of inspection by a 'workman' of the Estate's nomination.

He was to use all materials – stone, brick, etc – from the old building that were "of good quality and fit and proper to be used by him in the said new building without paying anything for the same" –

This latter point is significant, because the contract sum was to be unaffected by the quantities of material that might (or might not) be recycled from the earlier building, creating a clear incentive for such re-use.

1793 – Exley's Estimate for 3 cottages in Old Maltongate, on the corner with Church Hill. A plan drawing that accompanied this estimate survives also. The cottages themselves survive, but are of stone to the outside, at least – Exley's estimate specifies brick, and no mention of stone is made.

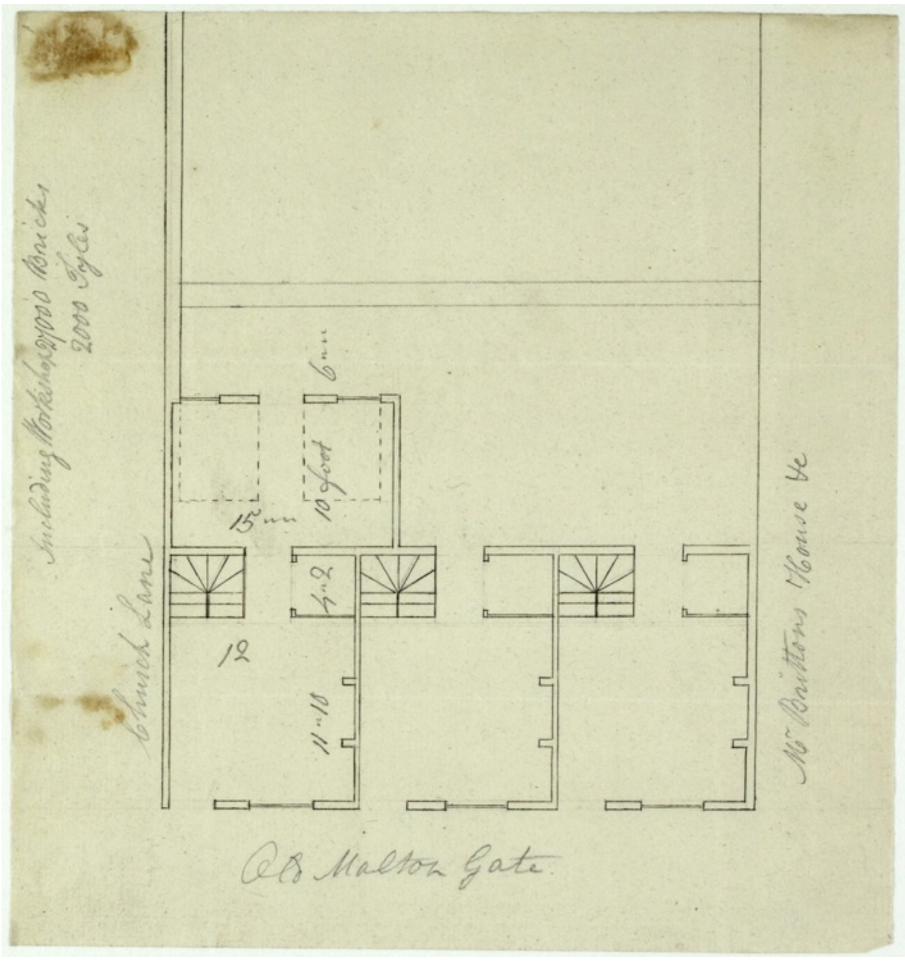
"Three cottages, each 12' by 16' side walls, 12' high and not garretted.

To 23 rood of 1 brick wall @ 3s per rood	£3	9s	-
To 8 rood of ½ brick wall @ 1s 10d		14s	8d
To 40 yards of chimney flues at 1s 3d per yard	£2	10	-
To 63 yards of brick floor at 4d per yard	£1	1	-
To 9 ½ squair of tileing at 5s per squair	£2	7	6
To 350 yards of plaistering at 3d per yard	£4	7	6
To 21000 of common bricks	£18	18	-
To 2000 B bricks	£3	-	-
To 1500 of tiles	£3	15	-
To 11 yards of ridging	-	15	7
To 10 chaldrons of lime	£4	-	-
To laths and nails	£3	5	-
To hair	£1	12	-
To three chamber hearths	-	10	-

The carriage of bricks and tiles, lime and sand	£5	16	-

	£56	1	3
If their are garrited, the addition in mason work All materials including will be	£19	-	-
	-----------------------		
	£75	1	3

This offers several insights: there is no distinction between bricks for walling and for flooring. A chaldron is a dry measure of volume, so that the lime may be deduced to be quicklime to be hot-mixed on site. The lath and nails (and some of the mortar) is for the pantile roof 'sheeting'.



Exley's drawing

House in the Market Place, on site of John Lyon's House 1798

"Malton 29th September 1798

I agree to erect and build on the front now occupied by John Lyon in the Market Place New Malton, a good and substantial Dwelling house or tenement all the width of the said front and to extend backwards twenty-two feet at the least within the walls to consist of a cellar, low room, chamber and garrett with a staircase behind the same. The cellar to be of the same depth as Ralph Rutter's adjoining and the low room to be nine feet from the floor to the top of the chamber joists, the chamber to be eight feet to the top of the garret floor joists and the side walls of the garret to be four feet above the floor, to be built of brick or stone and tyled and sheeted, the front thereof to be sashed and all the timber thereof to be good sound oak or Riga or Memmel fir of proper and sufficient scantlings. To pay a ground rent of eight guineas for the same and the two rooms behind it, the brewhouse on the opposite side of the yard and a two-stall stable above the prems to be occupied by John Lyon; to pay the rent from Michaelmas next and to enter upon the same as soon as convenient premises can be fitted up for Lyon.

Jonah Scurr, gunsmith, Pickering."

Thomas Luccock proposals for building a stone tenement 1799

3rd Augt 1799. I agree to build a tenement in the cow pasture in Malton Fields according to the plan hereunto annexed or with such alterations as may be made therein before the building is begun at the prices within mentioned, and to compleat and finish the same in a good and sufficient substantial workmanlike manner and to the satisfaction of Mr Hastings, so as to be fit for a tenant to go into it on or before Michaelmas next or forfeit five guineas, Witness my hand the day and year above, Tho Luccock.

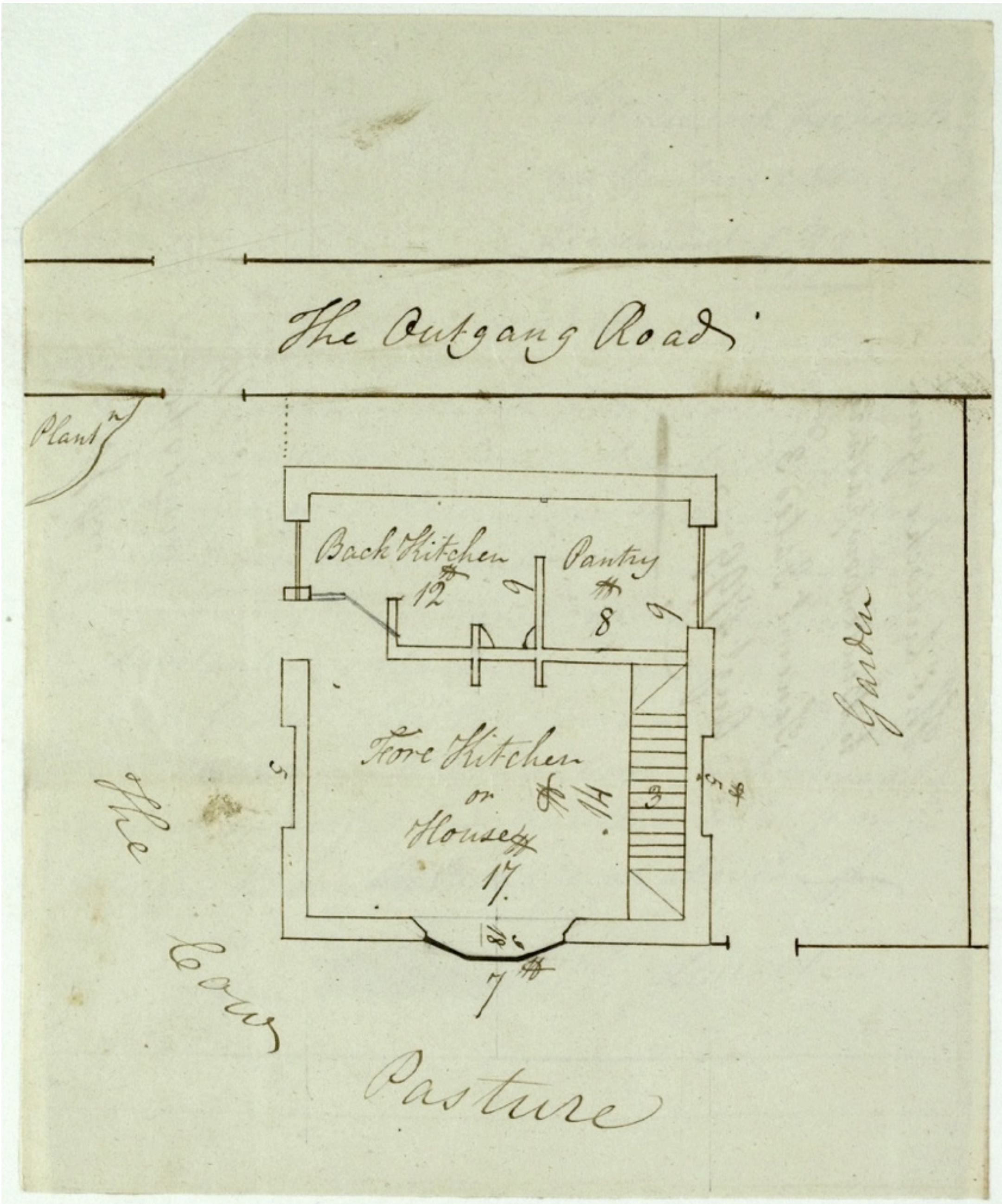
s	d	
6	-	per rood for walling stone
1	9	per rood for the stones, for loading nothing
2	6	per rood for leading stones
1	6	per rood for mortar without lime
11	9	without pointing [11s over-written]
12	6	if pointed [12s written in by Hastings]
1	9	per rood for brick of bredth walls
4	6	per squair for tiling
1	0	per yard for squaring and for laying common flags
1	0	per yard for each flew (flue)
0	3	per yard for two coat plastering

0 3 per yard for brick flooring

0 5 per yard for cellar digging and filling the stuff.

The plan shows:

'Fore kitchen and pantry, with bay window; back kitchen and pantry, with Outgang Road at the top (N), Cow Pasture to the W side and a walled (or fenced) garden to the E.



This estimate represents the latest documentary mention yet found of house walling in Malton using earth mortar.

1800 Mr Metcalfe's House, Market Place (top-side)

“ The groundfloor to be raised 6 inches above the level of the Market Place if it can be done without much inconvenience.
The top of the chamber floor to be 8 ½ or 9 feet above the ground floor
The garret floor 8 ½ feet above that and the side walls 4 feet above the garret floor.
The sash window in the end near the Market Place to be placed 2 ft 6 inches from the floor of the chamber. The garret windows 2 feet above that floor. This end to have coping and corbels.
The roof sheeted with stone ridging. The other end of the building may be tiled over.
The cellar stairs brick or stone covered with flags.
The projection over the lane 1 foot only.

Fixtures etc in the House in the Market Place lately occupied by Matthew Metcalfe:

In the shop – counter, shelves and glass door: £1 – 1s – 0d
Kitchen- Delf rack and chimney piece: 4s – 6d
Chamber – ceiling and corner cupboard: 12s – 6d
Back Chamber – chimney piece: 1s - 6d
Allow towards the Bow and sash window in the shop: £2 – 2s – 0d
Ditto for bricks in the oven: 10s - 6d

Received of Wm Hastings the above sum by me, Matthew Metcalfe

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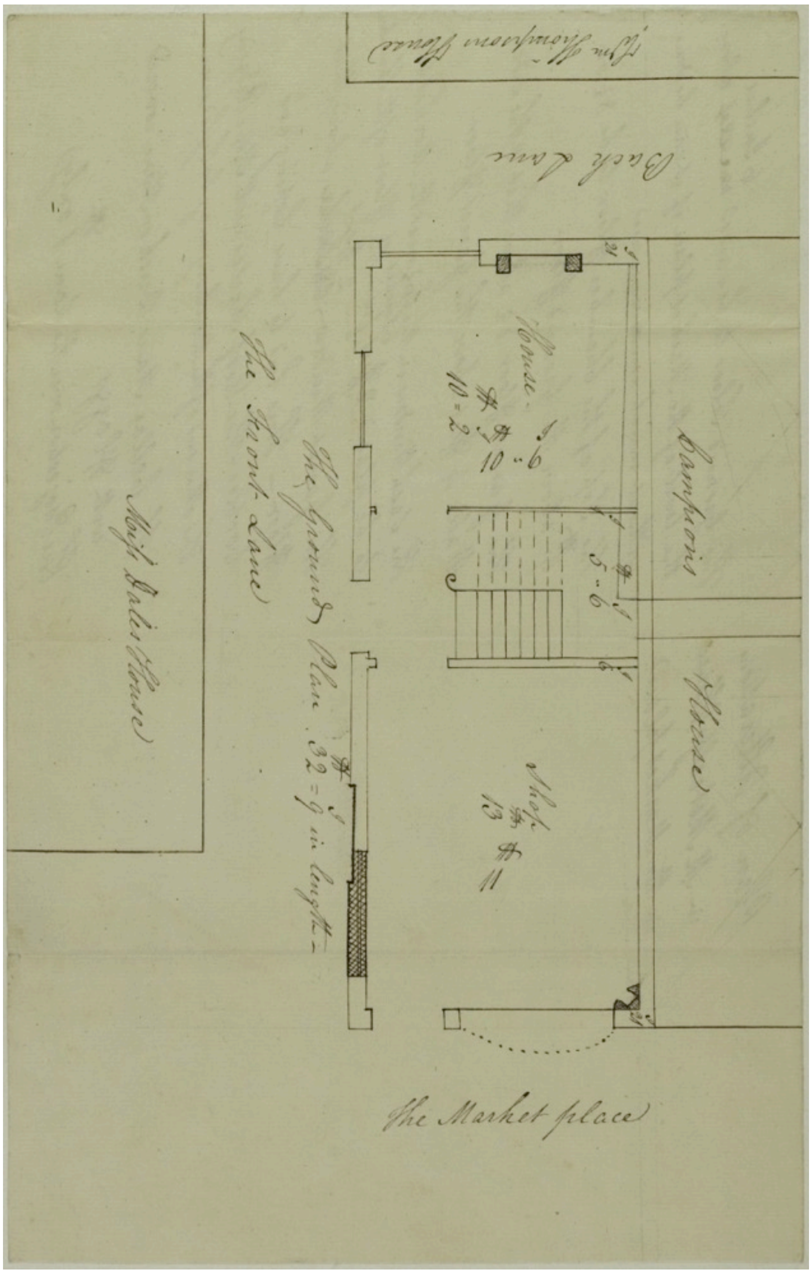
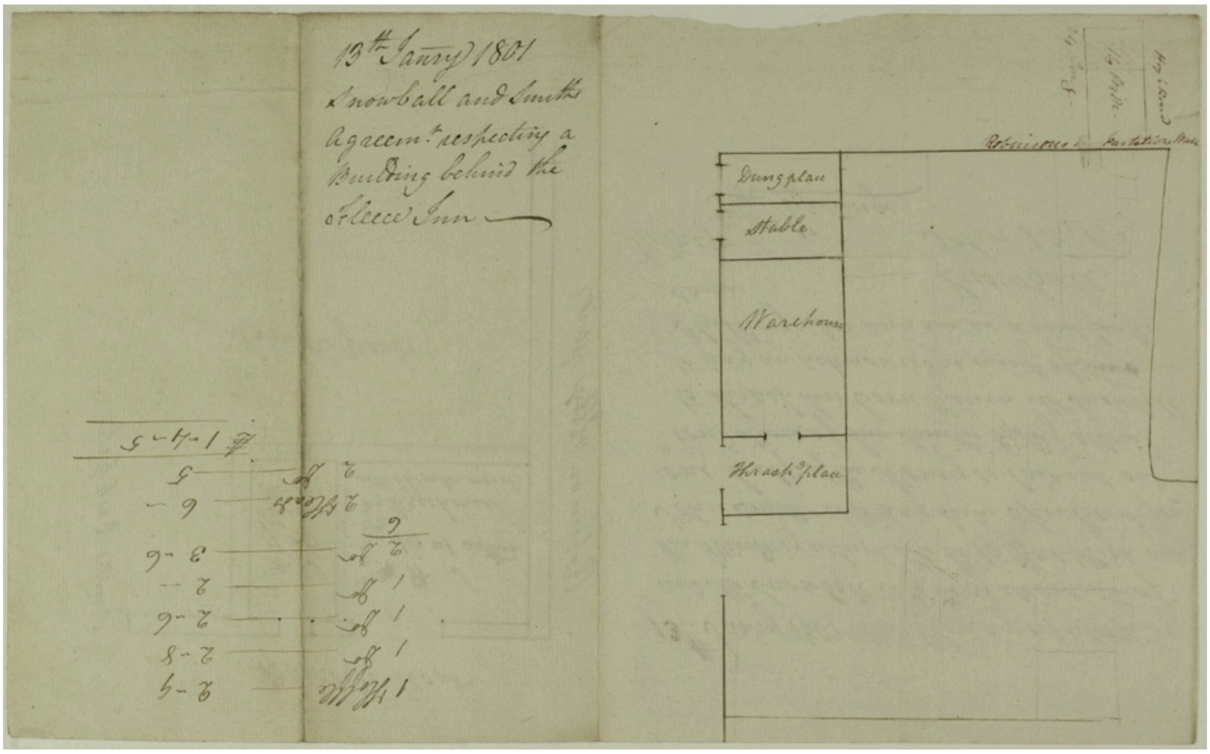
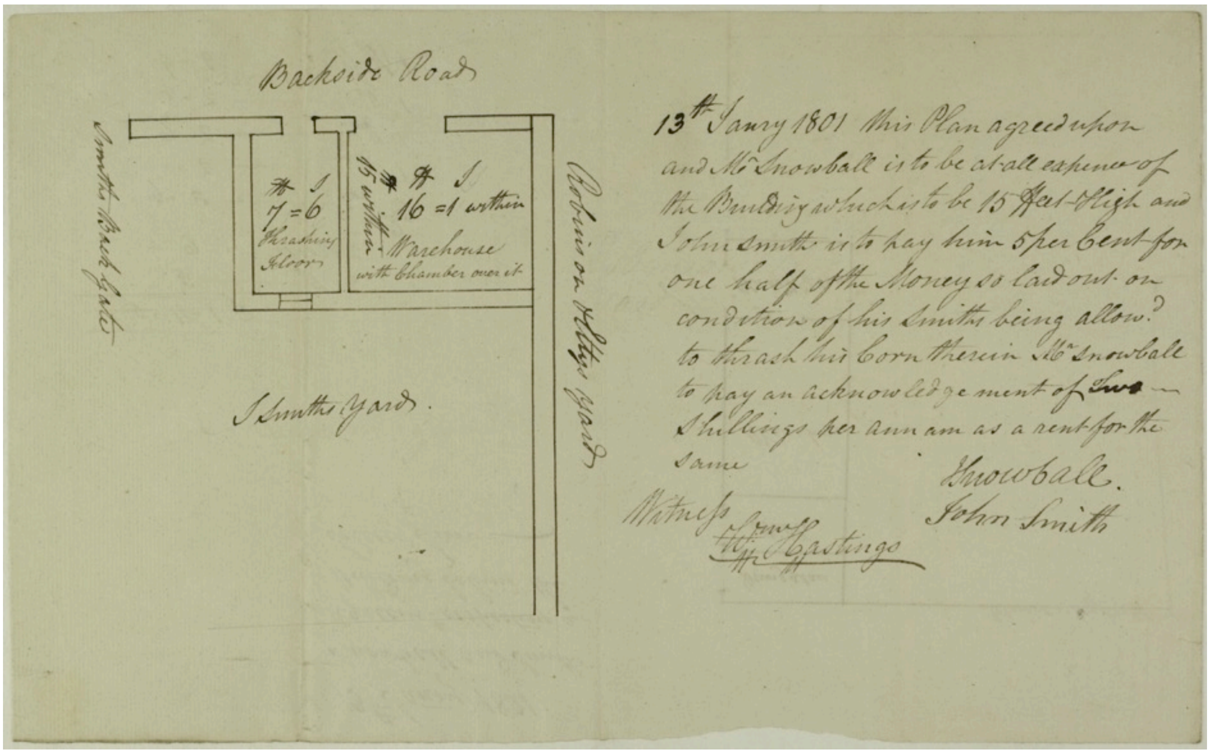


1801 Snowball and Smith agreement for 'thrashing room' behind Fleece Inn



13th Janry 1801
Snowball and Smiths
Agreemt respecting a
Building behind the
Fleece Inn

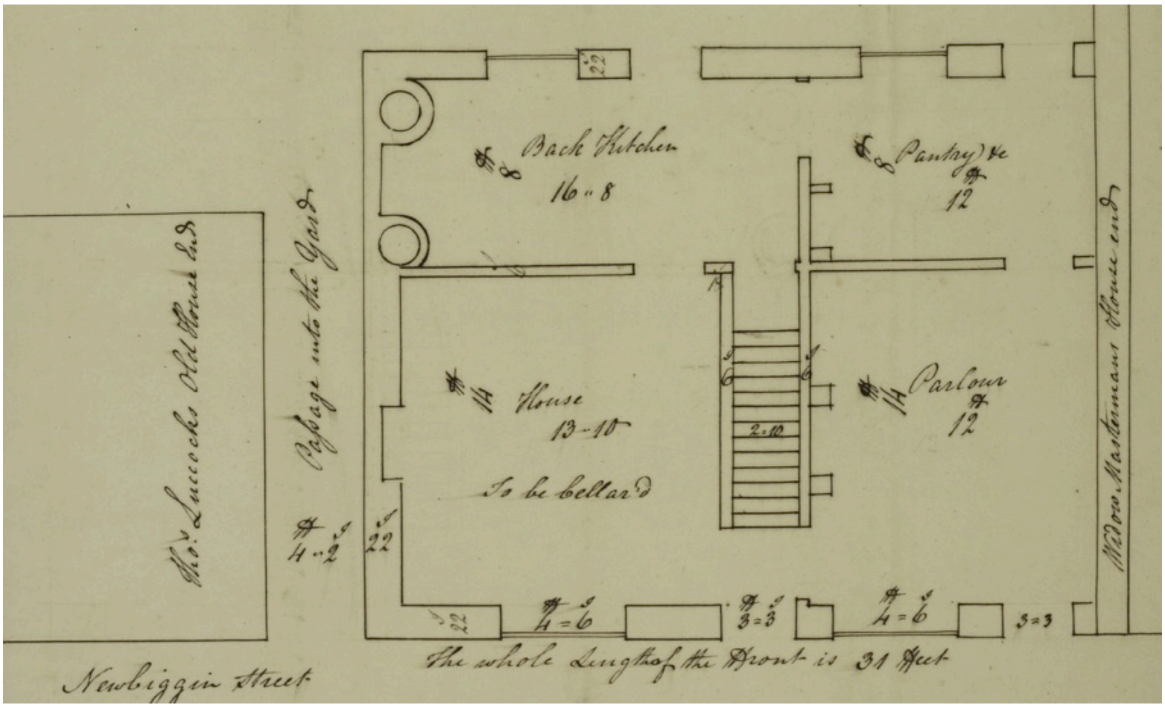


13th Janry 1801 this Plan agreed upon and Mr Snowball is to be at all expence of the Building which is to be 15 Feet High and John Smith is to pay him 5 per Cent for one half of the Money so laid out on condition of his Smiths being allowd to thrash his Corn therein Mr Snowball to pay an acknowledgement of Two Shillings per annum as a rent for the same

Snowball.
John Smith

Witness
Wm Hastings

1803 Luccock's proposal for house in Newbiggin

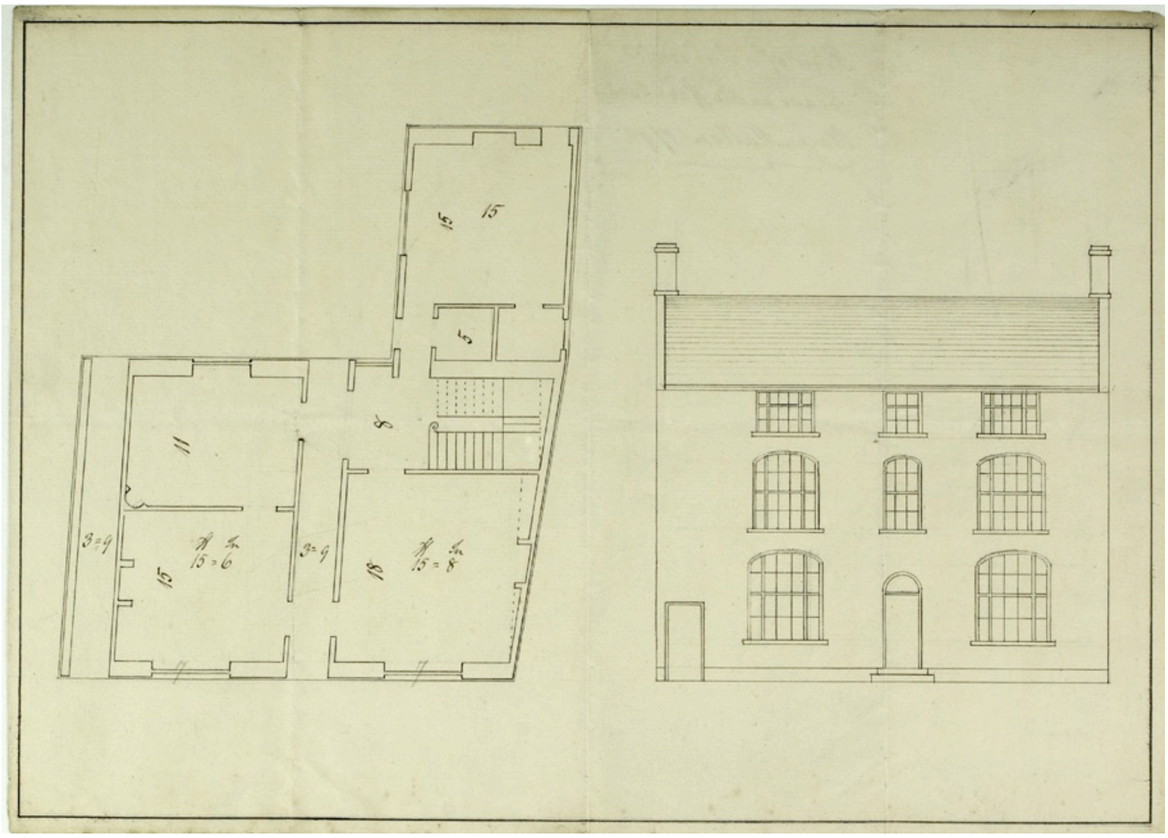


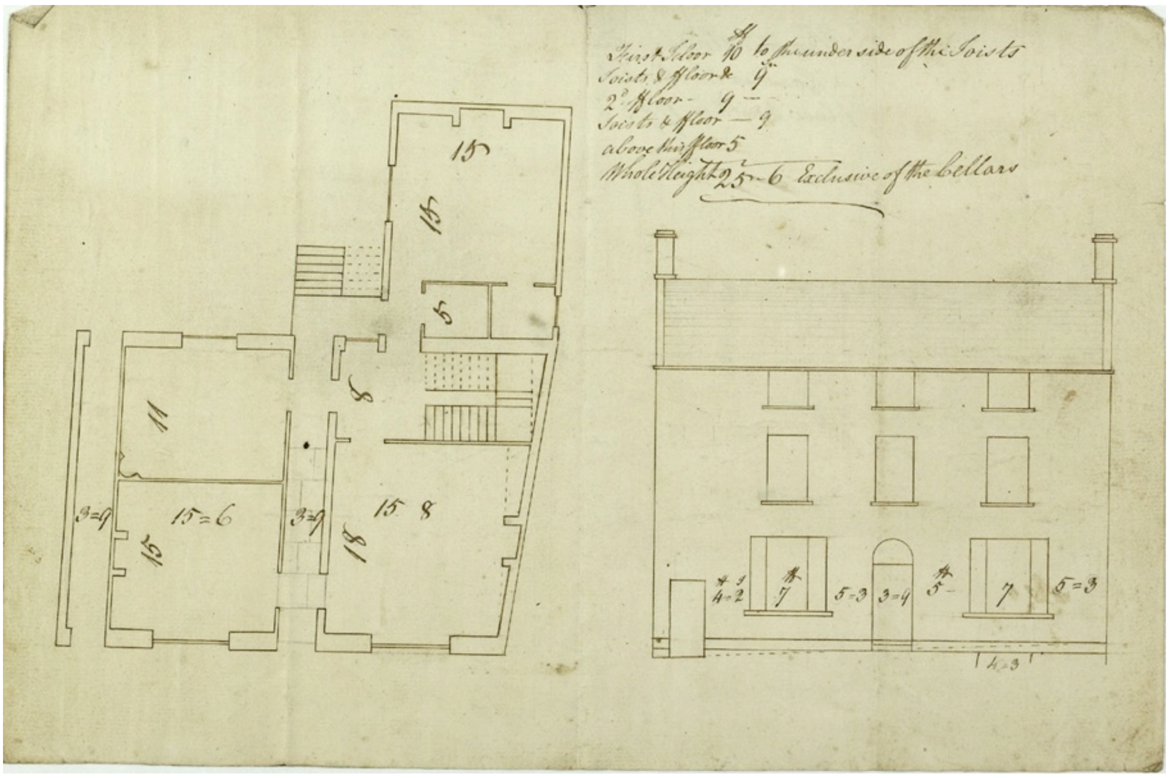
"Malton 15th February 1803

I agree to build a house upon the end of a piece of garden ground in Newbiggin, New Malton, adjoining to Widow Masterman's Freehold and now in the tenure of Widow Read & son, according to the plan hereto annexed of stone, brick and tile. To finish and compleat the same in a good and sufficient workmanlike manner and to the satisfaction of Mr Hastings, Earl Fitzwilliam's Agent on or before the 25th day of December next. To cellar the room marked in the plan over which I will turn an arch of stone the underside of the crown of which shall be not less than six feet from the floor thereof. To make the side walls of the said house not less than fifteen feet from the ground floor of said house. The low rooms to be eight feet clear and all the rooms properly plaistered and finished in a decent manner. The rent to be paid for the said garden to commence at Lady Day next and to be £10 per annum. To receive from his Lordship the sum of thirty pounds when the house is finished for which I agree to pay £30 per annum as an additional rent for the said house from Michaelmas next. All the timber to be made use of in the building of the said house to be of good sound foreign fir timber and to be cut of proper and sufficient scantlings for the different purposes to which they are to be applied and not less than those commonly used in his Lordship's buildings of the like nature at Malton. Witness my hand the day and year within written.

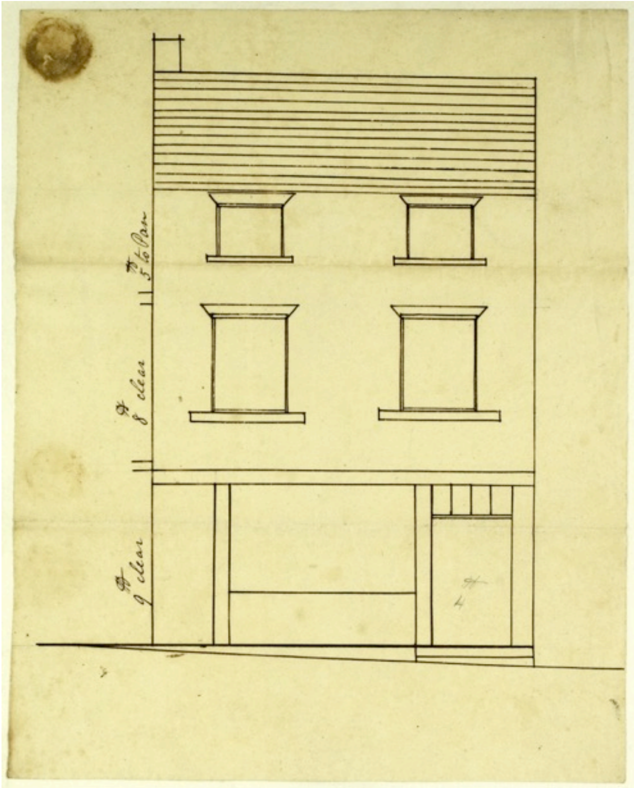
Witness Thomas Luccock
William Hastings

House in the Market Place, perhaps current Conservative Club. No spec. 1805

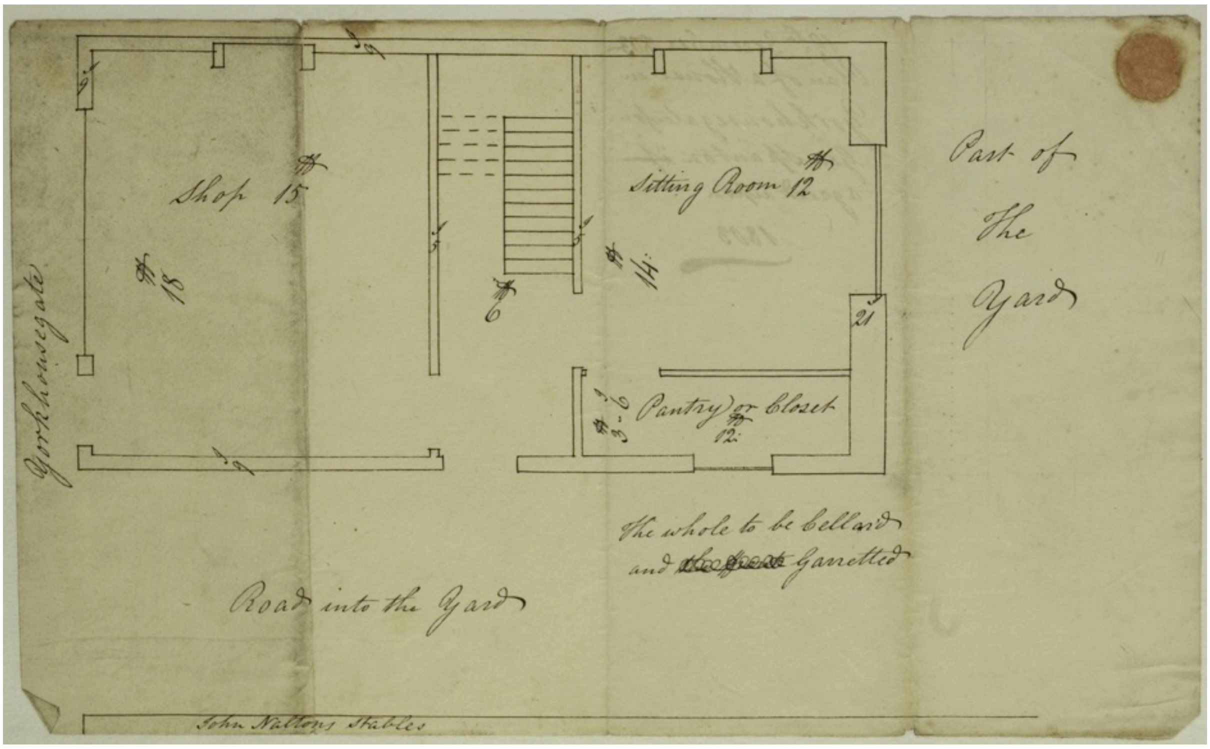




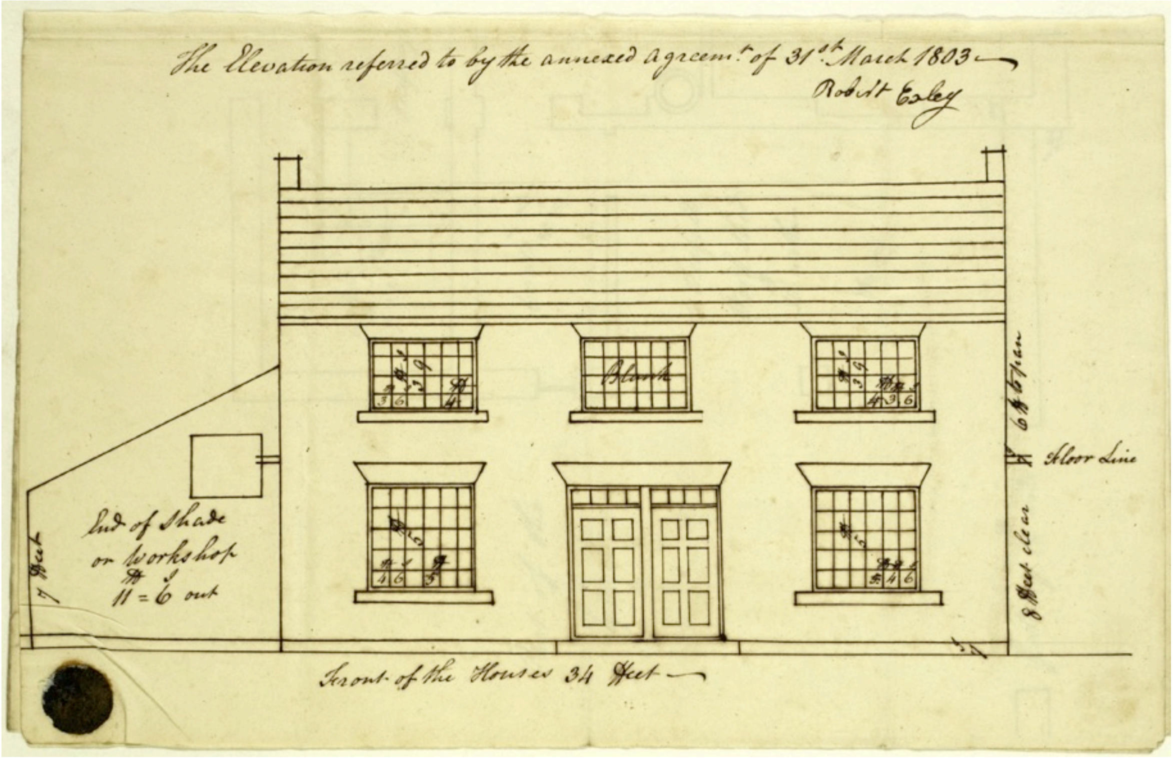
Brick house and shop Old Maltongate, 1802. Rogers, mason

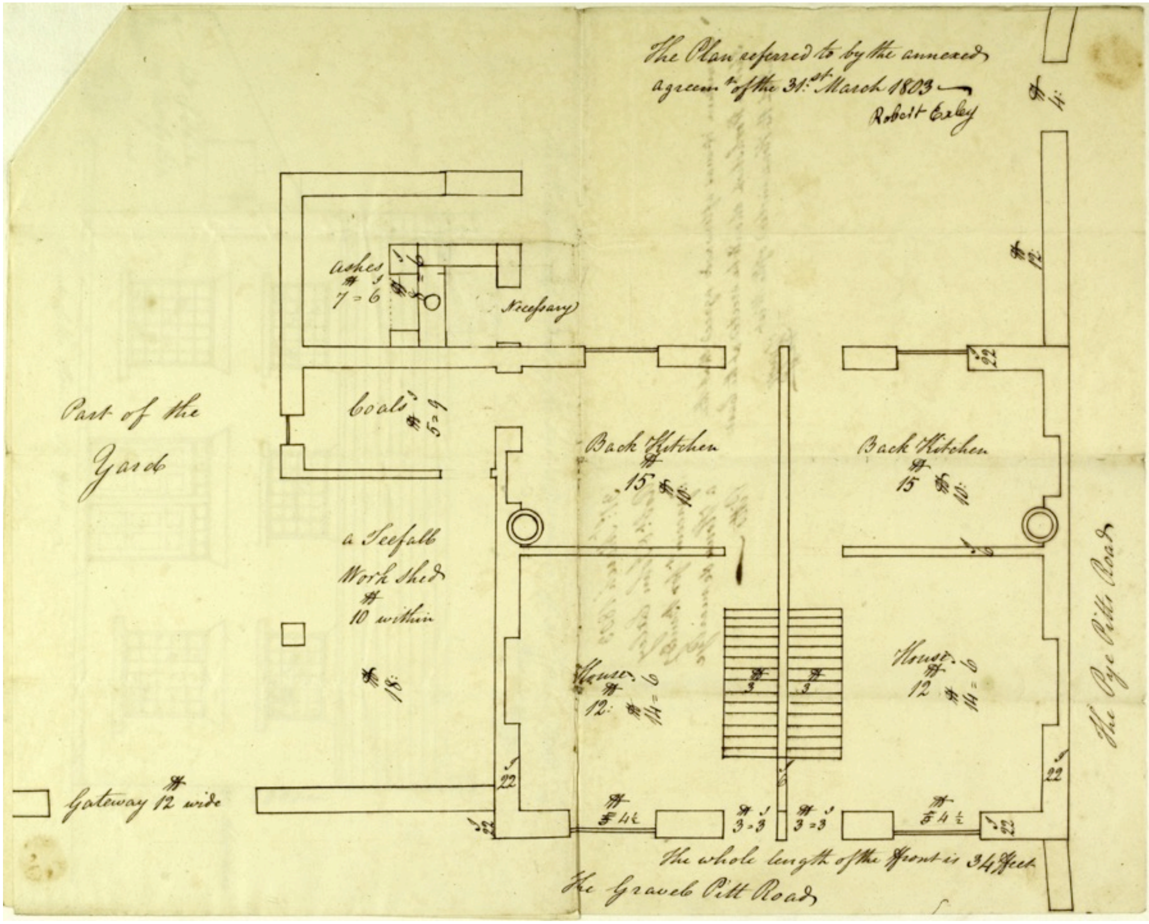


George Spaunton's House, Yorkersgate 1803



Proposal for a house adjoining Pye Pitts Road, Robert and John Exley 1803.





Malton 31st March 1803

We agree to build a house and other conveniences on a piece of ground now staked out in a field now rented by Mr Thomas Robinson, Postmaster, adjoining the Pye Pitts Road (including part of the same road) according to the Plan and Elevation hereunto annexed, of Stone, Brick and Tile.
To finish and compleat the same in a good and sufficient workmanlike manner and to the satisfaction of Mr Hastings, Earl Fitzwilliam's Agent, on or before the 25 day of December next and to make and erect a stone wall of the height of seven feet at the least round the remainder of the said piece of ground not otherwise built upon.

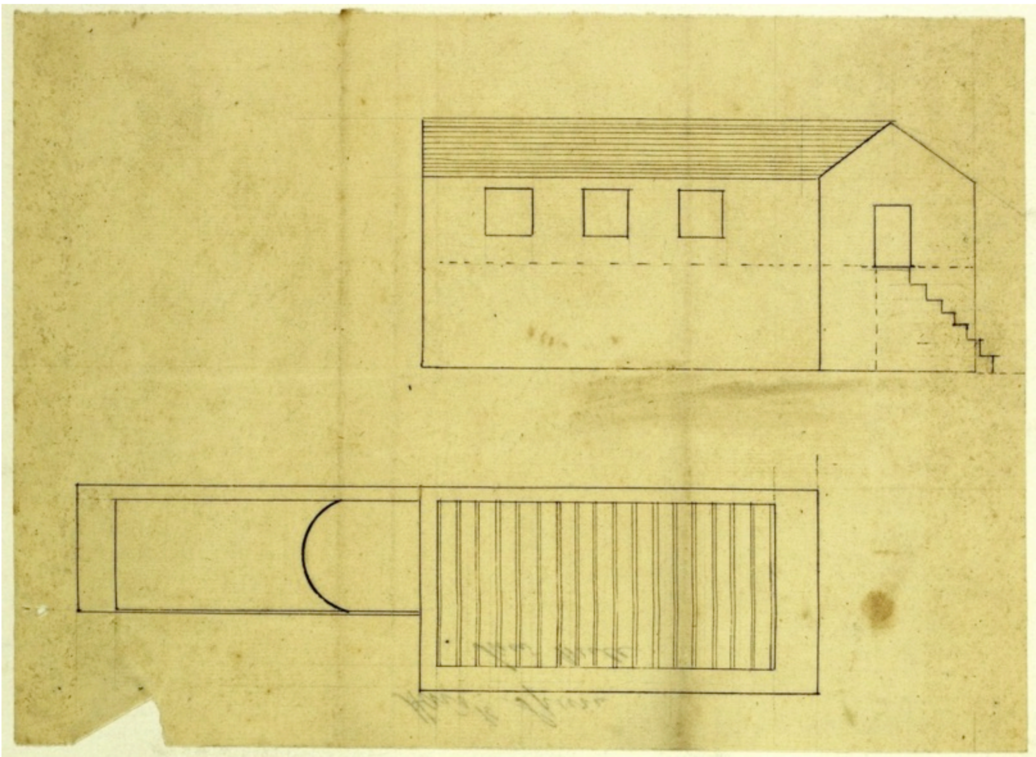
To make and carry up the side walls of the said house to the height of fifteen feet at the least to the underside of the pan. The low rooms to be eight feet clear at the least; all the rooms to be plaistered and finished in a neat and decent manner and the chambers to be underdrawn at a proper and sufficient height; the rent to be paid for the ground, which is to commence at Lady Day 1803, twenty shillings per annum and to receive from his Lordship towards building the said house, etc forty pounds when the house etc is finished for which we agree to pay the further sum from Michaelmas next; that we will in building the said house make use of no other than good sound foreign fir timber to be of proper and sufficient scantlings for the different purposes to which they are to be applied and not less than those commonly used in his Lordship's buildings of the like nature at Malton – we also agree to keep an account of all the gravel taken out of the Gravel Pitt in the adjoining field and to render an account thereof to his Lordship's Agent at Malton once a month or oftener if required.

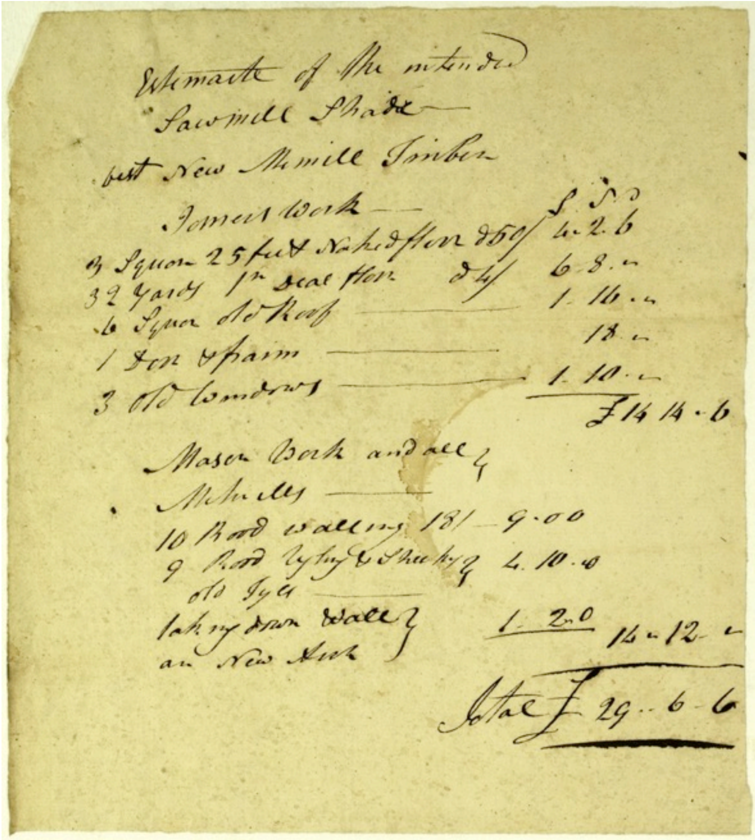
As witnessed our hands the day and year first within written. NB a lease for 21 years to be granted of these premises at the rent of £3 per annum

Robert Exley; John Exley

Added: Joists – 6 by 3
Spars - 3 by 2 ½
Ribbs – 7 by 5
Pans 6 by 3
Flooring boards- 1 inch
Stair bearers – 6 by 4.

Plan for a sawmill, undated.





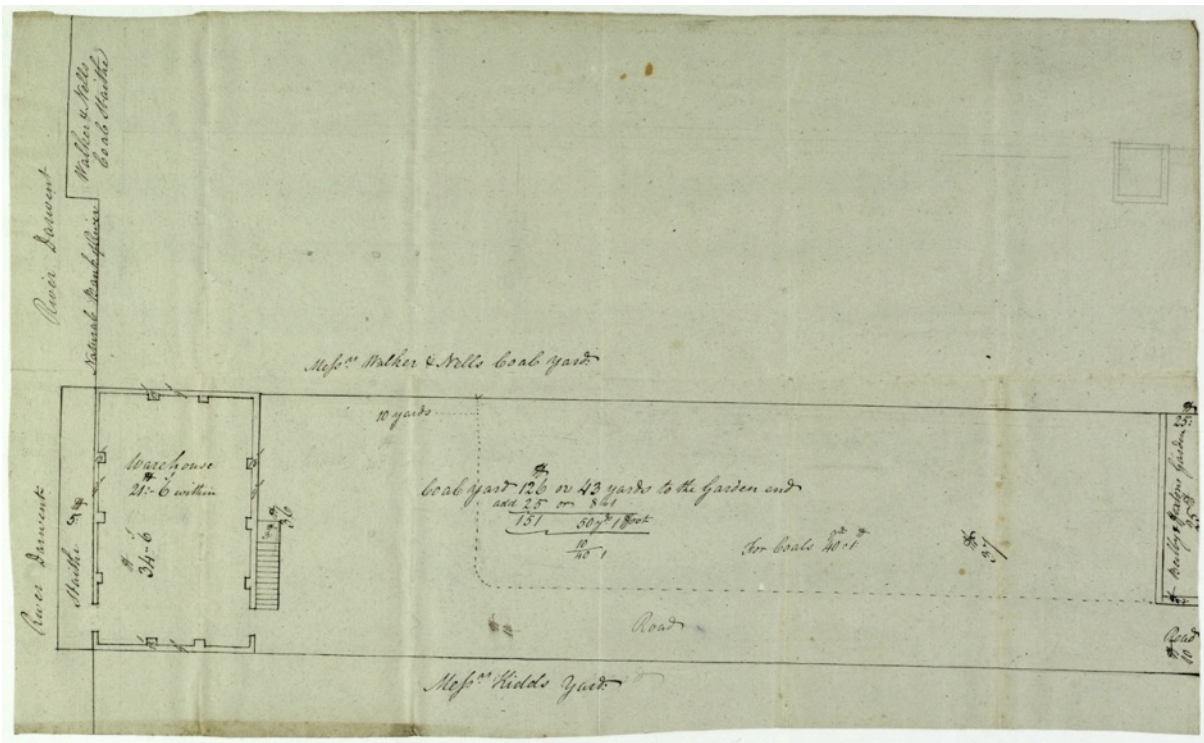
Estimate of the intended
Sawmill Shade
best New Memill Timber

Joiner Work — £ S D
4 Squar 25 feet Naked floor d 50/ 4.2.6
32 yards 1st deal floor d 4/ 6.8.–
6 Squar old Roof — 1.16.–
1 Door & frame — 18.–
3 old windows — 1.10.–
£14.14.6

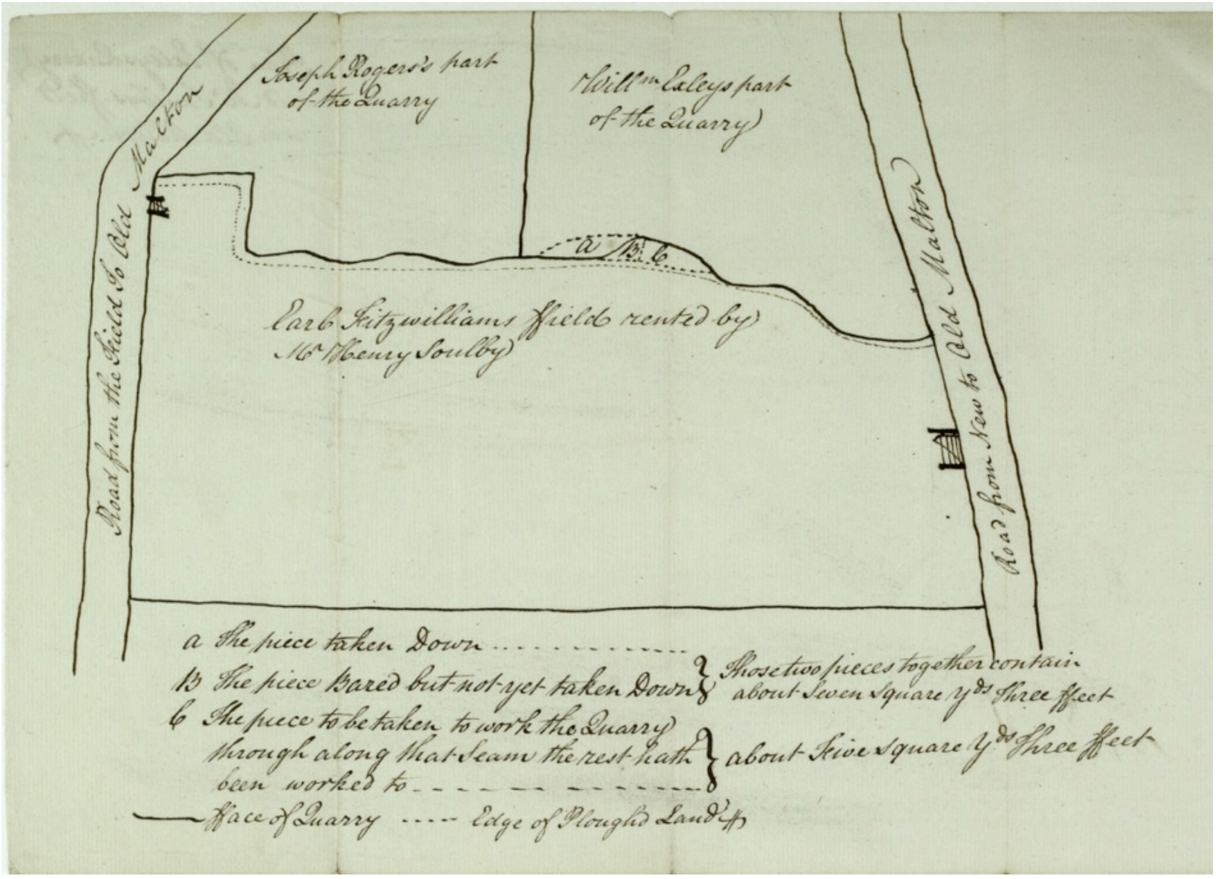
Mason Work and all Materials —
10 Rood walling 18/ — 9.0.0
9 Rood tyling & Sheeting old Tyles 4.10.0
taking down Wall an New Arch 1.2.0 14.12.–

Total £29..6.6

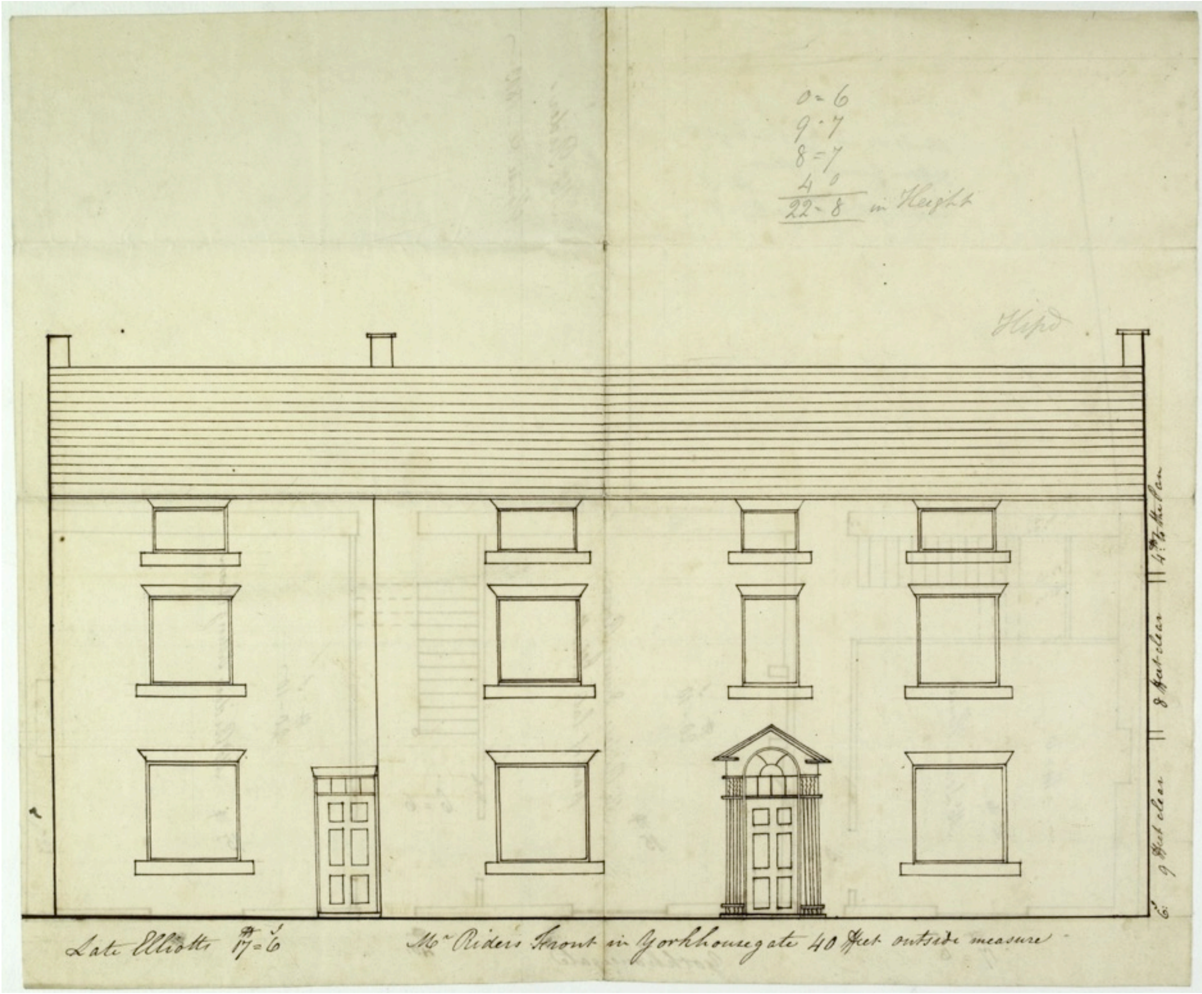
Plan for Coal-yard, Beilby's on site of 29 Yorkersgate, now Tui's restaurant

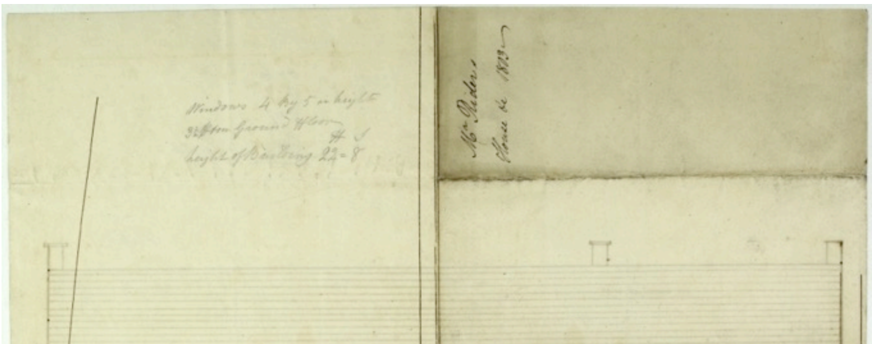


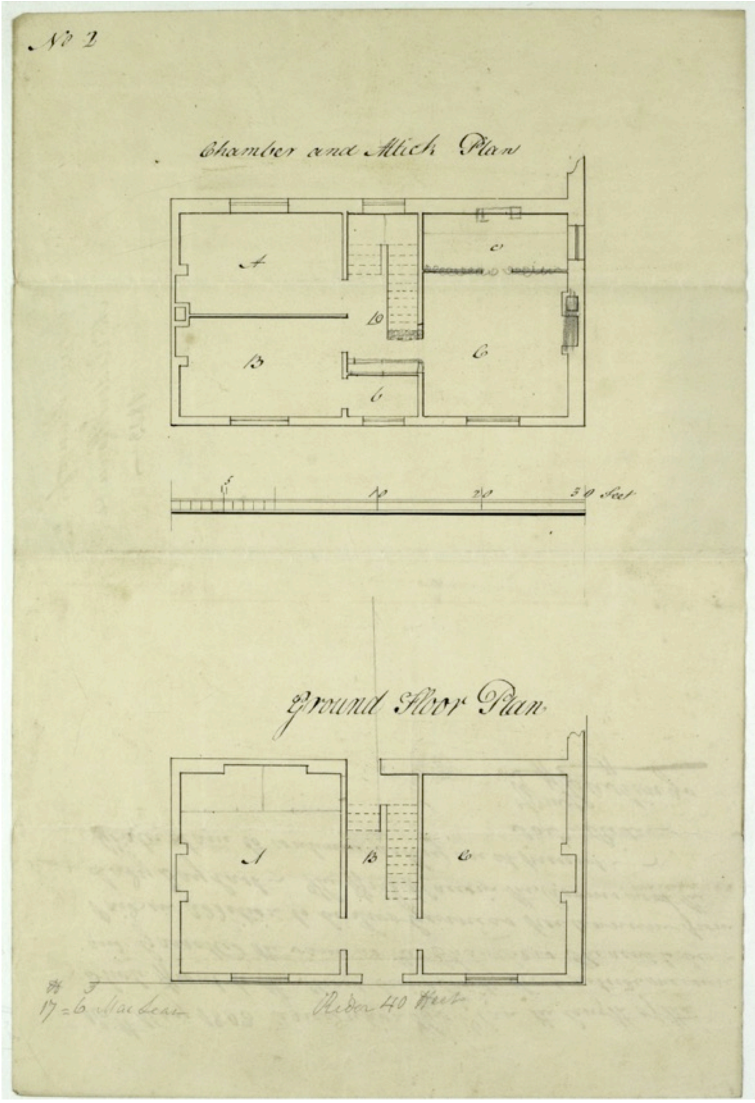
Plan, Exley's Quarry, nd



Joseph Rider's House Yorkersgate, adjoining Water Lane 1803


0=6
9=7
8=7
4 0
22=8 in Height
Late Elliotts 17=6
Mr Riders Front in Yorkhousegate 40 feet outside measure

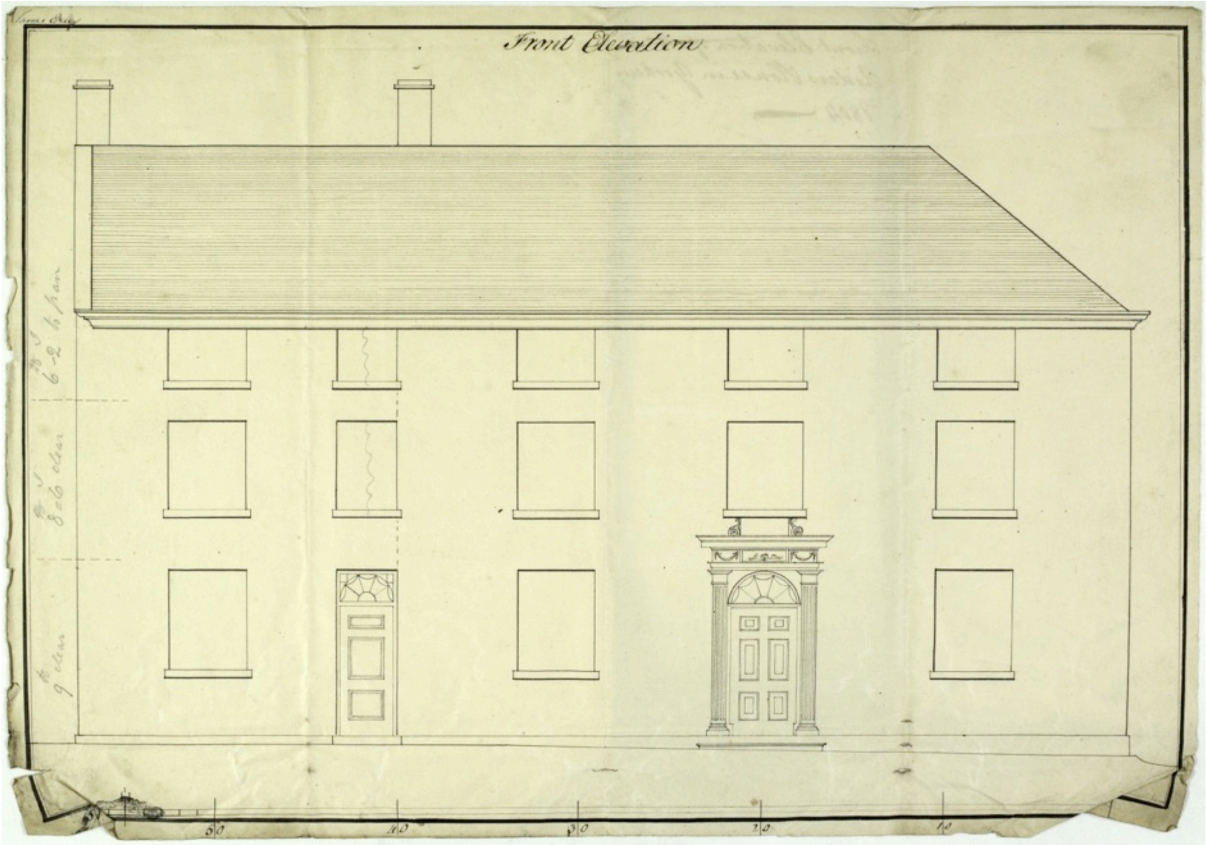

Mr Riders
House &c 1823
Windows 4 by 5 in height
Height of Building 22=8
Mr Riders Sitting Room
17=6
Yorkhousegate
40

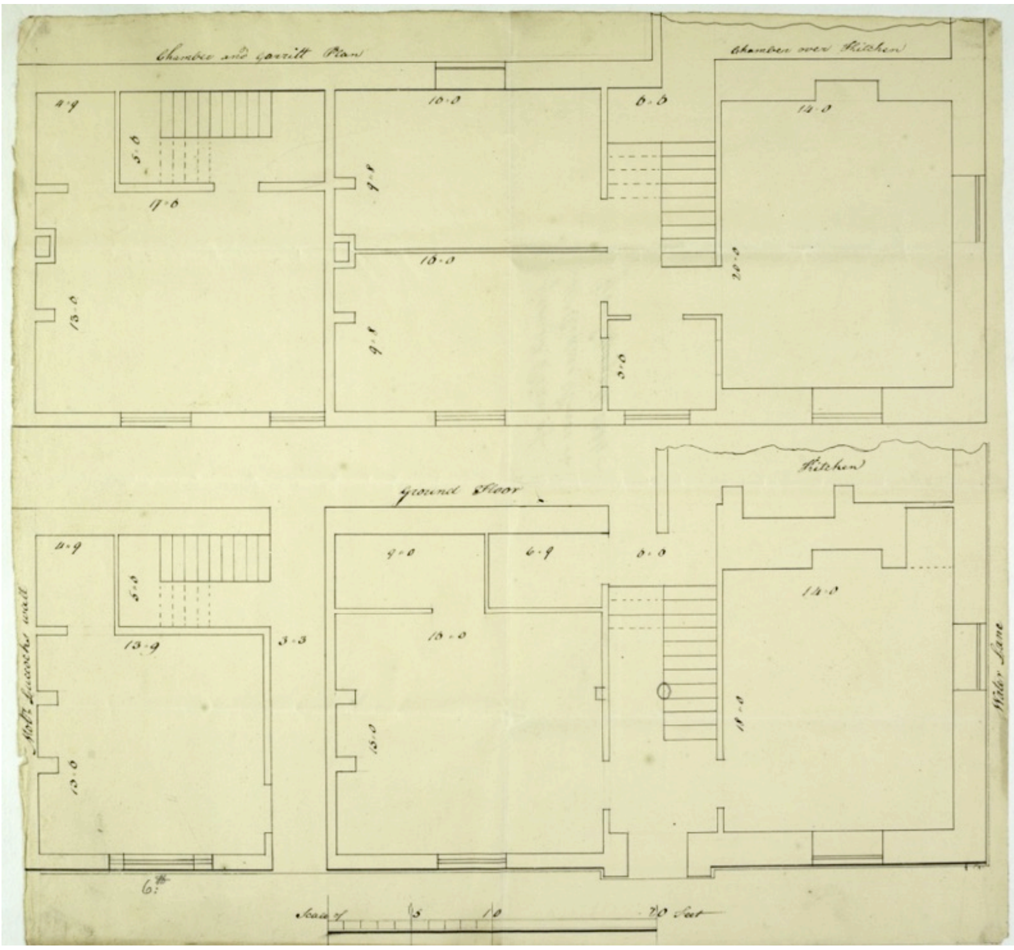


“16th May 1803

Agreed upon this plan, the length of the whole front to the street being forty feet outside measure and garretted the same as the chambers. The rent to be paid in addition to be two guineas per annum from Lady Day last – the fireplaces in the rooms next the water lane to continue as they are at present –
Joseph Rider, William Hastings.”

There is also an alternative plan, dated 1804


Front Elevation


Chamber and Garrett Plan
Chamber over Kitchen
Kitchen
Ground Floor
Scale of
20 Feet

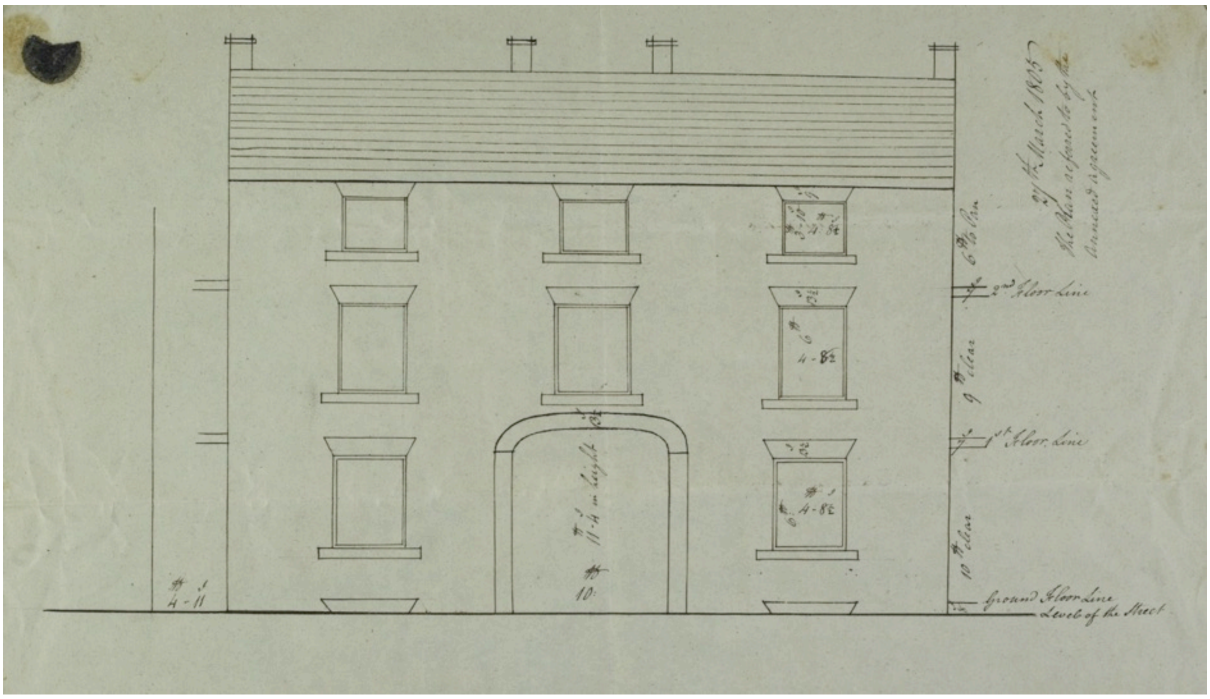
Several contracts survive in which tenants undertake to build or rebuild houses or other structures they will then lease, or continue to lease. Cleathing and Bell undertake to rebuild the White Hart public house, with a drawing attached of the same, confounding previous assumptions that this stone building and its cellars were significantly older, and building the brick addition to the corner of Yorkersgate and Market Street (then Swine Market).

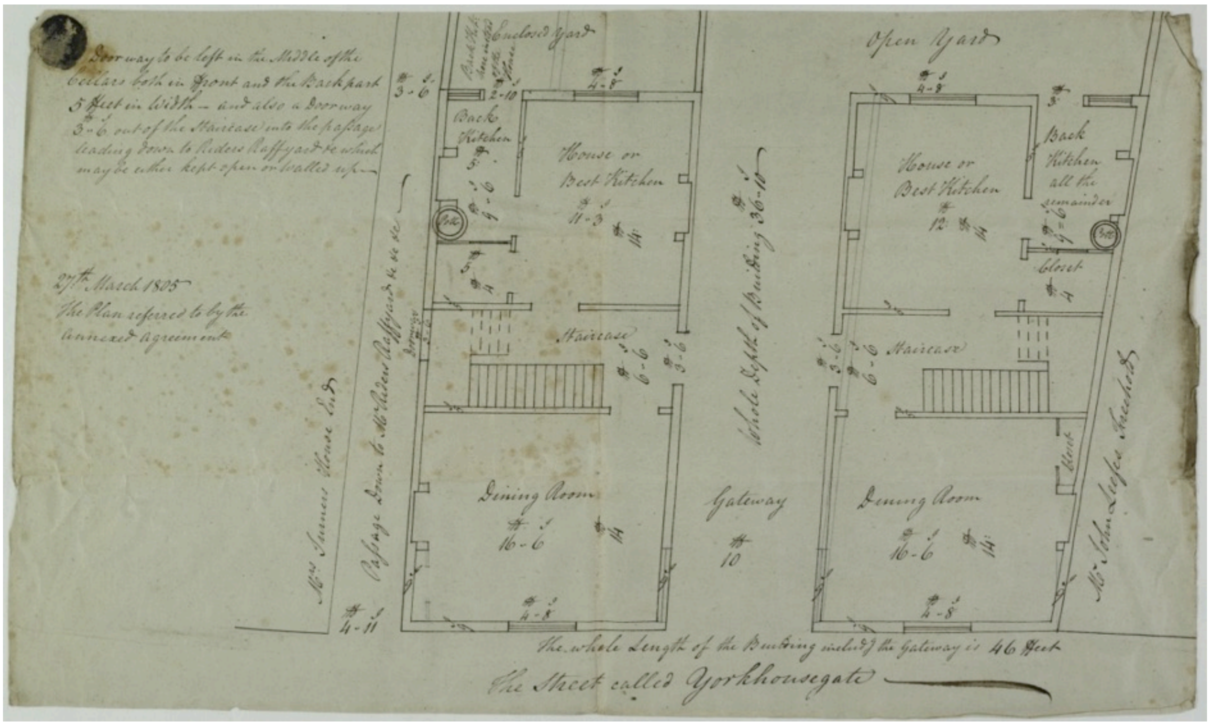
Sunman, a stonemason, commits to build a house in the 'new street' – this is what became Savile (now Saville) Street. In the 1843 Terrier, Richard Sunman is tenant of a house in Savile Street, three doors down from the Methodist Chapel, 2 up from the corner with Yorkersgate. This house seems to have been since demolished, its site now occupied by a circa 1970 brick shop. In 1843, it was listed as a 'temperance hotel, kitchen and stable, with joiners shop over.' A valuation of the same property, by now 'Mrs Sunman's House' (her husband having died) survives – see Malton Valuations, elsewhere.

1805

"We agree to erect and build on the site of the two houses in Yorkersgate, New Malton, now rented by us of Earl Fitzwilliam, one or more good, substantial brick and stone dwelling house or houses according to the plans annexed and <u>tile and sheet</u> the same – the whole to be cellar'd except the gateway and so much of that next Mr John Leefe's as would endanger his house to dig near the foundation thereof. The whole to be garrotted that we will in erecting the same house or houses make use of good sound foreign fir timber of proper and sufficient scantling" appropriate to its purpose and the norm in Malton. Estate to invest £250 towards the cost of this endeavour.

Signed Cleathing and Bell.



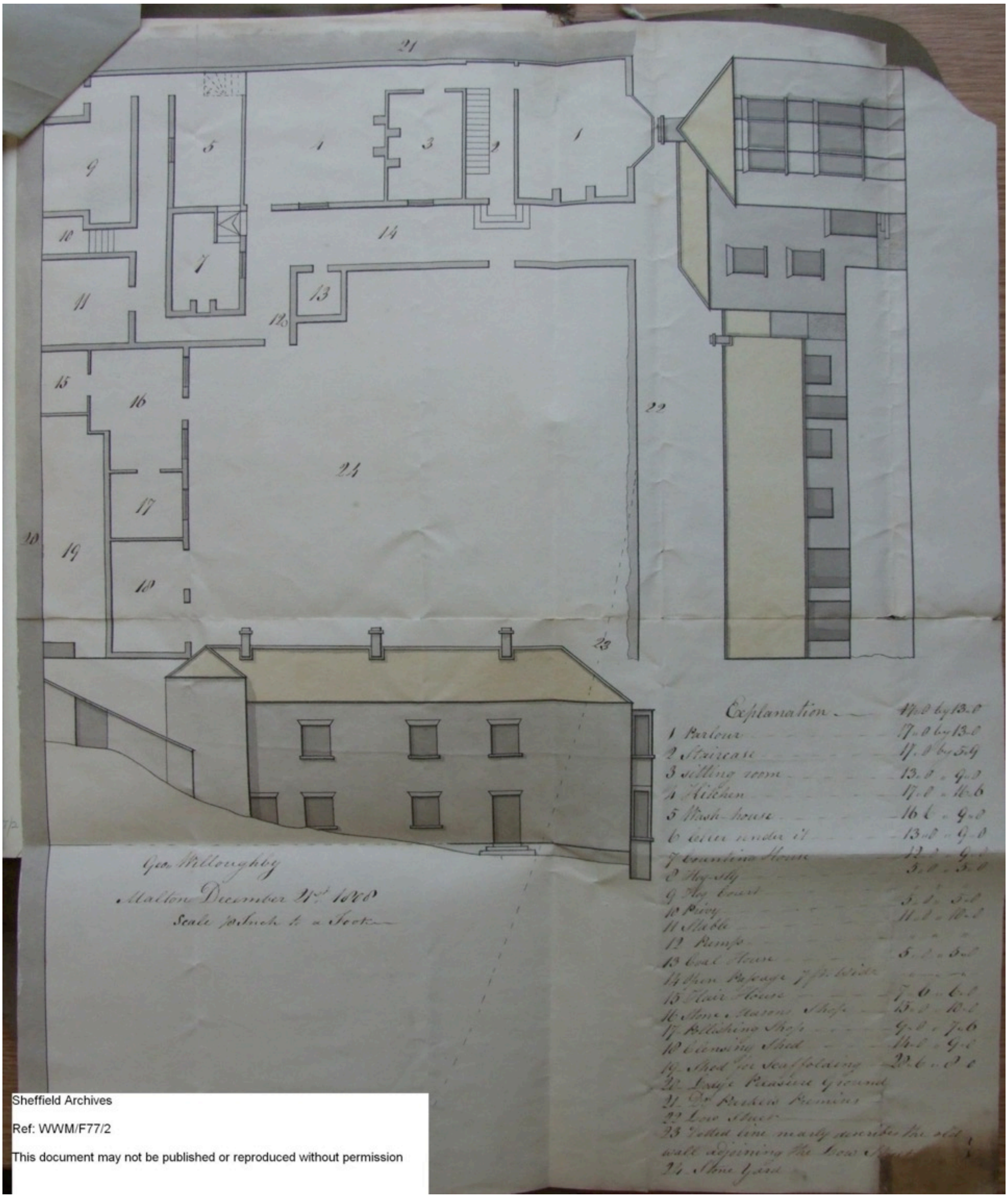


Cleathing and Bell were listed as coal merchants, corn merchants and wharfingers in Baines Directory 1823, and would have been based at Navigation Wharf to the immediate S of this property.

Castle Dykes, Low Street, 1806

Built as house and stoneyard by and for George Willoughby.

A note within NYCRO ZPB III 9/8 (a summary of oversight by Atkinson and Phillips, Architects) records that this Peter Atkinson signs off 'Willoughby's Stoneyard. It is also then recorded that the Estate buys the same from Willoughby on 12th June 1816, for £325 – 2 – 5.

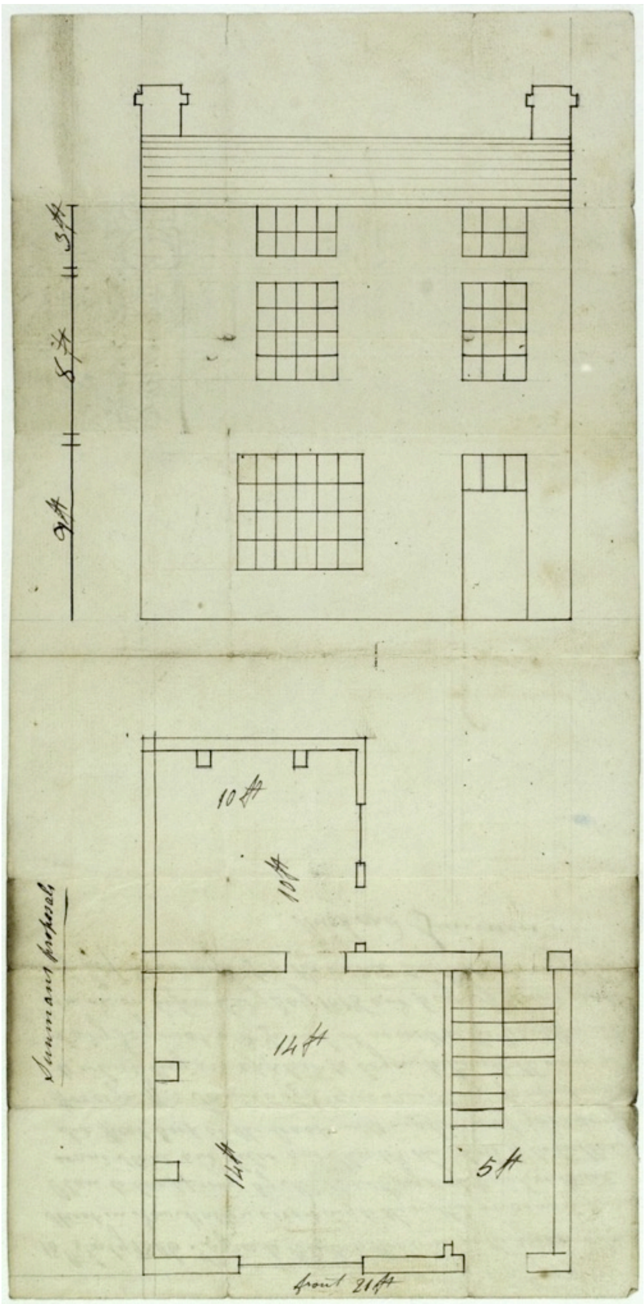


18th July 1806 – Sunman's proposed house in 'the new street'

"I agree to build a house etc in the proposed new street in New Malton according to the within or some similar plan to be approved by Mr Hastings, of brick or brick and stone and <u>tiled and sheeted</u> the whole to be cellar'd 6 feet deep at the least...(using) good foreign fir scantling, finish 1808"

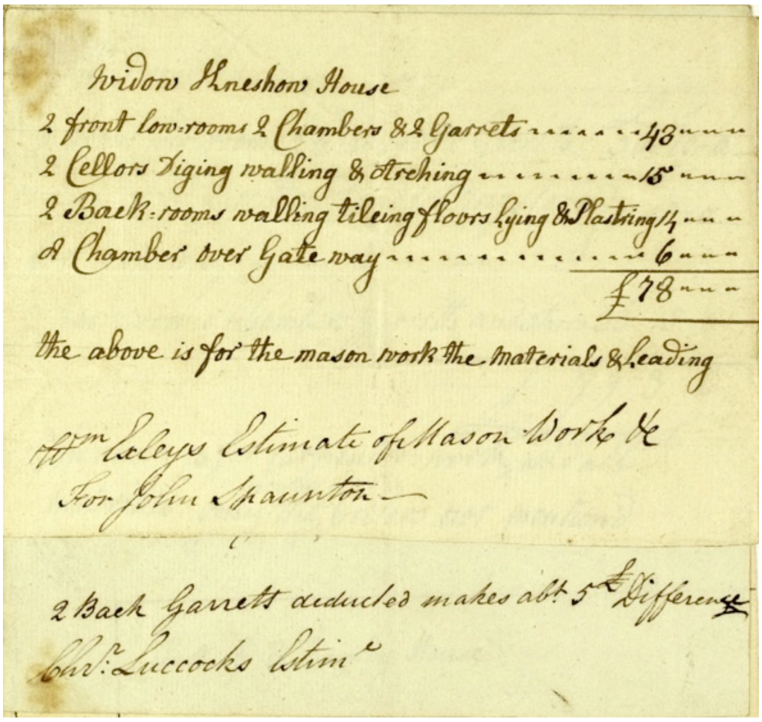
This house has been demolished, but a valuation of fixtures 'in Mrs Suman's House, Saville Street, Malton' dated November 21st 1860 survives (NYCRO ZPB III 8/7/2).

“Back kitchen – sheet iron oven, range, iron, boiler
Front kitchen – range crane and reckons
Front room – range
Back bedroom – range
High dining room – range
Garret – range
2 closets in front room 8’ by 4’ with two glass doors and shelves.
Gas fittings,
Total: £4 – 10 – 6.



This latter is of particular interest in showing that the creation of Savile Street was proposed as early as 1806, and expected to be well underway by 1808 – before the election debacle of 1808 which gave such impetus to construction work in Malton (see Malton Elections, MBG).

Widow Neesham's House



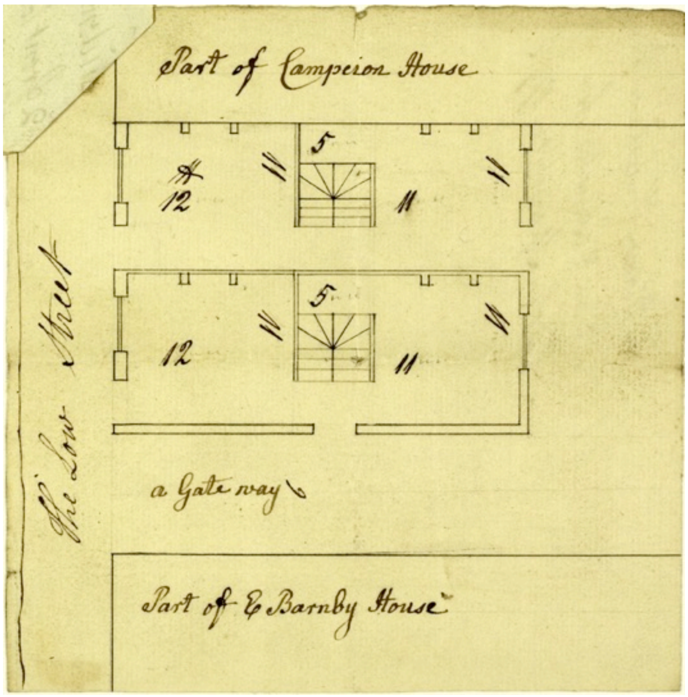
Widow Kneshaw House
2 front low=rooms 2 Chambers & 2 Garrets ....43 - - -
2 Cellors Diging walling & Streching ....15 - - -
2 Back=rooms walling tileing floors lying & Plastring 14 - - -
A Chamber over Gate way ....6 - - -
£78 - - -

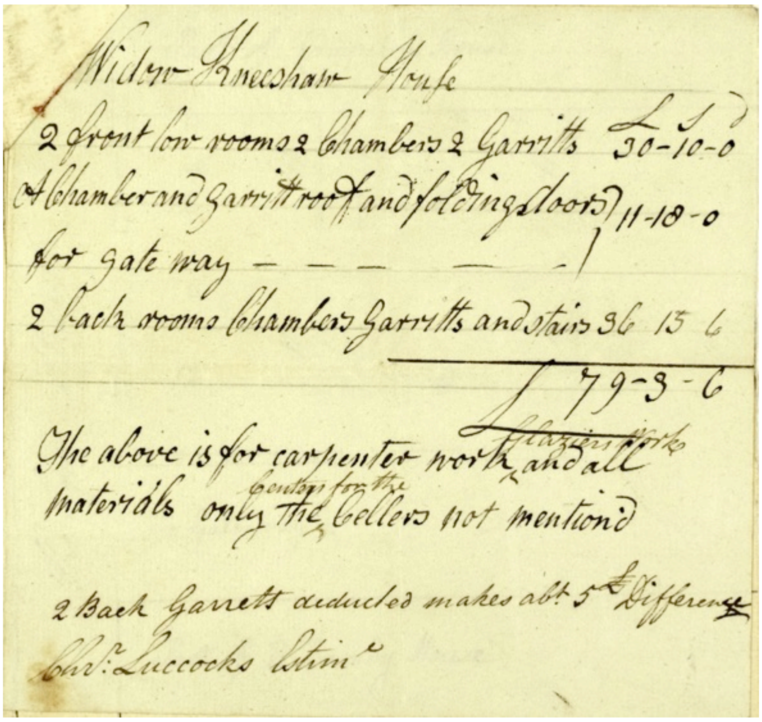
the above is for the mason work the materials & leading

Wm Exleys Estimate of Mason Work &c
For John Spaunton —

2 Back Garretts deducted makes abt 5£ Difference
Chrs Luccocks Estime

William Exley's estimate





Widow Kneeshaw House

2 front low rooms 2 Chambers 2 Garritts £ s d 30-10-0

A Chamber and Garritt roof and folding doors 11-18-0

for gate way — — — — 1

2 back rooms Chambers Garritts and stairs 36 15 6

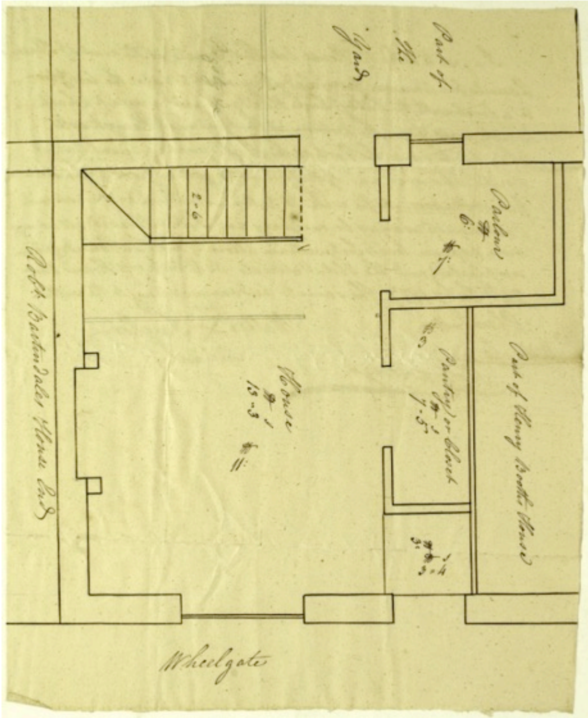
£ 79-3-6

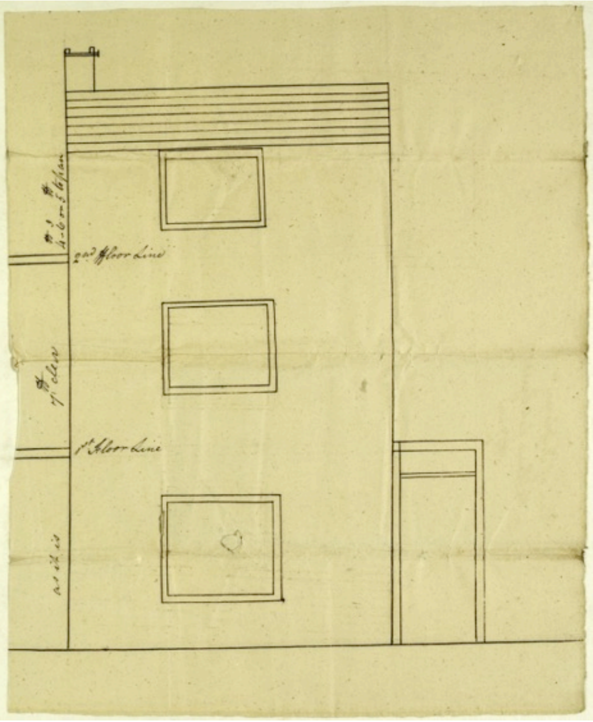
The above is for carpenter work and all glaziers work materials only Centers for the Cellers not mention'd

2 Back Garretts deducted makes abt. 5£ Difference

Chr. Luccocks Estim.

1807 Former house of Thomas Egart, taken on by Walter Taylor, Wheelgate

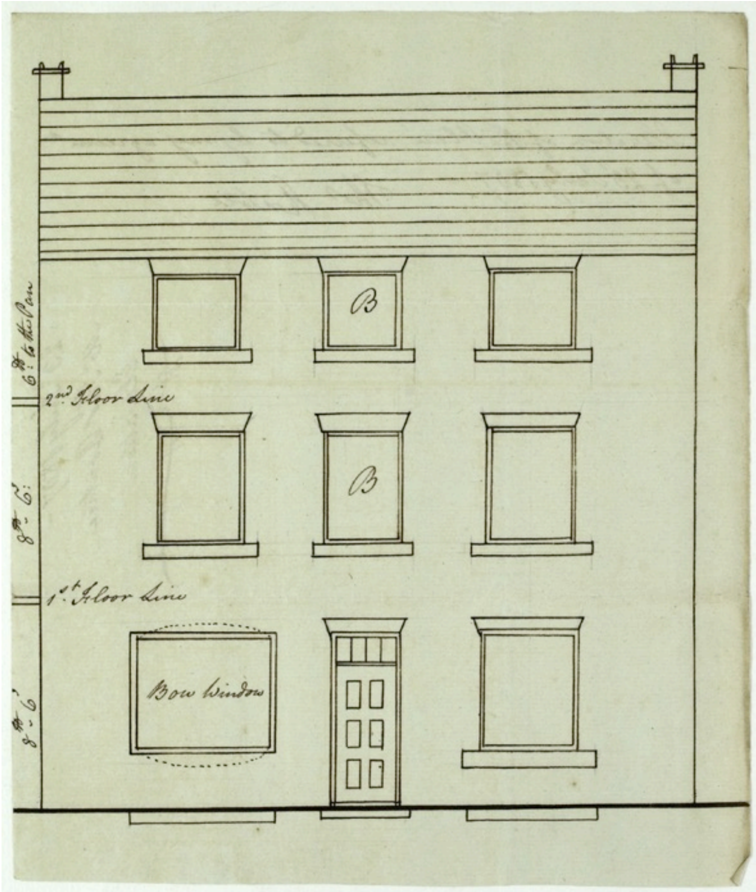




I agree to take the house late Mr Thomas Egart's at the rent of three pounds per annum from Lady Day next (and) to raise the low floor to a level with the entry, turn the stairs and carry up a half brick wall from the bottom at that end and next Henry Booth's chamber, to raise the roof so high as to make a decent garrett over the chamber and of sufficient height in front to get the garret window into the wall, to put on a new roof or at least such part thereof which may be necessary and tyle and sheet it all at my own expense, Earl Fitzwilliam allowing me ten pounds (when compleated) and the old materials. As witness my hand this 24th February 1807, the same to be done according to the written plan.

Signed Walter Taylor (his mark) and Wm Hastings.

Elevation of 'Rontree's House. 1807. No schedule or specification of works.

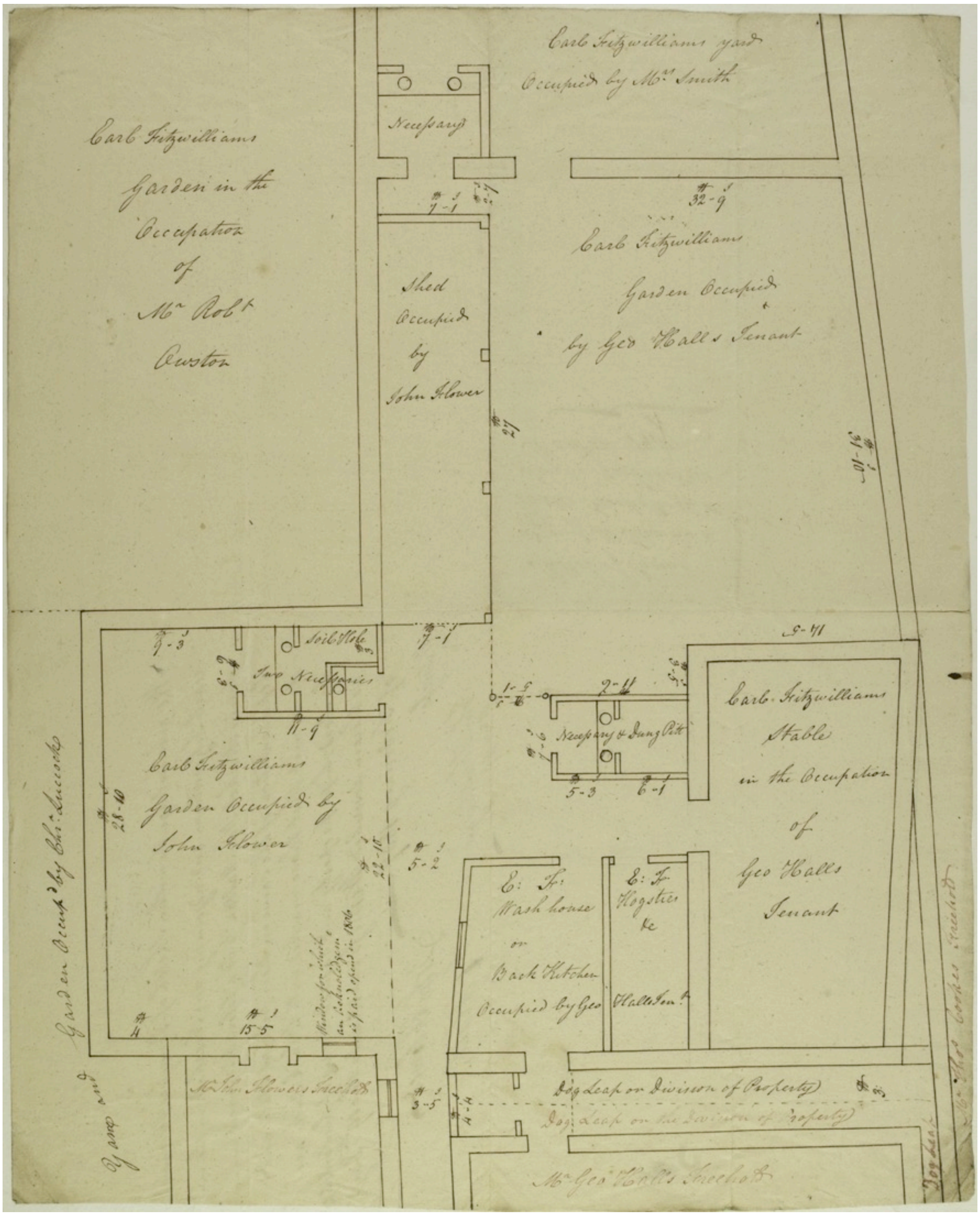


Properties in the Swine Market (now Market Street).

"Sketch of prems adjoining Mr Flower and Halls Freeholds in the Swine Market New Malton 1807.

We acknowledge the within sketch of premises belonging Earl Fitzwilliam and adjoining our freeholds in the Swine Market,, New Malton to be a tolerable correct representation of the same in their present state and do admit that those marked with black ink are his Lordship's property and rented by us of his Lordship as therein described. Witness our hands this 19th day of February 1807

John Hastings John Flower
G Hall."

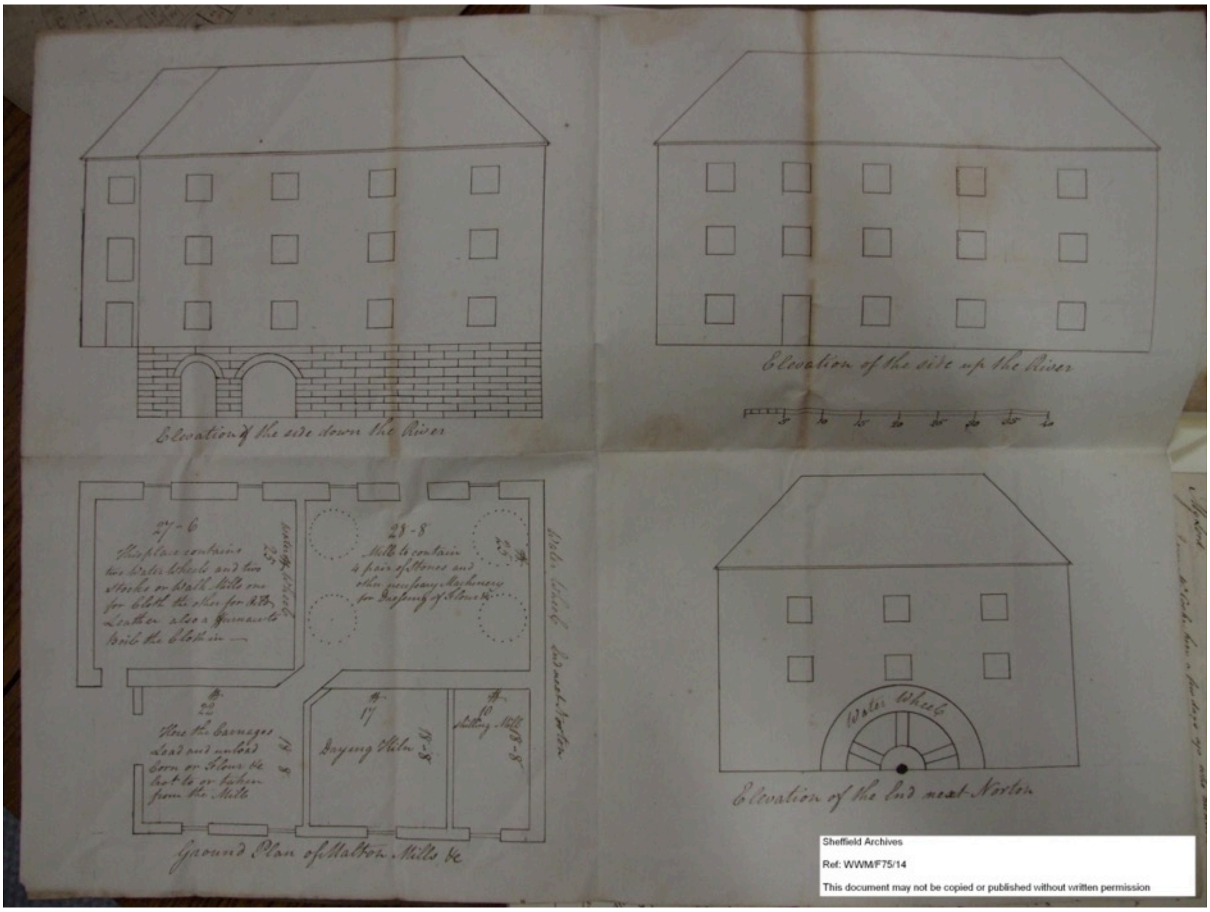


A house sale in this immediate area, and perhaps relating to one of these properties is recorded in NRRD Vol BS MIC 289 (NYCRO), in a memorial of indenture dated **1781**:

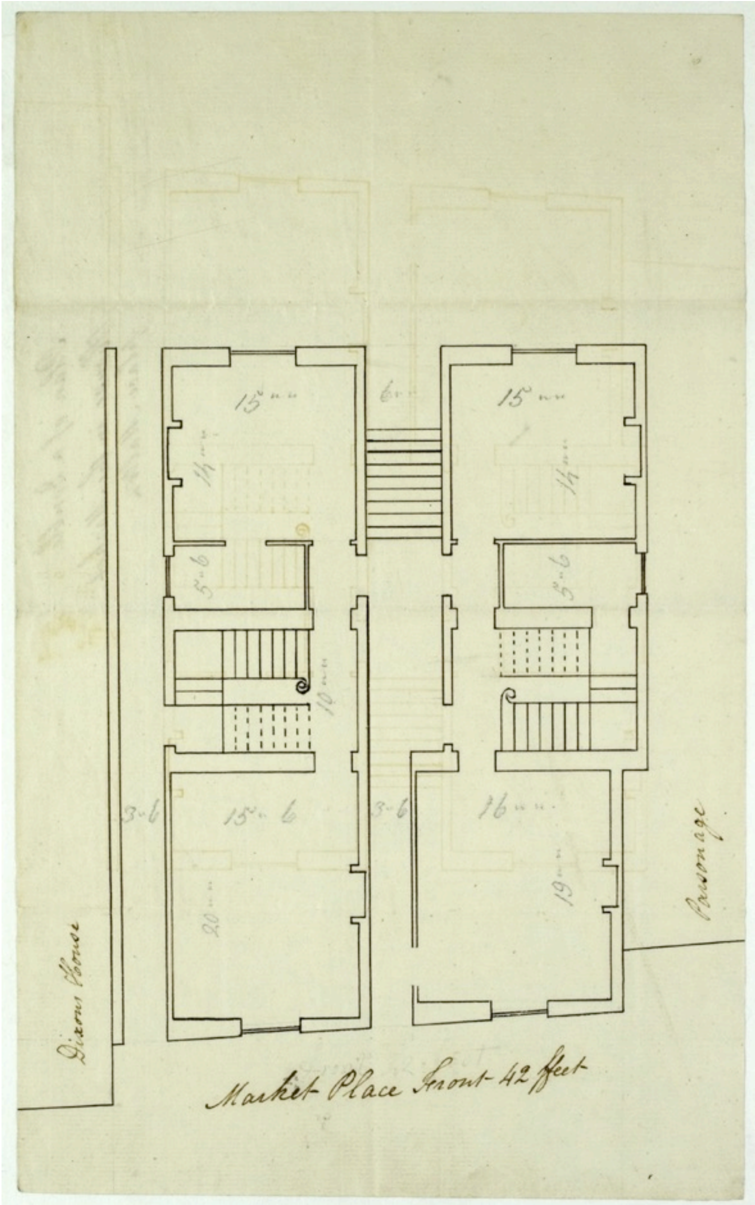
Indenture between John Gray of New Malton, and orange merchant, and Christopher Brigham, concerning a 'new erected' dwelling house " with the stable yard, outhouses and appurtenances lately rebuilt upon the site of all that south end or part of all that burgage house in a street called Swine Market and fronting the same." The front measured 15' 8". This was next to the house of Robert Cook in the possession of (blank) Allen on the south and of William Shepherd on the north. Also a back kitchen and workshop to the said front house. Matthew Spencer was tenant of the yard buildings.

There was a 'pig garth' and a moiety or half part of a passage from Swine Market into the yard and a one third part or share of common rights in and upon Old Malton Moor.

Malton Mills



Plan, Market Place, no date, no spec



1817 Works to Howe Farm, Peter Atkinson's General Statement of Workmen's Accounts:

George Willoughby's accounts: £178 – 16 – 5
Richard Sunman £28 – 3 – 2 ¾
George Nicholson £28 – 8 – 4 ½
George Hudson £10 – 4 – 9
George Jackson £67 – 6 – 1 ½

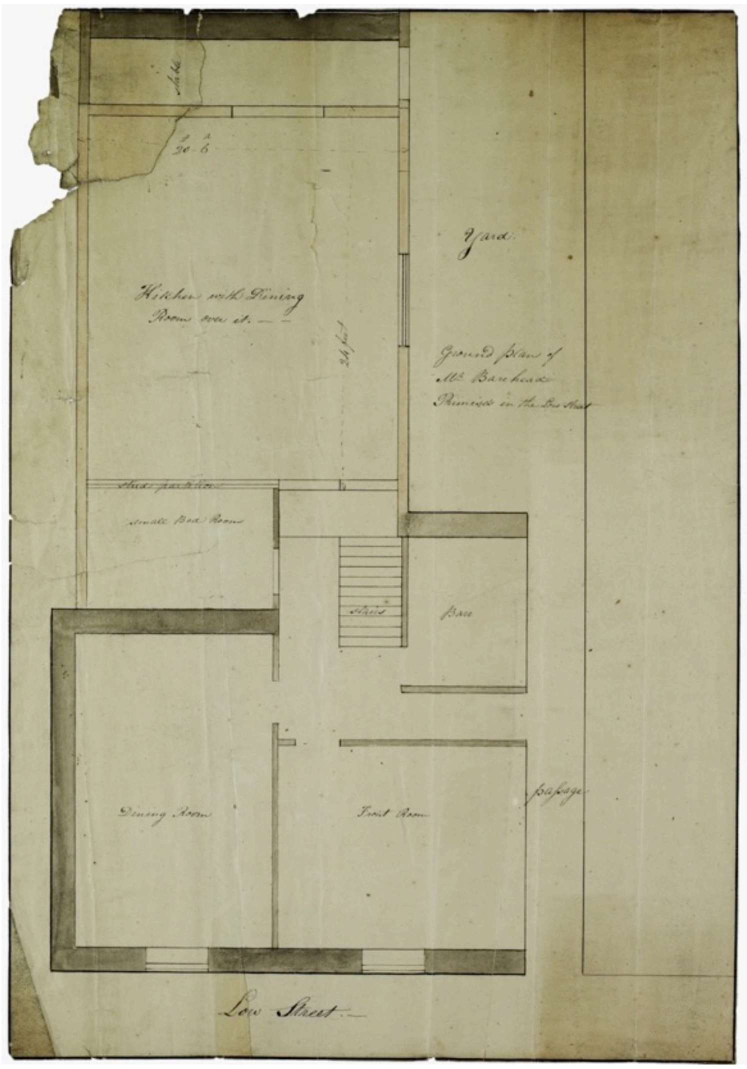
Also works to the Lodge, Stables at the (Talbot) Hotel, a house in Low Street and three tenements in Wheelgate, 'measured, valued and examined by Atkinson and Phillips, Architects, York, April 22 1818.

Sept 15 1819

"I do offer to build the kitchen and chamber above that is about to be built for Mr Thomas Barehead and find materials to the following dimensions – 20 feet in length, 20 feet wide and 20 feet high; the walls to be one brick in length viz bricks, lime, tiles to make up the deficiency which will be half the number wanted, hair, sheet and tile laths, sheet and tile lath nails, ridging, window sills, lime and hair for ceiling in the chamber and walls, which will be three-coat work, lay the kitchen floor with good common flags, 2 stone fireplaces for chamber, clear away old building well, rubbish put into the street, and finish the work in a workmanlike manner for the sum of £87 5s   4d. (£61,900 using average earnings index).

Signed Wm Monkman.

Drawing of same:



1841. Repairs to the Hunter's Hall. Old Malton – specified and drawn by John Gibson, architect. ZPB (M) 7/47.

This project might be characterised as the first 'conservation and repair' project for which we have documentary record in Malton – there is an emphasis upon

essential repair, not upon wholesale take down and rebuild, albeit recycling sound existing materials, evidenced hitherto. This may reflect the undoubted high status of Hunter's Hall; it may reflect Gibson's sensibilities. He was later the architect in charge of the extension and repair of the Lodge, the refacing of the garden elevation of which is notable for the faithfulness of its reproduction of the detail of this, as evidenced by its true reflection of the unrestored front elevation.

" Specification of the Manner of Executing the Different Works Proposed to be done in the Repairing of the Hunter's Hall at Old Malton.

General Conditions
The contractor to execute the different works in a good substantial workman like manner according to the plans, elevations, and specification herein named; also to find and furnish all things necessary for the completion of the work, except house stones and ? which will be found by,

Mason Work
The contractor to repair the window sills and architraves on the front of the house in a proper manner according to the same order as at present and shall take down and rebuild the crack front of the back wall, repair the chimney and take of the old tiles of house and kitchen and retile and sheet them, on the backside, shall point up all cracks etc in the back wall with good mortar, cover the ridges with good ridge stones and the front side of each end of house with 12" water-tabling and corbels in a proper manner, shall lay the floors of kitchen and entrance hall with good tooled flags, well squared and jointed in good dry sand, the back kitchen floor to be laid with the old flags got from the present kitchen floor, and the dairy with good common bricks, good flag thresholds to all the doors, sett all ranges with fire bricks in the proper manner.

Joiner Work
The contractor to repair and straighten the present roof of the house and to new spar the roof of the back kitchen, fix new ceiling joist to attics (?) and back kitchen chamber, 3 ½" x 1 ½", nailed to the spars, lay the floors of the three attics with 1" deal well-grooved and tunged togarther, ¾" ledge doors and 1 ¼" door casings to attics with common thumb latches to doors, 1 ¼" batten floor to best lodging room, 1" plain ? and window bottom to chamber windows, 1" stair steps and risers to back staircases with 11" x 1 ½" string boards to ditto. The tow (2) chamber floors and the back kitchen floors to be repaired etc; 7" x ¾" moulded plinth to the three lodging rooms, with common grounds, 5" single faced architraves round doors and angle beads round the windows and all projections, 2" framed 4 panel doors to the tow (2) best lodging rooms, 1" ledge door to the closet etc, shall lay 1 ¼" batten floor to the dining room, 1 ¼" frame, 1 ¼" frame linings and soffeats to door and window of entrance hall; 1" plain window boards and angle beads to window of kitchen, 12" basmoulding and plinth to dining room and entrance hall with common grounds, 5" single faced architraves and beaded grounds to the windows of dining room, 5" architraves to door and window of entrance hall, single mouldings to kitchen, 2" framed doors to the Low rooms and 1 ½" framed doors to kitchen and cellar under best staircase, 2" framed doors to outside, bead and flus. Low panels with 5 ½" x 3" doorframes, 1" ledge doors to the dairy and back kitchen, 60 feet of ? shelving to dairy, etc, Repair the steps and balusters of best staircase, repair the cornice on the outside in the proper manner. 1 ¾" hung sashes and frames to the front of house as per drawing shown on elevation. 1 ¾" sliding sash and frames to back kitchen and chamber over, hung sheet sash to attics and dairy,
The contractor to do all and everything; shall finish the plans in a good substantel and workman like manner to the true intent and meaning of the same, and to the satisfaction of the person who may be appointed to inspect the same.

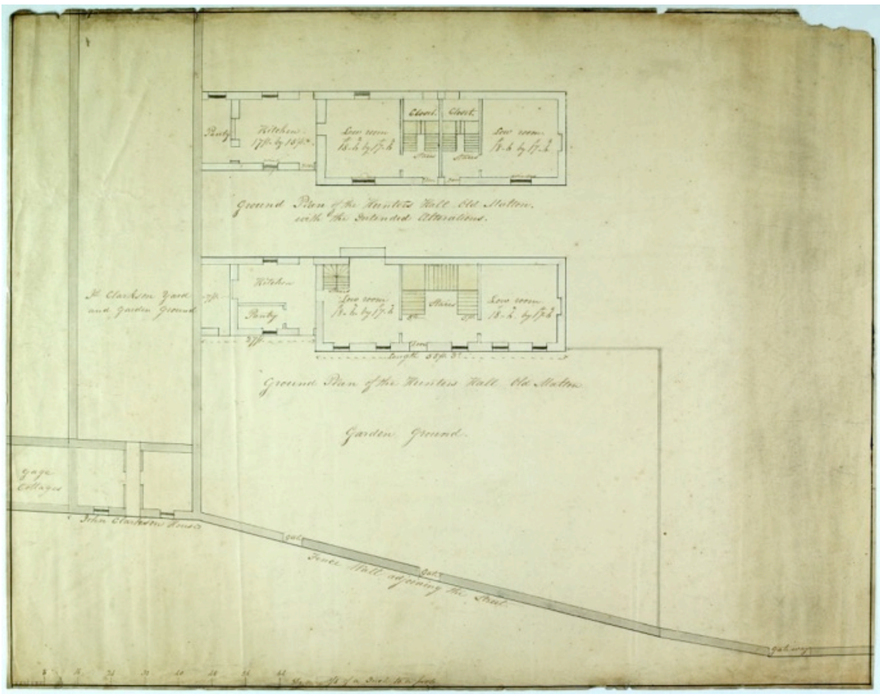
Slaters
The slater shall slate the front of the house and back kitchen with good Duchess Welch slate laid on good common fir laths nailed with tow (2) copper nails to each slate and pointed with good lime and hair.

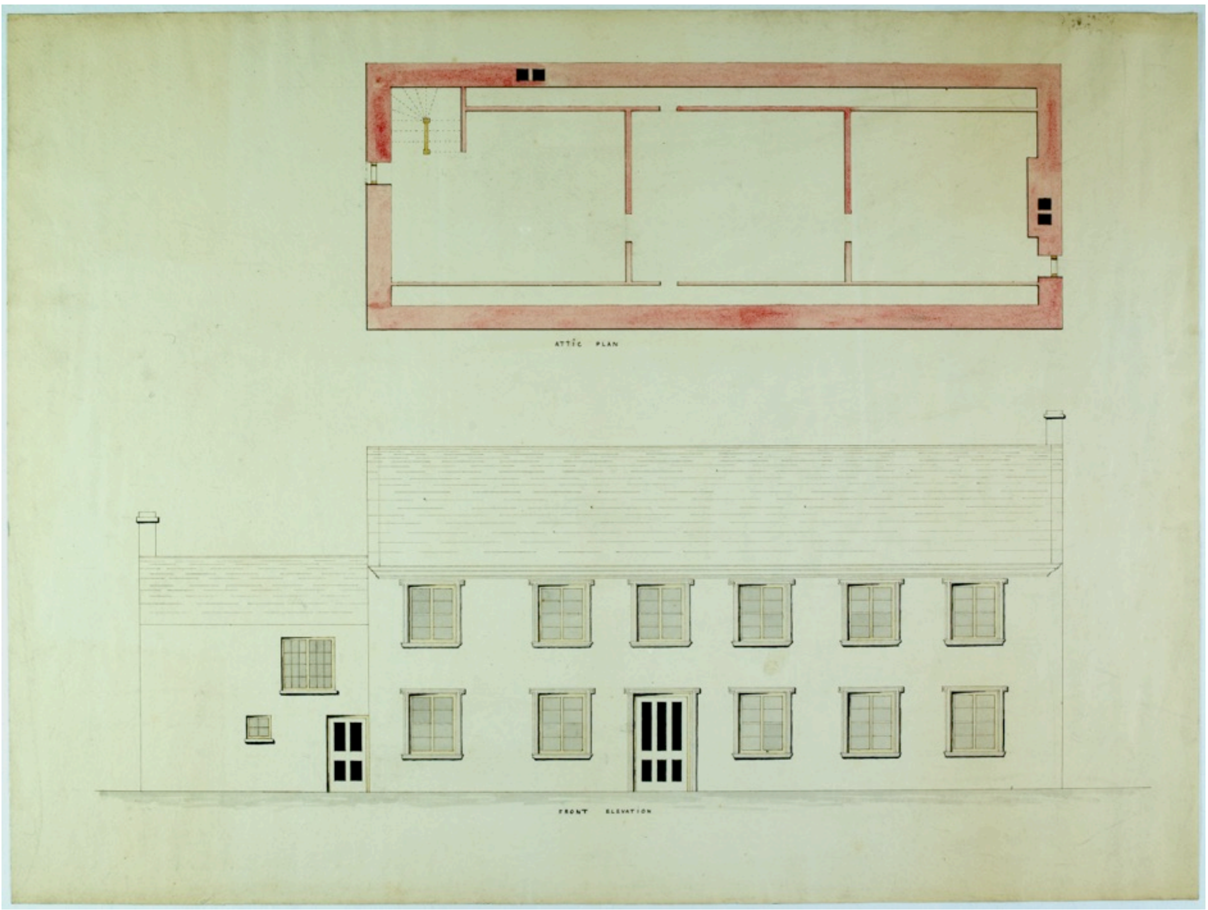
Plumbers and Glaziers Work
Shall flash the chimney shafts with 5 lbs lead to the foot superficial in a proper manner; will lay the back chimney gutter with 6 lbs lead to the foot superf, find all solder, hooks, nails etc necessary for the same; the glass in the front room windows to be good second Newcastle crown glass; all other to be good thirds...

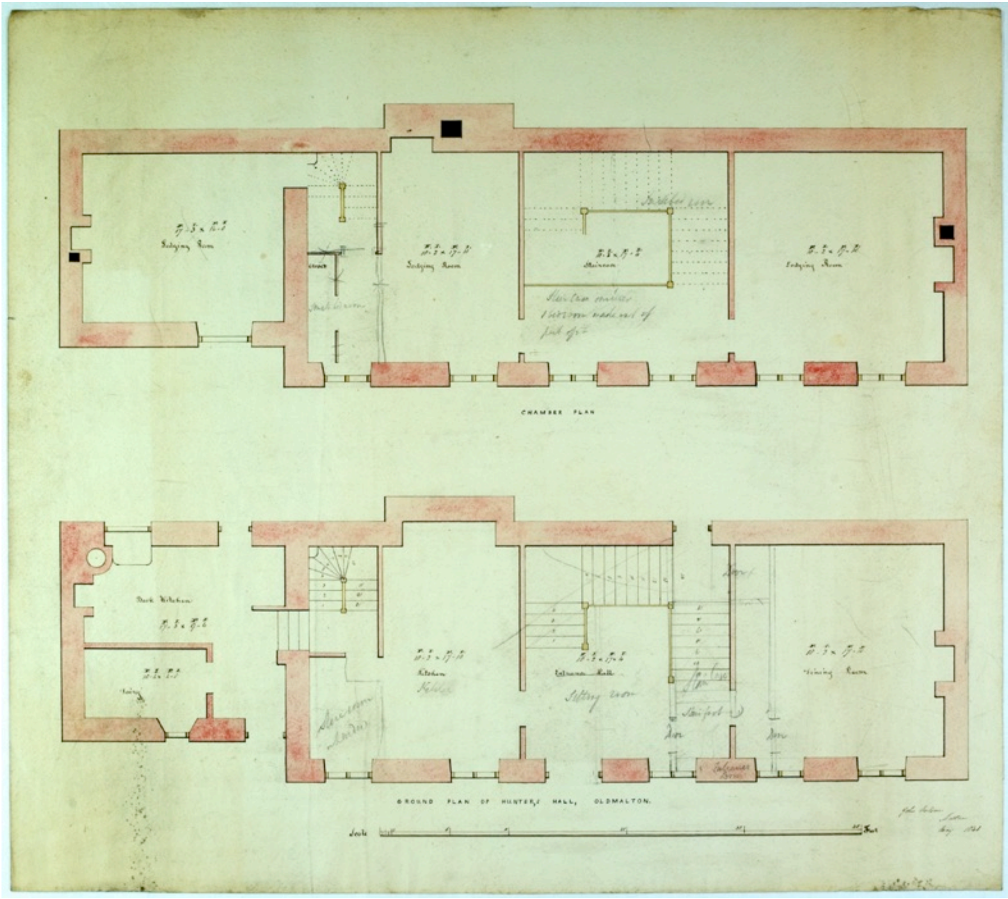
Painter
Will paint all the inside and outside woodwork and customary iron work, three times over in oil and white lead;

Plasterers
Will plaster the ceilings of low rooms and chamber with good three coat plaster, on good stout laths; three coat plaster on walls of low rooms and chamber, tow (2) coat ceilings to attics and back kitchen with good tow coat plaster on walls; will lath all lintels...

Locks, Joints and Fastners
Good mortice locks to front door, dining room, entrance halland low lodging room doors. 6/- each good iron rimlocks to the three outer doors with brass knobs averaging 4/- each. Thumb latches to all other doors, shutter latches and fastners to the dining room, good sash fastners to all windows... 4" butt joints and screws to all the outer and best room doors, good T-joints to all other doors."




ATTIC PLAN
FRONT ELEVATION


Lodging Room
Staircase
Lodging Room
CHAMBER PLAN
Back Kitchen
Kitchen
Entrance Hall
Sitting room
Dining Room
Door
Door
GROUND PLAN OF HUNTERS HALL, OLDMALTON.
Scale
Feet

1846 May 1st.

Estimate of the expence to build a room adjoining Joseph Longfield House, Low Street, viz length 20' by 12' within.

Brick walls 9" thick will take 4800 bricks

Tiles for the roof will take 550

18 sparrs for the roof, 3" by 2 ½", 12' long

2 ribs and pans 6" by 4"

15 bunches sheet lath for the roof and ceiling

8 bunches of tile laths

9 ceiling joists each 20' long

Boards for the floor – deals

14 joists 6" by 3", 14' long

Staircase steps and brackets

Low door and frame

2 beams 14" deep by 9" wide

2 windows 5' by 4'

2 doors, framed for the chamber

Smithwork and ironmongery

Lime for mortar – 2 chaldrons

Leading to the building

? deals for the roof

6 yards of stone ridging

18' by 14' ¾" deals. Staircase ceiling

Materials	£37	6s	3d	
Carpenter work	£3	4s	-	
Mason work	£3	2s	-	TOTAL £43 12s 3d

There is no signature.

It is notable, in this estimate, as well as others above, that the cost of materials dramatically exceeds the cost of the labour. Is this because labour was cheap, or because materials were especially expensive? In the modern building industry, it is a fair rule of thumb that the cost of labour and materials will be about the same, or that labour costs will exceed the cost of materials. As noted elsewhere, there is very little evidence that the income of craftsmen in Malton in the 18th or 19thC was low compared to the cost of living – the opposite, in fact.

Amongst a bundle of valuations (ZPB III 8/7/2 Valuations of Fixtures, 1853-1862, NYCRO), there are some building accounts – for Old Malton Windmill, for example.

"Scampston Works June 2nd 1860

I John Hodgson of Scampston, near Malton, Millwright, etc do agree to make and fix at Old Malton Wind-mill two new sails complet, also repair the other two sails with all wanted...also replace the top flags, beams, boarding and everything wanted for making a good job of the same. Also painting the top and sails twice over, one new gray Derby Shire stone and fixing in the place – the above includes all leading and railway dues for materials and workmen – for the sum of £80 2s. (£48,000 2010).

John Hodgson, Millwright."

This is preceded by a valuation of the windmill and dwell house, Old Malton Moor, dated 16th Oct 1859:

Windmill

2 pair of French and 1 pair of grey stones
1 barley mill
1 screen and blast
1 dressing machine
? gear
Chisels, picks, box and maul

Dwell House

Kitchen 18' x 12'
Dairy 15' x 12'
Back kitchen with copper and oven
Parlour 13' 6" x 13' 6"
House 13' 6" x 13' 6"
Front bedroom 13' 6" x 13' 6" with closet
Back bedroom 18' x 12'
Back bedroom 13' 6" x 13' 6"

Four-stall stable
Loose box
Small cow-house and small barn
Granary over stable and loose box.

1860, William Copperthwaite's specification for an extension to the Blue Ball Inn:

"Specification of the several works to be done in the Addition to the Blue Ball Inn Situate in a Street called Newbiggin, New Malton in the North Riding of the County of York and for the Right Honourable Earl Fitzwilliam.

Conditions

The contractor or contractors are required to provide all Materials, Cartage, Scaffolding and Tackle necessary to carry out the several works according to the plans and this specification. All the several works are to be performed in the most substantial manner and with the Best materials of their several kinds...

Should any or every part of the necessary works have been omitted to be described, the same shall nevertheless be executed in a sound and proper manner corresponding with the other part of the works and be considered as included in the consideration of the contract. W.C. Copperthwaite Esq, Agent for the Right Honourable Earl Fitzwilliam shall have power to order any alterations in any of the several works during their progress, the cost of such alterations to be added to or deducted from the Sum of the Contract without (nullifying) the contract. All the works of the several departments are to be left clean and perfect at the completion of the whole and to the satisfaction of the Architect [John Gibson] and WC Copperthwaite Esq.

The works to be commenced the day of 1860 and completed the day of

Masons Work

The whole of the stone used in the street elevations and chimney tops to be from the quarry at Appleton le St. All the string courses and window cills and dressing to doorway to be cleansed, the plinths cleansed. The strings and cills to be properly dripped and throated and set on the natural bed, the window cills to be 10 inch on the bed, the entrance door to have a good hard threshold 10 x 7, the entrance to be laid with 3" tooled west riding flags on brick sleeper walls.

To lay cleansed Hearths to sitting rooms and bedrooms, to fix cleansed jambs, mantles and shelves to fireplaces of the same quality as those in the new houses now being built adjoining Percy Cave.

To provide tooled ridgestone to all the ridges, these to be laid on by the slater.

Plasterers Work

The whole of the work to be plastered with good hair mortar composed of clean sand and <u>Grimston Lime Co lime.</u> All the laths to be good <u>Baltic red fir laths.</u> All the wall and stoothings to be finished 3 coats trowelled smooth for colour or paper. All the ceilings to be finished 3 coats with <u>fine lime putty,</u> the sitting room adjoining Newbiggin to have a neat plaster moulding 16" girth.

Excavators Work

To excavate for the foundations of the several walls and to clear the rooms in order that the floors may lay 12 inches above the ground line. To remove all rubbish that may accumulate during the progress of the building on to the ground on the east side of the house. To properly ram all the foundations and dig drains from fall pipes and fill and ram the same.

Bricklayer

The whole of the walls to be built with good hard well burnt bricks laid in <u>good mortar composed of North Grimston Lime Co lime and clean sand in the</u>

proportion of 3 of sand to 1 of lime. [This 1 of lime will be quicklime]. All the several walls to be correct to the height and the thickness shown on plan and in elevation.

To carry up all Chimney flues and properly plaster the same.

All the door & window opening to be discharged with 9" rough internal and 14" external openings, the whole of the external wall to be neatly pointed and black-lined.

To set all ranges with the necessary firebrick throughout.

To lay 4" lavatory tubes from fall pipes to channel side of curb stone.

To build all sleeper walls in sitting rooms and for flags in entrance.

The bricks for principal elevations to be selected as even in colour as practicable

Slaters Work

The roof to be slated with Welsh slate called Ladies. The laths to be Red Baltic fir laths 7/8 x 1 ½ the laths to be nailed on with iron nails, the slates with 2 copper nails each, the whole to be pointed with lime and hair to lay on and the ridge with lime and hair and leave all perfect at the finish of the works, the slater to insert the under flashings.

Plumber and Glazier

To lay gutter chimney and valley. To flash chimneys and adjoining Blue Ball Inn. All gutters to be laid with lead 5 ft to a foot all under and over flashings to be with lead 4 ft to a foot. To glaze all the windows with seconds glass well bedded in oil putty and to leave all perfect and clean at the completion of the work.

Painter Work

To properly clean, knot, stop and give the whole of the wood and fireplaces 3 coats of good paint white lead ground in linseed oil internal work and 4 coats outside. The cornice to be finished stone colour, the spouts to have 3 coats & be finished stone colour, the sashes and frames to be finished white. All internal plain colour.

Carpenter and Joiner

The whole of the timber or deals to be good red wood Baltic Produce free from sap, large and deal knots. American Pine may be used for internal doors, mouldings and architrives. To properly frame fit and fix all carpenter & joiner work.

To properly frame for chimney flues and staircase and lay joists 16" centres and cambers. To provide all necessary wood, pricks (?) and ??, the ?? to be 3" thick 7 have 9" hold, each end on walls and of the width of the thickness of the walls. To provide all necessary centres and cambers to properly box hearths. To fix stopps to all external angles. To fix 1 ½" rebated door cases rebated for 1 ½" doors to all internal doors. To fix 4 ½ x 3 rebated and beaded door frames to front and back door rebated for 1 ¾ doors. To lay 7/8" dressed and grooved batten floors in bedrooms and 1" dressed and grooved batten floors in sitting rooms. To hang 1 ½ double moulded doors 6.8 x 2.8 to bed rooms and parlour doors, and 1 ¾ moulded doors to front and back door. To fix closets on landing with framed front and end 1 ¼ thick moulded on one side...To carry up stairs with 1 ¼ string, 1 ¼ steps, 1" riser housed and wedged into strings to have 3 x 3 square newels 1

¼ x 7/8 square baluster and oval birch handrail with all necessary furring for plasterers, the ? to the stop champferred and to have turned ornaments on top of the newel.
To provide 1 7/8 sashes double hinge in deal, cased frames, double sunk sill, 7/8 pulley, stiles 5/8 lining, iron sash pulleys of good quality, good cords & sufficient weights.
To fix roof – see section, the purlins to be supported from head of stoothings and dogged to stoothing spars 16” center to center. To fix ceiling joists 16” center to center. To fix single mouldings to all doors and windows in bedrooms 2 ½ x1 and architraves to doors and windows in entrance and sitting rooms 4 ½ wide.
All the plinths in the bedrooms to be 5 ½ x ¾ torus plinth. All plinths in entrance and sitting rooms to be 7 x ¾ torus plinths.
All the windows & front & back door to have plain ¾ linings. To fix a Man Hole into roof 2’.0” x 1.4” ¾ casing and ¾ hatch.
Front and back door to have 7” iron rim locks x 2 – 8” barrel bolts & brass furniture. All sitting and bedroom doors to have 6” iron rim lock and brass furniture, the closet to have a good closet lock. All internal doors to be hung with 3 butts x 1 ¼ screws, the outer doors to have 3-3 ½ butts each x 1 ½ screws, the sashes to have good strong fastners. The sitting rooms to have 1 ¼ framed and moulded window backs.

Smith Work

To fix 6 – 0 gutter from eave spout, see elevations and 5” half-round eaves spout to back and 3” fall pipes. To provide 2 sham (?) fronts to sitting room fireplace.
Drawings for Blue Ball extension:


16


138.9
79.9
139.9
143.9

The Lodge.

More complete records of the Lodge survive than for any single building in Malton. There are very detailed building accounts from major works of extension and improvement in the 1880s and 1890s, when the rear elevation was refaced and the current lounge as well as the front porch added. There are other accounts from repair works earlier in the 19thC and from 1784, as well as plans and inventories from the mid- 18th and earlier 19th centuries.

It is important to remember that until relatively recently, the Lodge included all of the buildings of the Estate Yard, as well as the Estate Offices and adjoined Estate Foreman's house. The 'Lodge Farm', of which plans survive extended over Orchard Fields as well as across Old Maltongate. Final division of the site occurred when the Lodge was sold in 1992 and the extensive gardens behind were gifted to Ryedale District Council with a view to their being made a public space, which finally occurred in 2009.

The documents summarised or quoted below are from ZPB III 8/10 NYCRO.
"Account of money laid out in fitting up the Lodge at Malton now tenanted by Josiah Maynard Esq.

Oct. 24th 1784.

To Joseph Gaskin for raff, etc

Michael Atkinson and to Wood and Pattison for carpenter's work

George Nicholson for painting

Ralph Mathers for Glaziers work

John Jackson ditto

To Wm Exley for masons work (£117 – 4 – 5)

Andrew Race for leading (transport)

Materials:

Wm Wright for hardware

Thos Luccock ditto

John Luccock whitesmith work

Obborn for flooring boards

Wm Garanciers for lining the pew

Wm Normans for two marble chimney pieces (£21 – 11 – 9)

Labour, making a new garden – levelling, leading, rubbish and earth etc
Mr Kemp for pale fence; Wm Oliver, new pump: £74 - 4 - 3

Total expenditure: £532 – 13 – 10 ½ [£701,000 2010]

100 years later, architect John Gibson prepared a summary account of additions, alterations and repairs, 1887:

	£	s	d
Cottages, out-offices etc	281	7	4
Coach-house boxes etc	206	15	2
Stables, cow-house, piggery, fold yard Garden drainage, etc	315	15	11
Old servants wing, New bedroom to same:	188	5	8
Old House			

Repairs and alterations, bay windows, etc	334	15	-
Alterations to SW end of new wing, Bay windows etc	67	17	11
Garden wall	148	16	9
Total:	£1543	13	9
Account of first contract, new wing	£820	-	-
Ditto 2nd, out offices	£188	6	9
TOTAL	£2552	-	6

Using the average earnings index, this amounts to a little over £1m.

The mason, who won the job on a competitive tender, was Thomas Hodgson, who had a stoneyard in Greengate. The painter was John Shepherd, of Market Place. A Hughes and Son were the carpenter and joiners; John Hudson the Blacksmith. Architects were Gibson, Son & Channon, all of whom made significant contributions to the built landscape of Malton during the 19th and, then with Channon senior and his son, Guy, well into the 20thC.

Cast iron guttering, as well as iron hay racks, curve-fronted mangers and manger fittings were supplied by J Arthur Young & Co, Manchester.

Central heating was also fitted and the plan of the pipework, etc also survives.

Throughout the masons account and day-book, there is reference to 'sheet laths' – 25 bundles for the fold yard buildings, for example.

Account, May 3rd 1879: a mason and labourer each expend 35 hours 'sheeting roof'.

Sheet lath and hair mortar appear alongside one another throughout.

The masons are doing this sheeting work, clearly.

Hodgson's account for a new wall in the garden represents the construction of the E wall of the kitchen garden, which remains – with a brick inner face and a calcareous sandstone outer face:

"Account for new walls in the garden.

Roods of 20 stone walling in fair courses, faced with brick one side:
£105
50
240 quoins to pilasters:
£3

65 yds cube excavating in foundations:
£3/5-

63 yds Moor stone coping, 24” by 5” tooled
And throated, jointed with cement
£30/1/9

10 Moorstone caps to pillars, tooled,
Weathered and throated
£7/10/9

Mason, thos Hodgson.”

This contains the first reference to ‘cement’ in any of these contracts or accounts, although in the context of exposed coping joints. It may be assumed to refer to ordinary Portland cement, newly available in its modern form, or perhaps, more likely, to natural cement as still being produced at Port Mulgrave at this time.

The painter’s account is detailed also, but a few excerpts are below:

“clearcoling and distempering ceilings’; 3 gallons cream distemper colour.

‘preps window and pilasters, chimney piece etc of Little Drawing Room...Preparing and illuminating shield and figures over mantelpiece in Little Dining Room, in gold, silver and colour’.

{The chimney piece of the ‘Little Dining Room’ was removed from the building just before the sale of the Lodge in 1992, by the Estate workforce, along with several other original or early chimney pieces, though it was claimed at the time, by ‘thieves from out of town’. The overmantle referred to above remains in the Lodge; the chimney piece is probably the one currently in the Fitzwilliam Estate Foreman’s House. Both elements have been stripped of all paint since 1992. The chimney piece as described held a panel of Delft tiles in a frieze over its opening. A photograph of both in situ in the Little Drawing Room, taken in 1992, survives. The Little Drawing Room is now a bedroom, in the single storey W extension of the main coach-house building – the panelling within and the chimney piece were of the same period and style}.

Statement of Accounts for work in the erection of a New Drawing Room etc, the Lodge, Malton for the Rt H W Fitzwilliam, Gibson, Son and Channon Architects, Malton. June 1st 1887

To Thos Hodgson, Builder

Amount as per contract for Mason, Plasterer and joiners work etc 163-17-0…
17 yards sup. Extra cost of 2 coat plaster in lieu of rendering 0-4-3
Joiner – 3 hours cutting away; 3 hrs to air grate ceilings; 6 hrs st old ceiling joists;

5 days each at old ceiling joists and beams…(much more joinery – internal fit out, fluted pilasters, caps and bases, panelling, window shutters, etc)…

Credit by deductions

Differences in cost of cement rendering 0-10-0
Fixing fireplaces (Wilsons) 2-10-0…
(Willliam Wilson, joiner, Norton)

Bills of Wm Hodgson, Builder, slate merchant and slates, Dealer in Headstones, Tombstones, fire bricks, cement, stone flags, chimney pots, sanitary tubes etc, Greengate, Malton

(Multiple costs of mason, labourer and apprentice working on Gable, including costs for regular tool sharpening)

…Pointing on south front:
Foreman 20 hrs 0-15-0
Mason 20 hrs 0-12-6
Labourer 20 hrs 0-9-2
Cement 0-7-6

(Hours for:)

lifting ceiling; making tiles good and sheeting…
40 ft tile laths and pantiles and sheet laths; tile and sheet laths, nails, lime and hair…

fixing fireplace: foreman 33 hrs; apprentice 33 hrs; carpenter 33 hrs; plaster and cement…

15 yds cement rendering

fixing chimney top…3 ½ pecks of cement.

William Wilson account June 1887. Headed paper: Builder, Joiner, Cabinet Maker, Upholsterer, Licenced Valuer. Wood Street, Norton, Malton.

To oak fireplace, marble slips and fender, including hearth and fixings 22-0-10
7 blind rollers and laths…10 blinds cutting out and making; 16 yards blind Holland; 10 tassles; 1 dozen yards maroon blind cord…

Statement of accounts for work done at New Porch, the Lodge, Malton for the Rt Hon. Earl Fitzwilliam, per G Markham Esq June 1898 CH Channon, Architect

To Mr Thomas Hodgson, Builder, Malton

To amount as per Contract 155 - 5 – 3

11 yds cube extra digging to porch walls for removal of drain 0-13-9
taking out old drain etc 0-5-3
11 yds cube cement concrete 5-15-6
altering door head Mason 38 hrs Labr 13 hrs 1-16-7

10 cube feet of stone 0-13-4
dressing and cleaning old stone wall mason 35 hrs Labr 14 ½ hrs 1-14-11 ½
dressing flags for porch Mason 17 ½ hrs 6-15-9 ½
1 No. cleansed landing 5' 6" x 2' 6" x 4 ½" 1-7-6

Altering drains labr 328 hrs Mason 86 hrs 11-12-1
4 ½ bags of cement ½ load of sand 1-12-9
carting away surplus rubbish 1-0-0
(detailed inventory of pipes used)
160 glazed bricks
350 common bricks; 1 flag 3'2" x 2' 3" x 3 1/2"

Ventilating Cellar

Mason 78 ½ hrs Labr 83 ½ hrs Appce 74 ½ hrs 6-15-0
6 No. 8" pipes. Mortar. Cement & slag 0-17-0
2 barrows of slag, 1 bag cement. 30 bricks 0-10-6
4 buckets of Lime. 2 No. grate stones 24" x 11" x 3" & grates 0-14-0
1 No. round grate 1 No. 9" x 6" air grate 0-1-8
1 9" ditto Carting rubbish 0-4-4

Credit
By 15 ft less parapet, allowing for walling in lieu thereof 2-1-8
8 8/9 yds sup. 6" cement concrete 1-6-0
8 8/9 yds sup.encaustic tile paving 5-5-0
6 yds lin 4" drain and digging 0-10-6
1 No. saddle junction to old drain 0-3-0
amount allowed for contingencies 3-0-0

60 ft 1 ½" x 1" ceiling battening to allow ventilation under lead flat 0-4-6
1 ½ of 5" x 1 ¼" board for pendant 0-1-0
(finishing costs – door furniture etc)…

1 No. ceiling to porch whitened -5-0
3 small windows painting -6-0
7 yards sup overgraining to old door 0-10-6

APPENDIX SEVEN

Supporting Material Illustrating Changing Relations of Production.

It may be said that workability was the standard against which the quality and utility, as well as the proper performance of a lime mortar, was judged in the past – and particularly by craftspeople and that, rather than bemoan the slow and steady set of earth-lime and fat lime mortars, craftspeople valued these properties and were unimpressed by rapid and hard setting alternatives until social change and shifting relations of production within the industry in favour of fast-built speculative construction executed by employed gangs of workers, of which rapid returns on investment were demanded, coupled with the introduction of 'new' materials without the experience of traditional builders, such as steel, plumbing, electrics and the like, and increasing use (and need) for competitive tendering, led to the rise of architects and especially of quantity surveyors, initially (Powell 1980), over and above traditional craftsmen in the building site hierarchy in terms of material specification, and, for the first time, in terms of mortar design. Discussing commonly held later 19thC views about declining standards of workmanship, Powell (1980) summarises the issue thus:

"One origin of this was the erosion of autonomy of craftsmen by the growing practice of drawing up full details of buildings in advance of construction in order to aid estimating. The effect was to move decisions from site and workshop to the relatively remote designer's office. Hitherto, craftsmen had decided for themselves details of ornament and window, staircase and dormer, but now they were forced to yield responsibility to professional designers, often with different priorities. Another origin of concern for quality probably lay with the greatly increased volume of work carried out, much of it of low quality, as always".

The latter point was especially so in circumstances of higher alienation and greater rates of exploitation once traditional patterns within the industry had been eroded.

Outside of urban centres, that expanded dramatically during the 19thC, the housing stock growing from around 1,889,000 dwellings in 1811 to at least 7, 550,000 in 1911, and with many civic buildings, mills and factories built besides, and for all that this unprecedented growth was largely achieved using hot mixed lime mortars, prepared mainly on site, very many of the buildings that today receive the attentions of conservators or of conservation repair, were constructed within a very different context and according to different, less exploitative relations of production. Very few were built by competitive tender, which form of contract began to become more common as buildings became more complex and building companies larger and more generalised. Competitive tendering, with contracts invariably awarded to the lowest tender, became the norm by the last quarter of the 19thC, even in more rural situations. This may be clearly observed in the Fitzwilliam Estate archive in the context of building activity in Malton, North Yorkshire, when contracts were put out to tender and awarded by appointed architects from around 1875 onwards. Previously, contracts were awarded by agreement between the Estate and individual masons and carpenters, reflecting the most common earlier pattern – an individual, or an estate, wishing to build would forge agreements with a variety of separate trades, each responsible for their part of the project. This pattern may be observed in many of the transcribed building accounts that form part of the Appendix of this research. The valuation of works done was most commonly achieved via measured rates, mutually agreed before works commenced. On occasion, these were quantified by the piece – in the matter of bricklaying and roof tiling, this was normally paid for per 1000 bricks or tiles laid. Otherwise, valuation was by the 'square' (in roofing and other carpentry), or by the rod or the rood – typically 15 ½ to 16 ½, square, making 225 to 272 square feet, other times, as for paving and for plastering, by the square yard. Within larger estates, where repair and maintenance and new building all went on quite routinely, workers were paid by the day, again to long-accepted day-rates, which may or may not vary according to the season (in some cases, weekly pay was clearly averaged over a whole year) and, on occasion, single builds for private clients were executed to agreed day-rates. (examples).

"The drawing of draughts is most commonly the work of a surveyor, **although there be many master workmen who will contrive a building, and draw the designs thereof, as well, and as curiously, as most surveyors; especially those workmen who understand the theoretic part of building, as well as the practik " Moxon 1703.**

In Malton, an estate Agent's Memo Book survives, running from 1734 until 1808. This mainly comprises a series of agreements between fluid groups of masons and carpenters who would contract with the estate to carry out specific building projects. Typically, the dimensions of the proposed building were included, but little other detail. No material specifications are contained within these for the most part, although stone from a particular quarry might be nominated. Lime was supplied by the estate, 'fresh from the kiln', explicitly, on occasion, to be added to the 'best' mortar, which was of earth and which assessment would be made by the masons themselves. Materials are, of course, mentioned in the context of measured rates, whether these are brick or stone or thatch or pantile, daub (earth base-coats) or plaster (lime finish coats). In each case, the agreement is signed by all of the masons or carpenters involved, indicating that all were paid the same and that differential earnings were related only to speed or efficiency. Such a situation speaks of a deep co-operative spirit amongst craftsmen in the town, where all of them were resident, as well as tenants of the estate, occupying properties some of which remain but which today tend to be owned or occupied by middle class professionals and unaffordable to the working class residents of Malton.

Not included in the Memo Book are other, longer agreements from the later 18th and early 19thC, often with some of the same craftsmen, but which are more detailed, detailing joist dimensions, for example, as well as wall dimensions. In each case it is agreed that if either party has an issue with the work, its quality or measure, then the matter would be referred to a fellow craftsman for arbitration. This clearly indicates once more the co-operative relationships between individual craftsmen in the town.

In the same period, there are numerous agreements, one might even say proposals made, which include the measured rates for each constructional element, as well as a sketch by the mason of what the building will look like. (IMAGES). A number of these remain for comparison.

Measured rates prevail into the 19thC. In 1813 significant new building upon the site of the Talbot Stable Yard are accounted for by measured rate, but for the first time, the works are signed off by an architect, Peter Atkinson, of York, whose father had been a partner with John Carr. A few years previously, in 1808, Atkinson had overseen the raising by a full story of the adjacent Talbot Hotel, as well as designing a new rotunda over the site of an historic Spa in its grounds (IMAGE).

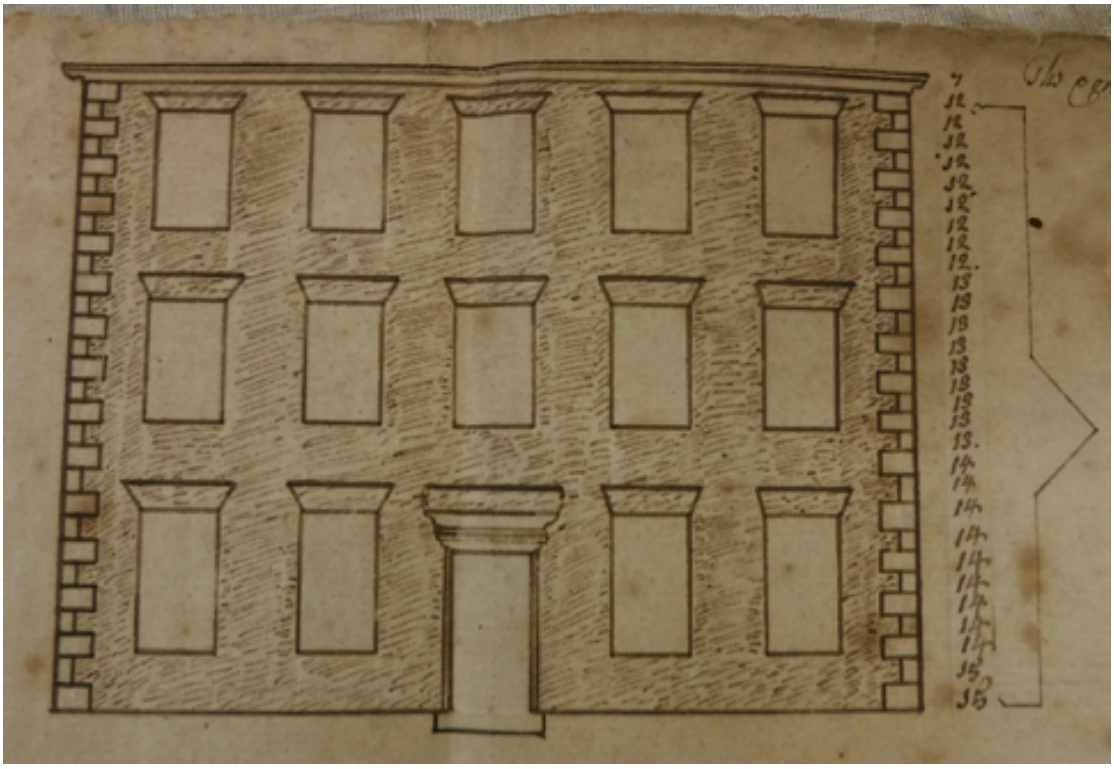
The first general building project for which architect's drawings and specifications survive in the archive was the repair (and conservation, perhaps surprisingly) of Hunter's Hall, a high status 17thC gentry house in Old Malton, designed and overseen by John Gibson, the son of the lead carpenter throughout most of the period of the Agent's Memo Book. Gibson also designed the Crown Spa Hotel in Scarborough, the first purpose built hotel in the region, and many of his proposal drawings for buildings in Malton survive, although the buildings themselves rarely matched his ambition in terms of their detail.

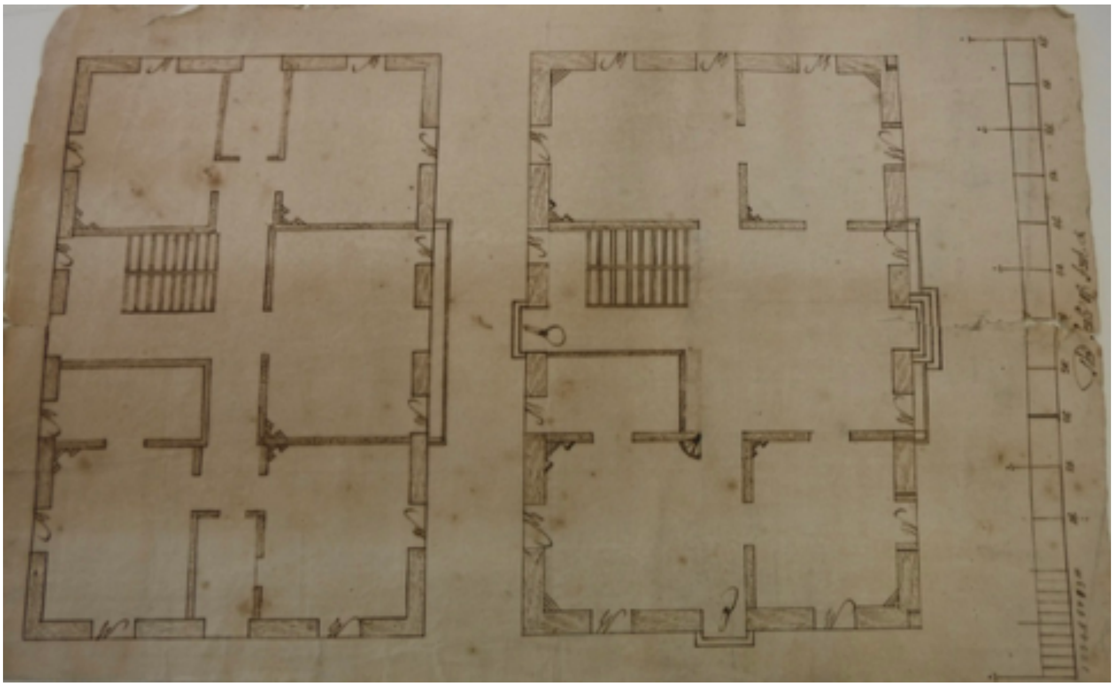
At the same time, the first Agent-written specification that survives in the archive – for the building of an extension to the Blue Ball public house, does contain very specific detail, including the nomination for the use of a lime from elsewhere, from North Grimston, which was probably feebly hydraulic by comparison with the immediately local oolitic limestone.

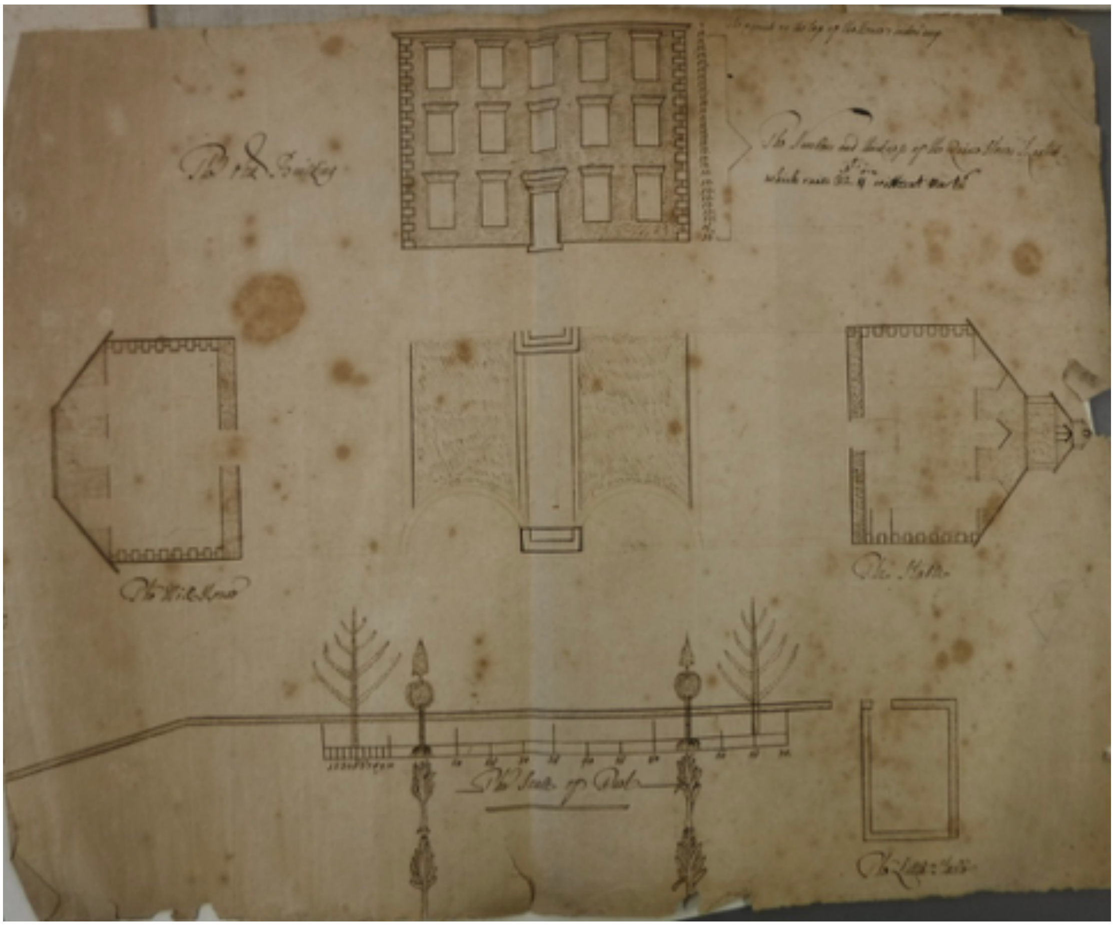
This evolution gathered pace during the second half of the 19thC until major works to the Old Lodge in 1875 were specified in great detail by an architect and were put out to competitive tender and awarded to the lowest bidder, a local stonemason whose works were some 100 yards away.

A set of documents held in Herefordshire History Centre, relating to the building of Treribble House, Langarran in 1724 offer similar insight into earlier forms of contract. The client agrees with local stonemason John Harguess the dimensions of the proposed house, as well as the number and the height of its stories and the style of the stonework, mostly local stone, neatly coursed, with Forest of Dean quoin stones, of which precise dimensions are given. All works to be paid for by the 'square', with different rates for the thicker external and the thinner internal partition walls, all minus the openings, which are themselves quantified. The mason provides a sketch of the main elevation and plans of each floor, as well as a sketch of the proposed site layout, with entrance and stable buildings. Cornices were to be laid by the day. The whole illustrates the dynamic interaction between new 'polite' styles and vernacular traditions. There is no mention of the mortars to be used, as this was understood to be the domain of the mason himself. The documents then include a 'particular of expenses in building the House, Treryble'.
Such bundles survive in all archives around the UK and all are generally similar in kind before the second half of the 19thC. This pattern of construction underwent significant change in Britain after this date, but broadly similar

patterns to those illustrated by Treribble and Malton, persisted throughout most of the world for somewhat longer than this and until the arrival of industrialised capitalism, and, in places, still exist, such as in Mali (Marchand 2009) the Yemen (Borelli 1999) and Bhutan (pers comm Nagstho Dorji), although manifesting in culturally specific ways.







So long as it had been that craftspeople designed the mortars of their trade, they chose to use eminently workable, relatively soft and efficiently prepared earth-lime and fat lime mortars, the former only generally displaced as bedding mortars when access to raw materials became restricted – such as enclosure of the common lands in England at the end of the 18thC. Architects generally preferred 'standard' materials, and the same forces that had diminished the power of artisans had also generated technologies to produce such materials on an industrial scale – pre-hydrated air lime; Portland cement and, on occasions when its inherent variability might be ignored, bagged, pre-slaked NHL, and these materials came quickly to be used in a variety of combinations, after an initial embrace of neat cement{sand mortars was adjudged to have been a mistake (US Bureau of Standards, Schaeffer). The removal of inevitable, if often minimal, variability in traditional limes, to be responded to on site, was also a significant de-skilling of the masonry and plastering crafts, just as the sudden embrace of structural steel was for the Carpenter. Reflecting the tension that existed even then between engineers wedded to hardness and apparent durability, Biston complained in 1828 that

Sometimes, the workers reject….types of lime which would be preferable to the ones they are accustomed to using. Thus, in the region of Calvados, **half of the limekilns produce hydraulic lime for the consumption of farmers to enrich their fields whereas this same lime is not at all used by the masons,** because it does not expand as much as the others and because it hardens quickly, therefore the workers would have to change how they work….

Ideological shifts followed upon these deep changes in the relations of production, and it rapidly became the norm to assert – after an initial acceptance than modern mortars were pale by comparison to traditional mortars, but that they had been forced upon the industry by circumstance – that harder, faster-setting mortars were 'better' and that air lime mortars were simply inadequate and inappropriate. Such shifts were erratic across the world, but always mirrored the ascendancy and then the hegemony of industrial capitalist production and the collapse of artisans and building craftspeople into the disempowered proletariat, their wages a measure of their exploitation, no longer of their generally higher and more independent status historically.

APPENDIX EIGHT

Binder Identification. Bill Revie. Unpublished.

Historic and Traditional Mortars: Is It Possible to identify Hot Mixed Mortars and differentiate between these and Putty Lime & Lime Hydrate mixes And Establish if they were placed hot or mixed Hot and placed Cold? *One Analyst's Perspective* – William Revie

When faced with a sample of mortar, plaster and render or Harl and the often asked question: *What is it? and How do I replicate it?* there is often the initial response "I do not know!" followed by "tell me more about it", what is its provenance:*Origin (ruin, building, structure), Where is it from (country, location, environmental exposure), Age, if known, History (Background information, changes, additions, past restoration/repair works)*. Although this information is not always available or forthcoming, in total, or in part, it is always advisable to relay what is known with the sample. With respect to the mechanics of carrying out basic mortar analysis, it is not always essential. However, any information that can be given to the analyst at the start can greatly assist in designing the programme and aiding the selection of techniques to be employed. It also can make the work more interesting and incentivise the analyst, which can lead to more useful information being fed back to the client, providing information on the characteristics of the mortar and its form of production, placing and performance.There is also the addition question of what information is required by the client, from the examination and analysis:

Composition of the mix;

Binder type;
Aggregate type, with particle size distribution, and potential source;

Form in which mortar was mixed and used;
Impact of weathering/chemical alteration, etc.;
Guidance in preparing a Specification for conservation or restoration works (including mix design(s), binder(s), aggregates and methods of mixing and application, curing and protection (where appropriate).
And lastly:
Costs and timescale for the laboratory programme, the more required the more time it can take.

After the preliminaries are settled and the Client decides to proceed, there are a number of approaches open to the analyst. However, in this paper the comments offered pertain specifically to addressing "Hot Mixed Mortars" (HMM), although most of the techniques involved are equally appropriate to the examination and analysis of mortars incorporating other forms (and more modern) binders.

Some General Considerations:

What information is required on Lime Mortars that may help in understanding them and in successfully replicating or matching their current condition;
What is Lime and are there different forms?
Is the mortar you are matching a Hot-Mixed Lime Mortar, a Putty Lime, or a Hydrate Mix?
Is a modern Hot-Mixed Lime Mortar the same as a Historic Mortar?
Why would you want to use a Hot-Mixed Lime Mortar?

What is Lime?

There are 4 basic types of lime commonly found in buildings in the UK: non-hydraulic ("High calcium", "Fat" or "Air") limes, Magnesium Lime (5 – 35% $MgCO_3$), Dolomitic Lime (35-46% $MgCO_3$) and Hydraulic Limes which contain Calcium Aluminates and Calcium Silicates along with Calcium Carbonate, and locally, Magnesium Carbonate.

The properties of each are determined, to a degree, by the properties of the rock processed in the kiln (i.e. it is dependent on the geology of the feed stock), in addition to the temperature and duration of the burn.

Therefore, as the local geology changes between different areas of the UK each will have produced quite different building limes. Chalky limestone in the south of England would produce air lime (non-hydraulic) and grey limes (feebly Hydraulic), whilst in Norfolk, North Yorkshire & Durham the lime produced could be Magnesian or Dolomitic, as well as High Calcium and Feebly Hydraulic. A high proportion of Scottish limes used historically tended to be hydraulic, most often feebly hydraulic but with moderate and eminently hydraulic limes being not uncommon, and a number of these being also Dolomitic to varying degrees.
In the UK we are fortunate in having a wide and diverse geology, and this has contributed to the landscape that we can enjoy as we travel across the country. It has also dictated the form of masonry, and to some extent, the Architecture, prevailing in different geographical areas.

This also introduced variation into the properties of the lime that was available for building applications and why a material that will work in one location may not perform adequately in another, particularly given the variations in weather, i.e. temperature and rainfall experienced in each region.

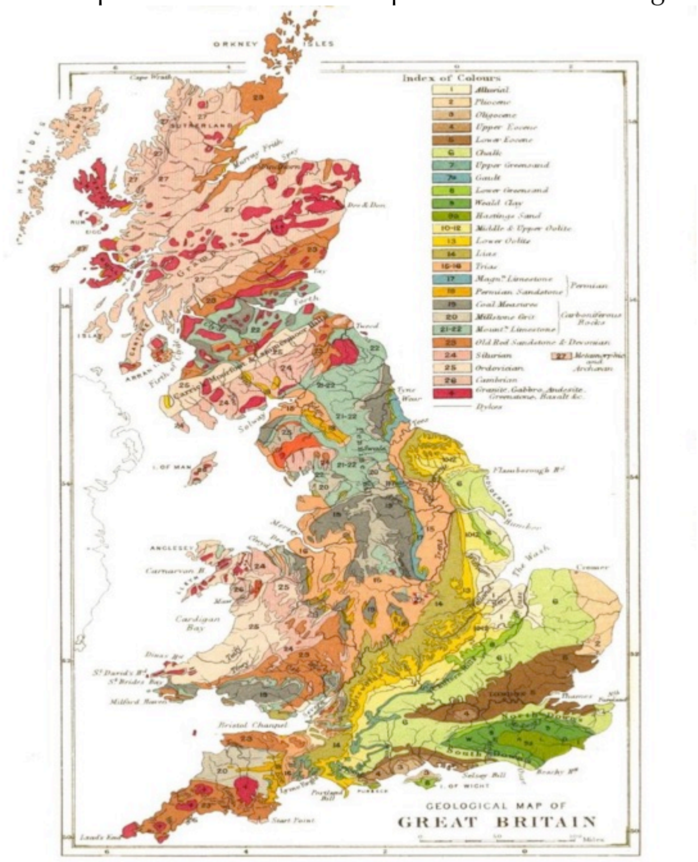


Figure No1: Geological Map of the UK showing geological Diversity
(It will be necessary to get permission from the BGS or other source for approval to use in paper)

Therefore, perhaps we should ask ourselves, at this stage:
Is it purely the geology that we can blame for the difficulty we can sometimes experience when trying to match historic mortars in different locations, or

is it something that our forefathers added to their mortars, or was it the way they mixed and used them, or something else?
Was it a function of the way they were burned, and the fuels used?

Traditionally limes were burnt following a wide range of methods.

Plate No. 1:
Burning Oyster Shell in a rick or clamp
Temperature typically 700 to 850°C.
Ash from these burns could be incorporated with some of the lime, accidently, or purposely, altering its properties.
Demonstration of a Lime burn at Colonial Williamsburg, Virginia, USA

This and many variants of this form of field burning limestone and shell was practiced along with the building and firing of clay-built kilns, where the lime could be contaminated with clays from the kilns, thereby incorporating a pozzolan into the mix.

Stone built kilns used as single burn batch kilns were also used, with this further developing into continuous draw kilns, thereby increasing the production rate significantly.

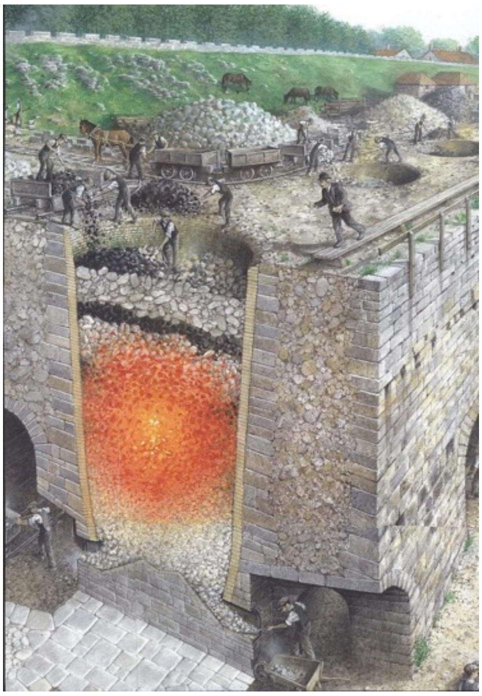


Plate No. 2:
Lime Kilns at Charlestown, Fife
Here limestone was burnt using local coal as the fuel, which also contributed to a proportion of impurities being present in the lime. Needs lump lime, preferably single size (3 to 6").
Limestone raised to 800 to 950°C, which is the disassociation temperature of CO_2 (de-carbonation), temperature could rise to 1050°C and locally to 1200°C.
Localised hot spots in kiln were quite common
Image from the Scottish Lime Centre Trust

Plate No. 3:
Rotary Kilns
First experimental rotary kilns came into production in 1880.
This method became the primary Kiln design in use from1904-1913.
Temperature typically up to 1100°C, but dependent on demand could greatly exceed this value.

Plate No. 4:
Modern Vertical Kilns
Burning Temperature typically 900° to 950C for high calcium lime but can be increased to 1050°C, higher temperatures are used in the production of Natural Hydraulic limes.
Temperature is restricted to 725°C for Dolomitic limes.

Plate No. 5:
Pair of Demonstration kilns
The left kiln is using coal as fuel with the fuel layered between the limestone charge.
The right kiln is using wood as fuel and is fired from below.
Demonstration to assess the difference in the product formed from a local metamorphic limestone.
The product was used in the production of HMM, incorporated into a project as a performance trial.

It can, therefore, be taken that there were differences in the methods that were used to burn lime, from its first use over the centuries, and as the design of kilns developed. It is likely, therefore, that during early production, the lime produced would be highly variable, both from the differences in the feed stock employed, and the methods of burning; with, and without, the effect of fuel contamination.

Traditional Lime Mortars

Is it important to know in what form the mortar was mixed, and used, when you are considering what materials, and in what form, they are to be used in a conservation or restoration programme? And, if so, is it the intention to match like with like!

If the objective is to match "like for like", defining "like" as the sample you have taken, this may bear little resemblance to that which was placed at the time of construction, due to the impact of weathering, chemical attack, and changes in use and sometimes the impact of history (battles, etc). Furthermore, there is the possibility that the sample is from a later mortar. A decision must be made, therefore, whether to match what is identified, and from the examination and analysis, modify to match a perceived 'original' mortar, perhaps from historic record, or simply design the new mix to complement the existing mortar, yet preserve the original fabric.

Was the original mortar a hot mixed mortar, or a variant of one, or was it a putty mix, or something else?

There is ample evidence in the mortar within a number of masonry buildings to show that "Hot-Mixed" lime mortars were used in the construction of many of our traditional and historic buildings and structures. From the examination of numerous samples, both by the author, and many other laboratories, it would appear that the practice had been widely followed throughout the UK and Overseas.

It is often quoted that if there are large angular inclusions in a mortar it was mixed as a "Hot Mixed Mortar" where the lime was added to the sand as a Quicklime and that it was used whilst still "Hot". However, this is not necessarily so, as was reported by Ewa Sandström Malinowski and Torben Seir Hansen in their "Hot Lime Mortars in Conservation, Repair and Replastering of the Facades of Läckö Castle" in Sweden. They found that lime inclusions only constituted on average 2% by volume of the binder in the Hot-Mixed Mortar mixes that they prepared as part of their research, whereas, it was found that in the wet putty mixes they prepared, lime inclusions formed 12-13% of the volume of the mortar.

Therefore, prior to describing a mortar as a HMM the question as to what formed the inclusions needs to be resolved, and to clarify this what techniques can we use to aid the identification of the form in which the binder was used, and help us understand how the mortars were produced, and if possible, how they were used.To know more about the mortar, it is necessary first to examine it, and often carry out an analysis of the mortar samples.

Typical steps are:

Visual Examination: As a hand specimen, with the naked eye or the use of a hand lens, or a microscope.

After this, additional information may obtained from analysis, using techniques such as:

Acid Digestion
Wet Chemistry
X-Ray Powder Diffraction, DTA/TG, etc.
Petrography
Scanning Electron Microscopy with Elemental Analysis (SEM-EDAX)

Techniques:

Visual Examination:

How to tell if a lime mortar was made as a "Hot Lime".

It is accepted that most traditional historic mortars were lime rich, compared to modern practice, with mix ratios as rich as 1 part lime to 1 part sand being relatively common and mixes as rich as 1: 0.25 identified in the analysis of old mortars. It has also been inferred that in some hot lime mortars, in addition to an excess of lime, there is also an abundance of lime inclusions. However, this on its own cannot conclusively confirm that the mortar was mixed from sand and quicklime, as early putty lime mortars were equally as rich, with an abundance of lime inclusions also present.

It is, therefore, the difference in the structure of the inclusions and the form and dispersion of the binder through the mortar that can assist in their differentiation.

Plate No. 6:
The plate opposite shows a piece of mortar that contains an abundance of lime inclusions, randomly distributed throughout. The inclusions in this mortar range from sub-round to irregular with a small proportion of angular inclusions also present. Therefore, what is it?

It is often quoted that if there is an abundance of inclusions within a mortar it is likely that it was mixed as a "Hot Lime" where the lime was added to the sand as a Quicklime and that it was used "Hot".

This is not necessarily the case as inclusions can also be formed from an accumulation of putty lime, with apparent angular margins formed from the force used in the action of working the mortar and in its placing. It has been recorded in laboratory trials that in comparative mixes made with both putty and quicklime that it is not uncommon for putty mixes to have an abundance of lime inclusions distributed throughout the mortar fabric.
It is the shape and the form of the internal fabric of the inclusions that indicate the form in which the binder was used, with this further confirmed by the increased abundance of overburnt, under burnt and incompletely hydrated particles present in hot mixed mortars, compared to putty lime mortars. There are also, sometimes, variations in the properties of the paste, encapsulating the inclusions, that can aid in determining how the mortar was used, and placed.

Hot Lime Mortars – Quicklime: Sand mixes

A significant number of the inclusions in a hot lime mortar are angular in shape, or at least sub-angular. Although, there will also be a large proportion of rounded to irregular shaped inclusions also present from the putty formed by the slaking of the quicklime at the time of mixing.

Plate No. 7:
Quicklime Binder, albeit the inclusions are rounded to sub-round.

Plate No. 8:
Quicklime Binder, where inclusions are angular to sub-angular.

Plate No. 9:
Quicklime Binder? Inclusions sub-round, sub-angular and irregular. No – The mortar was mixed in the laboratory from a Hydrated lime.

Plate No. 10: Old Clay lime mortar

Plate No. 11: Old Lime sand mortar

Both mixed from lime used in the form of Quicklime.

Plate No. 12: New Clay Lime Mortar. Mixed with Powdered Quicklime


Plate No. 13: New Lime-Sand mortar. Mixed using Kibbled quicklime.

To clarify the form in which the lime was used examine the inclusions and it should be possible in old traditional mortars to observe relic rock texture retained within some of the inclusions, with a number of the inclusions also displaying varying stages of calcining and hydration, this being due to all of the quicklime being added to the mix without separation of partially burnt or overburnt particles, which would commonly be screened out of a putty binder, prior to its use in a mix.

In addition, if the quantity of water added is less than that required to fully hydrate all of the quicklime - a not uncommon occurrence - there is likely to be an abundance of unhydrated/partially hydrated particles within the mortar. This is also the case where mortars are mixed hot, but used cold, albeit there tends to be a lower proportion of large inclusions as these are normally screened out of the dry-slaked sand/lime mix prior to its storage and use.

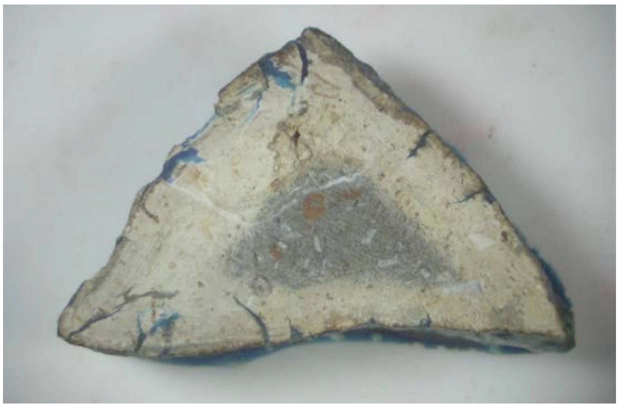


Plate No. 14:
A view of a large lime inclusion, selected as an example of what can often be seen in smaller inclusions, with this showing a central core surrounded by a partially burnt rim. Shrinkage cracks extend from the outer margins inwards and are the result of partial hydration of the inclusion.
Width of sample 20mm

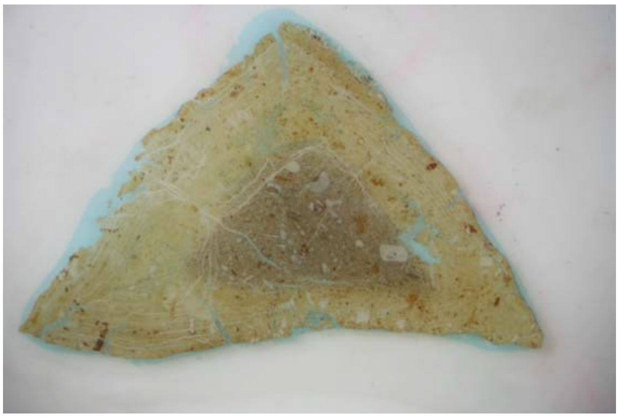


Plate No. 15:
View of the same lime inclusion in thin section showing the crack pattern and the colour gradation from the outer calcined part of the limestone to the inner underburnt part of the particle. The inclusion was impregnated in blue dyed impregnation resin prior to sectioning.

An examination of the fabric of the old mortar also usually shows a patchy consistency with areas displaying a high microporosity, which is more common in mortars that have been mixed and used whilst still hot. Hot-placed mixes also tend to display a dense margin, and density gradient adjacent to the contact masonry, which is a function of the mortar continuing to expand as it slakes *in situ*.

Some of these features can be seen by the naked eye or with the aid of a hand lens or low power microscope. However, in some instances it is necessary to make a petrographic thin section and examine this in a polarised light microscope to clarify the condition that the mortar was in at the time it was used.

To summarise, it is the shape and texture of the inclusions and the condition of the paste and presence of perimeter margins, both around the particles and at mortar/masonry interfaces that will guide the analyst in the identification of hot lime mortars.

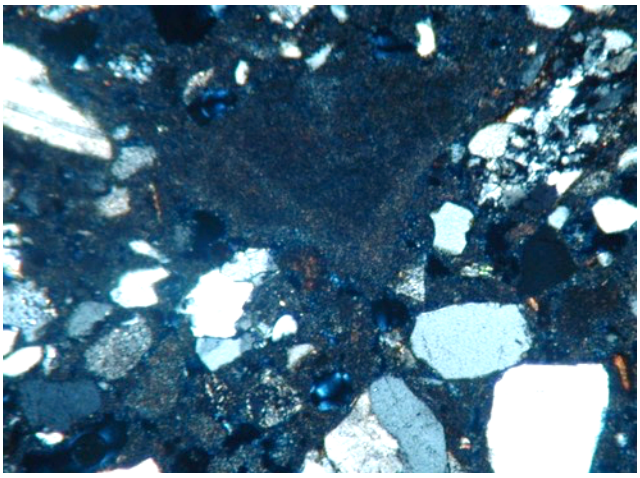


Plate No. 16:
View, in cross-polarised light of a hot lime inclusion within a hot lime mortar, in thin section. Note the sharp margin and the presence of a relic rock fragment within the core of this particle. Field of view 2.4mm

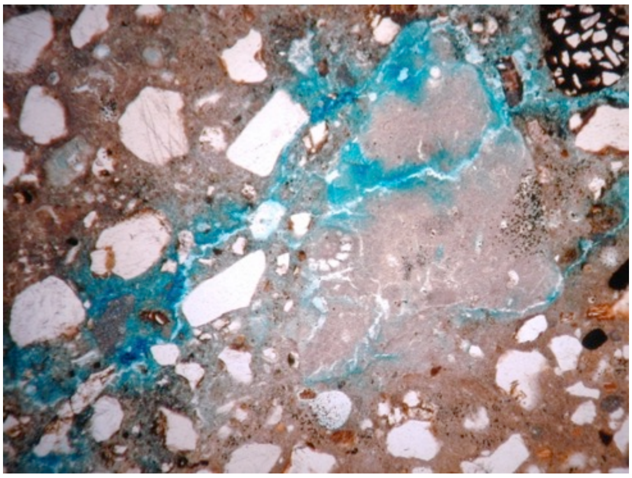


Plate No. 17:
Thin section view in plane polarised light, of a partially calcined and partially hydrated lime inclusion, within a hot lime mortar.
Note the presence of a relic rock fabric within the particle. Also note the higher microporosity in the surrounding paste compared to that at a distance from the particle.
Field of view 2.7mm

Putty Lime Mortars – Putty: Sand mixes

Some putty lime mortars, particularly binder rich mixes, can present a higher proportion of lime inclusions, compared to quicklime mixes of the same ratio. This can lead to their misidentification. However, the inclusions in putty mixes tend to have more rounded to irregular margins, show flow characteristics which, curve around aggregate particles and fill irregular shaped voids. Within the core of the inclusions the texture is commonly that of a paste that has undergone shrinkage, displaying typical plastic shrinkage patterns, i.e. these can occasionally be concentric in that they reflect the outer margins, with these cracks intersected by margin perpendicular cracks. Also, there are no definite rock texture patterns apparent within the inclusion. Occasionally fine sand grains are incorporated randomly within the inclusion, or concentrated within the outer rim.

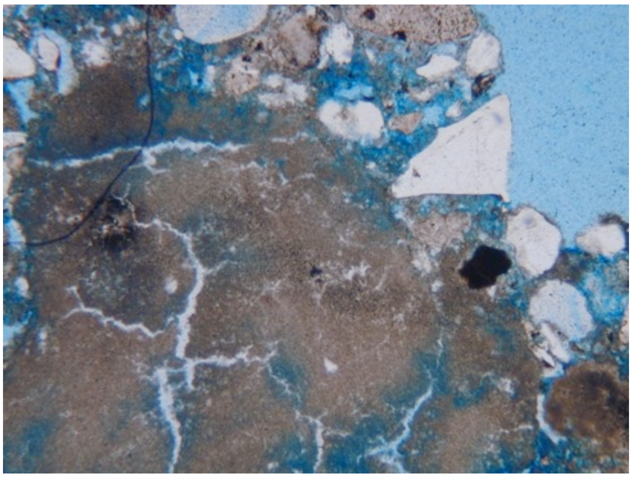


Plate No. 18: a putty lime inclusion within a lime putty mortar.
Note the absence of any residual rock fabric and the presence of a map crack pattern of shrinkage cracks. With the paste at the margins locally diffusing into the fabric with lime from the inclusion folding around peripheral aggregate particles.
Field of view 2.4mm.

As with hot lime mixes variations in binder distribution throughout the mortar can be observed, and areas of dense paste rich zones are not uncommon, but these are usually free of high microporosity and are commonly transacted by shrinkage cracks and locally by dissolution channel ways. Putty mixes commonly show plastic flow patterns with the texture of the inclusions lacking a definitive form.

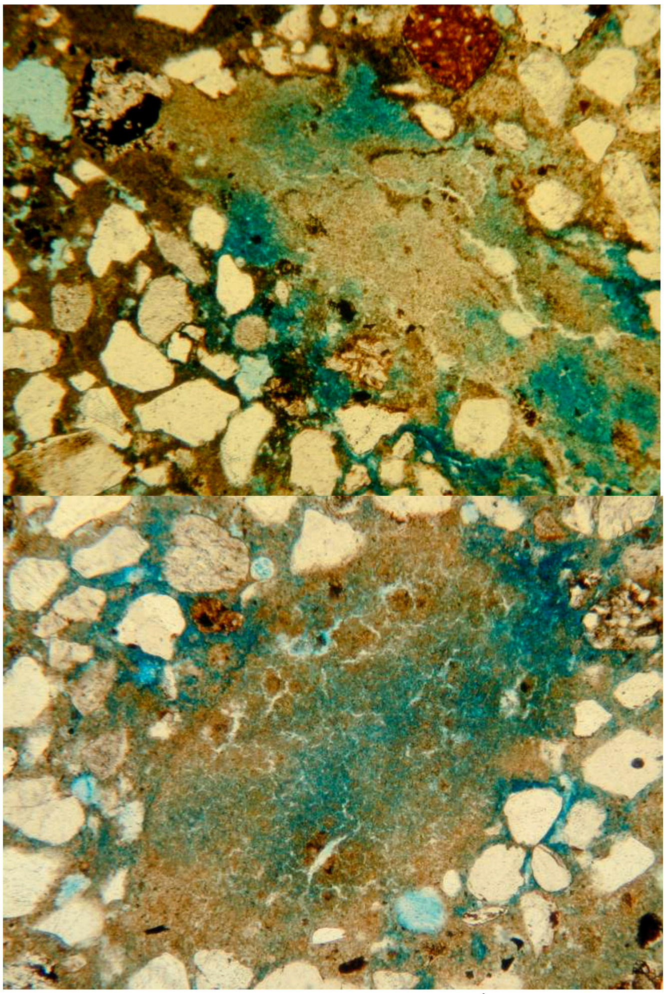
Lime Hydrate Mortars – Hydrate: Sand mixes

This form of mix is not normally encountered in historic stone masonry mortars but can be found in brick masonry where hot mixed mortars have been slaked to a dry condition, screened and remixed, and used cold, as was not uncommon. These mixes can have a fabric and texture typical of dry hydrate mixed mortars.
Lime inclusions tend to be rounded to irregular, with a granular internal texture, with fine sand/silt coatings, where they have formed putty coatings in the mix at time of placing. These inclusions tend to show a granular to powdery texture throughout, with irregular crack patterns, and occasionally with a calcite shell. The mortars tend to be more uniform throughout their thickness, with a good binder dispersion, unless they have been affected by leaching or chemical attack during service.

Examples:

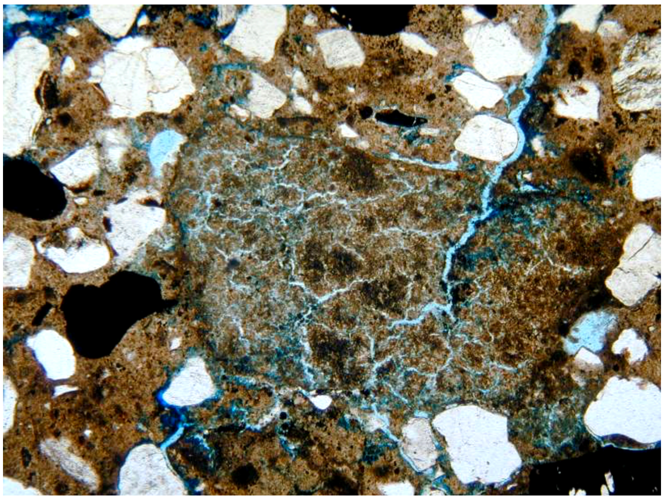
Plate No. 19: Quicklime in a 15th C Hot Lime Mortar

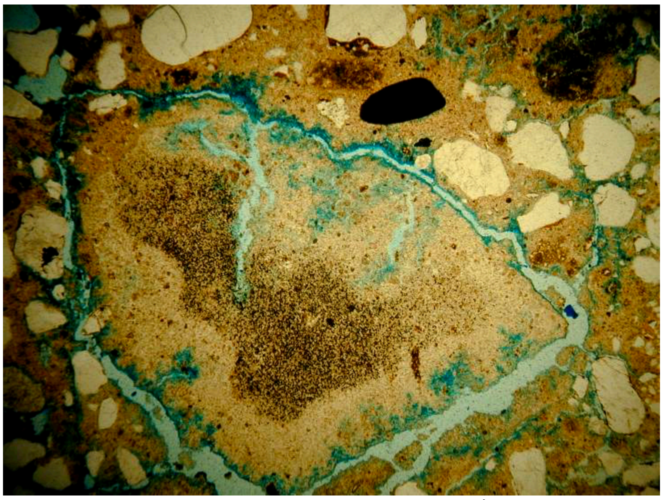
Plate No. 20:
Quicklime in a 15th C
Hot Lime Mortar.
Thin sections from this
sample are shown below



Plates No 21 & 22: Quicklime in a 15th *C* Hot Lime Mortar

Plate No. 23:
Quicklime in a 13th C
Hot Lime Mortar.
Thin section from this
sample are shown below





Plates No 24 & 25: Quicklime in a 13th C Hot Lime Mortar

How can we be sure which is which?

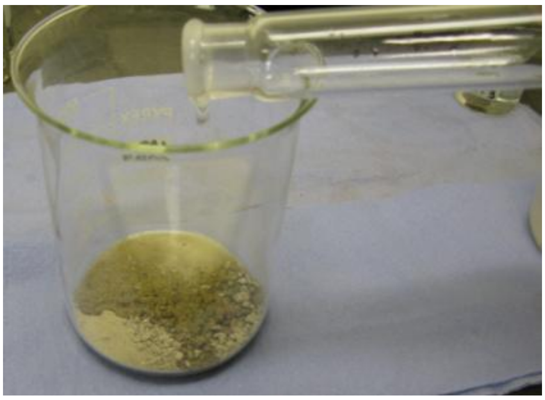
Study the shape of inclusions (angular with sharp edges);
Texture (do any inclusions retain an imprint of the rock fabric or retain harder cores or peripheral crusts) and margin with paste (do the inclusions all diffuse into the paste, or are some acting as discrete features).

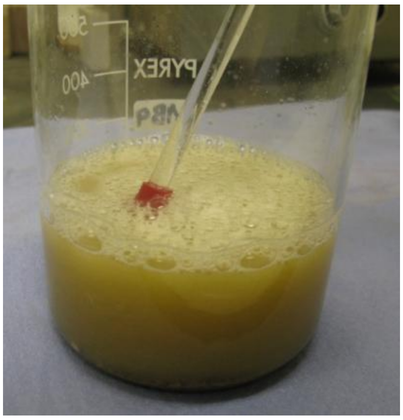
Analysis of the Mortar Samples.

When it is decided to progress further and analyse the sample, there are several options available, with the following giving a simple description of some those commonly employed.

Mortar Analysis By Acid Digestion.

Sometimes called the "kitchen Sink Approach" as it is very simple to undertake and requires relatively basic equipment:
A dried and weighed sample is digested in dilute hydrochloric, or acetic, acid and once the binder has been digested the aggregates are recovered, dried and weighed, the difference being taken as the soluble binder content. If the binder is a calcareous air lime the difference in weight can be taken as the binder content, this though is the weight of carbonated lime, and will need to be converted back from calcium carbonate to its equivalent quantity of calcium oxide, calcium Hydroxide or putty weight dependent on the form of binder considered to have been used, to determine the mix composition. Further assumptions may need to be considered if the binder was indicated to be hydraulic, Dolomitic, gypsum or have been gauged with a pozzolan or another additive.





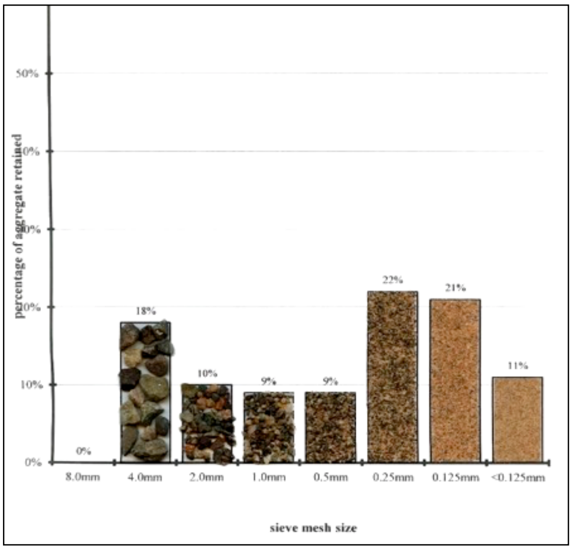
Plates No. 26 & 27: Adding dilute acid to a dried and lightly ground (disaggregated) sample.

Plates No. 28 & 29: Recovering the aggregate after digestion of the binder.

Plates No. 30, 31 & 32: Grading of the aggregate after drying to determine particle size distribution.

The recovered and dried aggregate is sieved through a Nest of BS Standard Sieves, and the fraction retained in each sieve is weighed, calculating the percentage retained and percentage passing. From this the grading of the aggregate can be reported and, along with a description of the mineralogy of the sand, this can be used in sourcing a suitable source for the supply of aggregate for use in conservation or repair works. The aggregate grading can be presented as a table, or in the form of an aggregate particle filled histogram, of the form favoured by the Scottish lime Centre Trust. This permits a visual comparison with the grading analysis and can assists in matching the mineralogy and shape of aggregates from various sand sources.

Sample Ref	SR2*** – S1 Building Mortar	
British Stand'd	Per cen	Per cen
10.00m	0	100
8.00m	0	100
4.00m	17.	82.
2.00m	9.6	72.
1.00m	9.4	63.
0.500m	8.8	54.
0.250m	22.	32.
0.125m	20.	11.
0.063m	5.9	
Passing	5.4	



Figures No. 2 & 3: Examples of two methods of reporting aggregate grading.

Mortar Analysis - Chemical analysis

Where mortars are indicated to contain hydraulic binders, whether Lime, Natural Cements, Portland Cements or Gypsum, analysis by BS 4551: 2005 + A2: 2013 is more appropriate.

This technique employs wet chemistry to determine the proportion of Soluble Silica as SiO_2, Calcium Oxide as CaO, Insoluble Residue (IR) and Loss on Ignition (LoI), as a minimum requirement.

In addition, the following can also be determined:
Sulphur as sulphur trioxide (SO_3), Total Iron as Fe_2O_3, Aluminium oxide as Al_2O_3, Magnesium oxide as MgO, Chloride ion (Cl^-).

This form of analysis, does, however, require the services of an analytical laboratory to carry out the work, preferably one which is accredited for carrying the analyses to the requirements of the Standard.

Results of Composition analysis

Chemical Analysis	% by mass					
Sample Reference:	S1	S2	S3	S4	S5	S6
Insoluble Residue	80.08	80.81	78.78	82.37	79.07	81.04
Soluble Silica (SiO2)	1.48	1.42	2.14	1.94	1.62	2.07
Calcium Oxide (CaO)	6.63	8.51	9.30	8.12	9.38	8.99
Loss on Ignition	8.65	8.25	9.70	6.71	9.22	6.77

Calculated composition of the sample expressed to the nearest 0.5% by mass on dry mass[1].

NHL 5 Binder	12.0	15.0	16.5	14.0	16.5	15.5
Sand	88.0	85.0	83.5	86.0	83.5	74.5

Approximate volume Proportions, calculated on the basis of the standard assumptions.

NHL 5 Binder	1.0	1.0	1.0	1.0	1.0	1.0
Sand	2.9	2.2	2.0	2.4	2.0	2.1

Comments

The analytical results presented above were evaluated by the method of BS 4551: 2005 + A1: 2010 + A2: 2013, on the basis of the following assumptions:

a. The Lime Binder content has been calculated on the basis that it contained[1] 10.58% soluble silica and 60.56% calcium oxide and had a dry bulk density of 850 kg/m^3.
b. The sand contained 0.2% soluble silica and no soluble calcium compounds and had a dry bulk density of 1675kg/m^3.
c. The mortar contained no mineral admixtures such as PFA, GGBFS or silica fume.

[[1] the above mortars were made with a modern NHL binder and the chemistry of this was determined along with that of the sand, with these values used in the calculation of the mix proportions].

Analysis of Binders by X-Ray Powder Diffraction

Powder X-Ray Diffraction is one of several techniques available to aid in the identification of the binder type used in the mortar. This allows for the identification of the mineral/crystalline components present within the mortar.

Where a binder rich sub-sample can be obtained, or preferably, if available, the material within several “lime” inclusions can be extracted from the mortar, this can provide a rapid method of identifying whether a mortar is a high Calcium Lime mortar, a Hydraulic Lime, a Natural cement or a Portland cement mortar, or a gypsum gauged binder.

If it is identified that the binder is a hydraulic lime, XRD can also be of assistance in assessing the degree of Hydraulicity of the binder, particularly when this technique is coupled to data processing software, such as Maud Program, which permits processing of the XRD data by Rietveld Refinement, which allows semi-quantitative analysis of the components present.

The presence of Pozzolans can often also be identified by this technique.

This technique requires access to specialised equipment and is best carried out by a commercial or University Laboratory, with the equipment and knowledge of employing this technique in the analysis of mortar samples and binders. Knowledge of the mineralogy and crystalline phases of binders is essential in the interpretation of the data obtained for success of the analysis.
Examples of labelled diffractograms are included below to demonstrate the value of this technique:

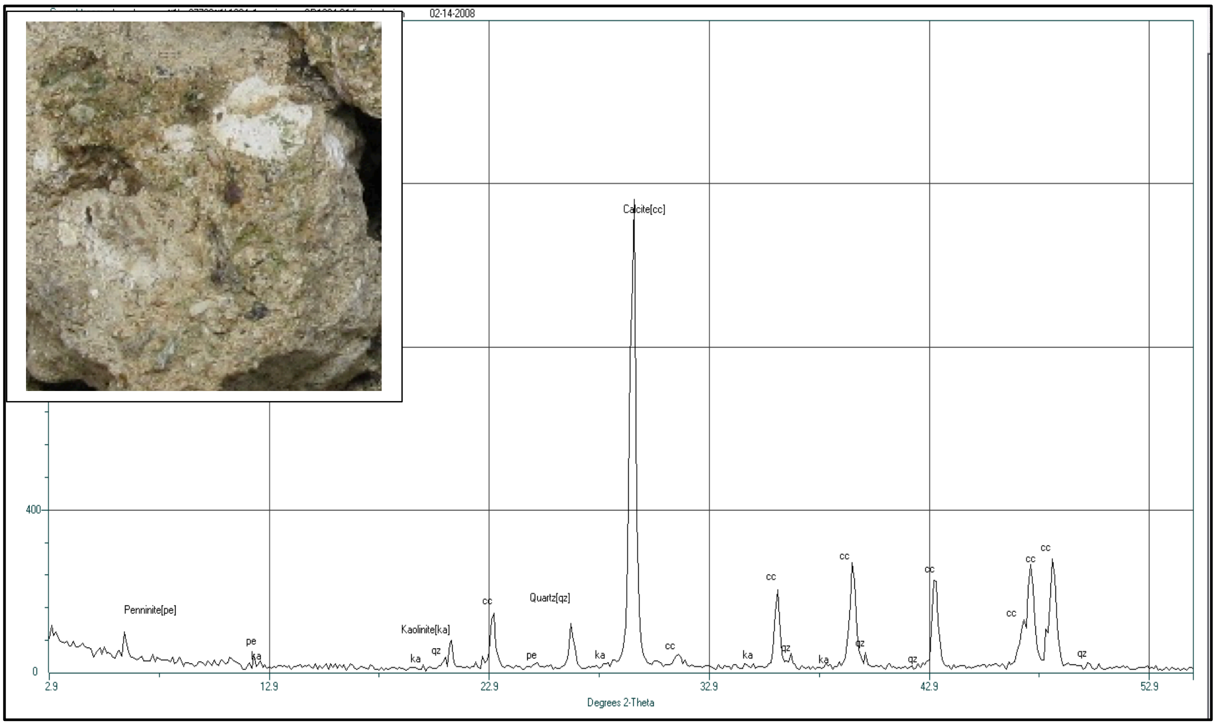


Figure No. 4: The above diffractogram shows he result of the analysis of a single lime inclusion picked from a piece of hearting mortar, taken from an old masonry wall. This confirmed that the lime was a non-hydraulic calcium lime.

cc = Calcite ($CaCO_3$), calcium carbonate, carbonated lime hydration products,
ht = Hydrotalcite ($Mg_6Al_2(CO_3)(OH)_{16}4H_2O$), Magnesium aluminium carbonate hydroxide hydrate, component of the lime binder produced from magnesium bearing limestone,
hy = Hydromagnesite ($Mg_5(CO_3)_4(OH)_24H_2O$), Magnesium carbonate hydroxide hydrate, binder component, from the type of limestone or from a reaction with fuel products.
ca = Calcium Aluminium oxide carbonate hydrate ($3CaOAl_3 3CaCO_3 2H_2O$), component of some lime binders produced from clayey limestone,
qz = Quartz (SiO2), dominant component of the aggregate in the mortar,
fs = Feldspar, various forms present, dominated by Albite, common aggregate mineral component,
pe = Penninite, clay mineral of the chlorite group, common decomposition mineral,
mi = Muscovite mica, component of the natural sand aggregate.

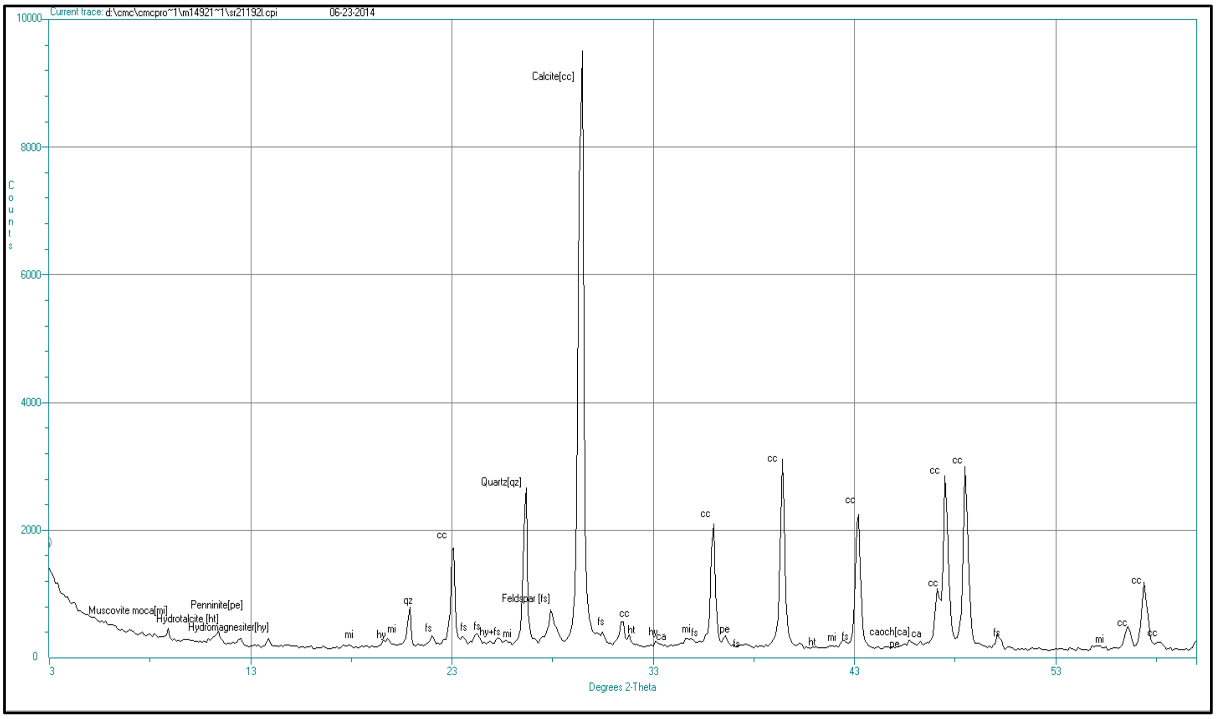


Figure No. 5: Analysis of lime picked from a number of inclusions in a hearting mortar in a 15th C Church ruin in Central Scotland.

Another X-Ray technique that can also be of value is X-Ray Fluorescence Spectrometry. Again, if a separated binder sample can be obtained, its chemical composition can be determined, in the form of its major oxides. This can also be determined by wet chemistry and once the data is obtained, the Cementation or Hydraulicity Index can be calculated to give an indication of the hydraulicity of the binder.

In addition, if there is access to historical data on the limestone in the area of interest it can be possible to establish the original source of the lime. One such source of the properties of limestone are given in the HMSO 1949 publication the "Geological Survey of Scotland", which provides the chemistry and mineralogy of most of the limestone deposits that were considered to be of commercial viability, many of which were the sources of historic lime production. There are similar publications relating to other areas of the country.

Mortar Analysis by Petrography

One of the most suitable methods of examining old mortars is by their examination in thin section under the Polarised Light (Petrographic) Microscopy, with composition determined by modal analysis.
This entails the making of petrographic thin sections of representative samples of the mortar under examination.

Plate No. 33:
The plates opposite show a piece of mortar from a 14th C castle in the west of Scotland and a thin section prepared from this.

A thin section is a slice of the mortar, impregnated with resin and bonded to a glass slide and polished to a thickness in the region of 25μm to 30μm in thickness. A fluorescent dye is commonly added to the impregnating resin, as this highlights the presence of porosity, voids and cracks within the mortar.

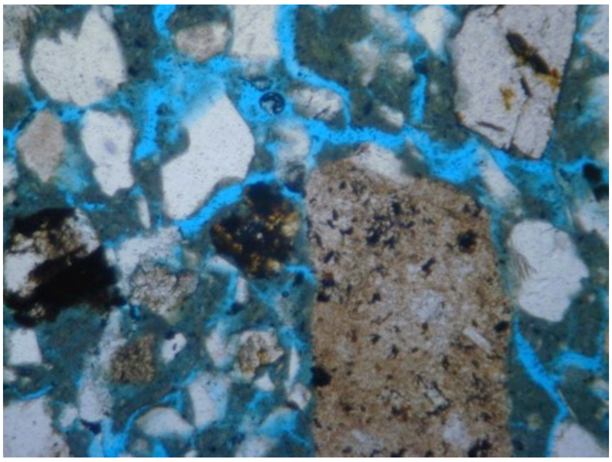


Plate No. 34:
The blue dyed resin highlights the porosity in this high calcium putty lime mortar.

In high calcium lime mortars the porosity and permeability are likely to be high. The porosity and connected shrinkage channel ways are highlighted in the section by the presence of the blue dyed impregnation resin.

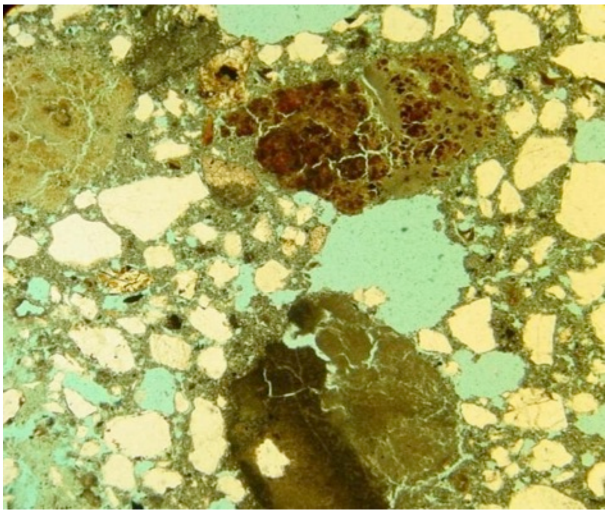


Plate No. 35:
Image of a “Hot Mixed Mortar” where inclusions can be seen within the mortar.
In this image there are two overburnt and only partially slaked inclusions (top and bottom centre) and one fully slaked, upper right.

Hot lime mortars can be non- to eminently hydraulic. Where they are not weathered or eroded they often display a dense structure, though still permeable. Hot limes expand on setting and in a confined space pack to give a very tight fabric.

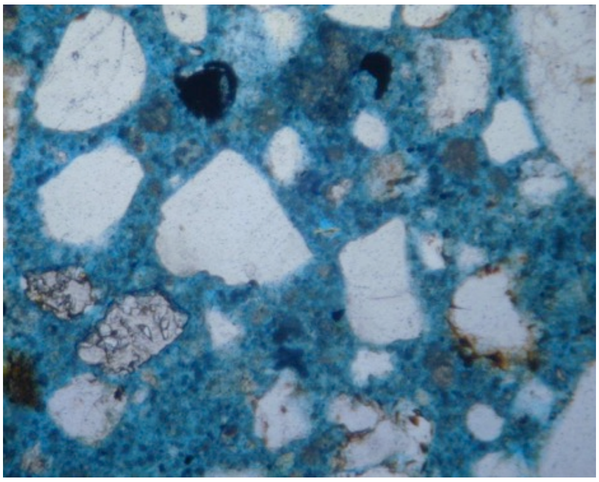
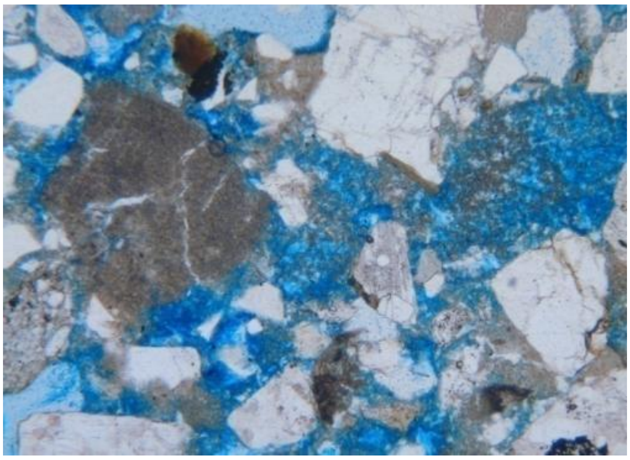
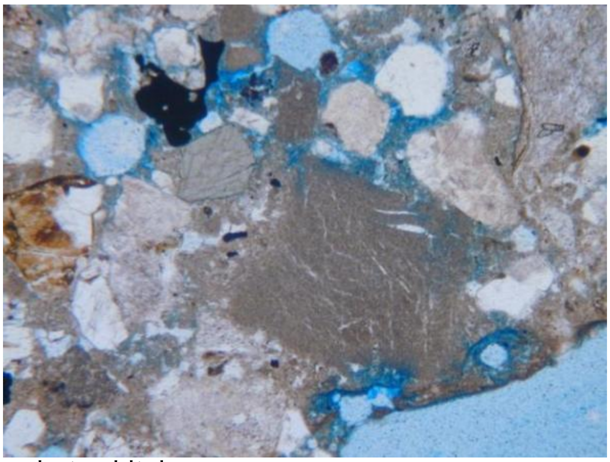


Plate No. 36:
Image of NHL 3.5 mixed mortar included for comparison. This mortar was made in the laboratory with a modern NHL3.5 binder mixed at a ratio of 1 part Hydrated Natural Hydraulic Lime to 3 Parts sand, and the mortar fully Carbonated prior to preparation of the slide.

Hot Mixed Mortars.

Plate No. 37:
Hot Lime Mortar sample.
The mortar contains an abundance of typical angular shaped lime inclusions, some extending up to 14mm in size.





Plates No. 38 & 39: lime inclusions with internal shrinkage cracking. There is a partial hydration rim around the perimeter of the inclusions, indicating that some hydration had occurred, but these lime particles have not contributed to the paste, and have effectively behaved as 'aggregates' in the mortar. Field of view 2.7mm, plane polarised light.

Putty Lime Mortars

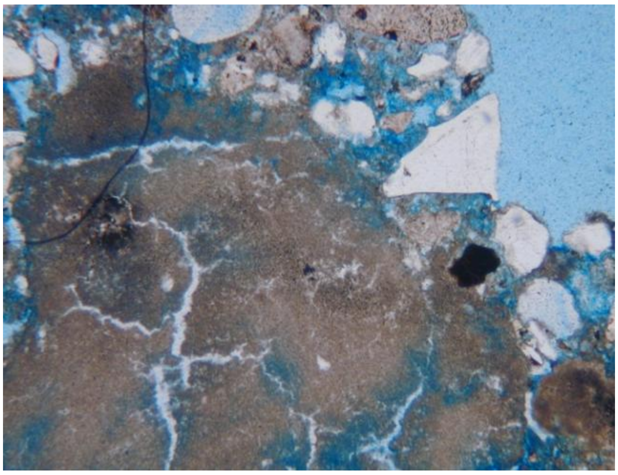


Plate No. 40:
As with hot lime mixes variations in binder distribution throughout the mortar can be observed, and areas of dense paste rich zones are not uncommon, but these are usually free of high microporosity and commonly contain an abundance of shrinkage cracks, and locally, dissolution channel ways, sometimes containing redeposited calcite.
Putty mixes commonly show plastic flow patterns with the texture of the inclusions lacking a definitive form
.

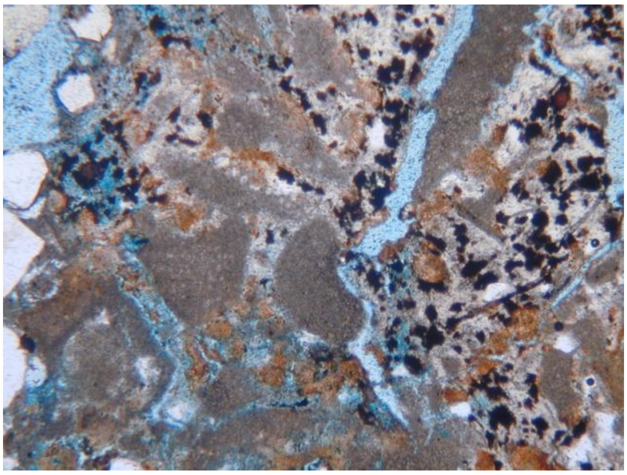


Plate No. 41:
A putty lime inclusion within a lime putty mortar. Note the absence of any residual rock fabric and the presence of a map crack pattern of shrinkage cracks. The paste at the margins locally diffuse into the surrounding fabric with lime from the inclusion folding around peripheral aggregate particles.
Field of view 2.4mm.

Lime Hydrate Mortars – Hydrate: Sand mixes

This form of mix is not normally encountered in historic stone masonry mortars, but it is not uncommon for characteristics typical of this form of binder to be found in brick masonry or in areas where air limes predominate where hot mixed mortars have been used cold in the form of "sand slaked and banked" mortars.

The inclusions in these mixes have a fabric and texture typical of dry hydrate inclusions, similar to the inclusions observed in modern Cement/Lime/Sand mortars and in some Lime mortars mixed using dry hydrate binders.

Any inclusions present tend to be rounded to irregular with a granular texture, with fine sand/silt coatings, where they have formed putty globules in the mix at time of mixing and placing. On probing, inclusions readily powder and show a granular texture and an irregular crack pattern, and occasionally form a dense calcite outer shell. Individual, or small clusters of sand grains can commonly be found within these inclusions

Determination of mix composition by Modal Analysis.

Modal analysis can be carried out on the thin sections by employing an automatic stage, fitted to the petrographic microscope, where the proportion of all materials within the section can be determined, along with the proportions of voids in the mortar. From this data the volumetric proportions of the mortar can be determined, and where inclusions are present, their proportion can be determined and the total lime content and the 'effective' lime content determined, i.e. that acting as a binder, excluding those contributing to the aggregate content.

Sample ref:	S1	S9	S5	S3
Type/Classificat	Origin	Origin	Early	Late
	% of Total Sample			
Quartz	40.0	32.6	11.0	41.1

Amphibole	11.0	16.8	21.0	
Limestone	7.8	4.0		2.0
Chert		1.0		2.0
Shell	6.0	11.9	12.6	
Feldspar			1.0	
Mica	Trace	2.0	1.0	
Quartzite		2.0	2.0	
Total Aggregate	64.8	70.3	48.6	45.1
Binder	28.0	23.7	49.0	50.6
lime inclusions	7.2	6.0	2.4	4.3
Binder	35.2	29.7	51.4	54.9
Secondary	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.	100.
Voids	20.0	28.0	5.0	5.0
Crack	Trace	0.0	0.0	0.0
Cracks/voids	20.0	28.0	5.0	5.0

Total Binder: Ratio by Effective Ratio by	1.0:1. 1.0:2.	1.0:2. 1.0:3.	1.0:0 1.0:1	1.0:0 1.0:1

Table No. 1: Modal analysis carried out on a selection of mortar sample from an old 13th church ruin on Gigha, an island off the West Coast of Scotland. Mortars taken from different periods of construction.

Lime Mortars

With all of the above, it can be concluded that in addition to determining the mix composition of a lime mortar it is also possible to determine the form in which a lime binder was used, and in some instances, it is may also be possible to establish if the mortar was placed as a hot mortar.

However, it requires a little practice and some study of typical examples to enable practitioners to hone their skills sufficiently to enable them to correctly identify the various forms in which lime binders were used. It is not difficult, but there will always be the requirement to employ more sophisticated examination techniques to confirm in which form the lime was used, particularly in leached, weathered and chemically altered mortars.

Selection of Materials

Is a modern Hot-Mixed Lime Mortar the Same as a Historic Mortar?

Not necessarily, and probably unlikely. Modern limes are burned primarily for other uses than for building or the construction industry, which takes a relatively low proportion of the annual production.
This means that most limes produced are very pure and the bulk of that available, to the construction industry, is supplied in the form of hydrated lime.

Although quicklime is now being supplied, both in powder and kibbled form, and on demand, in lump form, the material, however, is still very pure and is also possibly more reactive than that used by the early builders. This is likely to have been the case, in some areas up until the onset of the industrial revolution. This then needs to be considered when selecting quicklime for use in matching historic quicklime mortars and to provide a mortar that will perform, as the original, it may be necessary to consider gauging the mix with another material. This can either be an available pozzolan, Trass, Metakaolin, Ground Granulated Blast Furnace Slag, Pulverised Fuel Ash, Furnace Bottom Ask/Clinker, Crushed brick, Ground Tile, or a gauging with a hydraulic binder such as an NHL, Natural Cement, or Portland cement. That, however, would be for separate discussion.

Why would you want to use a Hot-Mixed Lime Mortar?

There are many reasons why a HMM should be considered for use in conservation and restoration works, these ranging from the purist philosophy of matching the original material, to minimising the carbon footprint of the project, in that in the production of quicklime the energy used is lower that that required for most other manufactured binders, and that most of the CO_2 evolved from the limestone during calcining in the lime production, is recovered and sequestered by the lime as it hardens and carbonates.
The making and use of quicklime as a common building material has been almost lost to the building industry in this country, and, by encouraging its consideration as an option, for use in conservation and restoration projects, this will re-establish both the understanding and use of the materials and regenerate the skills necessary for its successful use.

APPENDIX NINE

LIME READER, chronologically arranged.

EXCERPTED TRANSCRIPTIONS FROM HISTORIC TEXTS C160BC – 1964 AD

Cato (c160BC) De Agri Cultura

8 1 Build the lime-kiln ten feet across, twenty feet from top to bottom, sloping the sides in to a width of three feet at the top. If you burn with only one door, make a pit inside large enough to hold the ashes, so that it will not be necessary to clear them out. Be careful in the construction of the kiln; see that the grate covers the entire bottom of the kiln. 2 If you burn with two doors there will be no need of a pit; when it becomes necessary to take out the ashes, clear through one door while the fire is in the other. Be careful to keep the fire burning constantly, and do not let it die down at night or at any other time. Charge the kiln only with good stone, as white and uniform as possible. 3 In building the kiln, let the throat run straight down. When you have dug deep enough, make a bed for the kiln so as to give to it the greatest possible depth and the least

exposure to the wind. If you lack a spot for building a kiln of sufficient depth, run up the top with brick, or face the top on the outside with field stone set in mortar. 4 When it is fired, if the flame comes out at any point but the circular top, stop the orifice with mortar. Keep the wind, and especially the south wind, from reaching the door. The calcining of the stones at the top will show that the whole has calcined; also, the calcined stones at the bottom will settle, and the flame will be less smoky when it comes out.

If you cannot sell your firewood and faggots, and have no stone to burn for lime, make charcoal of the firewood, and burn in the field the faggots and brush you do not need. Where you have burned them plant poppies.

14 1 If you are contracting for the building of a new steading from the ground up, the contractor should be responsible for the following:— All walls as specified, of quarry-stone set in **mortar**, pillars of solid masonry, all necessary beams, sills, uprights, lintels, door-framing, supports, winter stables and summer feed racks for cattle, a horse stall, 2 quarters for servants, 3 meat-racks, a round table, 2 copper boilers, 10 coops, a fireplace, 1 main entrance and another at the option of the owner, windows, 10 two-foot lattices for the larger windows, 6 window-shutters, 3 benches, 5 stools, 2 looms, 1 small mortar for crushing wheat, 1 fuller's mortar, trimmings, and 2 presses. 3 The owner will furnish the timber and necessary material for this and deliver it on the ground, and also 1 saw and 1 plumb-line (but the contractor will fell, hew, square, and finish the timber), **stone, lime, sand, water, straw, and earth for making mortar.** If the steading should be struck by lightning an expiatory prayer must be offered. The price of this work from an honest owner, who furnishes duly all necessary materials and pays conscientiously, one sesterce per tile. 4 The roof will be reckoned as follows: On the basis of a whole tile, one which is one-fourth broken is counted two for one; all gutter tiles are counted each as two; and all joint-tiles each as four.
In a steading of stone and mortar groundwork, carry the foundation one foot above ground, the rest of the walls of brick; add the necessary lintels and trimmings. 5 The rest of the specifications as for the house of rough stone set in mortar. The cost per tile will be one sesterce. The above prices are for a good owner, in a healthful situation. The cost of workmanship will depend upon the count. In an unwholesome situation, where summer work is impossible, the generous owner will add a fourth to the price.

15 1 Construct the enclosure walls of mortar, rough stone, and rubble (the owner furnishing all the materials) five feet high, 1½ feet thick, with a one-foot coping, 14 feet long, and let out the plastering. If he lets the walls of the steading by the hundred feet, that is, ten feet on every side, 5 libellae to the foot, and 10 victoriati for a strip one foot by ten. The owner shall build the foundation 1½ feet thick, and will furnish **one modius of lime and two modii of sand for each linear foot.**
16 1 The following are proper terms of a contract for burning lime on shares: The burner prepares the kiln, burns the lime, takes it from the kiln, and cuts the

wood for the kiln. The owner furnishes the necessary stone and wood for the kiln.

Vitruvius (30-20 BC) *Ten Books on Architecture*. Translated by Rowland I D; eds Rowland I D & Howe T N (1999) Cambridge University Press.

Xiii Translators Preface.

No translator can approach Vitruvius without making hard choices about individual words in a text that has come down from antiquity with significant alterations. All of the surviving medieval manuscripts have many confusing or nonsensical passages and impossible – or missing – numbers for the dimensions of buildings, aquaducts and machines. From 1511 onward, however, readers of Vitruvius could avail themselves of a printed text in which many of these errors had been corrected by a brilliant process of guesswork. The editor of this printed Vitruvius was an Italian monk, Fra Giovanni Giocondo da Verona, who had worked both as a classical scholar and a practicing architect in Italy and France; he was one of the few people in the Renaissance, and one of the few people ever afterward, who had the range of experience to understand every aspect of Vitruvius's text and therefore to anticipate what might have been misread as generations of scribes copied down the Ten Books with all too human fallibility….the notes to the present translation show how often the Veronese monk seemed to be the first reader in fifteen centuries to understand what Vitruvius must really have said.

P21

BOOK 1.

THE PRINCIPLES AND THE LAYOUT OF CITIES

Chapter 1: The Education of the Architect.

1. The architect's expertise is enhanced by many disciplines and various sorts of specialised knowledge; all the works executed using these other skills are evaluated by his seasoned judgment. This expertise is born both of **practice** and of **reasoning**. Practice is the constant, repeated exercise of the hands by which the work is brought to completion in whatever medium is required for the proposed design. **Reasoning,** however, is what can demonstrate and explain the proportions of completed works skilfully and systematically.
2. The architects who **strove to obtain practical manual skills but lacked an education have never been able to achieve an influence equal to the quality of their exertions;** on the other hand, those who placed their trust entirely in theory and in writings seem to have **chased after a shadow, not something real.** But those who have fully **mastered both skills,**

armed, if you will, in full panoply, those architects have reached their goal more quickly and influentially.

P22 3) (the architect) ought to have a native talent, and be amenable to learning the disciplines (of the profession). For neither native talent without learning nor learning without native talent create the master craftsman.

BOOK 2

BUILDING MATERIALS

(Section on mud brick masonry, of which Vitruvius approves and declares to be common).

P36. Chapter 4. Sand for Concrete Masonry

1. In concrete structures one must first enquire into the sand, so that it will be suitable for mixing the mortar and not have any earth mixed in with it…the type that crackles when a few grains are rubbed together in the hand will be the best, for earthy sand will not be rough enough.

(pit sand is the best; river sand next; beach sand the least good, mortars made with it being slow to set up and if used for walls and then plastered, the wall will 'give off salt and dissolve the surface)…

2. Excavated sands, on the other hand, dry quickly in construction, and the plastering stays in place…(but should be freshly quarried) (p37)…But even though newly excavated sands have so many virtues in construction, they are not useful for plaster precisely because in mixing with lime, because of its own density, and with **straw,** it cannot dry without cracks, it is too intense. Although its fine grain makes it useless in construction…, river sand, when flattened down by the action of a plaster float, acquires firmness for plasterwork.

Chapter 5: Lime for Concrete Masonry

1. Now that everything has been clarified about supplies of sand, then we must be careful about our lime, and whether it has been cooked down from limestone or silex (hard limestone). And that which is made from denser and harder stone will be useful in construction, and that made from porous stone, for plaster *[this notion, that the durability of lime was in direct relationship with that of the limestone from which it was made was accepted by all writers on lime hereafter, until Smeaton disproved it. As an idea, it persisted even then]*. **When it has been slaked, then the materials should be mixed so that if we are using excavated sand, three parts of sand and one of lime should be poured together.** *[Is this proportioned before slaking – when mixed by the 'ordinary' methods, this would be so, as Pasley insists it always should be, in 1826]*. If, on the

other hand, it is river or sea sand, **two parts of sand** should be thrown in with one of lime. In this way the rate of mixture will be properly calibrated. Furthermore, if one is using river or sea sand, then **potsherds**, **pounded and sifted,** and added to the mixture as a **third part,** will make the composition of the mortar better to use.

(Morgan translates this as:
….. After slaking it, mix your mortar, if using pit sand, in the proportions of three parts sand to one of lime; if using river or sea-sand, mix two parts of sand with one of lime. These will be the right proportions for the composition of the mixture. Further, in using river or sea-sand, the addition of a third part composed of burnt brick, pounded up and sifted, will make your mortar a better composition to use.)

2. When lime absorbs water and sand it reinforces the masonry. Evidently this is the reason: because stones, too, are composed of the four elements. Those which have more air are soft, those with more water are dense with moisture, those with more earth are hard, those with more fire are more friable. Because of this, if we take this stone before it has been cooked, pound it fine and mix it with sand in masonry, it will neither solidify nor bond. If, on the other hand, we throw it into the kiln, then, caught up in the flame's intensity, it will shed its original property of hardness, and with its strength burned away and sucked dry, it will be left with wide-open pores and voids. Therefore, with its air and water burned away and carried off, it is left with a residue of latent heat. When the stone is then plunged in water, before the water absorbs the power of its heat, whatever liquid enters into the pores of the stone boils up, and thus by the time it has cooled it rejects the heat given off by lime.
3. Therefore, whatever the weight of stones when they are cast into the furnace, they cannot have retained it by the time they are removed, when they are weighed, although their size remains the same, they will be found to have lost a third part of their weight because of the moisture that has been cooked out of them. And thus, **because their pores and spaces lie so wide open, they absorb the mixture of sand into themselves and hold together; as they dry, they join together with the rubble and produce the solidity of the masonry.** *(This seems to describe hot mixing, despite what was said above].*

Chapter 6: Pozzalana for Concrete Masonry.

1. There is also a type of powder that brings about marvellous things naturally. It occurs in the region of Baiae and in the countryside that belongs to the towns around Mount Vesuvius. Mixed with lime and rubble, it lends strength to all the other sorts of construction, but in addition, when moles (employing this powder) are built into the sea, they solidify underwater. (Supposes this effect due to their having been affected by 'huge fires' beneath)…Hence, when these three ingredients

(lime, fired rubble and pozzalana), forged in similar fashion by fire's intensity, **meet in a single mixture, when this mixture is put into contact with water, the ingredients cling together as one and , stiffened by water, quickly solidify.** Neither waves nor the force of water can dissolve them. *{Once again, this reads as a description of hot mixing of lime concrete, with brick aggregate and pozzalanic sands].*

(Morgan:
There is a kind of powder which from natural causes produces astonishing results. It is found in the neighbourhood of Baiae and in the country belonging to the towns round about Mt. Vesuvius. The substance when mixed with lime and rubble, not only lends strength to buildings of other kinds, but even when piers of it are constructed in the sea, they set hard under water.

P38

4. [In building with pozzalana underwater] unlike and unequal entities that have been forcibly separated **are brought together all at once.** Then the moisture-starved heat latent in these types of ingredients, **when satiated by water, boils together, and makes them combine.**

P39

Chapter 8. Styles of Concrete Masonry.

1. These are the types of masonry: *reticulatum* ('network'), which is used by everyone now, and the old style which is called *incertum* ('random work'). Of these, the more attractive is reticulatum, but it is inclined to split apart because it has discrete seams and junctures in every direction. Rubble, in opus incertum, with stone sitting upon stone and sloping every which way, affords a masonry that is not pretty, but is more durable than reticulate construction.

2. Either type of masonry should be built up of the most fine-grained ingredients, so that the wall surfaces, **thickly saturated by a mortar of lime and sand,** will hold together longer. For soft and porous in nature, as they are, **they dry out by sucking the sap from the mortar.** When the supply of lime and sand superabounds, the wall surface, having more moisture, will not become feeble quickly, for it is held in bond by these two substances. As soon as the **moist power** has been sucked out from the mortar because of the porous structure of the rubble, the lime pulls away from the sand and dissolves; the stones, in turn, cohere with neither lime nor sand, and in the long run it makes for ruined walls. *[Vitruvius seems to saying that the slow carbonation of air lime mortars represents a structural advantage and that this is weakened once carbonation has occurred to full depth and throughout a solid wall…a radical notion].*

3. This can be observed, indeed, in some monuments that have been erected around the City of marble or squared stone. Inside they have been filled with rubble work, and with the mortar weakened by age and sucked dry by the porous nature of the tufa, they go to ruin…

4.For which reason, if one wants to avoid falling into this error, reserve a hollow zone in the middle of the wall along the orthostates *[the backs of the independent skins of masonry should be as upright as the faces of the same, leaving a clean cavity]*. On the inside, two-foot walls should be constructed of squared Anio tufa or terracotta or split stone, and along with these the front surfaces should be linked by iron clamps and lead. For in this way the work is not heaped but coursed, forever flawless, because the beddings and joins, settling with one another and bound together at the seams, will not bulge the masonry outward, nor do they allow the orthostates (which are clamped together) to slip out of place.

[It is not the mortar which is at fault here, but the form of construction, with an almost independent rubble core, little attached to the facing masonry, as the below indicates:]

5. Therefore the masonry of the Greeks is not to be condemned. They do not use a surfaced masonry of soft rubble, but whenever they depart from building with ashlar blocks, they lay courses of split stone or hard flagstone, and bind the joints together in alternate layers just as if they were building in brick, and thus they achieve powers of durability for the walls such as they will last an eternity. (p40) They construct these walls in two types….one is isodomic, the other…pseudoisodomic.
6. Masonry is called isodomic when all the layers are constructed of an equal thickness; pseudoisodomic when the rows are alternating, and unequal layers are preferred. Both of them are durable for these reasons: first, because the flagstones themselves are of a dense and solid nature and will not, therefore, suck the moisture out of mortar, instead, **they preserve its moisture intact** even to the greatest age. And similarly, because the bedding for this masonry has been planed and levelled, it does not allow the mortar to settle, for it is bonded all along to the thickness of the walls, held in place to the greatest age.

P73 Chapter 12.

Ports.

…This is how harbour enclosures should be designed. The masonry that will be underwater should be made by bringing in that powder (pozzalana)…this should be mixed **two-to-one** as if with a mortar and pestle. 3. Then, in the place that has been marked out for the purpose, caissons of oak planks, bound in chains, should be sunk into the water and set firmly in place. Then, within their (p74) perimeter, from small crossbeams, the lower part should be levelled underwater and dredged out, and the place should be heaped up with pounded rubble, and the mortar mixed as has been described, until the space between the caissons has been entirely filled…

BOOK 7 – FINISHING.

P87 Chapter 1 Flooring.

P88…When the decking is finished in an upper story, it should be strewn with fern, or otherwise with straw, so that the woodwork will be protected from damage by lime. 3. Above this the underlayer is set down a layer of stones no smaller than can fill the hand. Once the underlayers have been installed, if the rubble for the sub-pavement is new, then mix it **three to one with lime;** if it is re-used, then the mixture should be **five to two.** Then the sub-pavement is laid in with wooden rods by ten-man work gangs, and compacted by steady pounding. By the time the pounding is done, it should be no less than a *dodrans* (three-quarters of a foot) thick. Above this, a core of **crushed terracotta** should be installed, **mixed three-to-one with lime,** and it should be no less than six digits thick. Above the core the pavements should be laid to the square and to the level, whether they are in stone inlay or mosaic….

…Pavements in Tiburtine herringbone tile work should be carefully executed so that they have neither protruberances nor ridges, but are uniform and polished on the level. Above this, once the floor has been ground with rough and fine polish, powdered marble is sprinkled over it, and coats of lime and sand are laid down over this.

Chapter 2 Plasterwork

1….This will be done properly if clods of first-rate lime are softened **long before there is need for them**. *[This is the first time Vitruvius discusses laying down slaked lime before use – in the context of plastering, not general building].* If a clod is baked lightly in the kiln, then, as it is softened over many days, the remaining liquid, forced to boil away, will bake the clod to an even degree *{the lime is being slaked to a stiff paste].* If it has not been softened all the way through, but is used when only recently fired *[he does not say when recently slaked, which may suggest hot mixing]* then, when applied, it will develop blisters, because it has **raw grains hidden inside.** If these grains are put into the work without having been softened to an even degree, they dissolve and break apart the finish of the plasterwork.

(Morgan's translation reads quite differently:

Book VII -Chapter II The slaking of Lime for Stucco
….if the best lime taken in lumps, is slaked a good while before it is to be used, so that if any lump has not been burned long enough in the kiln, it will be forced to throw off its heat during the long course of slaking in the water,…. When it is taken not thoroughly slaked but fresh, it has little crude bits concealed in it, and so, when applied, it blisters. When such bits complete their slaking after they are on the building, they break up and spoil the smooth polish of the stucco.)

3. If the softening has been done reasonably, and the work is to be prepared with care, take an axe, and chop through the softened lime to its core as it lies in the pit, just as if it were wood being chopped. If the axe meets with granules, (p89) then the lime is not yet ready. When the tool comes through dry and pure, it indicates that the lime is weakened and parched. When it is rich and properly softened, then, clinging all around that tool like glue, it shows that it has been tempered in every respect. Then get the machines (the editors suggest this means scaffolding) ready and set the ceilings of the rooms…*[No mention is made of mixing this lime with sand – as it is for the walls.}*

*(*Description of preparing the background of ceilings, with battens to receive 'Greek reed'. The tops of the ceilings to be sealed with 'a mortar of lime and sand')….Once the ceilings have been laid out and interwoven, their lower surfaces should be plastered, then sanded, and then polished with chalk and marble.

[It seems very likely that the lime prepared as above is to be used for ceilings without any addition of sand. When discussing the plastering of walls – below – sand and lime *mortars are specified, with a base coat of 'rough plaster. There is no specific indication that all lime for all aspects of plastering should be laid down to mature (or rather, to fully slake) other than the finish (and only) coat on ceilings and, it may be presumed, those for the three marble finish coats detailed below. This passage was translated thus by Morgan Hickey:* But when the proper attention has been paid to the slaking, and **greater pains have thus been employed** in the preparation for the work, take a hoe, and apply it to the slaked lime in the mortar bed just as you hew wood. If it sticks to the hoe in bits, the lime is not yet tempered; and when the iron is drawn out dry and clean, it will show that the lime is weak and thirsty; but when the lime is rich and properly slaked, it will stick to the tool like glue, proving that it is completely tempered*]*.

When the ceilings have been polished, then crown moldings should be placed underneath them, which ought to be as slender and fine as possible, for if they are large, they will be pulled down by their weight and unable to stay in place. For these, **gypsum is the last thing one wants to mix in;** instead, they should be composed of marble sifted to a uniform consistency, **so that one part will not anticipate the other in drying, but the whole will dry at a uniform rate…**5. Once the crown mouldings have been put in, **the walls should be plastered as roughly as possible,** and afterward, when the plaster is nearly dry, the layers of sand mortar should be applied so that the planes of the walls are flat and on the level, their rise on the perpendicular and their corners at right angles…As the plaster dries, a second and third layer should be applied. Thus the more solid the levelling produced by sanding, the sounder the solidity of the frescoes, and the more durable. 6. If no fewer than three layers of sand mortar have been applied, in addition to the rough plastering *{which may even be of earth, perhaps]*, then coats of large-grained powdered marble should be applied and levelled, so long as the material is of this consistency: when it is being worked, it never clings to the trowel, but instead allows the tool to come free when it is removed from the mortar. Once the layer of large-grained marble powder has been applied and is drying, then another layer of medium-grained powder should be laid on. When this has been worked and sanded down well, then a layer of fine-grained marble dust should be applied….

P90. 10. The Greek plaster makers not only create long-lasting work according to these principles, but they also do this: **when the mortar trough has been set in place, with the lime and sand poured together into it,** they bring in ten-man work gangs who pound the mortar with wooden pestles, and they use it after it has been vigorously worked by these teams.

Chapter 4 Plasterwork in Damp Locations.

…For rooms on ground level, instead of sand mortar, terracotta sherds should be rough plastered and applied up to a height of three feet above pavement level, so that these parts of the plaster will not be damaged by moisture.

(If constantly damp, then a cavity wall should be built with a drainage channel at its base and weep holes to the outside and ventilation holes higher up.)…

Then the walls should be whitewashed with lime dissolved in water, so that they will not reject the terracotta rough plastering, for because of the dryness induced in the tiles by baking them in the furnace, they cannot absorb the rough plastering nor hold it in place unless the addition of (p91) lime glues each component together and forces them to join. Once the rough plastering has been laid on, with broken terracotta in place of sand, then everything else should be completed as has already been described in the instructions for plastering.

Correctness in Painting, Winter Dining Rooms.

…This form of decoration for the pavements, used by the Greeks for their winter dining rooms, will give not unattractive, not to mention inexpensive and useful, results: underneath the level of the dining room one should excavate to a depth of about two feet, and when the soil has been packed down, either lay in a rubble underpavement or a terracotta pavement, sloped so that it has openings onto a channel. Then, onto coals that have been trampled to compactness, a **mortar mixed of gravel and lime and ash** should be laid to a thickness of half a foot. The topmost layer, planed to the rule and the level by polishing with a whetstone presents the appearance of black pavement.

Pliny the elder (23-79 AD) The Complete Works of Gaius Plinius Secundus Delphi Classics ebook (2015) Hastings. Delphi Classics Publishing

BOOK XXXV

Chapter 48 (14)

…Have we not in Africa and Spain walls of earth, known as 'formaeoan' walls, from the fact that they are moulded, rather than built, by enclosing earth within a frame of boards, constructed on either side. These walls will last for centuries, are proof against rain, wind and fire, and are superior in solidity to any cement…what person, too, is unacquainted with the fact that partition walls are made of hurdles coated with clay and that walls are constructed of unbaked bricks?

Chapter 49

Walls of Brick, the Method of Making Bricks

Earth for making bricks should never be extracted from a sandy or a gravelly soil, and still less from one that is stony; but from a stratum that is white and cretaceous, or else impregnated with red earth. If a sandy soil must be employed for the purpose, it should at least be male sand, and no other. The spring is the best season for making bricks, as at midsummer they are apt to crack. For building, bricks that are two years old are the only ones that are approved of; and wrought material of them should be well macerated before they are made.
There are three different kinds of bricks; the Lydian, which is in use with us, a foot-and-a-half in length by a foot in breadth; the tetradon and the pentadoron…These last two kinds…are named respectively from their being four and five palms in length, the breadth being the same. The smaller kind is used in Greece for private buildings, the larger for the construction of public edifices….the Greeks have always preferred walls of brick, except in those cases where they could find silicious stone for…building, for walls of this nature will last forever….At Rome there are no buildings of this description, because a wall only a foot-and-a-half in thickness would not support more than a single-story; and by public ordinance it has been enacted that no partition should exceed that thickness…

BOOK XXXVI The Natural History of Stones

Chapter 52 Cisterns

Cisterns should be made of **five parts of pure, gravelly sand, two of the very strongest quicklime,** and fragments of silex (*finely ground silica stone, such as flint)* not exceeding a pound each in weight; when thus incorporated, the bottom and sides should be well beaten with iron rammers…

Chapter 53 Quick-lime

Cato the Censor disapproves of lime prepared from stones of various colours: that made of white stone is the best. Lime prepared from hard stone is the best for building purposes, and that from porous stone for coats of plaster. For both these purposes, lime made from silex is equally rejected (hydraulic lime?). Stone that has been extracted from quarries furnishes a better lime than that collected from the beds of rivers; but the best of all is the lime that is obtained from the molar-stone, that being of a more unctuous nature than the others. It is something truly marvellous, that quicklime, after the stone has been subjected to fire, should ignite on the application of water!

Chapter 54 The Various kinds of sand, the combinations of sand with lime

There are three kinds of sand: fossil sand, to which one-fourth part of lime should be added; river sand; and sea-sand; to both of which last, one third of lime should be added. If, too, one third of the mortar is composed of bruised earthenware, it will be all the better….

Chapter 55 Defects in Building. Plaster for Walls.

The great cause of the fall of so many buildings in our City is that through a fraudulent abstraction of the lime, the rough work is laid without anything to hold it together. The older, too, the mortar is, the better it is in quality. **In the ancient laws for the regulation of building, no contractor was to use mortar less than three months old; hence it is that no cracks have disfigured the plaster coatings of their walls.** These stuccos will never present a sufficiently bright surface, unless there have been three layers of sanded mortar, and two of marbled mortar upon that. In damp localities and places subjected to exhalations from the sea, it is the best plan to substitute ground earthenware mortar for sanded mortar. In Greece, it is the practice, first to pound the lime and sand used for plastering, with wooden pestles in a large trough. The test by which it is known that marbled mortar has been properly blended, is its not adhering to the trowel; whereas, if it is only wanted for white-washing, the lime, after being well-slaked with water, should stick like glue. For this last purpose, however, the lime should only be slaked in lumps.

At Elis, there is a Temple of Minerva, which was pargetted, they say, by Panaenus, the brother of Phidias, with a mortar that was blended with milk and saffron: hence it is, that, even at the present day, when rubbed with spittle on the finger, it yields the smell and flavour of saffron.

Chapter 58 Maltha

Maltha is a cement prepared from fresh lime; lumps of which are **quenched in wine,** and then pounded with hogs' lard and figs, both of them mollifying substances. It is the most tenacious of all cements, and surpasses stone in hardness. Before applying the maltha, the substance upon which it is used must be well rubbed with oil.

Chapter 59 Gypsum

Gypsum has a close affinity with limestone, and there are numerous varieties of it. One kind is prepared from calcined stone, as in Syria…for example….In Syria they select the hardest stones for the purpose, and calcine them with cow-dung, to accelerate the process…Gypsum when moistened must be used immediately, as it hardens with the greatest rapidity…It is very useful for pargetting, and has a pleasing effect when used for ornamental figures and wreaths in buildings….

Chapter 62 Terrace-Roof Pavements

The Greeks have also invented terrace-roof pavements…In making these…the proper plan is to begin with two layers of boards, running different ways, and nailed at the extremities, to prevent them from warping. Upon this planking a rough-work must be laid, one-fourth of which consists of pounded pottery; and upon this, another bed of rough-work, two-fifths composed of lime, a foot in thickness, and well beaten down with the rammer. The nucleus is then laid down, a bed six fingers in depth, and upon that, large square stones, not less than a couple of fingers in thickness, an inclination being carefully observed, of an inch and a half to every ten feet. This done, the surface is well rubbed down with a polishing stone….Wheat-ear tessellated pavements are laid down in a similar manner.

Chapter 63 Graecian Pavements

The ground is well rammed down, and a bed of rough work, or else broken pottery, is then laid upon it. Upon the top of this, a layer of charcoal is placed, well trodden down with a mixture of sand, lime and ashes; care being taken with line and rule to give it a uniform thickness of half a foot. The surface then presents the ordinary appearance of the ground; but if it is well rubbed with the polishing stone, it will have all the appearance of a black pavement.

Sextus Julius Frontinus (40-103 AD) De aquaeductae Urbis Romae Translation Bill Thayer
http://penelope.uchicago.edu/Thayer/e/roman/texts/frontinus/de_aquis/text*.html
Also Rogers B (2003) Sextus Iulius Frontinus On the Water-Management of the City of Rome University of Vermont

123. Repairs that should be executed without cutting off the water consist principally of masonry work (*Rogers says 'concrete work'),* which should be constructed at the right time, and conscientiously. **The suitable time for masonry work is from April 1 to November 1, but with this restriction, that the work would be best interrupted during the hottest part of the summer, because moderate weather is necessary for the masonry properly to absorb the mortar, and to solidify into one compact mass; for excessive heat of the sun is no less destructive than frost to masonry.** Nor is greater care required upon any works than upon such as are to withstand the action of water; for this reason, in accordance with principles which all know but few observe, honesty in all details of the work must be insisted upon.

125. "The consuls, Quintus Aelius Tubero and Paulus Fabius Maximus, having made a report relating to the restoration of the canals, conduits, and arches of Julia, Marcia, Appia, Tepula, and Anio, and having inquired of the Senate what it would please to order upon the subject, it has been RESOLVED: That when those canals, conduits, and arches, which Augustus Caesar promised the Senate to repair at his own cost, shall be repaired, **the earth, clay, stone, potsherds, sand, wood, etc., which are necessary for the work in hand,** shall be granted, removed, taken, and brought from the lands of private parties, their value to be appraised by some honest man, and each of these to be taken from whatever source it may most conveniently and, without injury to them, remain open and their use be permitted, as often as it is necessary for the transportation of all these things for the purposes of repairing these works."

Medieval

Colvin HM (1971) Building Accounts of King Henry III. London. Oxford University Press.

Dover Castle 1220-1221

P31 *On Saturday, that is on the day of the Beheading of St John the Baptist [29 August] a payment was made by the …overseers.*

To slake 200 loads of lime and quench them…By task the slaking of each hundred costs 32d.
And to remove lime from Peverell's Gate to the adjoining chamber…
And to Robert of Whitfield for 10 days…
And to William of Colchester for 10 days…
And to Copin, mason, for 10 days…
And to Ralph Albespine, mason, for 3 days…

P47 *Payment made on the vigil of Whitsun [29 May] in the 5th year of the reign of King Henry.*

For 155 boat-loads of small stones brought from Folkestone to Dover…
And for 6,300 loads of sand and stone carried…
And for portage of 207 loads of lime from the kiln to the work…
And for portage of 200 loads of water…
And for breaking chalk up into small pieces for two kilns made by us below the cliff, that is for 157 loads…
And to Robert Whitfield, mason, for 3 days
And to Copin, mason, for 8 days…
And to Simon, mason, for 5 days…
And to Eilmer, mason for 8 days
[and to six other masons for 8 days]….
And for one sieve bought for the works of Dover Castle…
And for slaking 225 loads of lime
And to two men watching over the aforesaid lime kilns for 3 nights…

P49 & 51 *On the vigil of St John the Baptist [23 June] a payment was made for the works of Dover Castle.*

…To Richard Portefer for 300 loads of lime…
And for portage of 300 loads of lime…
And for slaking 300 loads of lime
[And for 12 masons for between 3 and 16 days each].

Winchester Castle 1222

pp137/139 *And paid on Sunday next before the Invention of the Holy Cross [1 May] for things needed to repair the castle obtained during the week immediately preceding*
…for wood for the kiln…
for one bowl and two buckets…
for withies *[for scaffold hurdles]…*
for 12 boards to make barrows…

for one hare-skin for bellows…
for cement…
to (a brother) who went to London to the Bishop of Winchester to obtain masons…
for one box to measure lime…
to Adam the lime-man for making one kiln…
to Godfrey of St James, in whose land chalk is dug for the kiln…
to Geoffrey Black for 3 sesters of lime…

The week in the same year (1222) containing the feast of the blessed Mary [8-14 September].

Note concerning the Treasury doorway.

For the wages of a mason repairing a certain doorway in the tower…For the wages of two masons doing the same for the same period…
For wages of a labourer to serve the said masons in the castle for the whole week…
For three carts to carry water and chalk during the week…For the purchase of 30 sesters of lime…for 40 potts of red sand…for 100 potts of white sand…For two cart-loads of brushwood to found lead for the clamps of the tower…For withies bought for scaffolding.

Westminster Palace 1259

First payment

For Lime. and to fell and carry to the water the old oaks in Windsor Forest with which lime will be made for the works…

[Second Payment – mainly for stone-cutting, in case of masons. No payments associated with lime].

Third payment

Lime. And for 3 hundredweight and a half of lime for the said chimney and lavatory bought from Agnes the lime-burner of London…

Sand. And to Richard the Cellar for 36 cart-loads of sand dug and carried by task. And to Robert of Bridge (for similar).

Fourth payment

[payments to 'layers and setters' as well as to masons].

Lime, Sand. And to Agnes the lime-burner for three hundredweight of lime for the said gutter and cistern….And to Ralph of Bridge for 25 loads of sand…To the same for 75 loads of sand…And for mortar of lime and sand bought of dom. Hugh of St Albans the monk….

'sester' = a quarter or 8 bushels. Quarter is ¼ of a hundredweight.

Turton R B (1895) The Honour and Forest of Pickering London North Riding Record Society

Cost of the New Hall. (within Pickering Castle) Clearing, digging and levelling the place within the castle where the bakehouse was burnt to build there a Hall with a chamber—**building the stone walls of the Hall and chamber, getting and carrying 400 cartloads of stone, digging and carrying soil for mortar, buying 27 quarters of lime**—contract for joiners' work, wages for those employed to saw planks and joists, 152 planks for doors and windows, 80 large spikes, 600 spike nails, 1000 broadheaded nails and 20,000 tacks, 22 hinges for the doors, 28 hinges for the windows and 2600 laths with carriage for the same—lid-roofing the buildings with thin flags by piece-work, collecting moss for the same, **plastering the floors of the upper room and several walls within the chamber, making a chimney piece of Plaster of Paris,** together with the wages of the chaplain who was present at the building —

1313-1314 Duchy of Lancaster Records MINISTERS' ACCOUNTS, Bdle. I. No. 3

Ibid Vol IV

New Work round the Castle Barbican. **Wages of masons, quarrymen, carpenters, limeburners,** carts hired for carrying stone and sand and other men working about the walls and ditches of the barbican and the foundations of the walls, with iron and steel purchased, and the wages of smiths working the iron and steel into hinges and several tools for masons and quarrymen, and in several times sharpening and repairing the same tools, and in the purchase of nails, scaffolding [?] and sundries for the work as appears in two indentures with particulars made against John de Bulmer, Thomas le Taillour and Ralph de Morton—£278 16s 10 ½ d

Browne J (1862) Fabric Rolls and Documents of York Minster. York. Surtees Society.

Excerpts relating to lime.

*[There were limekilns on site. Limestone was brought to site – some of it oolitic limestone; more of it magnesian limestone. No explicit payments for mortar mixing or lime slaking except in the final account of 1581 when there is an entry for **sleckinge, beatinge, and siftinge of lime**, indicating hot mixing/dry slaking].*

1371
Outgoings for lime. 206 'mel' (mel. Miel. Miell/mele must mean 'load') of lime (stone) 8s. And 144 mel of lime(stone) carried, given for the mel (per mel) 2d.

1399
2 loads of lime(stone) sold to Master John Staynton for 2s 8d.

Lime expences. For 3300 wall tiles (bricks) with carriage…and for 18 chaldrons of sea coal, and carriage for the same. And for emptying said lime kiln by employed workers with 3 'terbarell' (wheelbarrows?)…and the expense concerning the burning of the same 'toralis' (kiln) overseen by Hugo Hedon. Total 114s 9d.

C1400
And in 15 chaldrons of sea coal, paid for transport: 65s. And in expenses in burning lime, per annum 8s 7d. And in 60 loads lime(stone) paid to Thomas Terry and his (mates) for transport (including tolls?) …Total: 71s 10d

For sand from Hugo Carrier 118s

1405
For 13 chaldrons of sea coal for the lime kiln, with carriage 65s 3d. And for 67 loads of limestone, with carriage £4 16s 9d

1415
Lime Expences: For 19 chaldrons of sea coal paid to William Leming 74s 8d. In carrying said coal to the cemetery *(the masons yard was in the cemetery),* 9s 4d. And for 1000 (M) faggots (ascelwod) paid to John Leming 21s 6d….In expence of firing the lime kiln (?) 14d.

Sand costs: In carrying 400 sarcinarum (sacks) of sand from Clementhorpe to the Monastery 22s 6d (sand taken from the Ouse).

1418
Lime costs. For 30 loads of limestone to Robert Spalmon 28s 4d. In carrying the same to the Cloister 7s 6d. For 10 chaldrons of sea coal, 50s. In carrying the same 6s 8d. For 9 chaldrons of sea coal, 45s. In carrying the same to the Monastry 6s 8d. For faggots, paid to Robert Crake 28s 10d. Actual cost of burning the lime 3s 2d. Total £8 16s 2d.

Sand cost: For carrying 430 (sacks) of sand from Clementhorpe to the Monastry to John Garton 21s 4d

1419
Lime Costs. For 16 loads of limestone, to the vicar of Broghton (Broughton, near Malton). For 6 chaldrons of sea coal, to John Hall 26s. In carrying the

same to the cemetery, 3s. For 8 chaldrons of sea coal, paid to the said John 32s. For 1000 faggots to John Bouland for carriage 25s. The expense of each burning (charge) of the kiln 18d. Total 109s 10d.

For 2 casks of plaster (of Paris) to Richard Plasterer, 6s. For 7 casks of plaster, to John Hegges 14s 8d. For 6 casks of plaster, to John Sale de Morton 15s.

1421
For 45 loads of lime(stone) paid to John Sawmon of Broughton, for carriage 12d, 45s. For 55 quarters of lime, paid to Robert Wodd and Adam Ryche of Shirburn 25s *(if Sherburn in Ryedale, this will be chalk lime; if Sherburn near Tadcaster, it will be dolomitic)*. John Newton, Alan Couper, Richard Foxholes and Robert Lumby for carriage of said lime from Shirburn to the limehouse of St Peter's in the Cloister 26s. Total £4 16s.

For 9 casks of plaster, to Walter Hales of Gainsborough, 27s. To John Kirkham tiling and plastering 68 days, 34s 3d. To John Pulane tiling and plastering for 75 days….

1433
Cost of plaster and lime and tiling, 29s 10d. For 11 casks of plaster 29s 10d….For 23 carts of quicklime bought in Tadcaster, with carriage 70s 9d.

1471
To John Smith of Buttercram for one quarter and 2 bushels of plaster 2s 6d

1479
Plaster cost. To John Ryther of Gainsborough for 6 casks of plaster bought plus stallage 16s. John Forman of Selby for 9 casks of plaster 22s 6d. And John Botrell of Buttercram for 2 quarters of plaster 3s 8d.

1516
Costs of (hemp?), plaster and lime….Robert Bawmebrugh for (?) quarters of plaster, 6 modus and (?) quarters and 7 bushels of gypsum 5s 4d. Nicholas Pullan for 8 quarters of (quick)lime, a man of Tadcaster for 1 load of lime; Nicholas Pullan for 4 quarters of lime and 2 quarters 17s.

1519
Haulage of lime and gypsum bought. Barnard Pavar for two loads of lime(stone) 3s 4d. And for 3 loads lime(stone) 9s 6d. For 2 loads (quick)lime bought in Tadcaster, 15s 6d. For 4 quarters gypsum bought from Robert Bawmeburgh 8s. For 2 casks of uncalcined gypsum 5s 4d. For one cask 3s. Total 38s 6d

The accompte of Stephen Streate, clerk of the workes, prom 1 Jan. **1580** to 1 Jan. **1581**. For a dosen and a half of cotrelles to the glasse windowes, 2s. For two longe yron gaddes for stayinge of a pynnacle of the churche, lis. For mendinge a pynnacle on the north side the quere, 3s. 4d. To John Gell, tyler, in pavinge the grounde under the table in the quere, 10d. To two labourers helpinge to carie into the wright hous the greate standerdes from the glasse windowes, 4d. **For sleckinge, beatinge, and siftinge of lime, 9d**.

Stell P M (2003) York Bridgemasters' Accounts. York. York Archaeological Trust.

1435
…A tiler and his servant on the tenement of Davy Payntour and others…for lime…And for 400 waltyle in the tenement of Roger Joynour for a chimney…And for carriage of sand, lime and plaster…And for one mele and a half of lime…And for 27 bushels and three peckes of plaster for the same chimney…

1440

Conyngstrete. …And paid to John Sharow for three and a half bushels…and in firing a kilne of plaster in Castelgate…And paid to William Plumpton for carriage of twenty loads of lime, tiles and sand…And paid to various men for five tuns and a barrel of plaster at various times…

Castelgate. …William Plumpton for carriage of 25 loads of lime, sand and other things…And Robert Canmsmyth…**for le betyng of one kiln of plaster…And for 2000 turf for firing the plaster kiln in the aforesaid messuage…And to a labourer for betyng plaster in the same messuage…And paid to William Walker for dobyng…And paid for earth, litter, dobyng and water…**And to William Plumpton for carriage of forty loads of lime, sand and other things…**And to William Bouland, limeman, for five mele of lime**…And paid to William None for carriage earth and tiles…And to John Brigg for paving in Nessgate..And to William Plumpton for three loads of cobles.

1444

…And for firewood for burning plaster with carriage of the same…And for pounding of the same…And to Thomas Goodesalve, carrier, for carriage of three tuns of plaster…And to the same Thomas for twenty seams of lime and sand…And to Ralph Somer for two days burning plaster…And for repairing the tubes….

…For carriage of lime, sand and tiles…And to Richard Porter for carriage of lime…And for ashes of a chimney of John Herte and Joanna Guyl…And for lute and straw with working on the chimney of Elizabeth Bellows…

1445

…Paid for pounding of plaster…And paid for ashes of a chimney…Paid for carriage of three tuns of plaster…And paid…for carriage of 40 seams of sand and tiles…And paid,,,for carriage of three meles of lime…

1449

…To a man pounding plaster for one and a half days…And for 500 tiles…to tiler for 3 days…And his servant same time….And to John West for carriage of lime…And to Robert Hynderwell for carriage of thirty seams of sand…And to Thomas Killom for working on a barn in Holgate Lane for five days (and servant the same)…AAnd to Robert Hynderwell for carriage of **twenty two seams of sand and lute**…And to John Usburn for doubyng there for ten days…

1459

Paid to William Ball for piles…and for seven piles from John Forster…And paid for carriage of the aforesaid timber from the staithe and from a close of the monastery…And paid to Robert Fressell for stone flags bought and placed on the top of the aforesaid piles in the earth..And paid for a cart-load of lute bought for claying of the said piles and for repair of various walls of earth…And for wages of a labourer in claying of the same piles for half a day…And for wages of two carpenters for working and making the said post, somers, bandes and piles, and nailing of the floor of the said tenement there by the space of the foot of a man…And for wages given to John Forster, master carpenter, for his labour, advice and help…And paid for fifty sapplattes and **straw bought for mortar**…

1462

…And for wages for labouring and dobyng within the tenement of John Barneby…and paid for nine seams of lute carried to the same tenement…And paid for four bushels of plaster bought for the repair of a wall in the tenement of William Litwyn…And paid for a burdyn of lime there…

And for wages for labouring and dobyng within the tenement of John Barneby for three days…and paid for nine seams of lute carried to the same tenement…

1468

Paid to John Garnet for a cart-load of lime…and for six modii of plaister bought for repairs of a chimney…and for six bushels of plaister…and for 1000 walltiell…

Paid for carriage of seventeen seams of lute for doubyng…including 4d paid for straw bought for mixing with the same…And for wages for working and doubing…And paid to William Gayle for carriage of fifteen seams of sand to various tenements this year….

1472

Paid for three cart-loads of earth for repairs of a floor…And paid for two waggons of earth for repair of the daubed walls…And paid for straw for the same job…and paid for 50 lattes for the same job…And paid for two waggons of earth for repairs on the house in the tenure of John Barneby and the house of Michael Bradford…and paid for eighty laths for the same job…And paid to the same dawber for doubyng in the same house…And paid to two pavers for paving on Fossebrig…And paid for four carts of earth for the same paving…And paid for cobills for the same job.
(to the house of John Taillour and Isabel Santon)…for four bushels of lime…And paid to a tiler there for tiling on a houseof William Colstane..And paid for two seams of sand for the same job. And paid for 200 tiles for the same…And paid for 300 dawbing nailes…

And paid for construction of a chimney…and paid for a glass window…And paid for a modius of plaster for repairs of Isabel Santon…And paid to a plasterer plastering there…And paid for making a wall of earth in the house of William Fraunk…

1486

Stores Bought. And for various payments for two wagon-loads of burnt lime…And for 400 hartlaths price 7d per hundred…and for 700 saplaths at 6d per hundred…Nails, namely 1000 le double spikyng; 1000 mydel spikyng; 1000 skotchym; 1000 stanebrod…twenty four loads of lute…twenty loads of sand; 500 tiles for walling and for le rigge tiles. One quarter le playtre; three loads of stones; one pound of solder….

For various payments for dibyng for twenty-eight days…on various tenements…

1488

…And for purchase of a cart-load of lime bought for the store…And for the purchase of three cart-loads of lute called dobyng earth bought and used…And for the purchase of four quarters of plaister…And paid to James Broun for working and labouring for ten days in le dobyng in various tenements…

1462

Paid to John Spynk for three cart-loads of lime with 4s paid for carriage of the same and 8d for putting in le storehouse 10s 3d. And for five and a half tuns of plaister bought for a price of 2s 9d per tun plus 1d – 15s 6d

And for wages of Thomas Rymour, tiler, for working and repairing walls of plaster and tiles on the tenements of William Guislay.

(Repairs to the Bull)…and for lattes bought for the repair of various walls of earth there with 2s 8d paid to Robert Beltoft, labourer, for working and repairing several earth walls…And paid to Robert Cambyssh, paver, for working and paving the pavement in front of the said tenement…

And paid to John Botterell of Buttercrame for six bushels of plaister bought for the tenement of William Marsshall…And paid to John Savage for 800 hertlattes and 700 sapplattes…

Paid for four cart-loads of old timber….and they have paid …for three posts and new spares of timber for the same house…and paid to John Walus for two sele tre and a panpece *(ceiling beams and wall-plate)*. (Payments to carpenters)….**And paid to Thomas Plumpton for leading *sabulum* (sand) for twenty seams of earth and (daubing)…and paid to a man of Clifton for five cart-loads for daubing of a new house there and paid to John Pereson for daubing and leccyng of the said parclose in the *aula* there…And paid…for daubing the same new house by agreement made in gross. And paid to the same Thomas for working there three days receiving 4d in the day…And paid to William West for carriage of six loads of lyme for pergettyng of the same house…**And paid to Thomas Plumpton for five seams of cobles for the same job (in Gilligate). And for eight seams of wase for the same job there. **And paid for dung bought for daubing there…**

And paid to John Copper, sledman, for carriage of old timber…And paid for 30 (fagottes) with carriage of the same to the same kylns…And paid to Thomas Rymour, tiler, and his servant for working on the said kylns…And paid for 60 (words missing, probably loads of lime) and carriage of the same…and paid…for pounding of the same (lime, probably lump lime)….And paid to the same Thomas Rymour and his servant for making a plaster kiln (alabaster?)…And paid to James Porter for carriage of 60 loads of lyme…

1464

…For seven cartloads of lime bought of John Garnett…for the wages of James Porter for carriage and sledding of the same…For five tuns of plaster bought on le Stathe (of) a stranger at various times….

Paid for 3,300 thaktele…10s the thousand…And for 200 waltele (at 8d the hundred)…for 600 stanlattes…1,400 sapplattes…

Barn in Holgate. And for the wages of Nicholas Thornthwayte, carpenter, for working in the barn at Holgate…And paid to HJohn Copper for daubing for the walls there, 3d for each cart-load…And for wages of Robert Tynly, labourer, for working and repairing the earth walls there…

Skeldergate. …And for wages of William Tynly, labourer, for …daubing walls around the garden adjacent to the postern of the Friars Minor for ten days…for the wages of John Capper for whitewashing…And paid to John Capper for four cart-loads of daubing earth…And paid for straw and hay for daubing of the walls there bought from various men at various times…And paid in expenses made by Ralph Pullen, his servant James Porter for providing and leading a boat full of sand from the sandbed…namely in bread, beer and meats…And for wages of Ralph Pullen, tiler, and his servant for…tiling the house interior and making a wall called plastering for 18 days…

Bouthombarr. …for the wages of William Barley for working and labouring..in making earthen walls for two days….And for the wages of John Pereson and William Tyndale for…daubing in the tenement of Thomas Fournas for four days.

Fossgate with Fossbrygg….

For the wages of William Gaille and Andrew Blyth for carrying 326 seams of tiles, sand, lute ('liquid clay or cement used to seal a joint') and wase (bundle of hay or straw)…And to the same…for 45 seams of coble for le paving at various places this year…And for wages of John Plompton for leading sand…And to James Johnson, porter, for 146 pounds of lyme and plaster at various places this year…

Simpson D. (1960) The Building Accounts of Tattershall Castle 1434-1472. The Lincoln Record Society.

1434-1435

Price of 74 cartloads of fuel, felled…in Tateshale chase for burning in 10 limekilns for the said works, to each kiln 7 ½ cartloads….

1438-1439

490,700 (bricks) called waltile made by Foys Brekmaker £69 5s 1 ½ d…Cash paid to Baldewyn Brekmaker for making 8000 of such bricks….Purchase of such bricks at my Lord's kiln at Boston, with their carriage….

Wages of masons called brekmasons…Wages of John Ramsey and his mates called roughbrekmasons…

Cost of making quicklime, including purchase of stones and charcoal, with carriage, £42 16s 5d

Wages of labourers…inclusive of board…and for carrying bricks, lime, sand and suchlike from the water into and outside the castle.

1439-1440

Purchase and carriage of freestones…Expences on the brick kiln….Carriage of timber, faggots, stone and coal by water…Expences on the lime kiln, with purchase of coal and fuel…Purchase, carriage and mixing of plaster of Paris…

Walker S (2010) Oxford Historical Society. Building Accounts of All Souls College Oxford 1438-1443. Oxford. Boydell Press.

1438

Lime, sand and red earth

224 quarters of (quick)lime, price per quarter, including carriage 20d. £17 13s 4d
And for 42 quarters of (quick)lime at 19d per quarter
And for 23 quarters of quicklime, at 18d per quarter.

And for 312 loads of sand, 2d per load
And for red earth with sand for making mortar

(Similar 1439)

1440

For lime. Bought this year 56 quarters of (quick)lime, price per quarter 16d.

And for 246 quarters 4 bushels of lime bought, price per quarter 17d.

Dawbers

To John Mirthe, dawber for 6 days at 5d a day and his assistant for 6 days at 4d.

(Numerous further entries for daubers).

1441

For lime.

64 quarters 1 bushel at 18d per quarter; 112 quarters and 1 bushel at 17d per bushel; 6 quarters at 16d per bushel.

For sand.

For carriage of 158 loads of sand from Brokenheys (gravel pit in Oxford) at 2d per load.

For clay

For 36 loads of clay bought for the interior walls of the College at 4d per load

1442 More lime purchased.

Still daubing.

Knoop D and Jones G P – The Medieval Mason, An Economic History of English Stone Building in the Later Middle Ages and Early Modern Times (1933 & 1967) Manchester University Press.

P44

Lime. – In some cases, as at Beumaris, Caernarvon, York and Eton, those responsible for building operations obtained limestone and burnt it to make the lime they required. In other cases, as at Vale Royal and Westminster, the authorities appear to have bought the *(quick)* lime ready for use. At the repair of Rochester Castle in 1368, the master of the works paid a lime burner for making and burning lime, the master of the works supplying the coal and the lime burner the chalk. At Kirby Muxloe Castle in 1480-4, large quantities of lime were purchased…but on one occasion lime burners were paid for burning lime…At York Minster, on the average of the first six complete printed fabric rolls, 1 ½ % of the total annual expenditure was incurred on lime. At Vale Royal Abbey in 1278-80, and at Rochester Castle in 1368, the cost of lime (including carriage) was almost exactly 2 ½ % of the total outlay…

Sand. - In several of the building accounts there is no reference to the cost of sand; presumably it could be dug practically on the spot *(as could earth)* by the labourers whose wages were charged to the general account. At Caernarvon in 1316-17, and at Beamaris in 1330, there are references to carting sand, and at Rochester Castle in 1368 to the purchase of a sieve for sifting sand and lime *(after hot mixing to a dry slake, presumably)*.

Salzman LF *Building in England Down to 1540, a Documentary History (1952)*

Wattle and Daub

'Torching' is one of the terms applied to this plastering with mud; as for instance at the Tower in 1278 - '*in arcillo empto ad torchiandum'* and in 1337. 'for torching the penthouse beside the smithy, with mud, laths and nails of the King's finding, 10s' *[this may be roof-work, of course]*. Sometimes other terms are used, as at Cambridge in 1486 - '*pro (4) bigatis de clay, 16s, item pro claying murorum 19s',* or at a lodge the New Forest in 1368, where two men were employed digging red earth *pro parietibus plastrandis',* though 'plastering' is usually applied to the finishing of a wall with plaster. The expression used at Bath in the 15th C was 'rudying' - as, for instance, 'for riding the old walls of the chancel' and '*pro casting de terra et rudyng'* of a house for which wattling had been made *[ruding is more likely to refer to the painting of the walls with raddle,* *it should be said, red pigment].* At Penshurst in 1470 there is a reference to radelyng and daubing the walls of the barn; and carriage of clay called '*lombe'* for the said work'. More often the word used is, in Latin, *'terrand',* which simply means earthing. For walls in Cambridge Castle, in 1267, we find 'splenteware' and ;batthes' bought, and wyttthes for binding them, and a payment 'to daubers for making the said walls and tearing the kitchen'. And in 1454, when a gable was made to a stable in Stamford, there were payments 'to a man 2 days teryng ye same gavel xd; for 2 lodes of earth to ye same warke 6d'. The common term, however is 'daubing'. As this is latinised indiscriminately as *dauband and dealband* and the workmen *as daubatores or dealbatores,* it is often impossible to be certain whether the process alluded to is daubing or whitewashing…At York in 1423 we find 200 stoures (stakes) provided for daubing over the kiln house, and also rods, templis, which are also rods, and withies, and similarly in 1531 at Durham rods and 'dalbyngstours' were bought for daubing above four fireplaces in St Giles Street. At Clarendon in 1480 payments are made for collecting rods and shredding them to make the walls in the new chamber, and for bredyng and dawbyng the same walls…'bredyng' is the braiding or wattling between these. Often in later times, laths rather than wattles were employed, as at Sutton in 1402, when Henry Dauber was paid 113s 4d for the lathing and daubing of the walls of certain houses re-erected there, or at Clare in 1347, when money was paid for the daubing of the countrelatthynge of a room, possibly implying laths on each side of the wall. …In 1341, there is a charge for daubing the king's room at Clare, on the outside and plastering it and for stopping cracks round the queen's room.

To make the earth, or mortar, adhere properly it was customary to mix with it some fibrous material such as hair, straw or hay. Palsgrave, writing in 1530, says that 'daubing may be with clay only, with lime plaster, or lome that is tempered with heare or strawe'; and two years later we find lxx stone of heare provided for the plasterers' at Westminster, and also 'cowheare to make mortar for dallbyng of walls,. In 1286 'white straw' was bought for plastering the walls of the hall in Cambridge Castle in 1375 at Leeds Castle, 8 cartloads of straw were bought for daubing the floors and walls of various buildings. In Ripon in 1454 we have 3 wagon-loads of mud for a room, 2d spent on litter and water for the same mud, and 20d paid for two men for the daubing of the same room and the making of its floor. The churchwardens of St Michaels, Bath, used hay and straw for daubing in 1477, and those of St Mary-at-Hill, London, provided 'strawe to make mortere with to the dawbere' in 1491.

Closely allied to daubing was pargetting or rough-casting, the chief difference…being that in
pargetting, mortar or a coarse form of plaster was used instead of clay or loam. The surface of the parget might refinished either smooth, with a coat of lime wash, or as rough-cast with sand or small stones. For work at Launceston in 1469 'six dozen seams of sand called roughcasting sonde and helynsonde (= covering sand) were supplied, and Thomas Lucas in the accounts for building his house at Little Saxham in 1507 distinguishes between the two types of finish:

‘for lathing, row and white casting of part of my kechen range’: ‘for lathing, par getting, tiring and white casting of all my roves, walls, partitions and staires’: ‘for lathing and laying with here (=hair) and mortar of 4 chambers, with par getting and white casting thereof.’ As early as 1237 we read of the par getting of the wall behind the leaded chamber’ at Marlborough; and at Corfe in 1285 there is reference to Stephen the Dauber who pargetted the long chamber…daubers and pargetters are identified at Wallingford in 1390: ‘for 8 casters of walls and party-walls…otherwise called daubers…lathing and daubing a great gable at the west of the hall and newly lathing, daubing and par getting a party wall of the Almerhouse - and completely casting with rowe mortar a great portion of the castle wall’…. A variant form of the word occurs in the north, as at Finchale in 1488, ‘for the pargenyng and weschyng of the church’, for which chalk and lime were bought; and at Durham in 1531: *‘in le pargenyng et emendation foraminum’*.

Earth Mortar *[extrapolated from chapter below, p152]*

In Collyweston accounts for 1504: ‘for sifting or mortar earth owt of the old walls’. The expression mortar earth occurs again in 1367 in the account of some repairs to the lodge of Beaumont in the Forest of Rutland: ‘for digging earth for *mortarherthe’* for the said lodge’. Apparently when lime was not available ordinary soil was sometimes used instead *[!!!]*. So at Clarendon in 1363 we find mention of ‘digging and carriage of 2 cartloads of white earth for making mortar’ and at Oxford in 1453, ‘a cartload of red earth for making mortar’.

Mortar: Cement

…It was customary from the earliest times (of masonry building) to use mortar composed of lime and sand, the common proportion being one part of lime with two or three parts sand….

Naturally, purchases of lime and sand are among the commonest entries in building accounts. Lime…might be bought ready burnt, or it could be burnt in kilns specially constructed in the neighbourhood of the building operations. In a Westminster Palace account for 1258 we find 3s paid ‘for mortar of lime and sand bought of Sir Hugh of St Albans, monk’, and also purchases of 98 cartloads of sand and 300 of lime. For the most part lime was bought by the cartload, quarter, or, in smaller quantities, bushel, but a variety of other measures occur. [*most purchases are of lime in form of quicklime, but]* …At Wallingford in 1390 we have 10s paid *‘pro v dolis de slekkydlym’* - for 5 casks of slaked lime; at York lime was bought by the ‘mele’ or tub, which was defined in 1327 as containing 2 quarters and costing 10d, which was still the price 40 years later…

An early instance of the construction of a kiln for the special purposes of building operations occurs at Winchester in 1222, when 50s was paid to Adam de Calce ‘for making a kiln.’ Seven years later the Abbot of Abingdon allowed the king to clear the timber from 26 acres of Saghe Wood for fuel for two kilns required for work on the city walls and one for the castle at Oxford....In 1242 Master Elias de Derham was granted wood for a kiln for building the chancel of Harrow Church. A kiln was built at large cost of £14 8s in 1236, and another for £20, in 1240, for work at Windsor, and the Hundred Rolls of 1275 complain that the king's two lime-kilns had between them devoured 500 oaks in the forest of Wellington. Such destruction of timber...was lessened by the use of coal, which was common where the presence of coal pits or access to the sea rendered such fuel available. The use of 'sea coal' for burning lime was unavailingly denounced as a nuisance in London at least as early as 1285, and as much as 1,166 quarters of sea coal was bought in 1278 for the kilns in connexion with work at the Tower....

For (a kiln) built in 1400 at York 3,300 bricks and 33 loads of clay were required....

The actual mixing of the mortar was also unskilled - and, too frequently, unskilful - labour, so that 'mortarmen' usually received the wages of ordinary labourers, and the work was even sometimes done by women, as at Woodstock in 1271, when 2 women servants were employed in making mortar; more often the women simply carried water for the mortar makers. There is a reference in 1399, at Westminster to 'a sieve in which to sift burnt lime for the making of free mortar'. Probably this means mortar to be used for plastering exposed surfaces of walls *[clearly to be hot mixed]*. Another term for it appears in a 14th C account for Leeds Castle, where the daubers had men 'serving them in the tempering of chefmortar'. The Westminster accounts of 1532 mention 'two seevys for the sifting of lyme and making of fine mortar', and also 'see cole...for making of black mortar necessary for the laying of Flynte, and 16 bushels of 'Smythys Duste provided for black mortar to be made of, requisite for the laying of Flynte' *[pozzalans to speed initial set]*.

Where masonry was particularly exposed to the influence of wet, it was a common practice to use instead of mortar a cement composed of wax and pitch and resin, applied in a molten condition.

Account for a buttress at Westminster Palace, extending into the Thames in 1340:

'for 60 lbs of pitch for making cement for the buttress - 3s. For 100 Flemish tiles for making dust for the same cement - 12d. For 3 earthen pans in which to make cement - 6d. For straw bought for the same buttress, to burn upon it and warm it after the Thames floods, because the stone could not otherwise have held the cement - 7d. For an iron for directing and pouring cement between the stones - 4d.'

Alberti L B (1460) On the Art of Building in Ten Books. Dover Press.

Lime is the opposite (to gypsum): it does not need to be crushed, but may be soaked while still in lumps; indeed, it should be allowed to soften in water for a good while before being mixed, **especially if intended for plastering,** so that any lumps not baked thoroughly enough by the fire will dissolve. If it is used too soon, before it has been properly steeped and softened, it may still contain some small half-roasted stones, which might with time begin to rot, soon developing blisters which disfigure the finish. It should be added here that **lime ought not to be soaked by a single dousing, but ought to be dampened gradually with several sprinklings, until it is evenly saturated.** It should then be left on its own, **mixed with nothing else,** in a damp shady place with nothing but a **layer of sand** to protect it, until the process of time has fermented it into a more fluid paste. **It is certain that this lengthy fermentation greatly improves the lime.** We have ourselves seen lime that has been recently discovered in an old deserted cave, left for more than five hundred years, as numerous indications make abundantly clear, which stayed damp and viscous, and so mature that it was far softer than honey or the marrow in bones. Surely there is nothing else to be found more suitable for whatever purpose. **Lime prepared in this way requires twice the sand as when mixed freshly slaked** *[which, by implication, it commonly was at this time].*

…Remove the lime from the kiln immediately, and store it in a shady, dry place, and then soak it. For if it is left in the kiln, or anywhere else where it might be exposed to the breezes, the moon, or the sun, especially in summer, it will very soon turn to ashes and become useless.

FOUNDATIONS

As for lime, if on removal from the kiln the lumps are cracked or broken , or extremely powdery, it is not to be recommended: such lime is thought to be too weak for use *[already having air slaked, or having begun to do so, it may also have begun to carbonate…].*
The lime that is recommended either is purified by roasting, to become white, resonant and light, or will give off a loud crack and throw up a great cloud of smoke when doused with water. The first kind, having less strength, clearly requires less sand, whereas the latter, being stronger, requires more. Cato decreed that for every foot of work, one *modius [a dry measure for grain; 8.73 litres, equivalent of]* of lime should be used to two of sand, but opinions vary. Vitruvius and Pliny recommended that it be mixed with four measures of sand, if the sand is from a quarry, or three, if the sand is from a river or the sea *[this must be quicklime].*

Finally, if the nature and quality of the stone require the mortar to be more fluid and supple, the sand must be sieved; but when a thicker mortar is required, half a measure of sharp gravel and tiny stone chippings should be mixed with one of sand *[the lime already slaked].* It is universally agreed that **the addition of one-third measure of crushed tiles will produce a far stronger mortar.** Whatever the mix, you must constantly knead it until even the smallest particles are absorbed. And so some will stir and pound the mixture for some time in a mortar trough, in order to mix it thoroughly.

….One can tell that lime has been properly baked if, once it has been slaked and the heat has died away , a froth, like that from milk, rises from every lump. Equally, if you come across **pebbly chips** when you mix lime with sand, it shows that it has not been given long enough to mascerate. If too much sand happens to have been added, it will be too coarse to adhere properly; if, on the other hand, less has been added than the quality and strength demand, it will become dull and clinging like mud, and difficult to manage.

Lime that has not been properly slaked,…is more safely used in the foundation than elsewhere in the wall, and in the infill rather than in the outer skin…

Very large stones were laid, for preference, on a bed of fluid stuff. The main reason for this seems to have been not so much the need for adhesion, as the need for a slippery bed that would allow the blocks to be more easily moved into position by hand during construction. On the whole it is best to make the mortar beds soft and slippery like this, as it will prevent the crushing of the stones when labouring under uneven loading.

…A break in construction is necessary every now and then, the exact height being dependent upon the thickness of the wall, and on location and climate. Whenever you decide to stop building, you should cover the top of the work with straw to prevent the juice from being drawn out by the wind and sun, and evaporating instead of drying in and making a timely bond. When you wish to resume work, pour clean water over it several times, until it is properly soaked…Nothing consolidates the strength and stability of the work more, than for the stone to be doused thoroughly in water…

…There are other kinds of masonry construction – some where **mud, not lime,** is used in the joints, and still others where the stones are fitted together without the support of any mortar….

Any stone to be smeared with a **mortar of clay** should be cut square, but **most importantly it must be dry;** the bricks most suited to this are fired ones, or even better, unfired ones that have been well dried out. **A wall of unfired brick is very healthy for those who live within,** completely impervious to fire and little disturbed by earthquakes; on the other hand, unless it is reasonably thick, it will not be capable of of bearing the weight of the flooring. For this reason, Cato recommends that we incorporate masonry pillars in the structure to support the beams.

Some assert that mud, if it is to be used as mortar, should be **like bitumen, and they consider the best mud to be that which dissolves slowly in water, is**

difficult to wash off the hands, and contracts markedly on drying. Others prefer it to be sandy, being easier to mould. This sort of work ought to be coated on the outside with lime, and on the inside, if you wish, with gypsum, or even silver clay. In order to make it adhere better, fragments of earthenware should be inserted occasionally into the cracks between the blocks during construction, so that they project like teeth and support the rendering more firmly.

Where the masonry is left uncovered, the blocks must be cut square, and they ought to be larger than usual, as well as being solid and extremely strong. There must be no infill, but the courses should be absolutely even and the joints continuous, and frequent use should be made of cramps and pins. Cramps are devices to fix two blocks together on the same level to form a continuous row. Pins…fix two blocks together one above the other, so as to prevent any rows being pushed out of line. There is little objection to cramps and pins of iron, although if we inspect the works of the ancients, we will notice how iron rusts and does not last, in contrast to brass, which lasts almost forever.

Throughout the buildings of antiquity extremely strong walls are to be found built of nothing but rubble *[concrete]*. These are constructed in the same manner as the mud walls common in Africa and Spain: a temporary form, of panelling or wickerwork, is set up as shuttering to contain the material as it is poured in, until it has hardened. The only difference is this: with the former they pour in an almost liquid dough made of aggregate; with the latter they make the mud pliable by moistening and kneading it, and then pummel it down with beetles and their feet. The ancients would insert a rubble-like layer every three feet as bonding…In Africa, they mix the mud of their earth with Spanish broom or sea rushes; the resulting work has a remarkable resistance to wind and rain.

…Walls consisting of 'shell' – as I prefer to call it…- should be constructed of seasoned wickerwork and reed matting; this is not a work of any distinction, but was often used by the plebians of ancient Rome. The wickerwork is smeared with a mixture of **mud and straw** which has been kneaded for three days. It is then dressed…with either lime or gypsum, and finally adorned with pictures or reliefs. If you mix your gypsum two to one with crushed tiles, it will have less to fear from being splashed. If mixed with lime, its strength will be enhanced. In the damp, frost or cold, **gypsum will be entirely useless.**

…ROOFS

…Flat tiles are better….

To prevent gales from dislodging the tiles, I would recommend that, particularly in public works, they be **set in a bed of lime.**

Floors

For pavements not in the open, Varro recommends the following for its exceptional ability to stay dry: Dig to a depth of two feet, and pack down the soil, then lay a pavement of either rubble or brickwork. Leave a few openings for the water to drain away along channels; pile on some coal, then once this has been packed down and consolidated, cover it with **a cake consisting of a mixture of gravel, lime, and ashes to a depth of a foot and a half.**

…ORNAMENT

Revetment may be either applied or attached. Gypsum and lime are applied. But gypsum may be used only in an extremely dry place. Moisture found in old walls is hostile to all forms of revetment. Stone, glass, and so on are attached. These are the types of revetment that are applied: **white plaster, relief work and fresco.** …to deal with applied work first:

Lime is prepared like this. It should be soaked in pure water and allowed to macerate for a long time in a covered pool; it should then be chopped with a trowel, like wood. If, during this operation, the trowel meets no solid particle, it shows that the lime is fully macerated. Lime **is thought to require three months before it is sufficiently mature.** Preferably, it should be thick and extremely glutinous; for if the trowel comes out dry, it shows that the lime is weak and not moist enough. When the sand or some other crushed substance is added, work it over and over again with great vigour; then turn it over once more, until it appears to foam. For the outer coat the ancients used a mortar to pound the lime and temper the mixture, so that it would not stick to the trowel during application.

While the coat is drying and still fresh, apply a second coat; take care that all coats dry uniformly. These coats should be consolidated by packing them down with a light tamper and baton. If the final coat of pure plaster is rubbed carefully, it will shine like a mirror. …In our experience, cracks may be avoided in this type of revetment if, during application if, during application, as soon as a fissure appears, you brush it in with a hisbiscus bundle or a broom of esparto grass.

Should you be applying the coat…somewhere hot, beat some old rope and cut it into little pieces, then mix it into the paste.

Scott Mylne Rev. R (1893) The Master Masons to the Crown of Scotland and Their Works. Scott & Ferguson and Burness & Company. Edinburgh

Account of the Master of the Work of the Bridge at Dunkeld 1514:

P 20 For reward of the labour of Sir Anthony M'Dowale building the boat which is now at the quarry, for carrying stones from the quarry to the carts…

For the charges of a boat of lime bought in Perth by the bishop and for carriage to the work
For burning of the kiln of lime of oyster shells in Crawnmond, carried to Perth.
For 15 chalders of lime at 12 shillings the chalder and 26 chalders at 1 merk each.
To the boatmen for meat and drink on two occasions carrying lime to Perth.
To unloading the boat and carrying the lime to Bothame
For 18 chalders 9 bolls of lime
For carriage of the lime
For rent of the lime house in Perth

P21 for 5 chalders 3 bolls 2 bushels of smiddy coals *(probably for pozzolanic addition to lime mortars)*
For ten hods for carrying cement to the masons

P23 numerous payments to masons for hewing stones

P25 for 932 loads of clay for the foundation of the *landstaile* and of the piles of the bridge
To David Ghent and John Rogie…serving the masons in building the *landstaile*
For 2500 loads of wall stones for the work of the bridge…

1514
for digging and leading 1235 loads of sand
to the masons and their servitors erecting the first arch of the bridge of Dunkeld
to the workmen placing the bulwark for the purpose of holding back the water from the arch, from 10th May to 28th June within the present account.

For the cooper for mending the mortar tubs
For two ryddillis for cleaning the lime for cement *(mortar)* to the hewn stones…
For mending the irons of the masons and other necessary smith work for the bridge.

For digging and leading 376 loads of clay
For leading 512 wall stones of our own to the work of the Bridge

(most likely that the bedding mortars are of clay, sand and lime, with sand and lime pozzolanic mortars for finishing).

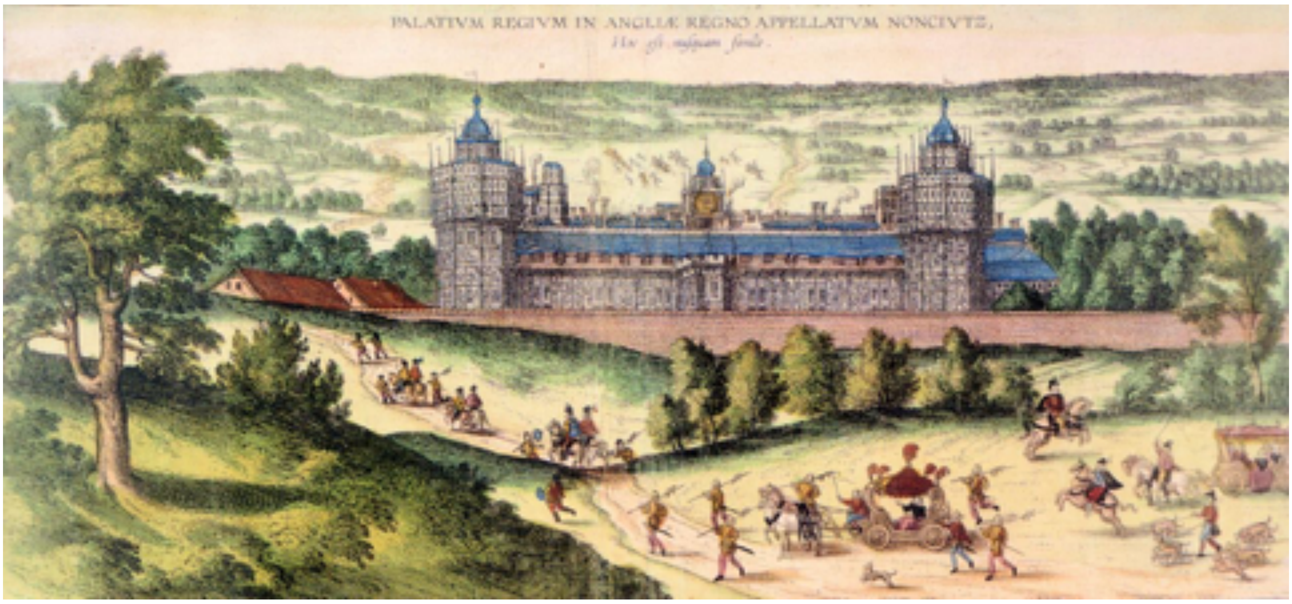
1516

Paid to the masons in drink money for laying the first stones upon two *brandeirs* and for placing the keystone of the *pend*.

Paid to the men who carried beams for making the masons' house on the south side of the Tay and to the boys watching the ford on various occasions against floods
To John Rogy for cutting and joining timbers for the masons' house and constructing the same, with walls, thatch and rafters.

Dent J (1970) The Quest For Nonsuch. London. London Borough of Sutton Libraries and Arts Services.

From Dent's transcription of surviving building accounts for the construction of Nonsuch Palace 1538. Extracted from E101/477/12, National Archives, Kew.



13 mounts (30 cwt each) of plaster of Paris purchased from John Fyner of St Mary Overies.at 5/- a mount…and of 3 mounts from John Frank of Billingsgate…at the same price.

Certain hair bought by great 37/- by convention. Riding costs, to take the said hair, 2 days at 8d a day in addition to wages. A parcel of hair bought by great, 20/-. Carriage from Reigate to Cuddington, 15 wain loads at 1/8 a load.

(a damaged page relates to a payment to) Thomas Carter of Cuddington for (building) lime kilns. Cartage of 5 loads of bricks from Hampton Court to Cuddington to make the lime kilns at 8d a load.

A bow of iron for the mouth of the lime kiln, 36 lbs, 4/6.

Hoops of iron for the mouth of the lime kiln, 2 at 28 lbs, each 7/-…

Working 4 mouths of iron for the lime kilns, 176 lbs at ½ d a lb.

2 axes for the lime burners 1/- each, and 2 hatchets, 7d each; 2 axes to break wood for the lime kiln…2 fire forks and a prong for the kilns…

(Compensation for damage to crops)

For 1 ½ acres of rye and wheat where the lime kilns are, 16/- paid to Robert Hall of Ewell. For 2 acres of barley where the brick is made, 15/- …

To John Seborow, William Hudson and William Merten of Stoke D'Abernon for digging, moulding, setting and burning 600,000 bricks at 2/- a thousand standing in the kilns, the king finding wood.

Lime-burning. Payments to John Paige of Uxbridge for setting and burning kilns each containing 10 loads at 8/- a kiln delivered outside the kiln mouth, the king finding wood. By convention, 8 kilns, 23 kilns, 22 kilns, 36 kilns…

Carriage of lime from the kilns to 'the place' by Thomas Whytfield of Ewell. 100 loads at 4/8 for 25, 21 kilns (210 loads) at 1/10 ½ a kiln, 150 loads at 5/4 for 25.

Purchase of lime…16 loads of 40 bushels bought from William Dean of Kingston at 6/- a load delivered.

Scuttles for the lime kilns, a dozen at 2d each

Bushel measure for lime, 8d; binding with iron, 1/-.

Chalk Diggers

Stone axes steeled to hew chalk at 2d a lb.

Steeling 4 mattocks for the chalk diggers 4d each; 12 mattocks steeled for the chalk diggers 19/…Steeling and mending 27 mattocks and hammer heads for the chalk diggers and miners of the church…*(a village and its church were demolished to make way for the palace)*.

Pails 4 at 4d each. 17 at 2d each, 42 at 2d each to put mortar in for the masons and rough-layers to set their stone with….

Wheelbarrows. 20 carted from Hampton Court to Cuddington 8d…

Hoops for vessels at the mortar heaps, 50 at 1d each, 18 at 1d; 48 on tubs that hold water, 1d each. …

Wax 1lb, 6 ½ d and Resin 1 lb, ½ d to make cement for the masons.

De L'Orme P. (1567) Le premier tome de l'architecture (The first book of architecture) Paris. Frederic Morel. Translated by Emma Michel 2018.

Philibert de L' Orme (otherwise Delorme) was Royal Architect 1548 - 59 (Henri II) and 1563 – 70 (Charles II & Catherine de Medici. The majority of masonry buildings in France in De L'Orme's time were built with clay or with earth-lime mortars. This pattern persisted until the 20thC in certain regions of France, such as Normandy. His procriptions for the manipulation of lime should be seen in this context, the lime being used primarily for pointing, plastering and render mortars, as well as for limewash over earths.

Lime and stones to make it, some sands and waters to use to make mortars with and the difference and natures of those sands.

We say the best stone to make mortars is the hardest, because it is fattier and more glutinous. Mortars made from marble or stones similar in nature are wonderfully good. **So that when used hot, as straight out of the kiln, and mixed with small gravel and sharp river sand which carries other small gravel, (the lime) adheres and thickens (*conglutiner = the idea of a liquid becoming viscous*) very well with time, such that the whole becomes a rock, a mass of a single piece…**You would admit that the best lime is the heaviest and when hit, it sounds like a earth pot well burnt.

We also know (the lime) is of a good quality, if when it is wetted, the vapour and dense 'smoke' rise up immediately and suddenly: better still, if it binds with the larry when mixed (*the verb used is 'broyer' = to crush*). We have been aware through long-standing hearsay - and I think it is true - that lime from a particular place behaves much better in masonry made with stones from the same place and quarry...

As for the sand, we need good supply, whether to preserve the lime or to mix with it to make a mortar….I would like to advise that sands have different natures, and different qualities: some sands mix better with lime than others. Some are so fat that it needs five parts, even seven, for one part of lime. **Some can be mixed with two or three parts and some are so bad that they need as much lime as sand**. Some sands are good and adequate for walls above ground, others for underground work; some for plasters, some to make cement or to be used as real cement along with a pozzolan - a black sand used in Rome - which has the nature of a true cement.

Consider Pliny's work about the diversity of earths, the sand of Putzuoli and of several sorts of earths which harden like stone. The best sand in this country (France) and in other places is pit sand…because it is taken from the middle of a field inland, much better than that from rivers, and makes a noise when handled due to sharp grains like little rocks, which is the reason it makes a good mortar.

[…] Sands have various colours, white, yellow, red and black. You will know their quality when they are wet as they do not soil a sheet as mud does and do not dirty the hands as bad sands do. Have a look at Vitruve's writings on the subject.

As for water, which is the third element in the composition of a mortar […] I say sea water is useless to make a mortar because it never dries out and leaves [the mortar] always humid and stops it from binding with the stones. It is the same for marsh and swamp waters […] but those from rivers, wells and fountains are really good and clean.

Ways to soak lime, that it may last longer once used and keep a long time and safely, and its use by painters.

In the way that some materials were kept in good supply, not everyone knew how to keep their lime, and when they wanted to use it, **it had lost almost all its force, having been badly soaked and prepared in ways other than it should have been**. […] Some are strong; others less so. It comes from the nature of the lime which some soak when it comes out of the kiln with water, but not sand, and make a big mass […] However, they are in the danger of burning or drowning it, with too little or too much water, **either of which will greatly reduce its strength.** Once soaked, they store it in one heap and then, when they need to use to it, they soak it again and mix it again with sand […]. **The other way, as soon as the lime is out of the kiln, is to mix it with a bit of sand and water and make a mass (*a coarse stuff*) to keep until they want to use it, when they mix in more sand.** This method is better than the first one but the one I am going to describe is best, since the lime can keep its strength and fattiness by this method….

The method is this: when you take the lime from the kiln, you will put it in a (pit) with a depth of 2 or 3 feet and of any length and width you would like. You will put a good quantity of pit or river sand of about one or two feet of depth over it […].

You will then well water the surface, in such a way that the sand is so wet that the lime beneath cannot fuse, nor burn. If you see cracks in the sand and see vapours emerging, you will close those cracks in order to prevent their escape. With the sand well wetted, all the lump lime will convert into a mass of fat which may be used in 2, 3, 10 years - it will be as a cream cheese and the material will be so fat and sticky that it will be almost impossible to use the larry and will consume great quantities of sand and will be such a good mortar that it will stick to stones as if it was a real and good cement. You will need to ensure when wetting the sand that the lime is fully covered and not be exposed to the air….

(In decoration), the lime soaked thus will not burst the plaster or kill the colours like other mortars do. Sometimes, after soaking the lime, the painter, having produced beautiful work, [discovers] some time afterwards that his colours are fading, or that the lime cracks the plaster and painting, so that some pieces fall or swell like blisters, which is damage and loss for the lord who commissioned the work and a great dishonour to the painter.

Palladio A The Four Books of Architecture (1570) (Ware translation, 1738). Dover Press.

Chap. IV Of Sand

There are three sorts of sand commonly found: pit, river and sea sand. The best of all is pit sand, and is either black, white, red or ash-coloured, which last is a kind of earth calcined by sunterranean fires pent up in the mountains, and taken out of pits in Tuscany.

They also dig out of the earth in Terra di Lavoro…a sort of sand called Pozzolana by Vitruvius, which immediately cements in the water, and makes buildings very strong…The best river sand is that which is found in rapid streams, and under water-falls, because it is the most purged. Sea-sand, although the worst, ought to be of a blackish colour, and shine like glass; that which is large-grained and nearest to the shore is best. Pit sand, being fattest, makes, for that reason, the most tenacious cement, and is therefore employed in walls and long vaults; but it is apt to crack.

River sand is very fit for covering and rough-casting of walls. Sea sand soon wets and soon dries, and wastes by reason of its salt, which makes it very unfit to sustain any considerable weight.

Every kind of sand will be good that feels crisp when handled, and, if laid upon white clothes, will neither stain or leave earth behind it. But that sand is bad, which, being mix'd with water, makes it turbid and dirty…

Chap.V Of Lime, *and the method of working it into mortar*

The stones of which lime is made are either dug out of hills, or taken out of rivers. All those taken out of hills are good when dry, brittle, free from moisture, or the mixture of any substance, which being consumed by fire, diminishes the stone. That lime will therefore be best which is made out of the most hard, solid, white stone, and which, being burnt, is left a third part lighter than the stone of which it was made.

There is also a spongy sort of stone, the lime of which is very good for covering and rough-casting of walls; likewise a scaly, rugged stone, taken out of the hills of Padua, that makes an excellent lime for such buildings as are most exposed to the weather, or stand under water, because it immediately sets, grows hard, and is very lasting.

All stones taken out of the earth are much better to make lime of, than those which are collected; and rather taken from a shady, moist pit than from a dry one. The white are better than the brown, as being the most easily worked. The pebbles found in rivers and rapid streams, are excellent for lime, and make very white neat work; therefore it is chiefly used in the rough-casting of walls…When calcined, they must be wetted, in order to slack them; **observing not to pour on the water all at once, but at several times,** to prevent it burning before it be well tempered; and afterwards **must be laid in a moist shady place, only covering it lightly with sand,** taking care not to mix anything with it; and when used, the more it is worked up with the sand, the better will be the cement; except that made with scaly stone, like that from Padua, because that must be **used as soon as it is slacked,** to prevent its burning and consuming away; it will otherwise be useless.

To make mortar, lime should be mix'd with sand in this proportion: three parts of pit sand to one of lime; and but two of sea or river sand to one of lime *[this, from Vitruvius, though he meant one of quicklime].*

Knoop D & Jones G P (1936) Building Accounts of Bolsover Castle 1612 - 1613.
Ars Quator Coronatorum Vol XLIX Part i.

A very detailed account of labour and materials expended by William Cavendish in the rebuilding of Bolsover Castle to designs by John Smythson, son of Robert. Below, the lime-related elements mainly. These would indicate that lime was burned in a kiln built on site for the purpose, fired by coal. Also, that lime was dry-slaked – probably by the lime-burners – sieved and mixed with the sand immediately, the coarse stuff being screened and banked for later tempering immediately prior to use. Works continued throughout the winter, with lime being burned, slaked and mixed to a mortar, but most winter works were to the vaults. During the winter months, earlier and ongoing work was covered (wall tops) with thatch and/or bracken to prevent water ingress and subsequent frost damage. A notable number of labourers, particularly those associated with the lime burning and the serving of mortars to the stone-layers, were women, as well as boys, although both were paid less than the male labourers. Lime burning and mortar making goes on alongside stone quarrying, dressing and laying throughout, the kiln built as the first stone was being quarried and dressed at the quarry.

23 January – 6th February 1612

Workmen at the making of the lime kiln;
Labourers at the lime kiln

6th – 20th February

Workmen at the lime kiln and scappling of arch stone;
Carriage of clay and limestone getting (*the kiln likely built with clay mortar);*
23 loads of clay to the lime kiln, 60 loads of limestone.

6th – 20th March 1613

Masons and layers at the lime kiln and scappling;
Carpenters making hods;
Wilson, 1 day setting of the lime kiln, 6 women helping him at the same*);*
Labourers carrying earth from the foundation and sand to the lime kiln *(sand is regularly delivered to the lime kiln, indicating the mixing of quicklime straight from the kiln with this sand – initially dry-slaked and sieved, but probably mixed hot and then the mortar 'harled', a regular operation, often in association with sifting of the lime; sometimes the entry is lime harled, at other times mortar is harled. Miriam Webster dictionary gives this definition: 'dialectal, British* **:** *to drag, scrape, or pull (an object) usually along the ground' indicating that harling in this context is the mixing and beating of lime and sand, otherwise larrying the lime and sand or lime alone to fully mix for either coarse stuff or just before use. One reference to 'harling up lime' suggests it may be banking of the lime and/or mortar);*

Carriage of limestone, coals for the lime kiln;
Breaking of limestone;
(Freemasons are now working in the quarries in earnest and 'layers' are at work on site).

20th March – 3rd April

Payments to the lime burner and women both at the lime kiln and at the foundation;
Limestone getting and breaking – 90 loads;
Carriage of limestone and coals to the lime kiln – 27 loads of stone, 9 loads of coal, 1 load of wood for the lime kiln.

2nd – 17th April

To the Limeburner and women at the kiln;
Labourers at serving the layers and harling of lime (48 man days);
4 labourers at drawing of water for lime (38 man days);

Boys at sifting of lime (28 boy days).

17th – 30th April

(Freemasons, layers at work; carpenters erecting scaffolding and centres);
Limeburner at the kiln (15 days);
Labourers at serving the layers at the foundation (55 man days);
Labourers at tempering of mortar and sifting and harling of lime (47 man days);
Sifting sand and slecking of lime (21 ½ man days);
5 labourers at drawing and carrying water;
6 women at the lime kiln;
Getting and breaking stone for the kiln;
Carriage of limestone and sand from the More;
Coals for the lime kiln.

30th April – 15th May

(Masons and layers at foundation walls of the castle);
The Limeburner and 6 women at the kiln;
2 labourers at drawing of water;
Labourers at sifting and harling and tempering of lime for the work (53 ½ man days);
60 loads of limestone got and broken;
Coals for the lime kiln;
Paid the colliers for 15 loads of coals for the lime kiln;
Carriage of sand (7 loads).

15th – 29th May

Labourers at sifting and harling of lime;
Drawing and carrying of water;
Serving the layers; women carrying sand;
Limeburner and 6 women at the kiln;
Limestone getting and breaking.

29th May – 12th June

(Freemasons at both quarry and castle; layers);
Limeburner and 6 women at kiln;
2 labourers at sifting of lime and harling of mortar (48 man days);
Labourers serving of the layers of the walls of the foundation;
Boys serving layers;
Limestone getting and breaking and one sieve for lime.

12th – 26th June

(Masons now above foundation level, pillar bases fixed);

Freemasons and layers at walls;
Labourers tempering mortar;
Labourers drawing and bearing water; sifting and harling mortar;
Labourers serving layers;
Limeburner and boys carrying sand;
Getting of sand and limestone.

26th June – 10th July

(Masons, layers and scaffolders on site);
Labourers tempering mortar and harling lime;
Labourers drawing water;
Labourers serving masons and layers;
Boys serving layers;
The Limeburner and women at serving the layers with filling stone and carrying of sand to the lime kiln;
Getting and breaking of limestone and sand;
Carriage of limestone, getting sand;
Coals for the limekiln and carriage.

10th – 24th July

Labourers at harling and sifting of lime;
Labourers serving layers;
The lime man and women at serving of the layers with filling stone and carrying sand to the lime kiln.

24th July – 7th August

Boards for making hods, scaffolding and centres;
Labourers at harling and sifting of lime and carrying water;
Labourers serving layers and getting of filling stone and sand;
Women carrying filling stone and sand.

7th – 21st August

Labourers carrying water and harling of lime;
Labourers serving layers;
Women serving of layers and carriage of sand from the old wall

*(Women paid between 3s 4d and 3s 8d; male labourers 5s 6d a day;
boys 3s 8d but as low on occasion as 10d for one of the crew)*.

Limestone breaking;
Coals for the lime kiln all winter, 10 loads; boards for hods and trowes.

21st August – 4th September 1613

At carrying water and slecking and harling lime;
Serving layers and freemasons;
Lime burner and women serving layers;
Coals for the kiln, 10 loads.

4th – 18th September

(Building on-going)

Labourers serving layers;
Boys serving layers;
Women at the lime kiln and sand carrying;
Breaking limestone;
Stacking 100 loads of stone.

18th September – 2nd October

(Masons in quarries, carving and dressing rough stone);
Layers still on site;
Serving of layers and harling of lime;
Coals for the kiln; limestone breaking.

2nd – 16th October

Labourers sifting and harling up of lime;
Labourers serving layers;
The Thatcher covering the walls of the house;
Labourers and women at getting of bracken for the cover of the walls;
Limestone for the kiln; coals for the kiln.

16th October – 6th November

(Works focused on locations more protected and more easily protected from the weather, but continuing at reduced pace and volume)

Layers at the vaulting of the great beer cellar;
Labourers serving layers and making of mortar (average of 6 hours each, 14 men);
Getting of bracken and thatching of walls;
Coal and limestone.

1st – 14th November

Layers at the wall;
Work done for the cover of the walls (thatcher 5 days, his labourer 5 days; 5 women getting of bracken for the thatcher);

Labourers at the foundation and making of mortar;
Breaking limestone; coals for the kiln.

14th – 27th November

Layers at the building;
Labourers serving lime to workmen;
Bracken for cover of walls;
Coals for the kiln, 10 load.

27th November – 11th December

(Freemasons still at quarry; work on vaults of larder and cellar);
Work about the cover of the walls and centres;
Labourers serving layers and making mortar;
Labourers at the lime kiln and at sand and filling stone getting;
(A lot of quarrying; taking down of old castle wall);
Stone and sand sorted for the work;
Hurdles for scaffolding, 6 dozen;
Carriage of stone for vaults;
Coal for the kiln.

11th – 25th December 1613

(Freemasons at quarry – finishing capital of the pillar of the larder, springer of pillar, 28 feet of water table, 66 feet of 'window stuff' in Freestone);
Workmen at the vaults;
Labourers serving of layers of the vaults;
Women at getting bracken and carrying sand;
Smythson's charges – 10 meals and for his horse *(These are regular)*.

25th December – 15th January 1613

(Fewer workers generally – still in quarries, scappling stone; masons and layers at vaults and centres - 5 and 6 man days)
making mortars for vaults;
Women carrying and sorting sand and stone;
(Gathering other materials, such as wall fill);
The lime kiln set;
Coals for the kiln.

15th – 29th January 1613

(Much as above);
Paid James Wilson for 6 days at setting of lime kiln; paid Rode's wife and 6 more of their fellows for 10 days a piece at filling of the lime kiln and getting away of rubbish;

Carrying water, harling and sifting lime; carrying of sand;
Breaking limestone.

29th January – 12th February 1613

(Stone working);
Harling and sifting of lime;
Lime kiln setting and drawing;
Sifting of lime;

(Saw-pits built).

12th – 26th February 1613

Layers at the old house;
Serving of layers and harling of lime;
Sorting of sand and wall stone;
The lime kiln setting and drawing, Wilson and 7 women;
Harling of lime; sifting of lime.

26th February – 12th March 1613

Lots of wall stone scappled;
Layers at larder and cellar of old house;
(Sawyers very active; carpenters also);
Labourers serving layers at old house;
9 labourers at harling of lime and sorting of stone;
Sifting harling and lime.

Welch E (1967) Plymouth Building Accounts of the Sixteenth and Seventeenth Centuries. Devon and Cornwall Record Society.

The early Guildhall was a stone building, of immediately local limestone and of 'moorstone' brought down from Dartmoor. Moorstone was the softer, more weathered and tractable granite that might be won from the surface, rather than deep-quarried; the roof was stone slated. Deliveries of sand and lime, but not of earth suggest lime-sand mortars, lest earth was being won on site. For the new, later Guildhall, however, lime, sand and earth is carried to site, suggesting earth-lime mortars improved before use by the addition of sand. The evidence of the Shambles and later Guildhall accounts is that the mortars were both earth-lime and lime – the former probably forming the bedding mortar; possibly the base-coat plasters, although when plasterers are being paid, lime, lime-ashes, sand and hair are also listed. It may be that the interior plastering was effected with haired earth-lime and then haired lime-sand finish mortars; with the exterior plastering haired lime and sand mortars throughout. The Orpanage accounts show lime and sand for the moorstone masonry, though earth may have been won in situ. Towards the end of the project, payments are made for 'white hair', as well as the first specific payments for 'quenching' and sifting lime. This would *indicate that the finish plasters are being made from dry-slaked and sieved lime to facilitate the removal of lumps. The finish coat almost certainly comprised lime and (white) hair only. By implication, all other mortars, of both earth and lime, were being hot mixed. The lump lime for the Guildhall is being carried and stored in canvas sacks, not by the load or in barrels, at least to the site itself. There was a kiln close to the site, but carriage costs for burned lime to the site are high. Stone, although quarried only a mile away, was loaded onto boats which brought it within ¼ mile of the site; the same seems to have occurred with the lime, hence the need for limesacks. Sand was drawn from the rivers. Lime ashes are as commonly delivered as lime. Lime ashes are a mixture of fuel ash and quicklime, but would make a pozzolanic mortar slaked together on their own or as a gauge for clean lime mortars. Lime ashes likely preferred for the below-ground masonry, laying floors upon; perhaps in the roof works, perhaps as a general pozzalanic addition. Plymouth limestone, as Smeaton demonstrated in 1756, produces a fat lime for all that it is hard and dense and will take a polish.*

At the Guildhall, lime is being burned in the 'town kiln' – associated payments are for burning and carrying the lime, not for the limestone or lime itself. There are entries for sand and for earth. Most payments to day-workers do not identify the work for which they are being paid. Generally, three trades are using lime – masons, plasterers and roofers.

The Building of the Guildhall 1564-65.

1564

Item: for 6 yeardes of canvas for make lymesackes.

Item: payed to Rafe Clayton for 9 quarters and half of Colles…
Item: paied for beringe and hevenge of the sand…Payed for furse and woode
Item: payed to John Nychole for drawing stones for the kyll 2 days…
Item: payed for furse and woode…
Item: payed for Roberte the Kilburner for one weike 23d…
Item: payed to Roberte Kilburner for one wieke 3s 10d
Item: payed to John Grepe for Carrege of the lyme stones…
Item: paied to Nicholas Hale for one daie to drawe lyme stones…
Item: payed to Roberte Kilburner for one weycke 3s 10d
Item: payed to Roberte Kilburner for one weke 3s 10d
Item: payed to Roberte Kilburner for one weyike 3s 10d
Item: paied to John Vesye for 8 quarters of Coles and 2 bushells…
Item: paied to Roberte Kilburner for one weicke 3s 10d
Item: paied to John Walter for 3 days to drawe stones *[lump lime from the kiln]* 2s 6d
Item: paied for a whilbarrowe
Item: paied to Roberte Kilburner 3s 10d
Item: paied to John Walter for 1 day to drawe stones 10d

Item: paied for beringe 6 quarters of Lyme *[quicklime] 2s*
Item: paied for caryenge of 6 quarters of Lyme 18d
Item: paied to John Walter for 2 days to draw stones
Item: payed to Roberte Kilburner for one weicke 3s 10d
Item: payed to Pomery for caryenge of 6 quarters of Lyme 12d
Item: payed for caryenge 6 quarters of lyme aysshes
Item: payed to Pomery for caryenge of lyme Ayshes
Item: payed to Pomery for caryenge of 4 quarters of lyme and 4 quarters of lime ayshes
Item: payed to Roberte Kilburner for one weycke 3s 10d
Item: payed to Pomery for caryenge of 17 quarters of lyme…
Item: payed to Pomery for caryenge of 13 quarters of lyme…
Item: payed to John Roche for 16 quarters of Cole…
Item: payed to Roberte Kilburner for one weicke 3s 10d
Item: paied to John Walter for 2 days to drawe stones…
Item: paied for 2 quarters of lyme…
Item: to Roberte Kilburner for one weike…
Item: to Roberte Kilburner for one weike…
Item: paied for a bucket 12d
Item: paied for the caryenge of 1 quarter of lyme…
Item: paied to John Walter for one daie to drawe stones…
Item: paied to Roberte Kilburner for one weicke…
Item: paied for carieng of 6 quarters of lyme…
Item: paied to Roberte Kilburner for one weicke…
Item: paied for 2 seifes (sieves) 13d
Item: paied to Roberte Kilburner for one weicke 3s 10d….

Item: paied to John Grepe for 15 score lode of lyme stones…

Item: paied for a bushel to mete lyme (measure lime) 20d

The Shambles and the Guildhall 1606-1607

The Shambles

July 1606

The first weeke

To the Masons:

Thomas Creese 3 dayes 3s
John Werye 3 dayes 3s

To Lawrence Hunne for carieng 1 bote (boat) of Stones 2s

To Thomas Skorye for 2 doss of earthe 3s *['doss' is an unknown measure, the author thinks a small amount, which seems most unlikely, as it costs 3 times the cost of a quarter of sand]*
Paid for 1 quarter of sand 1s
To Alse Jory for bearinge 1 quarter of sande, 1 quarter of Lyme ashes and 1 quarter Lyme 1s 6d

The seconde weeke

To Richard Shepheard for 4 doss of earthe…
To George Palmer for 6 botes of stones at 4s per bote…
To Thomas Nyle for 5 botes of stones…
To Phillip Tookerman…in parte of payment for paving

Item to Alice Joyce for carienge of 12 bushels of Lyme and 4 quarters of Lymes Ashes…
To Lawrence Hunne for carienge 4 botes of stones…
[£2 4s 6d paid to the Masons this week and £2 8s 8d the following week].

August

Item for carienge of 1 doss of earthe 1s 6d…
[15s paid to labourers for 18 man days]…
To Alice Jorye for carienge 3 quarters and 6 bushels of Lyme Ashes and 2 bushels of Lyme 2s.

[Significant payments to carpenters, masons, labourers, sawyers, helliers (roofers) and Pavers]…

To Walter Symons for carieng 20 doss of Ruble…
To Alice Jory for caryeng of 2 quarters of lyme more to her for 14 bushels of sand and the carryage…

The fifth weeke
For 4 bushels of heare (hair) at 8d per bushel
For 2 doss of earthe caryeng away…
For 6 bushels of heare at 9d per bushel…

Item to Alice Jory for carieng 22 bushels of lyme and 8 bushels of sand, and for the sand…

[Payments to the above trades *and* to Plasterers for the first time]:

2 labourers **beating mortar** eache 3 days at 8d per day….

Sixth week

Item to Alice Jory for bearing 1 quarter and ½ of Lyme, 2 bushels of sand and 1 quarter 2 bushels of Lyme Ashes and for the sand…
12 bushels of heare…

[Payments this week to Helliers, Sawyers, Plasterers, Pavers, but *not to masons*]

Seventh week

To Alice Jory for caryeng 1 quarter and ½ of Lyme

[payments to carpenters, sawyers, plasterers, roofers].

Eighth week.

[Payments to plasterers, roofers, carpenters]

To Alice Jory for carieng 1 quarter 7 bushels of Lyme
More for carieng 1 quarter of Lyme Ashes

The Guildhall, beginning 22nd August 1606

First week

Payments to masons and labourers pulling down the old Hall. Deliveries of timber and stone.

To Alice Jory for caring 8 quarters of lyme and 5 ½ quarters of sand at 6d per quarter.
To Alice Hume for caring ½ quarter of lyme and 1 ½ quarters of sand…

[strongly indicates lime-sand building mortars, for the footings, at least].

Second week
Paid Seller for bringing 1 bote of Slatt 10s
For 1 bote of earth to him 4s
More to him for 1 great Lighter of earthe of 10 tonns 9s
To Lawrence Hunne for caryeng 4 botes of stones 8s

To Alice Jory for caryeng 16 quarters and 1 bushel of lyme
More 9 quarters of sand for the Hall.

[Payments to masons, labourers, sawyers].

To George Palmer for 1 bote of sand and 1 bote of stones…
To 2 labourers carieng 1 bote of earth…
To John Hore for 3 days carieng of Ruble…
To John Hartope for carieng Ruble 2 days...

Paid for rope for the Stage…
Paid to William Swingsbury for a Corde for the Stage and 1 seve (sieve) hee bought in the market.

Thirde weeke

[Labourers, masons, sawyers, carpenters]

to Alice jory for carieng of 7 quarters of Lyme, 3 quarters of lyme Ashes and 6 quarters of sand…
To Cornishe and his Company being 6 persons for carienf plankes and mastes for Skaffoldes…
To Robert Drake for coloring the Shambles and Myles howse…£1 3s

Fourth weeke

Paid Paskowe Pepperell in parte for his Lyme…
To John Geynes for 1 bote of Rowecaste Sand…
For carieng 1 bote of Rowecaste Sand…
To Alice Jory for Caring 9 quarters of Lyme and 4 quarters of sand…more for caring 1 bote of Rowecasting Sand….

[rowecasting sand = roughcasting sand]

Fifth weeke.

[Masons, moorstone hewers, labourers, carpenters, sawyers and *plasterers* for first time].

Sixth week

[Masons, sawyers, carpenters, labourers; no plasterers]

To Alice Jory for bearing 7 quarters of lyme, 2 quarters of sand….

{Small volumes every week hereafter. Roofers and masons on site. Plasterers reappear in 10th week, and are working intensively thereafter until the 28th week, regularly supplied with lime and sand, after which most payments are to joiners}

Weeks sixteen & seventeen
Plasterers: Hercules Roe 5 days; 1 labourer 6 days; another, 6 days…for caringe 2 quarters of lyme…for 3 ½ bushels heare…more paid for 1 ½ bushels of heare…to the Plasterer 5 m (1000) of lathe nayles…

[Plasterers typically using 1 quarter of lime a week; hair, but no sand].

22nd and 23rd week

Plasterers: William Gydley 12 dayes; Robert Lynn 12 dayes; Nicholas Crocker 12 dayes…
To John Vinton for 1 ½ doss of yearthe…
To Alice Jory for bearing 2 quarters of Lyme… for 7 bushels of heare

24th week.

4 Plasterers 4 or 5 days

to Alice Jory for carrying a quarter of lyme…
to John Vinton for 1 doss of yearthe…
for caring up a bote of morestones…

25th week

To John Hore and John Vynton for 2 doss of yearthe
To Thomas Betts in parte of £4 which he is to have for ending the playstering worke except the walle…To Alice Jort for a quarter of lyme bearing…to Cornish for carrying a bote of Moorestones…

[Masons reappear in week 39, with stone, lime and sand paid for as well as, in week 41, rowcasting sand. Roofers and carpenters reappear week 41].

Week 43

To Pascoe Pepperell's wiefe for Lyme
For carrying 3 ½ quarters of lyme this week and the last
For carrying 14 bushels of Rowcasting sand and 2 bushels of lyme which Bettes had long since.

Hereafter, finishing and furnishing works.

Orphans' Aid Accounts 1614-1620

March and April 1615

[Along with stone…]

To Joan Pepperell widow for 1 quarter of lime…

To James Jorrye, his wife for bearing of 4 quarters of Lyme ashes and 1 quarter of Lyme…

[Throughout May, a lot of stone and 6 quarters of lime (but no sand) delivered. Similar in June, plus timbers and roofing but only 3 quarters of lime ashes.

Regular deliveries of lime and lime ashes to the masons thereafter, with masons still active in October, when 5 bushels of lime and a quarter of lime ashes delivered. November to March, deliveries of stone and lumber but next delivery of lime (ashes) on 30th March 1616; lime and lime ashes regularly thereafter, typically 3 quarters of lime and 2 of lime ashes each week. Roofing has commenced).

October 26th – December 4th 1616

[Roofing complete, with gutters being installed. Plasterers at work within].

January

For 4 bushels want a little haire for playstering

February

To Jorryes wyffe and her sister for carrying 20 quarters of lime
For a seeve for sifting of lyme
To John Light 6 days to quench Lyme
For 3 bushels and 3 pecks of hayre
For 15 ½ bushels of hayre for plastering…
For 19 bushels of hayre to Roe of Beare…

Marche

For 20 quarters of Lyme to Joan Pepperell…
To Constantin Sam for lathing 6 days
To Constantin Sam for lathing 3 days
To Constantin Sam for 5 ½ days…
To Jorye his wyffe for carrying 7 quarters of Lyme

April 1617

Payments to plasterers and carpenters

For 7 quarters of lyme for plastering
For 4 bushels of lyme…for 5 bushels of lyme ashes and 4 bushels sand…

June 18th
To John Rogers for 2 moulds for the plasterer.

March 1618
For a small boat of sand for the garden and pointing the walls

1619
To Constantyn Sam for Lyme, haire and stones for repayring that house and for his man to work on it 2 days

September 1620
To Richard Greep, Carpenter for his worke on the portal in the courtlage and for timbering for plastering of Mr Isteed's study…

To Constantyn Sam, hellier, for his worke on the portal to cover itt and for nayles, mortar and stone.

Blackman M E (1977) Ashley House (Walton-on-Thames) Building Accounts 1602-1607. Guildford. Surrey Record Society.

Some 795,000 bricks were used in the construction of Ashley House and between 1602 and 1604 11,705 bushels of quicklime were carried to site by boat from Kingston by 'Harbard the Lymeman', delivered in one bushel sacks. Sand for the mortar was excavated on site. The exterior was coloured with red and black pigments from 1603 as parts of the building reached completion. Although the account is very detailed and thorough, there is no explicit mention of slaking or of mixing mortar, which was presumably performed by the bricklayers themselves. There are numerous entries for labourers wheeling or carrying 'sande to the lyme' or 'for the lyme', however. Wax and rosin were used in the making of 'cement' for specific uses, such as to interior pillars (perhaps for 'marbling' the same rather than as a strong bedding mortar).

In September 1602, 5,132 one bushel sacks were delivered; and 6,547 in October before a break until 20th January, when a further 800 sacks arrived. Building began at the same time. Thereafter, the flow was similar to that in September and October 1602. By the end of October 1604, most of the brickwork was complete, internal plastering was well underway and 46,805 hundreds of lime had been consumed. There were 25 bushels to the hundred, so 1,170,125 bushels were used in total. Hair for plastering began to arrive on site at the end of January 1602, costing between 4 ½ d and 6d per bushel. It was sourced from tanneries in Leatherhead, Weybridge and Staines, the final delivery on 10th April 1605 being 'to temper with the finishing mortar for the gates and doors and stopping joints'. A total of 1,547 bushels were 'spent in plasteringe'.

For 4 lbs of waxe for the pillors at 16d the pounde
For 6 lbs of Rosen for the same use at 2d the pound

16 April 1603

to workeman that weeke paste for culloringe and finishing part of the brickwork by day…
to 2 labores 23 April for digging and caryinge of sande…*[pointing mortars are being mixed and used immediately, therefore].*
the same daye to a carpenter for making of cleats and 3 shorte ladders for the worke…

to goodman Tilte the same daye for 5 dayes culloringe of the brickwork at 16d the day…
then to Tho: Dalyn for 5 ½ dayes the like…
then also to Ferdinando for the like worke at 10d a daye
to William Horsenele 28 April for 3 dayes culloringe at 16d a day
to Davyson the same day for 1 day poyntinge 10d
to William Horsenele 2 May for culloringe 3 dayes…
to Rote Dodson for the like 4 dayes…
to Tho: Dallin then for 6 days for the like…
to Nando Davyson then for poyntinge and culloringe 6 days…
[24 man days more of this].
10th September 1603 of red oaker for culloringe of the brickeworke 14s…
March 1603 for a dozen ½ of blacke for culloringe of the brickwork at 1d the pound….

Rosen and pitch for sementinge…more july 1604 for 6 lb of waxe for sement at 14d the lb…

For 1 ½ lbs of white vernishe for the greate Chamber chymneye peece at 8d the pounde.

Painters' cullors and paintinge paide for

1604

for 16 gallons and one quart of linseed oyle…for a rundlett for the same oyle…for 3 dozen of white lead ungrounde….then for 6 lb of whiteleade grounde…for 3 dozen of reddeleade ground…for 7 dozen and 3 lbs of Spanish white…for 22 lbs of Englishe oaker…for 4 lbs of vermilion…for casements and barres…for 2 dozen of spruce oaker nott grounde…for 1 dozen spruce oaker grounde…for 1 lb of Masticote…for ½ lb of Widgreace…for 1 lb of Lambeblacke…for glasscullor…for 1 lb of umber…for a basket to packe up the foresaide cullors in…for carriage of the foresaide thinges from Redcrosse streete to Ashly…

Paid before Christmas anno 1604…to the Paynter for 91 dayes worke at 20d per diem…to a labourer for grinding of cullors etc for the Paynter for 92 dayes at 8d per diem…

More pigments as above plus ½ lb Indico; 1 lb black leade…Spanishe brown.

Summ total: for cullors and carriage: £10 3s 5d
For wages per diem: £14 12s 4d

Chettle G H (undated) The Queen's House, Greenwich, Being the Fourteenth Monograph of the London Survey Committee. London. The Trustees of the National Maritime Museum, Greenwich. HMSO

From Appendix IV Extracts from the Building Accounts of the Seventeenth Century.

1616-1618

Bricks…£207 16s 6d

Lyme (some delivered by William Grammatt)…£63 16s 6d…

Flints 44 lodes…102s 9d

Sande 360 lodes at 10d the lode…

Stone saws 11s

12 wheelbarrowes

Baskette viz 10 dozen and 6.

Shovells 7 dozen

Pails 24

Lime sives viz 6 at 12d the pece and for one more limesive two foote.

Caske, viz two barrels…and two hogsheads…to make watertubbes.

Cariadge by lande and water of stone, deales, Carlinge planke, briskes, sand and other provisions…to and from sondry places.

Masons at 2s 4d, 20d and 18d the pece per diem: 115s 10d
Carpenters at 2s 4d, 22d, 20d, 18d, 16d and 14d the pece per diem: £27 5s 6d
…Bricklayers at 2s 4d, 22d, 20d, 18d, 16d, 15d, 14d and 12d the pece per diem: £63 10s 1d

Samuel Avery, William Browne and others for slacking, sifting and wetting of lyme into morter at 12d the hundred.

[The above would indicate that the lime is being processed at the same time as building proceeds; that it is being dry-slaked and screened before hand-mixing with shovels to a mortar. Most of the masonry work in this account is for brick-laying. Flints appear alongside sand. Pulverised flint <u>may</u> be being added to the mortar for some notional 'pozzolanic' effect, although brick dust would be a

more likely addition had this been deemed necessary. The flints may be for the core of footings, therefore].

1661

Labourers imployed in **slacking and sifting of lime**…in beating way through a brickwall into ye parke…(and) in digging the foundations for ye bricklayer.

Wotton H (1624) The Elements of Architecture, Collected by HENRY WOTTON Knight, from the best authors and examples. London John Bill.

(Refers throughout to Vitruvius and occasionally to Alberti).

P1. Well building hath three Conditions: Commoditie, Firmness and Delight.

P13 Philibert de L'Orme, the French Architect, would have the Lyme made out of the very same stone which we intend to use in the Worke; as belike imagining that they sympathise and joyne the better by an Original kindred (though Wotton counts this an unnecessary conceit)….Always it must be confessed that to make Lyme without any great choice of refuse stuff, as we commonly do, is an English error, of no small moment in our buildings. Whereas the Italians, at this day, and much more the Antients, did burn their firmest stone, and even fragments of marble, where it was copious, which in time became almost marble again, or at least of indissoluble duritie

Scott Mylne Rev. R (1893) The Master Masons to the Crown of Scotland and Their Works. Scott & Ferguson and Burness & Company. Edinburgh

Maissounes at Edinburgh Castle

1626

24th July Item. furneist to the abbay dykes of the north yaird for pinning poynting and helping of sum holls with the caipes thairof to James Robiesoune for xi laid of lyme at vi s viii d the laid is.

Item, to the said men for xx laidis of sand to the said lyme at vi s the laid is
to Andro M'Nauch cowaner for thrie dayes wark and ane half in mending the saidis dykes

21st August 1626.—Item, laid in be Williame Wallace to the vtter yett thrie laid of lyme at iiii s iiii d the laid

Item, for six laid of sand at iis the laid,
to ane barrowman half ane day at the riddilling and mixing of the sand and lyme

to Williame Wallace for ane day at the pointing and kaiping of the vtter yett,

to ane maissoune and ane barrowman half ane day at the vpputting of
the bak of the constabulles chimlay.

Ane Compt of Sum Small Warkis done at the Castell off Edinburghe and the Abbay of Halyrudehous sen the Seyint Day of October 1626.

Item, to William Wallace tua dayes in pointing and filling of the *alreines* of the counsallhous of Holyrudehous and Johne Boig maissoune with him,
to James Logy that maid the plaister lyme to thame and servit thame, .
For ane staine of hair,
Mair to William Wallace for foure great lek staines for the soill of the oven at Holyrudehous..., mair for carying of thame from Leith to the abbay,
to James Gilbert thrie dayes at the hewing and laying of the soile of the oven…

to Williame Wallace for his charges in Leith quhen he bocht the oven
stanes with onwaitting at the wark,

for xii laid of lyme,
for xxiiii laid of sand. *(suggesting a 1 quicklime: 2 sand proportion for the mortar)*.

Robert Dinmure Smith his Compt (Nodate)

Item, mair to Williame Watsoune four days in dichting and redding of the lymehous and filling of some hollis in the clos and bigging up sum baks chimleyis and going to the Stennes for lyme,

laid in be Johne Ros in the Stennes of lyme with his awn horse tuentie ane laid for laying of the pavement of the consallhous at ix s the laid
to his men to drink,

p162 Agreement between George, Earl of Panmure and "John Mylne master mason to His Majestie, to erect and build a guid and sufficient plain ston work…according to the designs of John Mylne (to begin work) betwixt and the first Tuesday of April next." **Four able barrowmen, skillful in making mortar and carrying stones, long or short, receive 18s Scots a week….The masons work till the middle of October…**(*Mylne died 1667).*

(New agreement with Alexander Nisbet, mason, January 1668). Nisbet undertakes "to provide 30 skilled masons to hew and lay the stones, and to enter them to work againe the tenth day of Februar nixt…"

The Earl undertakes "to furnish timeously all stones, long and short, lyme and sand, iron work and lead" etc; to "provide a good and sufficient ludge for the masons to hew their stones, either in foul or fair weather;" to furnish barrows, mortar tubs, shovels, etc…

Best H - Rural Economy in Yorkshire in 1641: Being the Farming and Account Books of Henry Best Published by George Andrews, 1857.

The best strawe for thatchinge is wheate strawe and rye strawe; barley strawe is good alsoe, if it bee without weedes and not over shorte; haver-strawe is accounted the worst, because birdes meddle most with this kinde of strawe; but the course which many use to prevent this is to mingle water and lime, and not to temper it too thicke, but to make it thinne like unto puttie, and soe the thatcher (whoe all wayes beginneth att the bottome or ease, and soe goeth up to the toppe or ridge of the howse) is to bee forewarned that hee call for this (when hee hath finished his cowrse or layer), and soe take his trowell and anoynte it all the way, as hee cometh downe againe.

Plat H (1653) The Jewel House of Art and Nature, containing Divers Rare and Profitable Inventions, together with sundry new Experiments in the Art of Husbandry…London Bernard Alsop

P73

92. A profitable and cheap Morter for building wherein either no Lime or small store of Lime shall be requisite.

A Wise, wealthy,and ancient Sope-boiler, dwelling without Algate, hath for the better encouragement of others , long since erected a fair and stately edifice of brick for his own habitation, upon the good successe whereof, he hath also very lately built one other house of some charge and good receipt, the morter whereof did consist **of two loads of waste Sope ashes, one load of Lime, one load of loam, and one load of Woolwich sand.**

So likewise one other of the same faculty, being likewise of good credit and great experience, hath used onely loam and sope-ashes tempered and wrought together instead of morter, whereby he hath laid both the foundations, chimneys, and their tunnels in his dwelling house (p74) in Southwark, and they have endured those storms already which have overturned many others, both new and old tunnels, that hath been built with the ordinary morter. It may be many limemen, and some of those Bricklayers that are in fee with them, may bend their force against this new practice, and labour to discredit the same by all means possible, but there is no reason that can hold against experience nor no malice so great, but that truth in her time shall not be thought a competent number to give credit to a new invention. I will upon reasonable request and warning, back and confirm them, with threescore more at the least, which I can produce, already made and executed within the City of London, and the Suburbs thereof, insomuch that whosoever will take a careful view of our late buildings that consist of Brickwork (especially within the Suburbs of the City) he shall find great store of these waste ashes to be imployed in them.

The History of the Royal Society of London Vol 4 (1872) A Millar London.

P363.

A letter of Mr Musgrave to Mr Aston, dated at Oxford, January 31 1684/5 was read, containing an answer to Sir William Petty's query about mortar and plaister, as follows….

The plaister used by our plaisterers here in Oxford is generally of two sorts, coarse and fine. 1. Coarse mortar is made of lime, sand and hair; the lime used here is of two sorts, viz 1. Chalk-lime, made of chalk-stone, dug at Netlebed etc and burnt; 2ndly, hard stone lime, which is made of hard rag-stone burnt; this last sort of lime is much stronger, and will go two yards square in five farther (for it takes up a far greater quantity of sand and water), than the former, which is the finer of the two, and the more glorious to the eye. One bushel of chalk lime, one bushel of sand, and one peck of hair, mixt altogether, with water, will make coarse mortar; but if you use hard stone lime then one bushel of lime will require a bushel and a half of sand, and a bushel of hair. 2ndly In the making of fine mortar, mix one bushel of chalk-lime with half a peck of hair, or a bushel of hard stone lime with a peck of hair, and as much water as is necessary. Coarse mortar is used next to the lathing, stone, or brick wall; fine mortar is drawn on the other, and makes it white and beautiful.

Clay mortar, or loam mortar is made with clay as much chopt straw as the clay will take in, by the help of water. Whiting is made by dissolving Spanish white, either in size or in water, that with size is not easily washed off….it was asserted that Spanish white, dissolved in sour milk, will make whiting as apt to stick, as if it were made with size.

Wren C. Life and Works of Sir Christopher Wren. From the Parentalia or Memoirs by his son, Christopher

Thoughts as Commissioner for the building of 50 more churches in London (Wren having already completed St Paul's and 50 churches. 1708

(p194)

I shall mention something of the Materials for publick Fabricks. It is true, the mighty Demand for the hasty Works of thousands of Houses at once, after the Fire of London and the Frauds of those who built by the great, have so debased the Value of Materials, that good Bricks are not to be now had, without greater Prices than formerly, and indeed, if rightly made, will deserve them; but Brick-makers spoil the Earth in the mixing & hasty burning, till the Bricks will hardly bear Weight; though the Earth about London, rightly managed, will yield as good Brick as (p195) the Roman Bricks, (which I have often found in the old Ruins of the City) & will endure, in our Air, beyond any Stone our Island affords which, unless the Quarries lie near the Sea, are too dear for general Use. The best is Portland, or Roch-abbey Stone; but these are not without their Faults.

The next Material is the **Lime; Chalk-lime is the constant Practice, which, well mixed with good Sand, is not amiss, though much worse than hard Stone-lime. The Vaulting of St. Paul's is a rendering as hard as Stone; it is composed of Cockle-shell-lime well beaten with Sand; the more Labour in the beating, the better and stronger the Mortar.**

I shall say nothing of Marble, (though England, Scotland, and Ireland, afford good marble, and of beautiful Colours) but this will prove too costly for our Purpose, unless for Altar-pieces. In Windows and Doors Portland Stone may be used, with good Bricks, and Stone Quoyns. As to Roofs, good Oak is certainly the best; because it will bear some Negligence: The Church-wardens Care may be defective in speedy mending Drips; they usually white-wash the Church, and set up their Names, but neglect to preserve the Roof over their Heads: It must be allowed, that the Roof being more out of Sight, is still more unminded.

Next to Oak is good yellow Deal, which is a Timber of Length, and Light, and makes excellent Work at first, but if neglected will speedily perish, especially if Gutters (which is a general Fault in Builders) be made to run upon the principal Rafters, the Ruin may be sudden.

Our Sea-service for Oak, and the Wars in the North Sea, make Timber at present of excessive Price. I suppose 'ere long we must have recourse to the West-Indies, where most excellent Timber may be had for cutting and fetching.

Our Tiles are ill-made, and our Slate not good; Lead is certainly the best and lightest Covering, and being of our own Growth and Manufacture, and lasting, if properly laid, for many hundred Years, is, without question, the most preferable; though I will not deny but an excellent Tile may be made to be very durable; our Artisans are not yet instructed in it, & it is not soon done to inform them.

Glamis Castle Archive Box 141 Bundle 11

Contract between the Earl of Strathmore and John Sherres Sklaitor 1701

…the said John Sherres binds & oblidges him to cast and harle the said noble Earles Castle of Glammis old and new work thereof with lyme on the front sides and round the same as also to point and make water-tight the roof of the said Castle old and new work thereof so soon as lyme, other materials & necessary engines shall be furnished for the work, which he is to perfect and finish betwixt the date hereof (30th March 1701) and the first day of September next to come…as much lyme to be mixed with sand sufficient and sowered as shall cast and harle the said castle and lyme sufficient for pointing etc the roof of the same. *(This would indicate dry slaking with sand/sand slaking, and then banking the mortar to sour before it is knocked up to a mortar for use. This* *might indicate a hydraulic lime; it might be to allow for some late slaking, or both. The mortar may be wetter, however, before souring and banking. Souring is the process of allowing time for late slaking to occur before use. The necessary period of souring might vary with the lime)*. Together with a sufficient strong cradle for holding two men for working and harleing strong rops and pullyes sutable & necessary for the upper part of the work. Togither also with two strong ladders for working and harling below so far as can be worked upon the same as also to provide three or four workmen according as need shall require for constant attendance with every thing also that may be found necessary to the perfecting of the said harleing which the said noble Earl is to provide and have in readiness in due time…

Machin R (Ed) (1983) The Building Accounts of Mapperton Rectory 1699-1703. Dorset Record Society

(Quarrying account)

1699

May & June

Pd Wm Crowther for 5 days work and a half at opening the Quarry and drawing of stones in the Parsonage orchard
Pd Wm Crowther for 6 days at drawing stones in the said quarry 5s…
Pd Arthur Evans for 4 days work at drawing stones in the said quarry 3s 4d

(Both are paid for the same until September when both are paid for 'throwing earth' and 'filling the earth' into the quarry.
Quarrying begins again on April 12th 1701, but by Crowther and Richard Burbridge. and continues into August, with 36 man days expended in October).

(Hamstone account)

1699

July. Pd for Ale given to the Carters at bargaining for carriage of the stones from Ham Hill
31st July. Paid the freemasons in earnest for and in part of their money to be paid them by agreement for the Windows etc…
Nov 27th. Paid the Hamhill Masons more in full for the Windows, Tunns *(Turns? – chimney stones),* Somers, Trusses and 60 foot of water table for the Parsonage house….
Pd Tho: Knight and Sam Strood for half a days work each for putting the Windows into house to preserve them from frost.

1701

Dec 13th Pd Hamhill Quarries for 13 foot of Natched water table to perfect the house.

1700

August 26th Pd the Newmans in part for carriage of the Hamhill windows
Sept 9th. Pd the Newmans more in full for the carriage of the 20 two-light Windows
Nov 19th. Pd the Newmans more in part for the carriage of the 4 single-light windows, turns, etc.

1701
July 26th. Pd Richard Hardy for bringing the great Parlour Clavel and jamb *(Clavel the fireplace lintel).*
Sept 9th Pd the Newmans in full for bringing the Turns, Water Tables, Somers, Trusses and other stone
Nov 20th Pd John Munden for bringing of a pair of Trusses from Hamhill to perfect the work.

(Carpentry account)

1700
Nov 19 Pd John Clark in consideration of the carriage of the binding beams etc
Jan 4th Pd John Clarke in part for the timber for the roof

1701

Aug 16th Pd Daniel Wade for a day's work in making of Centers for the Arches of the Windows and doors and felling and hewing the clavel for the kitchen both himself and son…
Oct 22nd Pd Will Clift for making 88 deal window Barrs
Dec 6th Pd John Clarke in full of his bargain for the Roof of the House
Jan 23rd Pd George Shepherd for 1600 of Heart Lathes at 17d per 100
Jan 23rd Pd Tho: Wilkins for 102 foot of Inch Oake Board at 2d per foot
Mar 7th Pd Richard Brodrepp Esq for 150 deal boards…
Mar 11th Pd (Clarke) for 17 jysts and 16 foot of square timber in two pieces…
Pd him for lathing of 11 Lathes of the parsonage house

1702
June 17th Pd Mr James Daw of Evershot for 34 Oake Boards containing 244 foot at 17s 6d per hundred
Pd Mr Daw more for 50 Elme Boards containing in the whole 439 foot at 12s per hundred
June 20th Pd John Roper the Carpenter for 12 ½ days work at framing Speers at 1s 2d per day…
Pd Dan: Wade for 6 days work for himself and son viz two days at sawing Jysts for the Kitchen and four days for sawing timber for roofing the Brewhouse…
July 18 Pd Wm Clift senr for 9 days work about planning oake and deal boards for Laying ye Rooms…

(Thatching account)

1701
Dec 2nd Pd farmer Hounsel for half a hundred of Reed and carriage
16th Pd Wm Angel for 1400 of Osier Twigs for the house
Pd him for 1400 of Ledgers for thatching the house
Jan 17th Pd Mr Hallet of Wooth for 200 reed sheaves…
Jan 20th Pd the Thatcher for Thatching the house 50s and gave him to drink 1s
March 11th Pd Mr Banger of Burcombe for 91 reed sheaves and carriage…
1702
March 26th pd Mr John Hennell for 100 reed sheaves
1703
May 10th Pd Mr Hain of Catstock for 100 reed sheaves …
Oct 15 Pd Wm Cole the Thatcher for 4 ½ days work for himself and boy
Pd Wm Cole for 500 Sparrs used on the skilling (lean-to)
Pd him for 200 Osier twigs used on the same
Pd him for 120 Hooks for the same use
Pd farmer Nich: Pitman for half a hundred of Reed.

(Masons account)

1700
Jan 9th Gave the masons to drink on conclusion of the Bargain for the House

21st Gave the masons the consideration money given them by agreement to find themselves in drink whilst about the building.
March 6th Pd Edward Hitt for a Grinding stone for ye Masons and Carpenters

1701
Oct 18 Pd the Masons in part for building the House £20
Nov 22 Pd the Masons more in part for building ye House £28
Pd them for work done in the Quarry in cutting out Clavell & Jambs & Durnheads
Pd them for hewing the Clavel & Jamb of one of the chamber chimneys which was not included in their Bargain
Pd them for hewing the Skew Stones that were not included in ye Bargain.
Dec 3rd Pd Mr Stone for a Dozen of Hurdles for scaffolds
1701
Feb 21st For Paper & Stamp duty on which the Articles of Agreement with the Masons were written.
1702
March 25th Pd Thomas Gale the Mason for 48 days work about the Skilling house and hewing the partition stones at 1s 2d the day.
March 25th **Pd Rich: Brodrepp Esq for Lyme for ye house and Skilling 0-2-11**
25th Pd Sam: Gale for 2 ½ days work about ye Skilling
Pd him for 9 days work for his boy attending them.
April 30th Gave the Axminster Quarries to drink upon concluding for the Pavement.
June 20th Pd the Axminster Masons for 577 foot of pavement and for Laying and bringing ye same at 4 ½ d the foot
Pd Tho: Gale of Lostcombe for 4 days work at daubing of Speers in the Lower Rooms…
July 4th Pd Henry Knight for 2 days work at mixing Mortar and carrying the same for making the Spears (this may be earth or earth-lime mortar)
11th Pd Tho: Knight Junr for a day's work digging Earth against Ryelands to daub ye Spears
Aug 12th Pd Tho: Gale the Mason for 2 days work laying the partition stones in the Rooms
Pd Tho: Gale ye Mason for 5 days work daubing ye Spears
Pd him for 5 days work about hewing stones for the Kitchen Buttry pavement
Pd Tho: Gale the Mason for 3 days work about walling in the Lyons and Laying ye window boards
Oct 3rd **Pd John Lack Jnr for 4 days daubing ye Chamber Spears 4s**
Pd Tho: Gale of Melplash for 4 days work with him 4s 8d
March 20th Pd Tho: Gale ye Mason for 4 days work at ye same 4s 8d…
Paid him for 16 days work about hewing and setting of the pavement in the porch and Kitchen chimney and the 3 Thrasholds and ye 2 small chimney hearths.
(Gale and boy working on making furnace and oven).

(Other expenses)

1701
May 31st Pd Sam'll Stroode & Abraham Crandon for pulling down the timber and walls of the old Parsonage House
Pd Wm Cole the Thatcher for pulling down ye Thatch…
Pd Tho: Banger for a cheese for the Masons & Carpenters at their setting up ye Couples
Pd for half a peck of Wheat to make a Loaf for them
Pd Mr Purchase for 3 bushells of Malt, old measure, to Brew half an Hogshead of Ale for them…
Pd Ric: Hine (for) Clamps, Boardnails and Iron crooks for the scaffolds.
(Payments for many nails, for casements, bolts, staples, latches and catches, iron bar)

(Carpenters and Joiners wage account and timber beginning August 1st 1702 – stairs, doors, door casements, oak boards, bottle racks and shelves, joists, partitions)

Paid the Plaisterers etc and for Materials etc

1702
Sept 4th Paid a Lyme Burner of Uplime for 5 sacks of Lyme for plaistering at 2s 8d per sack *(Uplime is on the Lower Lias formation but also had deposits of much purer lime – would a hydraulic lias lime be used for interior plastering over earth base-coats already applied by the masons?)*
Oct 22nd Pd George Shepherd for 30 hundred (3000) sap lathes
29th Pd the Lime Burner of Uplime for 6 sacks of lime more
Pd Elias Combe for 3 Hogsheads of Lime for Brown Mortar *(is this earth-lime mortar?)*
Nov 7th Pd for 10 bushells of white Goat's Hair net bought at Preston for the white Mortar
(Lias lime would not deliver 'white mortar', lest White Lias was used)…
Dec 23rd Pd John Manning for plaistering my Wives closet with 2 Mortars at 2d per yard
Pd John Manning for plaistering the Kitchen chamber with two Mortars…
Pd him for plaistering the Hall chamber (and the passage chamber, little Parlour, Kitchen and passage out of the Hall)
Dec 23rd Pd John Manning for plaistering the Hall being 77 yards 4 foot 11 inches…
Pd him for plaistering the Buttry next the entry with one Mortar…(also the Kitchen Buttery)…Pd him for pointing of 27 windows now glazed at 1 ½ d per light
Paid him for going to Preston to buy Goat's Hair for the White Mortar
Pd him for his Man helping home of sand for the work

Jan 2nd Pd Jno Legg the Tanner for 10 bushells of Color'd Hair at 6d per bushel
Pd him for 2 bushells and half of white hair at 1s 6d per bushel

Pd James Shepton for 41 bushells of Black and White Hair…

1703
April 15th Pd John Leg's Wife of Hook for 4 bushells of color'd hair
19th Pd John Manning for Rusticking the Dutch Cap Windows as by agreement with him
Pd him for white washing the two Butterys
Pd him for Glew he bought to make size
Augt 11th Pd him for plaistering the Porch with two Mortars…
Pd him for plaistering ye study with two Mortars
Pd John Manning for pointing of 15 Window Lights
Oct 14th Pd the Lime Burner for 2 Hogsheads of Lime used about the plaistering of the Porch, Studdy etc

(Account for glazing and painting).

July ye 3rd 1706

Pd for plaistering my Parlour and the chamber over it as followeth:
Pd Wm Clift for three days work for himself and son
Pd for 5 Hogsheads of Lime
Pd Legg the Tanner for Black & White Hair
For lath nails
Pd John Stone for plaistering

(Later Accounts)

Oct ye 27th 1704
Laid out for repairing My Chancel as followeth:
For Lime 13s 4d
For 300 of Potter's Tiles & 4 Cresses (ridges)
For lath nails
For 17 foot of Water Table & a Summer
For laths
Pd Dan: Wade for work…Pd John Stone for 16 days work for himself & son….

May ye 3rd 1706

Pd for Building my Barn & Stable, as followeth:

Pd Sam: Gale & son for building the walls 10-5-0
Pd Dan: Wade for 42 days work about the Barn & Stable for himself & son 3-13-4
For a Bushell of Lime 0-0-6 *(this is a relatively small quantity, indicating that the primary mortar will be earth, with a little lime added)*
Pd George Demot for Lath & other nails 0-16-0

For hooks for the Stable Door 0-1-0
Pd Hugh Silt for Lathes 0-7-6
Pd for 300 of Reed 2-19-0
Pd Phil: Shinner (Skinner?) for twenty days work in thatching my Barn & Stable & for flakes, spars, hooks & twigs 1-16-?

July ye 25th 1720

Laid out for Tiling My Chancel
For 4 sacks of Lime 0-10-0
For nails 0-10-6
For carpenters work 0-3-6
For a piece of timber 0-2-0
Pd for 600 of laths 0-9-0
Pd for a bag of lime 0-1-3
Pd Henry Townser for work done about my Chancel 1-15-6
Pd for a peck of Hair 0-0-4
Paid the Pottman for 1000 Pan tile *(clearly locally made)* 1-0-0
Pd the Potteman for 4 Creas Tile 0-1-0

Appendix. Contracts for Building a House at Evershot. (DC- Ilchester Collections D124).

(This clearly shows that separate agreements were made with each tradesman for their part in the construction process. It also quantifies the traditional measures as locally understood).

Mem: about the house of John Biddells intended to be built in Evershot.

14th May 1715

Agreed with Joseph Chiles as followeth viz that hee shall worke, fitte and sett up in a good Workmanlike manner the Timber work of the floores viz Girders, Jestes etc and of the Roofe and also the doore cases and Windowes att 9s per square viz **10 feet square** and **hee is to use as much of the old stuffe that comes out of the house as possible hee cann.**

Also agreed with Robert Crew, a Mason, for doing all the Mason's worke att 1s 6d per perch reckoning 15 ½ (ft) to the perch, and to be measured from Bottom of the Sellars to the Topp att one and the same price and for working Quines 2d per foot; windows 3d per foot heading

Also agreed with him stones 1d per foot for the Masons worke of the two Stackes of Chimleys that are to be built in the house, each of which stackes are to have 4 separate flews or draughts for carrying Smoake, that is 4 Chimleys in each stacke for which I am to pay the said Robert Crew £12 10s and the back of the Chimley which stands in the wall is to be measured as wall.

November 1715

Agreed with Robert Crew for Arching my Sellars in the said house, strongest with Graines or otherwise as the said John Biddell shall thinke strongest and the same is to be done with Chaulke stone, which stone is to be drawed, fitted and laid and all the Masons worke about the same completely done by the said Robert (Centers, lime and carriage of the stone only excepted), for all which said worke the said John Biddell is to pay the said Robert Crew the sume of Ten pounds.

!st August 1716

(Agreement with carpenters for making and fitting stairs and partition walls, joists)…

Agreed with Paul White for 6s a perch superficial Measure for my Tyling worke, a perch sup-ficiall measure is 15ft square.

Agreed with William Chinnocke to give him 6d a square for my Shash windows and 6d per foot for what other new glass hee doth (supply) and 3d per foot for Leading and soldering my old glass and also 1 ½ d for the Shashwaites. *(Early for sash windows)*.

11th January 1716
Agreed with John Parsons for putting boxes for Seates in the Windows of the Hall and little room and making window Shutts to the same windows and hang them and to make and hang fower Doores to the same rooms and to Case the Darrnes of the same Doores and to make and sett up a Chimley peece against the Chimley and to putt Moulding att the Corners of the Windows and to make Shelves in the Little Roome as I shall direct and to sett up a boarded back in the back of the Roome and to make a place in the Little Roome for writing on and for all this worke I am to pay him £3 10s

16th Sept 1717

Agreed with William Churchouse of Yeovill, Joyner, to make me a doore for the Kitchen Chamber of Deale in a strong wainscot way, another doore between the Kitchen Chamber and little Chamber, wainscutt way with 2 pannells, the Panells to be of Beach & ye rest deale and to make two double doores against the Kitchen of Oake, that is Doores in two parts to open each side and the Face to be done with Mouldings as in Wainscutt. He is also to fit on bolts and lockes on the said Doores and to hang them, I finding hinges, lockes and bolts for the same. He is to cleanse over the floores and Stairhead which he laid with the Plain and he is to putt up sealing Jests in the Kitchen Chamber and over the staires and fit the same for the Plaisterer….For all this worke he is to have 1 10s and 1s 10d for one dayes worke.

Agreed also with Richard Budding to plaister my House, the Kitchen and Staires with 2 Mortars and all the Seelings and the two Chambers with one Mortar only and for the Seelings he is to have 3d a yard and for the walls and stairs 2d per yard.

Moxon J (1703) ***Mechanic Exercises*** **The doctrine of handy-works ; applied to the arts of smithing, joinery, carpentry, turning, bricklayery** ; to which is added, Mechanick dyalling: shewing how to draw a true sun-dyal on any given plane, however scituated ; only with the help of a straight ruler and a pair of compasses, and without any arithmetical calculation. / by Joseph Moxon. Moxon, Joseph, 1627-1691.London : Printed for D. Midwinter and T. Leigh..., 1703. --
Downloaded 2015 from the Hathi Trust.

Moxon suggests that his work is the first to treat seriously of the hand-crafts and intends that it should disprove the notion that such work is to be despised and the integrity of its practitioners assumed to be weak. He seeks to assert the 'nobility' of skilled labour. It is a summary of later 17th C craft practice.

Of Lime

There are two sorts, one made of stone, which is the strongest, and the other made of chalk, both sorts being burnt in a kiln.
The lime that is made from soft stone or chalk is useful for plastering of seelings, and walls or on the insides of houses, and that made of hard stone is fit for structures or buildings and for plastering without doors, or on the outside of buildings that lies in the weather, and that which is made of greasy, clammy stone is stronger than that made of poor lean stone, and that which is made of spongey stone is lighter than that made of firm, close stone that is again more commodious for plastering, this for building.

[Moxon is here distinguishing between pure air limes and feebly hydraulic limes, both of which were being used in London at this time. The 'chalk' and 'stone' lime distinction was one made by craftsmen at the time, indicating the different properties and typical uses. Elsewhere in the country, such a clear distinction would not have been likely or possible].

Also, very good lime may be made of *millstone,* not coarse and sandy, but fine and greasy *[i.e., not millstone grit, a sandstone, but either Derbyshire limestone* *without inherent hydraulic potential or Belgian blue limestone, which may have been feebly hydraulic]*

Likewise of all kinds of flints (but they are hard to burn except in a reverbratory kiln), except those which are rolled in water, because a great part of its increase goes away by a kind of glass.

But the shells of fish, as of cockles, oysters etc are good to burn for lime.

And the fire in lime burnt, assuages not, but lies hid, so that it appears cold, but water excites it again, whereby it slakes and crumbles into a fine powder.

Lime also is useful in divers things, for tis useful in ils and wines, and good to manure land with; some season new wine with it, mitigating the unpleasantness of the wine therewith.

Moreover, quick lime being cast into an arched vault and water thrown upon it, consumes dead bodies put therein *[or, at least, makes more sterile their decomposition…]*.
Also, diers and tanners use it, and likewise physicians use it, but they choose the newest, to wit, that which is newly drawn out of the kiln, and not slacked with water or air.

It will burn so vehemently that it forms crusts and will fire boards or timber against which it lies, but being slacked for sometime, it burns no more, yet warms and dries, and dissolves flesh, and being washed three or four times *[??],* it bites and eats not, but dries quickly.

Lime mixed with sand is much used in building, and Vitruvius says, that you may put **three parts of sand that is digged (or pit sand) and one part of lime to make mortar; but if the sand be taken out of a river, or out of the sea, then two parts thereof and one of lime; as also to river to sea-sand, if you put a third part of powder of tiles or brick, (to wit, tile or brick dust), it works the better.** But Vitruvius, his proportion of sand **seems too much, although he should mean the lime before it is slacked;** for one bushel of lime before it is slacked will be 5 pecks after tis slacked. *[4 pecks make a bushel, so expansion here is only 25%, indicating that Moxon is referring to probably moderately hydraulic lime here, not pure lime, which will more than double in volume, making Vitruvius's proportions entirely appropriate and indicating that he is referring to air limes].*

Here at London, where for the most part our lime is made of chalk *[but frequently of feebly hydraulic 'grey chalk'],* we put about 36 bushels of pit sand to 25 bushels of quicklime; that is about 1 bushel and a half of sand to one bushel of lime *[leading to a little less than 1:1 mortar on the volumetric expansion referred to above - 6 pecks of sand to 5 pecks of lime. Using a pure airline such a ratio would lead to a mortar of more lime than sand, at least 1 1/2: 2].*

And lime mixt with sand, and made into mortar, if it lie in a heap for two or three years, before tis used, it will be stronger and better, and the reason of so many insufficient buildings, is the using of the mortar as soon as it is made, as Agricola saith. *[the insufficiency is unlikely to have been for this reason, it should be said, but recent research indicates that hot mixed mortars laid down improve in strength but at the expense of some of their larger pores (Viega et al 2014)].*

Moreover there is other mortar, used in making of water-courses and cisterns, fishponds etc, which is very hard and durable, as may be seen at Rome, as this day, which is called Maltha, from a kind of bitumen dug there; for as they build most firm walls thereof naturally, so they use it in making of cisterns to hold water, and all manner of water-works, and also in finishing or plastering of fronts to represent stone.

[a discussion of ancient glues and of 'metalists' which included quicklime…]

…In latter times, two kinds of cement are in use, in both of which they use the powder of marble, or other stone, to one is added the whites of eggs, to the other is added pitch…

Another material which bricklayers use are laths, which are made of **heart of oak**, **for outside work,** as tiling and plastering, and of **fir for inside plastering and pantile lathing;** their usual lengths being 5 foot and 4 foot, and sometimes longer or shorter; their breadth sometimes 2 inches, and 1 1/2 inches; their thickness about 1/4 inch or thicker. But for pantiling the laths are about 10 foot long, one inch and a half broad and half an inch or more thick.

[description of nails and of oak tile-pins]

They also put Ox or cow hair into the mortar which they use for plastering, being called lime and hair, which hair keeps the plaster from cracking or chapping, and makes it hold or bind together.

And whereas they make use of the sharpest sand they can get (that being best) for mortar to lay bricks and tiles in, so they choose a fat loamy or greasy sand for inside plastering, by reason it sticks together and is not so subject to fall asunder when they lay it on seelings and walls.

[naming and descriptions of bricklaying, tiling and plastering tools, which gives some insight in methods of working also:]

a Striker, which is only a piece of lath about 10 inches long, with which they strike or cut off the mortar at the britches of the tiles…

A setting trowel, being less than the laying trowel, with which they **finish the plastering when it is almost dry, either by towelling or brushing it over with fair water, <u>or else</u> by laying a thin coat of fine stuff made of clean lime and mixed with hair without any sand, and setting it, that is to say, towelling and brushing it.**

Brushes of three sorts, viz a stock brush, a round brush and a pencil. With these brishes, they wet old walls before they mend them, and also brush over their new plastering when they set or finish it and moreover, white or size their plastering with them.

Floats, made of wood, with handles to them, which they **sometimes use to float seelings or walls with when they are minded to make their plastering very straight and even….Likewise, they use floats, made to fit mouldings, for the finishing of several sorts of mouldings with finishing mortar to represent stone, such as cornices, fascias, architraves etc.**

The finishing mortar to represent stone should be made of the strongest lime and the sharpest sand you can get, which sand must be washed in a large tub, very well, till no scum or filth arise in the water, which will sometimes require to have water 5 or 6 times, when the sand is somewhat foul, and it requires to have a greater proportion of sand than the ordinary mortar, because it must be extremely beaten, which will break all the knots of lime, and by that means it will require more sand.

Sieves…to sift the lime and sand withal <u>before they wet it</u> into mortar or lime and hair *[this would indicate previous 'dry-slaking' of coarse stuff]….*

A skreen made of boards and wyer, which performs the office of a sieve, and with which one man will skreen as much lime, mixt with sand or rubbish, as two men can with a sieve *[again indicating dry-slaking].*

[then into building method, stressing the necessity of paper plans at the very least, if not wainscot models, of all floors and lay-outs, so that…]

there will be no need of alterations or tearing and pulling the building to pieces after it is begun, for besides the hindrance of the procedure of work, it makes the building lame and deficient, **nothing being so well done, when tis put up, and pulled down, and set up again as if it were well done at first. Besides, it makes the workmen uneasy, to see their work, in which they have taken a great deal of pains, and used a great deal of art, to be pulled to pieces.**

The drawing of draughts is most commonly the work of a surveyor, **although there be many master workmen who will contrive a building, and draw the designs thereof, as well, and as curiously, as most surveyors; especially those workmen who understand the theoretic part of building, as well as the practik.**

[contrast Moxon's positive attitude towards craftsmen to that of most 'scientific' writers on the subject in the second half of the 19th C, such as Burrell].

….Because the well-working and bonding of brick walls conduces very much to their strength, I will here add some necessary rules to be observed in the laying of bricks, to make the walls strong and durable:

First, That the mortar be made of well-burnt good lime, and sharp sand and that it have a due proportion of sand, that is to say, if it be very sharp, a load of sand, being about 36 bushels, is sufficient for an hundred of lime, being 25 bushels or a hundred pecks…to wit, **to one bushel of quicklime, a bushel and a half of sand** *[giving a mortar 1.25: 1.5 or even 1:1 using hydraulic lime]*. But if the sand be not very sharp, then you may put a greater quantity of sand, for mortar which hath its due proportion of sand is stronger than that which hath less sand in it, altho' some think otherwise.

Secondly. **When you slack the lime, take care to wet it everywhere a little, but do not over-wet it, and cover with sand every laying, or bed of lime, being about a bushel at a time, as you slack it up, that so the steam, or spirit of the lime may be kept in, and not flee away, but mix itself with the sand, which will make the mortar much stronger than if you slack all your lime first and throw on your sand altogether at last, as some use to do.**

[Important to note that Moxon is not meaning slake the quicklime to putty, leave and add much later when cold and mature, but is counselling against the method later advocated by Burrell (1857) of slaking to a paste before quickly adding to the sand and mixing, oftentimes, at least, whilst the paste was still hot and possibly still slaking].

Thirdly. **That you beat all your mortar with a beater three or four times over before you use it, for thereby you break all the knots of lime that go through the sieve** and incorporate the sand and lime well together, and the air which the beater forces into the mortar at every stroke conduces very much to the strength thereof *[Moxon is encouraging the removal of as many 'lime lumps' as possible from the mortar. Beating might, however, be seen rather to reduce the entrained air content and reduce the size of the pores…which would increase compressive strength, as he implies, but not for the reason he imagines. It may reduce its durability in face of severe frost or salt. The heat may mitigate this effect, however].*

If I might advise anyone that is minded to build well, or use strong mortar for repairs, **I would have them beat the mortar well, and let it lie 2 or 3 days, and then beat it well again when tis to be used.**

Fourthly. If you lay bricks in hot, dry weather, and be it some small piece of work that you would have very strong, **dip every brick you lay, all over in a pale of water,** which will make the wall much stronger than if the bricks were laid dry; the reason why I mention a small piece of work is because it is a great deal of trouble to wet them for much work, or a whole building, and besides it makes the workmen's fingers sore; to prevent which they may throw pales of water on the wall after the bricks are laid *[this would only be possible without washing out some of the lime when hot mix was used],* as was done at the building of Physicians College in Warwick Lane, by order of the surveyor, which was the aforesaid Mr Hook, if I mistake not.

Fifthly. Cover all your walls in the summer-time, to keep them from drying too hastily, for the mortar doth not cement so strongly to the bricks when it dries hastily, as when slowly.

Sixthly. Be sure to cover them very well in the winter-time to preserve them from rain, snow and frost, which last is the enemy **to all kinds of mortar, especially to that which hath taken wet just before the frost.**

(other points about construction method and bonding)

…Tenthly. In summer-time use your mortar as soft as you can, but in the winter time pretty stiff or hard.

(descriptive account of the Act of Parliament for building in London).

Twelfthly. When you lay any timber on brickwork, as morsels for mantle-trees to lye on, or lintols over windows or templets under girders, or any other timbers, **lay them in loam, which is a great preserver of timber, for mortar eats and corrodes the timber. Likewise the joyst ends and girders which lye in the walls, must be loaded all over,** to preserve them from the corroding of the mortar. Some workmen pitch the ends of the timber that lye in the walls to preserve them from the mortar.

….There are two forms of cement which some bricklayers use in cementing of bricks for some kind of mouldings, or in cementing a block of bricks, as they call it, for the carving of scrolls or capitals or such like, etc. One is called cold Cement; the other is called hot Cement…the cold cement being accounted a Secret, is known to but few bricklayers, but the hot cement is common.

To make the cold cement

Take half a pound of old Cheshire cheese, pair off the rind and throw it away; cut or grate the cheese very small, and put it into a pot. Put to it about a pint of cow's milk. Let it stand all night; the next morning get the whites of 12 or 14 eggs, then take 1/2 a pound of the best, unslaked quicklime that you can get and beat it to a powder in the morter, then sift it through a fine hair sieve into a tray or bowl of wood, or into an earthen dish, to which put the cheese and milk, and stir them well together with a trowel…breaking the knots of cheese, if there be any. Then add the whites of egg and temper all well together and so use it. This cement will be a white colour, but if you would have it the colour of brick, put into it…some very fine brick dust, or Almegram *[?],* not too much but only just to colour it

To make the hot cement

Take one pound of rosin, 1/4 pound of bees-wax, 1/2 an ounce of fine brick dust; 1/2 an ounce of chalk dust…sift both the brick dust and chalk dust through a fine hair sieve…boil altogether in a pipkin or other vessel, about a quarter of an hour, stirring it all the while with an iron or a piece of lath…then take it off and let it stand 4 or 5 minutes, and tis fit for use.

Note. That the bricks that are to be cemented…must be made hot by the fire before you spread the cement on them and then rub them to and fro on one another, as joiners do, when they glue two boards together.

Mortimer (1708) The ART of HUSBANDRY; Or the Way of Improving of LAND.— BOOK I.

BEING a full Collection of what hath been Writ, either by ancient or modern Authors: With many Additions of new Experiments arid Improvements not treated of by any others. AS ALSO, An Account of the particular Sorts of Husbandry used in several Counties -, with Proposals for its farther Improvement. To which- is added, The Countryman's Kalendar, what he is to do every Month in the Year. LONDON, Printed by J. H. for H. Mortleck at the Phœnix, and J. Robinson at the Golden Lion in St. Paul's Church- Yard, MDCCVIII. 1708

[Whilst not extensively about lime, this offers a compelling snap-shot of building practice in 1708].

If you design to make your Cisterns under your House, as a Cellar, which is the best way to preserve it for culinary Uses, you may lay the Brick or Stone with Terrace, and it will keep Water very well; or you may make a Cement to join the Bricks or Stones with, with a Composition made of slacked sifted Lime and Linseed Oyl tempered together with Tow or Cotton-wool. Or you may lay a Bed of good Clay, and on that lay your Bricks for the Floor, then raise the Wall round about, leaving a convenient space behind the Wall to ram in Clay, which may be done as fast as you can raise the Wall: so that when it is finish'd, it will be a Cistern of Clay walled within with Bricks, and being in a Cellar, the Bricks will keep the Clay moist (altho' empty of Water) that it will never Crack.

Or you may make a Cistern or Pool to hold Water by daubing of it with Clay and Mortar, and after draw it over with Mortar; if any cleft happen, stop it with **a Cement of clean Hair and Tallow mix'd with unslack'd Lime and Yolks of Eggs well beat, and made into Powder, and mix'd well together.** I am told that in

Wiltshire upon the Top of the dry chalky Hills where there is any descent to catch the Water, they make Ponds, the bottom of which they cover with Chalk Rubbish, which they beat small, and when any Rain comes to moisten it, they ram it well, and drive Cattle into it, and fold Sheep on it to trample it, and it makes it hold Water-
This I have known to hold Water perfectly well in a shadowy place, tho' not in a Cellar. Thus in Gardens or any other places may such Cisterns be made in the Earth and cover'd over, the Rain-water being convey'd thereto by declining Chanels running unto it, into which the Alleys and Walks may be made to cast their Water in hasty Showers. Also in or near Houses may the Water that falls from them be conducted thereunto. .

But the usual way to make Pools of Water on Hills and Downs for Cattle, is to lay a good Bed of Clay near half a Foot thick; and after a long and laborious ramming thereof, they lay another course of Clay about the same thickness, and ram that also very well; and pave it very well with Flints or Other Stones, which not only preserves the Clay from the tread of the Cattle, & c. but from chapping by the Wind or Sun at such time as the Pool is empty. Note also, that if there be the least Hole or Crack in the bottom, it will never hold Water, unless you renew the whole labour.

As for the Farm-houses, I think one large Room with a large Chimney in it, to do the chief of their Work in, with a good Parlour, a good Dairy, with good conveniences of Butteries, Cellars, and Out-houses, enough for a Farmer; which several Rooms should be bigger or smaller, according to the bigness of the Farm that belongs to it.
To which Observations, I shall add some general Maxims for Contrivance in Building, as follows,

1. Let not common Rooms be private, as Halls, Galleries, Stair-cases, &c. and let not private Rooms lie open and common, as private Parlours, Chambers, Closets, &c.
2. Light also is a principal Beauty in Building, and the Rooms that respect each particular Coast, ought as near as you can to be accommodated to it, as those Rooms next the South for Winter Rooms, and those that regard the East for Summer Rooms, the North Windows are best for Cellars, Butteries, Use. Rooms that have thorough Lights for Entertainment, and those that have Windows on one side for Dormitories.
3. As for the size of your House, you had better build it too little, than too big, for a large House brings Company and Entertainment, occasions the keeping of a great many Servants, and often requires a larger Purse than is laid up for it.
4. As to the strength of a Building, Country Houses ought to be substantial, and able to encounter all the shocks of the Wind, and not to be above three Stories high, including the Garrets; and observe in working up the Walls, that no side of the House, nor any part of the Walls be wrought up three Foot above the other, before the next adjoining Wall be wrought up to it,

that so they may be all join'd together and make a good Bond, or else what is done first will be dry, so that when they come to settle, one part being moist and the other dry, it will occasion it's settling more in one place than another, which causes cracks and settlings in the Wall, and much weakens the Buildings. The Materials also ought to be substantial, and be sure if you build a Brick-building to take care of a good Foundation, and not be scanty in allowing Mortar, taking care that all your Brick-work be cover'd with the Tiling, according to the New way of Building, without Gable-ends, which are very heavy, and very apt to let the Water into the Brickwork. The want of observing of which three Things is the common decay of Brick Buildings.

5. Upon a good Foundation two Bricks or eighteen Inches thick for the heading Course is sufficient for the Ground-work of any common Structure, and six or seven Courses above the Earth to the Water-table, where the thickness of the Walls are abated, or taken in on either side the thickness of a Brick, which is two Inches and a Quarter.
6. But for large high Houses of three, four or five Stories high, the Walls of such Edifices ought to be from the Foundation to the first Water-table, three heading Course of Brick, or twenty eight Inches thick at the least, and at every Story a Water-table, or taking in on the inside for- the Summers, Girders or Joysts to rest upon, laid into the Middle or one fourth part of the Wall at least, for the better Bond ; but as for the Innermost or Partition-walls, a Brick and a half will be enough, and for the upper Stories nine Inches (or a Brick in length) wall will be sufficient.

The Beauty of a Building consists much in regular Form and a graceful Entrance, for Regularity and Proportion pleaseth the Eye and I think a fair well wrought Front of Brick, pleasanter than one of Stone, which soon loseth its Colour and turns black. The being let through a double Grove of Trees to a House, and to have fine Walks and Gardens behind, and on as many sides of it as you can, is very ornamental. And let your Offices, Barns, Stables, Etc. neither join to, nor be too near your House, especially your your Stable, which ought always to be a Building by itself, because of the Danger of Fire, upon the Account of the looking after Horses, and the Use of Candles in it.

To which Maxims, I shall add some general Rules to be observed in Building, as orderd by Act of Parliament for the Building of London.

General: 1. In every Foundation within the Ground, add Rules. Brick in thickness to the thickness of the Wall, next above the Foundation, to be set off in three Courses equally on both sides.
2. That no Timber be laid within twelve Inches of the fore-side of the Chimney Jambs, and that all Joysts on the back of any Chimney be laid with a Trimmer six Inches distant from the back.
3. That no Timber be laid within the Funnel of any Chimney, upon penalty to the Workmen for every Default ten Shillings, and ten Shillings a Week for every Week it continues unreformed.
4. That no Joyst or Rafters be laid at greater Distances from one another, than

twelve Inches, And no Quarters at greater Distance than fou teen Inches.
5. That no Joyst bear at larger lengths, than ten Foot, and no single Rafters are more in length than nine Foot.
6. That all Roofs, Window-frames, and Cellar floors be of Oak.
7. That the Tile- pins be of Oak.
8. That no Summers or Girders do lie less than ten Inches into the Wall, nor Joyst than eight Inches, to be laid in Loam, because Mortar is apt to rot all Timber, and therefore some Workmen pitch the End of such Timbers as they lay in Walls. .
9. That no Summers or Girders do lie over the Head of Doors or Windows,
10. That good Oak Timber be laid over Doors and Windows, and that good Arches be turned over them.

Where a Jamb is set upon moist Ground, dig the Earth two Foot deep, and after beating well, lay a Bed of Mortar, or Cement from either side to the Channel, a**nd then lay a Bed of Cinders upon the Mortar, beat it well, and cover it with another Cement of Lime, Sand and Ashes, this will drink up the Moisture and make it dry.**

But if the Earth you build on be very soft, as in Moorish-ground, then you must get good pieces of Oak, whose length must be the breadth of the Trench, or about two Foot longer than the breadth of the Wall, these must be laid cross the Foundation about two Foot asunder, and being well rammed down, lay long Planks upon them, which Planks need not lie so broad as the pieces are long, but only about four Inches of a side wider than the Basis or Foot of the Wall, and to be well pinned or spiked down to the pieces of Oak, on which they lie j but if the Ground is so very bad that this will not do, you must provide good Piles of Oak, of such a length as will reach the good Ground, and whose Diameter must be about one twelfth Part of their Length, which must be well drove down with an Engine, and then lay long Planks upon them, spiking or pinning of them down fast. But if the Earth is only faulty in some places and good in others, you may turn Arches over those loose places, which will discharge them of the weight. Note also, that you must place your Pile not only under your Out-walls, but under your Partition walls too, that divide the Building, for if they sink, it will crack and damage the Outer-walls too. And that you may know the proper Sizes of Timber for your ordinary Buildings; I shall, to what hath been laid already, add a Scheme of the Proportion of Timber, as agreed to by Act of Parliament for rebuilding of the City, that your Timber may in strength be answerable to the rest of your Building.

Bricklayers Work at London, where a Bricklayer hath two Shillings and Six-pence a Day, a Labourer twenty Pence, and that Bricks are fourteen Shillings a Thousand, Lime Four-pence half-penny a Bushel, and Tiles two Shillings and Six-pence a hundred. For the Bricklayer to find Bricks, Mortar, Scaffolding, Tile, for a House, is five Pound a Pole-square, that is, sixteen Foot and a half but for Walling, four Pound ten Shillings a Pole, if the Bricklayer finds all Materials, is enough. But for his Work only, 'tis one Pound two Shillings a Pole, that is two hundred seventy two square Feet, and a Brick and a half thick. In the Country they will build a Wall for eighteen Shillings a Pole, supposing the Wall to be a Brick and a half thick. The Bricklayers Work is measured by the Pole-square, that is deducting out all Windows and Doors in the Wall….Chimneys are commonly done by the Hearth. And note, that one Brick and a half thick is fourteen Inches, two Bricks is one Foot and a half, and that four thousand five hundred of Bricks will do a Pole-square of Walling one Brick and a half thick, and **twenty five Bushels of Lime where the Sand is good, that is, where 'tis of a large rough Grain, and not mixed with Soil**.

Tiling is measured by the ten Foot-square, Workmanship of which is three Shillings and Six pence a Square in the Country, to find all but Tiles, is twelve Shillings, and to find Tiles and other Materials is one Pound six Shillings a Square. **Three Bushels of Lime will do a Square of Tiling, but I prefer Loam and Horse-dung mixed together, and laid about the Middle of the Tile, so as not to touch the Pins or Laths, nor to be so near the point as to wash out, because Lime is too corroding, being apt to make the Tiles scale, and to grow with Moss. _**

'Plasterers. The Plasterer's Work is commonly done by the Yard square, for Lathing, Laying and Setting is Eight-pence a Yard, rendering on a Brick-wall is Three-pence a Yard, stopping and whiting one Penny half-penny a Yard, whiting a Penny a Yard ; but Lathing, Laying and Setting with Oak-Laths is ten or twelve Pence a Yard. **To daub a Partition-wall with Clay on both sides is Three-pence a Yard, and to rough cast it without, and render it on the inside, Four-pence a Yard in the Country.** Heart-Laths of Oak are one Shilling and Ten-pence a Bundle or Hundred. Sap-Laths of Oak are one Shilling and Eight- pence a Bundle. Fir-Laths are Twelve-pence a Bundle. A Bundle of Laths they reckon will do a Square . of Tiling, and five hundred of Nails.

Thatching with Straw is done from two Shillings and Six-pence, to three Shillings a Square, and with Reed for four Shillings a Square: Two good Load of Straw will do about five Square, the Square being a hundred square Feet ; and a Thousand of Reed will cover three Square of Roofing, which costs about fifteen or sixteen Shillings, both which Thatching most tie on with Withs, but old pitched Ropes unwound, are much cheaper, and more lasting to tie them with.

Chap. IV. Of Lime. Lime is commonly made of Chalk or of any Sort of Stone that is not sandy or very cold, as Free-stone, &c. All Sorts of soft Stone, especially a grey dirty coloured Stone, that if you break it will yield a white Powder, and all sorts of Marble, Alabaster, Slate, Oyster and all Sorts of Sea-shells, and all Sorts of Flints, will make an extraordinary Lime (but they are hard to burn, except in a Reverberatory Kiln, because they are **apt to run to Glass**, for the harder the Chalk or the Stones are, the better is the Lime; only they require the more Fire to burn them: Both Sorts may be burnt with Wood, Coals, Turf, or Fern which makes a very hot Fire.

The Kilns used for Chalk or Stone they commonly make in a great Pit that is either round or square, according as they have conveniency, and big according to the quantity they burn, which they make wide at the Top, and narrow by degrees, as they come nearer to the Bottom: The In-side of this Pit they line round about with a Wall built of Lime-stone; at the Outside near the bottom, they have a hole or door by which they take out the Ashes, and above that some have an Iron-grate, which cometh close to the Wall round about but others arch it over with Stone or large Pieces of Chalk; and upon this they lay a Layer of Stone, or of what else they burn in the Kiln, and upon that a Lay of Wood or Coals, which they repeat 'till the Kiln is full, only they observe, that the out most Lay be always of Wood or Coals, or what they burn their Lime with, and not of what they make their Lime, to which they give fire at the hole underneath.

Chalk is commonly burnt in twenty four Hours, but Stone often takes up sixty Hours: Ten Bushels of Sea-coal, or a Hundred of Faggots three Foot long will burn forty Bushels of Chalk, and forty Bushels of Chalk will yield thirty Bushels of unslaked Lime.
When Chalk is scarce, you may take the Chalk-rubbish and mix it with Water, working of it together as you do Clay for Bricks, which put into Brick-moulds, and drying of it, burn it, and it will make as good Lime as other Chalk.

But the Stone-lime is much the best for Land, and indeed for all other Uses; which in many places they carry out Upon the Land, and lay in heaps, allowing a Bushel to a Pole-square, or a hundred and sixty Bushels to an Acre, which they cover with Earth, letting of the Heaps lie 'till the Rain slacks it, and then they spread it:

But they reckon that if 'tis carried out upon the Land hot from the Kiln, that 'tis best; and that it doth best upon light sandy Land, or a mixed Gravel, and that wet or cold Gravel or Clay are not good for it. Dung, Mud, or fresh Earth mixed with it makes an extraordinary Manure, and is the best Way of ordering of it for Land that is sandy or gravelly. I am told that a Parcel of sandy Ground in Westmorland produced an extraordinary Crop of Barley and other Corn, being manured with Stone-lime and Cow-dung mixed together. The Nature of Lime is to work downwards, like Chalk, and therefore it s best laying of it upon a Laye the Year before you design to plow it up. Lime is reckoned to make Corn grow with a thin Husk; but 'tis not a lasting Manure, it seldom holding above five Crops.

To complete this article let us just take notice of the flooring, which it would be a considerable saving to the occupier to be properly secured: a mixture of lime, cut horse-hair, drift-sand, temper'd-clay, and horse-dung laid pretty thick, will make the floor impenetrable to vermin.

Neve R (1726) The City and Country Purchaser. David & Charles facsimile edition 1969

Neve was based in Sussex and in the context of lime and mortars, the most useful aspect of his work is to be derived from his discussions with local craftsmen. The main passages about lime and mortar are verbatim copies from Moxon, without the attribution he gives to others elsewhere.

Lime

(The majority of this is a direct transcription of Moxon's work. Beyond this),

About us in Sussex, lime is made out of hard chalk, dig'd out of the hills, and is burnt in Kilns, like brick-kilns; but with this difference, that they have no arches in them, but only a kind of bench, or bank, on each side, upon which they lay the largest stones, and so truss them over, and make an arch after the manner clamps for bricks. And when they have thus made an arch with the largest stones, they fill up the kiln with the smaller ones.

A Mason of my acquaintance tells me, That the Kentish lime is far better than that commonly made in Sussex, for, says he, a gallon of water will make as much more Kentish lime run, as it will a Sussex lime; so that it should seem…that *that* is the best lime which will run with the least moisture *[the Kentish lime will have been hydraulic and so expanding in volume less, requiring less water, therefore, to make it run than the pure chalk lime]*.

The ingenious gentleman Walter Burrel Esq, of Buckfield in Sussex, was the first that introduced the use of fern *[probably bracken]* for burning of lime, which serves that purpose as well as wood…and is far cheaper….

Load of lime, how much?

In the country, Lime is commonly sold by the load, which is 32 bushels. A Load of lime, some say, will make Mortar enough for 250 solid foot of stonework. And 8 bushels of lime (heaped measure) is the common allowance to every thousand of bricks.

Mortar

What. From the French mortar, a sort of plaister, commonly made of lime, and sand, and water, used by masons and bricklayers, in building walls of stone and brick. For plastering of walls, they make their mortar of lime, and Ox or cow hair, tempered well together with water, and this is called *white mortar*.

Of making common —As for making common mortar, and for the proportions of lime and sand to be used about it, **as many men are of many minds,** I shall give you their several sentiments, about this matter.

(Then Moxon's words about Vitruvius and 'about London')

…Other workmen in Sussex tell me that their usual proportion of lime to sand, in making of mortar, is 4 Court Loads (that is about 48 bushels) of sand to one load (or 32 bushels) of lime, which is exactly 1 1/2 bushels of sand to 1 bushel of lime, near the London proportion. But they tell me, tis of Stone Lime *[feebly hydraulic];* for they allow but 3 load (or 36 bushels) of sand to one load (of 32 bushels) of **run lime;** for, they say, a load of run lime is nothing near so much as a load of stone- (or quick) lime, which is but 9 gallons of sand to a bushel of lime.
Other workmen in other parts of Sussex tell me, that they allow 4 load (at 18 bushels to the load) of sand to one load (or 32 bushels) of lime, which is 2 1/4 bushels of sand to 1 bushel of lime.
Another workman in Sussex tells me that (to his knowledge) some London Bricklayers put as much lime as sand in their mortar, especially for frontwork.
A gentleman in Sussex tells me that the London Bricklayers make their mortar much more durable than our country ones *[again, perhaps, the difference between feebly hydraulic and chalk lime];* for he told me that at his brother's house, and at another gentleman's house, the mortar was scaled *[frost-damaged]* at all; but at his own house (which was done by country workmen) it scaled very much, and fell out of the joints. But (said he) the Londoners make their mortar by proportioning their lime and sand, viz by measuring it all; but the country workmen (for the most part) make it by guess. Now, said he, our country workmen do not make their mortar fat enough; for they put in it too little lime to their sand *[perhaps not, if they are using pure lime, as opposed to hydraulic].* Nevertheless, his workman told me, that he did put in as near as he could guess (by shovels full), at least twice as much lime as sand in his mortar, and took care to sift all his lime and sand *[indicating dry-slaking],* and yet (to my knowledge) some of his walls scal'd pretty much, **especially those that were done towards the latter end of the year,** tho' (said he) I never made mortar so fat in my life before. But indeed, **none of his walls were coped,** they were covered with straw on the top, and boards or slabs laid on it, which sometimes were blown off in the winter, and so **let in the wet; which (said he) was the cause of the scaling of his mortar;** but his master deny'd this and said it did so where it was never uncovered all the winter.

From all these various proportions (of lime and sand) above-mentioned, all asserted by able workmen, I think it reasonable to infer, **That the proportion of lime to sand in making of mortar, ought to be various, according to the goodness of badness of these materials; and therefore is rather to be regulated by the Judgment of experienced and skillful Workmen in each particular country; than by any fixed proportions.**

The Method of Making Mortar

Some workmen tell me, that tis the best way **not to use mortar as soon as it is made; nor,(in making it) to make the lime run before it is mixed with the sand (as some do), but rather to take the sand and throw it on the lime whilst it is in stones before it is run, and so to mix it together, and then wet it,** by which means, they say, it will be the stronger, and **when it has lain a while made before tis used, will not be subject to blow and blister.**

Others advise to **let mortar (when made) lie in a heap two or three years before tis used,** for so, (say they) 'twill be the stronger and the better; for the reason of so many insufficient buildings (say they) **is their using of mortar as soon as 'tis made.**

Others tell us, (1) that when you slack the lime, you must take care to wet it everywhere a little (but not over wet it) and cover with sand every laying or bed of lime (being about a bushel) as you slack it; that so the steam or spirit of the lime may be kept in and not fly away, but mix itself with the sand, which will make the mortar much stronger than if you slack all your lime first, and throw on your sand all together at last, as some do….*[and so on – copied straight from Moxon].*

Mr Worlige says, That if you intend your mortar to be strong, where you cannot have your choice of lime, you may choose your sand and water; for **all sand that is dusty, makes the mortar weaker**; and the rounder the sand, the stronger the mortar, as is usually observed in water-drift sand; that makes better mortar than sand out of the pit.
Therefore (says he) if you have occasion for extraordinary mortar, wash your sand in a tub, till the water, after much stirring, come off clear, and mix that with new lime, and your mortar will be very strong and durable. And if your water be foul, dirty or muddy, your mortar will be the weaker.

He also tells us, That it is **a great error in mason, bricklayers, etc to let the lime slacken and cool before they make up their mortar, and <u>also to let their mortar cool and die before they use it.</u>** Therefore (says he) if you expect your work to be well done, and long to continue, **work up your lime quick, and but a little at a time, that the mortar may not lie long before it be used.**
So that you see, that in this point also, **men differ** in their sentiments; **some affirming it best to use their mortar new, others, after it has lain made for some time.**

An old, experienced mason of my acquaintance tells me, That being at work at Eridge Place…at Fant in Sussex, they would have him make use of some mortar that had been made four years. But he…told them it was good for nothing by reason it was so very hard, that there was no tempering of it. Whereupon a Jesuit (residing in the house and who had been a great traveller) told him, That to his knowledge at several places beyond the sea, **they always kept their mortar 20 years before they use it;** but then (he saith) they keep it in cisterns for the purpose, and **always keep it moist.** Now, the old mason tells me, he believes this method may make the mortar good and tough.

*Of making other kinds of mortar beside the common mortar (*us'd in laying of stones, bricks and tiles) –

…*White Mortar* This is used in plaistering of walls and ceilings, **that are first plaistered with lome,** and is made of ox or cow-hair, well mixt and tempered with lime and water, (without any sand). The common allowance in making this kind of mortar is one bushel of hair to six bushels of lime. The hair serves to keep the mortar from cracking, binding it, and holding it fast together.

[then further excerpts from Moxon concerning exotic mortars].

….*Extraordinary good for Floors, Walls and Ceilings*.

If you temper Ox-blood and fine clay together, and lay the same in any floor, or plaister any wall or ceiling with it, it will becomea very strong and binding substance, as I have been told…by a gentleman stranger, who affirmed to me, that the same is of great use in Italy…

A wise, wealthy and ancient soap boiler, dwelling without Aldgate has…long since erected a fair and stately edifice of brick for his own habitation…the mortar whereof did consist of **two load of waste soap-ashes *[wood ashes], one load of lime, one load of lome, and one load of Woolwich sand…*.**Another gentleman…has used only **lome and soap-ashes**, tempered and wrought together for mortar…in Southwark

For laying of tyles. I know several places in Sussex where for laying of tiles upon houses, etc, they make a kind of mortar of **Lome and new horse-dung,** well-tempered and mix'd together. This some workmen commend for a good, strong and cheap mortar; and others tell me, That tis more agreeable to the tiles than the common mortar made of lime and sand; which, say they, corrodes and frets the tiles, causing them to scale and fly to pieces, which this does not.

Plaistering

Of walls. Some masons in Sussex tell me, That for Lathing and Plaistering of walls with **lome** on both sides, they have 3d a yard; but if it be done with white lime and hair mortar on both sides, then they have 4d per yard.

I am informed that, at Tunbridge Wells, the masons will do Plaistering of walls (where they plaister all over the timber) and ceilings for 2s 10d per square.

Of Ceilings. For ceilings, our masons in Sussex, have (for lathing, plaistering and finishing) 4d per yard….But if the workmen find all their materials, the price is 5d or 6d per yard.

With rough mortar or rough-cast. In some parts of Kent they commonly **rough-cast…upon old lome walls,** that is, they give them **one coat** (upon the lome) of rough mortar or rough-cast…tho' it be **commonly struck smooth** like lime and hair. For this they have 3 half-pence per yard, only workmanship; but if the wall be new and lathed, and **plaister'd with lome** on both sides and a coat of rough mortar on the outside, then they have 4d per yard only workmanship. But if the roughcast be wrought in flourishes *[pargetted?]*, then they have 8d per yard. But if the workmen find all the materials, tis worth from 1s to 3s per yard, according to the variety and goodness of the work.

On laths in imitation of brick. I know a house that is plaistered in imitation of brickwork, the mortar was made of powder of bricks, sharp sand, lime and some red oker. This house has been done this 20 years, and yet looks very well, and passes for a brick house…tho' be only timber plaister'd over.

Of white-washing. Whitewashing with size upon plaister'd walls is commonly reckoned at 2d per yard *[66% of cost of lome plastering].*

The Method of Making the Best Mortar at Madrass in East India; Described in a Letter from the Honourable Isaac Pyke, Esq; Governor of St. Helena, to Edmund Halley, L. L. D. Reg. Astr. Vice-President R. S. and by Him Communicated to the Royal SocietyAuthor(s): Isaac Pyke and Edmund Halley

Source: Philosophical Transactions (1683-1775), Vol. 37 (1731 - 1732), pp. 231-235 Published by: Royal SocietyStable URL: http://www.jstor.org/stable/104093Accessed: 06-01-2016 19:03 UTC

Take 15 bushels of fresh pit sand, well sifted; add thereto 15 bushels of stone lime: let it be moistened or slacked with water in the common manner, and so laid two or three days together. Then dissolve 20 lbs of Jaggery, which is coarse sugar (or thick molasses) in water and, sprinkling this liquor over the mortar, beat it up together til all be well-mixed and incorporated and then let it lie by in a heap….the mortar… proves extraordinary good for laying brick or stone therewith.

Letter to the Lord Advocate of Scotland from Sir Charles Clerk of Penicuik, 2nd Baronet 1738.

(Clerk was an antiquarian and classical scholar, which may be reflected in his thoughts on lime mortars).

First, as to lyme, few understand the way of using it with certainty. Some commend new slaken'd lyme or unslacken'd lyme with the common mixture of sand. Both may succeed if the lyme is reduced to a powder as small as flouer, but this is impracticable in common work wherefore it must be slacken'd or soured, as they term it; but if this be not done for a week, two or three or rather so many months before it be used, the main end cannot be attain'd because the round and half-burny particles, about the bigness of beans or peas, get not time to swell, ferment and dissolve by the mere moisture of the walls, but then these particles not being duely mixed with sand and water never unite with the stone.

Tis to this cause chiefly we owe our unbound walls which fall down into rubbish. This is the true secret of the antients and even our fore-fathers, who were better builders than we…

Twice a day or once at least, before the masons give over working, let them mix in tubs lyme, sand, gravel and water and fill up their work till it run over. This fills up all the interstices and vacuities and washes off all the earthy parts of the lyme and sand as the water flows over above, or comes out at the open spaces. These earthy parts (which) hinder the lyme, stone and sand be incorporated, for, it is to be observed, that there is a good deal of dust or powder in lyme, which is not lyme, viz the ashes of the coal, peats or timber with which the lyme stone is burnt. But there is still a better consequence from this practice, namely that the interstices, vacuities or crannies in the walls of the house are fill'd up, whereas the greatest care in the common way of building the walls of a house, are meer sives and resist neither cold nor rain. Tis to the neglect of this that half a score of your (Lorship's) acquaintances have houses good for nothing.

Courtesy Niamh Elliot.

Campbell Robert (1747) The London Tradesman, Being a Compendious View of All the Trades, Professions, Arts, both Liberal and Mechanic, now practised in the Cities of London and Westminster. T Gardner London.

The Stone-Mason is employed in cutting Stone Of the building and ornamenting. He is acquainted with all the Orders of Architecture, can cut each distinct Column or Pilaster, and charge them with their proper and peculiar Capitals and Ornaments: He knows how to cut all the Cornisses, 'Mouldings; ana other Decorations from the Architect's Plan. He is not only employed in cutting the Stones in their proper Figures and Dimensions, but in laying them, and building the Stone-Work of the whole Building:**On this Account, he is Judge of all Kind of Cements, and the Secret of preparing them for Use.**

The Stone Mason ought to be of a robust Constitution: His Work requires Strength as well as tuition. Ingenuity: He must have so much Judgment as to take in a large Compass of Figures; Geometry is-absolutely necessary; he must learn Designing, and to draw all the five Orders of Architecture, according to their several Proportions; his Skill in Drawing is likewise employed in taking with his Chalk upon the Block of Stone from the Architect's Plan, the Outlines of any Figure, Moulding, or Scroll, that is to be cut. In a word, without Drawing and Figures he cannot make a Stone-Mason, unless he is to be employed only in cutting and squaring Flag-Stones; It is an ingenious genteel Craft, and not unprotfitable. The Master may be ranked among the first Rank of Tradesmen; and the Journeyman, when employed, makes Three Shillings a Day, as Wages. at least Half a Crow; **but they are idle about four Months of the Year, unless they have some Skill in Sculpture, in which they may be employed all the Year....**

(Bricklayers)… are out of business for five, if not six Months in the Year; and, in and about London, drink more than one Third of the other Six...

(The Plaisterer) is employed in plaistering and white-washing the Ceiling, and such Part of the Walls as require it, or are not to be wainscoted.

He first nails on the Laths upon the Ceilings, **upon which he lays a Coat of Clay, mixed with Hair, or hay; over which, when dry, he lays a Coat of fine Plaister.** He is attended when plaistering by a Labourer, who holds the Plaister up to him in a hod; he takes it off the Hod with a Trowel, like that used by the bricklayer, and lays it up on a Trowel peculiar to his Business; which is a flat plate of iron, with a Handle fixed upon the Back of it instead of the End.

For Walls and Mouldings he uses another kind of Plaister, especially for Walls that are to be done, **commonly called Stucco**: **This is prepared only of Stone-Lime and two or three parts sand,** according as the Lime is of Strength, or as the Work is to be finished. If the Work is designed to explain, there is a coat of Mortar laid on rough; that is permitted to dry.

When the Workman raises his stile, that is, lays a quantity of Plaister at equal Distances along the height of his Front, he makes these as equal as he can by the eye; then applys his Level, and where he finds a Deficiency he supplies it with Plaister. This Part of the Work is allowed to dry; then he fills up the Distances between with Plaister, as near to the level as he can judge by his eyes; but to prevent all mistakes he takes a Piece of thin Deal, whose Edge is true, and having thrown water on the new-laid Plaister, applies one end of this ruler to the first stile, and the other upon the second, or as many as it will reach, beginning at sing it gently to the Wall, and holding it equal to the stiles, he pulls it along the Work: Stiles were before level, the Ruler carries with it as much as is above the Level; and what is below it he fills up with Plaister, and applies the Ruler again till the whole appears smooth; over this there is laid two thin Coats more, the last always thinner than the former. When the last Coat is near -dry, it receives the- last Floating, Water is thrown upon the Front to moisten it, and the Ruler is applied all over it till nothing remains but a plain Superficies.

… The Plaisterer is always White-washer.

Letter to the Lord Advocate of Scotland from Sir Charles Clerk of Penicuik, 2nd Baronet 1738.

(Clerk was an antiquarian and classical scholar, which may be reflected in his thoughts on lime mortars).

First, as to lyme, few understand the way of using it with certainty. Some commend new slaken'd lyme or unslacken'd lyme with the common mixture of sand. Both may succeed if the lyme is reduced to a powder as small as flouer, but this is impracticable in common work wherefore it must be slacken'd or soured, as they term it; but if this be not done for a week, two or three or rather so many months before it be used, the main end cannot be attain'd because the round and half-burnt particles, about the bigness of beans or peas, get not time to swell, ferment and dissolve by the mere moisture of the walls, but then these particles not being duely mixed with sand and water never unite with the stone. Tis to this cause chiefly we owe our unbound walls which fall down into rubbish. This is the true secret of the antients and even our fore-fathers, who were better builders than we…

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Courtesy Niamh Elliot.

Langley Batty (1750) London Prices of Bricklayers' Materials and Works Both of New Buildings and Repairs, Justly Ascertained. London Richard Adams 2nd Edition.

(p32) The several kinds of Mortar used in Buildings are Eight, viz

1. Inside and Outside mortar made of Lime and Sand
2. Terrace Mortar, made of Lime and Terrace
3. Brick-Dust Mortar, made of red Stock Brick dust and Lime
4. Bastard Terrace, made of a Smith's Forge Ashes and Lime
5. Pargetting Mortar, made of Lime and Horse-dung
6. Furnace Mortar, for Furnaces, Ovens, Kilns, etc made of Woolwich Loam or Windsor Loam only
7. (p33) Plaister Mortar, made of calcined Alabaster
8. Fine Mortar, called PUTTY, **for rubbed and gaged Works,** made of Lime only.

Inside Mortar

Inside Mortar is used for Vaultings, Foundations, Partition and Party Walls , insides of Fronts, and other Parts, which are hid from the Eye and not exposed to the Weather.

This Kind of Mortar is generally made with Pit-sand **which requires more or less Lime as it abounds more or less with loamy Particles;** and therefore when Pit-sand is of a loamy, fat Nature, to 1 Load, (viz. 24 heaped Bushels) put 1 Hundred of Lime; but when it is a clean sharp Grit as Thames Sand then to 1 Load of Sand put 1 ½ Hundred of Lime, **which mix up together as the Lime is slacked in small Quantities.** And since that Hundred of unslacked Lime is just 20 heaped Bushels, therefore in the first Case of loamy Sand, the Quantity of Lime is to the Quantity of Sand, as 20 is to 24; that is, in the lead Terms, as 5 is to 6 viz.
5 of Lime, to 6 of Sand.

The Expense, prime cost, of making a hundred of lime into inside mortar with loamy Sand, is as follows, viz

1. Hundred of lime	0	9	0
2. Load of Sand	0	3	0
3. A Labourer ¾ day, **to slack, sift, turn up and chafe**	1	1	6

(p37) Out-Side Mortar for Fronts, Tiling, &c. exposed to the Weather, should be made with the sharpest Grit-sand that can be had, as being best able to withstand the Insults of Rains, &c. which Loamy Sands cannot so well do — and which therefore should not be used in any Part of a Building, that is exposed to the Weather.

The Proportion that the Lime should have to the Sand, is as 2 is to1, viz. **2 heaped Bushels of unflacked Lime to 1 ditto of Sand**

(p40) Terrace Mortar

As Lime Mortars are made of Lime and Sand, so Terrace Mortars are made of Lime and Terrace. Terrace is a kind of Sand brought from Holland but from whence the Dutch have it, is unknown to me. It is sold by the Brick and Lime Merchants in London, and particularly by those on the Fleet-Ditch-side, at 3s. 6 d. per striked Bushel, and sometimes for less Money. Terrace Mortar is **chiefly used in Walls exposed to Water, as to Rivers, Ponds, Cisterns, Bog-Houses, Cold Baths &c.**

The best Terrace Mortar is made with two Bushels, &c. **of hot Lime**, and one Bushel &c. of Terrace, well incorporated by beating. And which Quantity to beat well, is a good Day's Work for a Labourer.

(p42) Bricklayers **also sell Terrace dry mixt, with slacked Lime made ready for Beating,** which must be done near to the Work where it is used, because of its setting very quickly - which it will always do if it is good and well beaten, and therefore must be instantly used in small Quantities as it is beat. *[the ingredients dry-slaked together].*

In the beating of Terrace, great Care should be taken not to over-wet it, but to beat it as stiff as can be and the oftener tis beat, the stronger it is.

(p43)

Of Brick-dust Mortar.

This Kind of Mortar is exceeding good, and in some Cases is better than Terrace Mortar; for **unless Terrace Mortar is always wet, 'tis not better than common Mortar made of Lime and Sand.**

This Kind of Mortar is thus made, viz.

To two heap'd Bushels of hot Lime put one heap'd Bushel of Brick-dust made from red Stock Bricks, which mix, beat, and work up, as before directed for Terrace.

(p44) This is an excellent Mortar for to lay Face Tiles or Ten Inch Tile Pavements in on Floors which are naturally wet or damp; and tor Brick Pavement and Tiling, unless for Glazed Tiles and then in the stead of Brick-
dust 'tis best to use Sea-Coal Ashes with some unburnt small Sea- Coal Dust mixt in the stead of the Brick-dust.

(p45) Of Sea-Coal Mortar, called Bastard Terrace.

This is also an exceeding good Mortar for to lay the Coping of Walls in, for to point glazed Pan-tilings, for to lay Slating, Purbeck and Portland Pavement, &c. in and many other Uses, where the Rains are required to be kept out. This Mortar is thus made:
To 3 heap'd Pecks of a Smith's Forge Sea- Coal Ashes (which is sold for 4 d. per heaped Bushel) intermix'd with the Iron Flakes put 1 heaped Peck of unburnt Sea-coal Dust and two heaped Bushels **of hot flacked Lime** which incorporate well by Beating, as before said of Terrace Mortar and use it up as 'tis beat.

(p46) Of Pargetting Mortar.

This Kind of Mortar is chiefly used for to plaister the Insides of the Funnels of Chimneys and is also very good for to point common Pan-Tiling, &c. and is thus made:
To 1 heaped Bulhel of fine skreened *clear Lime* add about a 4th Part of fresh Horfe-dung clear from Dirt and Straw; which incorporate with the Lime by well beating it, as is said of Terrace Mortar.

1 Bushel of *fine lime,* taken out of 2 bushels of unscreened Lime 0 0 4 ½

Horse-Dung and Labour to get it 0 0
1 ½
Labour to ***slack, sift, turn up*** **and** ***beat*** 0 0
4

(p47) Of Furnace or Fire Mortar.

This Mortar is made either of Woolwich Loam, or of Windsor Loam, viz. Loam brought from Woolwich in Kent or from the Brick Kiln at Gerrard's Cross by way of Windsor.
Both these Kinds of Loam endure very great Heats before they will vitrify.
The Manner of making them into Mortar is to well chaff and beat them, as outside common Mortar is done, and of such a Consistency as to work easy.

Of White Plaister Mortar.

Plaister prepared (vulgarly called Plaister of Paris) when mixt with Water, becomes a Mortar or Cement that sets very soon and hard; and **by Bricklayers is used for setting of Galley Tiles in the Covings of Chimneys, Cold Baths, Pastrys, etc.**

And as common Lime is made of Chalk calcined so Plaister is made of Alabaster-stone, or Talk, calcined and pulverized or first pulverized in the Raw stone and calcined afterwards in a Boiler.

(p48) To Calcine Alabaster-Stone, and to make Plaister commonly called Plaister of Paris, Beat the Stones to Pieces, about the Size of a Hen's Egg; then burn it or bake it, until the Shining Quality within each Piece (which is easily known by breaking some of them) be entirely gone, and they appear entirely white within like Chalk, then beat it on a flat Purbeck Stone, enclosed with a Frame, about 3 Feet square, and sift it through a fine Wire or Lawn Sieve into a Tub for Use.

(p50) Of Laths for Plain Tiling.

THE Laths used for plain Tiling, should always be made of good Heart of Oak and are there fore called Heart Laths. But too often when Buildings are built for Sale, the covetous Builder uses Fir Laths as being cheaper, but are of very short Duration. Heart Laths are made of two different Lengths, viz. 4 Feet and 5 Feet, which are both made up and sold in Bundles.
A Bundle of 4 Feet Laths should contain 20 Laths each 4 Feet in Length, making 480 feet…

A Heart Oak Lath, by the Statute Edw.III. should be 1 Inch in Breadth and ½ an Inch in Thickness, but now, tho' their Breadth is an Inch according to the Statute, yet their Thickness is seldom more than a Quarter of an Inch so that two Laths as they are now usually made, are but equal to one Lath according to the said Statute.

Fir or Deal Laths are about an Inch and Quarter in Breadth, and barely a Quarter
of an Inch in Thickness.

Of Laths for Pan Tiling.

Pan Tile Laths should be cut out of good yellow Deals, as being of greater Strength and Duration than white Deals.
They are generally made about 10 Feet in Length, or they are rather so called, for 'tis seldom that those which are called 10 Feet will work more than 9 Feet; because the Deals out of which they are cut, very rarely exceed that Length.
The Thickness of a Pan Tile Lath should be I Inch, and its Breadth 1 ½ inch, but they are seldom more than ¼ inch in Thickness

(p65) Of BULLOCKS-HAIR.

AS the Bricklayer has often an Occasion to use Hair in some of his Works, I must therefore take Notice of its Prices, prime Cost and Retail:

This Kind of Hair is sold wet, by the Tanner, at 1 s. per Bushel heaped; which the crafty Workman, after he has dried and thrash'd it, and thereby causes every Bushel to measure full two Bushels, retails it at 1s. 4 d per Bushel and thereby gets is 1s 8 d. in every Bushel; which is 166 per Cent. Profit.

Summary of Prices of materials.

Of unslacked lime per hundred…Of unslacked Lime per striked bushel…of slacked lime per bushel…of inside mortar…of outside mortar…etc

(p84)

Of rough un-jointed Place-Brick Walling.

Now, as I have already declared in p.35, that 25 heaped Bushels of unslacked Lime, and as many heaped Bushels of Sand are sufficient for one Rod of this Kind of Brick- work, it is very easy to find the prime Cost per Rod either of Materials and Labour or Labour only, in every Part of the Kingdom, where the Prices of Workmen's Labour, and prime Costs of Bricks, Lime, and Sand is known, and from thence to find the real Value which the Master ought to be paid….
(p84) **25 heaped bushels of unslacked Lime…A labourer ¾ of a Day to slack and screen the Lime, and to turn up and chaff the Mortar…**

(Similar for jointed place brick walling).

(p100) I have often experienced, that a tolerable good Bricklayer, without Hurry or Driving, but working of his own Free-will, will lay in very good Fronts 500 Grey-Stock Bricks per Diem (p101) with common Joints, which is about 1 Brick per Minute, with great Neatness.

(p132) **The Mortar in which rubbed and gauged Bricks are set is called Putty, and is thus made:**
Dissolve in any small Quantity of Water, as two or three Gallons, so much fresh Lime (constantly stirred with a Stick) until the Lime be entirely slacked, and the whole become of the Consistency of Mud; so that when the Stick is taken out of it, it will but just drop; and then being sifted, or run through a Hair Seive, <u>to take out the gross Parts of the Lime</u>, is fit for Use.

P135) Of common Brick Walling with Terrace Mortar, for Defence against Waters; as Walls to Rivers, Canals, Ponds, Basons, Drains, Sewers, Conduits, Mill-Heads of Water, Bog-Houses, &c

When Walls of this Kind are to be built next to a River, as against a Bank, to preserve it from being washed away; then to lay the Out-side Courses four Inches in Terrace Mortar, and the Back Part in common Lime Mortar, will be sufficient; and so the like for the Sides of Drains, Common Sewers, Mill- Heads, &c

But where Water is required to be kept in as in Cisterns, Basons, Canals, &c. whose Bottoms are secured, then every heading Brick, to make sure and sound Work, ought not only to be wholly laid in Terrace, but all the upright Inside Joints at the Ends and Sides (p136) of Headers, and Sides of Stretchers, should be carefully worked up in Terrace, that thereby such Water as may Filter through their Pores, shall go no farther.

(P326) Of Mortar for Outside Repairs

Tops of Chimneys, being wholly exposed, are sooner affected by driving Rains, &c. than any other Brickwork, and especially when the greedy Bricklayers don't **allow Lime and Labour sufficient** to make the Mortar good; they, or the general Part of them, having a very great Regard to the following Proverb, viz.
That the Decay of his work is the Life of their Trade.

Mortar for the Shafts of Chimneys, Parapet Walls, Tops of Garden Walls, Etc should be made with the sharpest and cleanest Sand, (free) from Earth or Loam, that can be got and therefore the drift Sand of Rivers, where it can be had, is the best sort of Sand for these Purposes that can be used. But where Sea- Coal Ashes, clean from Wood Ashes and Dirt, can be had, they are preferable to drift Sand, provided that the Mortar be well beat and used as bastard Terrace.

This Mortar is thus made.

To 2 heaped Bushels of unslacked Lime, put 1 heaped Bushel of Drift Sand or Sea- (p237) Coal Ashes which beat well, and <u>work up hot</u>, as 'tis made ready for Use.

(p329) Fronts of old Houses, when the Mortar is much decay'd, are frequently floated down, the old decay'd Mortar raked out, and the Joints fresh pointed anew; so that they look, when done, nearly as well as when first built.

Copy of plans and specifications of St. Patrick's Hospital, Dublin by Francis Corbet and George Semple c. 1750 Dublin: National Library of Ireland, Ms. 2758.

It is not intended that the morter, which is to be made use of in this building (St Patrick's Hospital), Should be made in the usual way; particularly for the outside walls. But the principle methods, which I intend to be taken, are Chiefly, To bring the lime in roach from the Kiln to the Work: To Slack but a small quantitie of it at a time, and to cover and mix that with sand directly, ready for the riddle (Whilst the spirit of the lime is hot and quick). But not to be in a hurry to riddle it, But to give it time to cool and infuse its strength among the sand. That the proportion of sand to lime…Be not richer than four of Sand to one of roach lime (That is about 2 to 1 of slack); That after it is riddled and turn'd up, That it be allow'd as much time to soak as conveniently the Work will admit of. That when the Workmen are making use of it that the Labourers shall only cut down a small bed of it at a time. And that Two of them – the one opposite the other – must each Labour each of them small beds, three or four times over with the beaters and then turn it by for the Hodd men etc. And above all, that there be as little Water be made use of in tempering it as possible. But to apply very hard Labour to supply the usual place of water.

1754 Contract of Agreement for Building an Exchange in the City of Edinburgh between the Magistrates and Edinburgh Town Council and the Tradesmen. Edinburgh Hamilton Balfour and Neill

…Patrick Jamieson, Alexander Peter, George Stevenson, John Moubray and John Fergus…shall at their proper risk, costs and charges, find and furnish all materials and workmanship, and…build, erect and finish, to the best of their art and skill, all that Building to serve for an Exchange for Merchants, and other people of the City of Edinburgh…

Particularly touching the mason work, That all the foundations shall be so digged as to make them proper and safe for building upon, in order to prevent crevasses and rents in the walls, and that the walls to be built…and the whole work in the foundations shall be laid with out and in-band large flat bedded stones packed in a sufficient manner, and with **good mortar made of lime mixed, and made up with sea-sand** …and as to the other parts of the said rubble-work, the bed of every stone shall be at least two inches broader than it is high, and in every other course the end of the stone shall be turned to the face of the wall, and the length of the stone shall be turned in through the wall: all which shall be sufficiently **bedded, grouted and filled up with mortar of lime and sea-sand, and the rubble walls shall be harled as they are carried up…**

Vaults…shall be built of good and sufficient flat-bedded stones and mortar as above described…

(Roofing slates to be shouldered with plaister lime 'to prevent the wind from shaking them')

(Paving in Piazza to be laid upon) a bed of till, at least six inches thick, over the whole vaults, composed of clay, lime and smiddy-culm, well and proportionally mixed and ramm'd, and the joints of the pavement, which is to be laid upon this till, to be secured with pan-cratch or terras sufficiently beat and prepared…(paving inside shops and kitchens) bedded in lime to prevent shifting…

and as to the plaistering work…the same shall be execute in the best manner, and with the properest materials and there shall be three coats of plaister done on the ceilings and walls of the rooms in the dwelling houses, Custonhouse and Exchange and all flotted; the stairs, passages, shops and printing houses, shall have 2 coats of good, well-prepared, sanded lime, with handsome, well-proportioned plaister cornishes to the whole rooms…which three coats of hard-finishing thro' the whole building, shall be done in the following manner, viz the first coat with lime, sand and hair, scratched, and thoroughly dried; the second with the same materials and flotted straight; and the third with fine sifted sand, and flotted straight; and plumb and float the whole plaister-work of every kind thro' the whole building…

And said Jamieson, Peter, Stevenson, Moubray and Fergus…shall…provide all necessary materials for scaffoldings, gangways, mortar-tubs, mortar-hods, centers for arches…for the beginning, carrying on and finishing the said work…

(Detailed and itemised quantities and costs).

Ware I (1756) A Complete Body of Architecture

Chap. XXIII

Of preserving LIME, *and making it into* MORTAR

As the lime is always best when the stone is carried immediately from the rock to the kiln *[replete with quarry-sap],* so the mortar is always best when the lime is slaked immediately on its coming out of the kiln.

The reason for this is evident, for the lime has at no other time so much strength: the air taking an effect upon it which is in a greater or lesser degree slaking, for in time it will be thoroughly slaked by the air, and fall to a weak powder. But it is not **always** convenient to work up the lime as soon as burnt; **sometimes** its is needful to keep it a long time, and finally, there are certain purposes which it never answers so well as when it has been thus preserved.

When lime is to be preserved only a little time after the burning for convenience of any kind, no more is required than to keep it dry, but when it is to be preserved longer, more caution is needful. For this purpose, let **a pit be dug in the ground,** and over this a vessel set**, as for making mortar,** with a hole stopped so as it may be opened at pleasure its bottom: **let the lime be slaked and worked up *[into a mortar]* in this vessel,** and then opening the hole, let it run into the pit *[whilst the slake is still underway, a sand/lime mortar will be liquid, before stiffening by evaporation of water and continued slaking].* As soon as the pit is filled let it be covered up with a **good coat of sand, and thus it will be kept moist and fresh.**

Another method is to **cover up a quantity of fresh lime with a yard thickness of sand, and then pour on as much water as will slake it, but not reduce it to dust.** If the sand crack, and the smoak rises through the openings, close them up, and keep all fast and without vent. The lime will be thus preserved ever so long, and will acquire a new value by the time of its lying. It will be more tough and clammy than any other kind, and less free to shoot out its salts when worked *[to burst due to late slaking?].* No lime is so proper as this for inside work, where great nicety is required, and none is so fit for painting upon, because it will not destroy the colours *[this is probably not dry-slaking ('not reduced to dust'), but slaking to a stiff, moist coarse stuff for later knocking up with additional water].*

MORTAR is made of a mixture of lime, sand and water, other ingredients are added occasionally for particular purposes, but this is plain mortar, and is the foundation of the different kinds.

(the quality of the lime and the nature (and cleanness) of the sand have a great bearing on the quality of the mortar, as does the use of clean water)

Our people are very careless in both these particulars…They take sand from the first pit, and their water often from the nearest kennel (canal)…(sand should be washed before use)…Spring is not so good for making mortar as river water, but the best of all is that taken from a clear pond. If it be set in the sun for some hours before it is used, or a quantity made hot and mixed with the rest, that all may be warm, it will slake the lime the more readily and perfectly…soft water slakes lime better than hard, and hot water more perfectly and more readily than cold *[it will speed the slaking before this generates its own heat, particularly of impure quicklime}.*

…*Palladio* observes that a larger quantity of pit sand is needful in mortar than of river sand, but when the pit sand is washed it becomes altogether the same in nature, and is to be used in the same proportion.

The advice of the author, **and the practice of our builders,** differ greatly with respect to the quantity of sand that is to be used in this mixture. He orders **three times the quantity of lime is to be pit sand, and twice the quantity of river or sea sand *[1:3 or 1:2, quicklime to sand],*** and the common practice of this time allows less than a third part, more in some places, and in others they are made equal.

To speak from experience and the result of many trials, it seems that Palladio's proportion of sand is too great, at least for a mortar to be used in our climate, and that what we commonly allow is too little. The medium perhaps will be best, and if any general rule may be laid down, it should perhaps be that two-thirds of lime and one of sand would be the best quantities. *[both are right, since Palladio means 1 quicklime to 3 aggregate, becoming 2:3].* …

Chap.XXV *Of mixing up the* MORTAR

When the ingredients of mortars are carefully chosen, the limes sound and fresh, the sand clean and sharp, and the water soft and pure, there remains another consideration in which the antients were very careful, and we are very remiss and negligent, that is, mixing them well together….

Our people throw in a great deal of water and then a little labour does; the antients mixed all by little and little, and might be very well said, in the language of the French proverb, to dilute their mortar with the sweat of their brows. They employed a great number of labourers, who constantly worked together upon the the same quantity of mortar, for many days, and it was this which blended every part of it so thoroughly together that when it united it hardened into stone.

We name these circumstances…to spirit up our builders to have more pains taken with that great article mortar, that they may make such as the antients did if they will take the pains the antients took to do it.

…The common floors used in mean buildings are made of **loam, well beaten and tempered with smith's dust, <u>and with or without an addition of lime.</u>** Some also make them of pure clay, ox blood and a moderate proportion of sharp sand, these three ingredients beaten together very strongly, and well spread, make a firm and good floor, and of a beautiful colour.

Le Sage B G (1769) [Examen chymique de différentes substances minérales ; Esais sur le vin, les pierres, les bézoards, & d'autres parties d'hiftoire naturelle & de chymie ; traduction d'une lettre de Monfieur Lehmann, fur la mine de]

plomb rouge. Paris, Lormel
There are several methods to slake quicklime…Quicklime ceases to be caustic and acquires various properties depending on its slaking. We can reduce them to three: in the air; slaked lime 'à la Française and à la Romaine'.

Air slaked lime. Quicklime exposed to the air attracts humidity, cracks, and splits into fragments to form a white powder…In this method, the lime loses its caustic quality and increases of 5 ounces per pound. This particular lime is not fast (tenacious?) and can be compared to chalk. Footnote : (h)We do not notice any sensible heat during this method, though, quicklime does unify with humidity in the air.

Lime slaked 'à la Française' is the one we employ for our constructions. Stonemasons pour some water on a pile of quicklime placed in a pit called a 'fourneau' (= *furnace, oven)*. They add water and stir the quicklime until it is very divided and of a gruel-like consistency. We then put it in big pits where we cover it to conserve it.

Slaked lime in this manner can obtain a bond with the sand, a property the air slaked lime does not have, but we could follow a simpler method, less cumbersome and which offers more advantages than the one we have been using up to this day.

Method to slake quicklime to make mortar as the Ancients did:

We have to thank M. de la Fay for this interesting method that fell into disuse because of a bad translation of Pliny and Vitruvius. The making of good mortar depends, according to him, on the method of slaking: here is the convenient way to obtain a mortar. We put the quicklime freshly burnt in paniers, we soak them under pure water and remove them immediately after. We then slake it on a floor where it burst, heats up, steams up and splits. 24 hours later, we take the 'unfused' pieces of lime and put them under water as the first time and we expose them to the air where they soon start to fuse. We throw away the bits that have not split. A barrel of unslaked quicklime made from this method gives three barrels of slaked lime. To make a mortar with sand, we mix three barrels of slaked lime with six barrels of river sand and enough pure water to give a good consistency.

To prepare mortar with limestone waste/ scraps (quicklime debris and fuel ashes – 'lime ashes'), you take one part of slaked lime for three parts of those scraps, mix them together and add water. This mortar when it is dried out, becomes tough and impervious to water. It is even difficult to differentiate this artificial stone from the beautiful limestone.

Equal parts of scraps of slaked lime and *'sablon'*, fine sand, form a very hard stone after this mortar has dried out. The water in wells is usually senelitic, therefore river water should be employed instead for lime and mortar.

These different mortars stay soft for five or six days in which we can beat them to give more solidity. To build with them, the weather has to be dry and they acquire their solidity after two months. It is possible to build with rubble stones with equal parts of lime and river sand, but we must raise the walls with the use of casing (formwork) and not use the rubble already crusted because the mortar will not have a good adherence.

To paint in fresco with this mortar, freshly applied, the colours need to be softened in lime water. To obtain a mortar with a white -glossy-colour, marble-like, you only need to coat the surface with thin layer of slaked lime.
(the finish) needs to be allowed to dry until it no longer sticks to the fingers, then we rub it with a hand or with a glove until it offers a beautiful polish that will not alter with water or time.

Robert Dossie (1758) The Handmaid to the Arts Vol 1. London Nourse. Accessed via Google Play/Books.

P207

Of the grounds for fresco painting - The substance or matter on which fresco paintings are generally made, is either plaster or canvas. When plaster of Paris without lime is used, and the surface made smooth, there need (be) no further preparation: but when any lime is used in the plaster, and any other colours are employed, except earths, or such as are prepared from mineral substances, the surface should be washed over several times with size and plaster of Paris free from lime, and suffered to dry then thoroughly before it be painted upon.

The Handmaid to the Arts Vol 2 Second Edition, with conſiderable Additions and Improvements. LONDON: Printed for J. NOURSE, Bookseller in Ordinary to his M A J E S T Y. MDCCLXIV; 1764 Accessed via Google Play/Books.

P32

Of cement; for rock-work, reservoirs, and other such purposes; a variety of compositions are used as cements for purposes of this kind, in the application of which, regard should be had to the situation where they are employed with respect to moisture and dryness, as well as to the magnitude of the bodies to be conjoined together, or the vacuities or fissures that are to be made good.

Where a great quantity of cement is wanted for coarser uses, the coal-ash mortar (or Welsh tarras, as it is called) is the cheapest and best, and will hold extremely well, not only where it is constantly kept wet or dry, but even where it is sometimes dry and at others wet; but where it is liable to be exposed to wet and frost, this cement should, at its being laid on, be suffered to dry thoroughly

before any moisture have access to it; and, in that case, it will likewise be a great improvement to temper it with the blood of any beast.
This mortar of Welsh tarras must be formed of one part lime and two parts of well-sifted coal-ashes, and they must be thoroughly mixt *(*P33) by being beaten together; for, on the perfect commixture of the ingredients, the goodness of the composition depends *[the coal will be anthracite, later to be preferred for burning hydraulic limes]*. Where the cement is to remain continually under water, the true tarras is commonly used, and will very well answer the purpose. **It may be formed of two parts of lime, and one part of plaister of Paris,** which should be thoroughly well beaten together, and then used immediately.

For the fixing shells, and other such nice purposes, putty is most generally used. It may be formed for this purpose of **quick-lime and drying oil, mixed with an equal quantity of linseed oil**; or, where the drying quicker is not necessary, it may be made with lime and crude linseed oil, without the drying oil.

The stone cement, prepared as above of the bees wax and resin, is also an extremely good composition for this purpose. But resin, pitch, and brick-dust, in equal parts, melted together and used hot, are much the cheapest cement for shell-work, and will perform that office very well, provided the bodies they are to conjoin be perfectly dry when they are used.

Dossie R (1771) Memoirs of Agriculture and Other Oeconomical Arts Vol 2 London, J.Nourse, Accessed via Google Play/Books.

P16
TO make a coping of plaster for all exterior walls, such as garden-walls, pond heads, park-walls, &e. take a quantity of such plaster as is commonly used for floors. Any tarras, plaster, or calcined gypsum, may be applied to this purpose as well as that here mentioned to be obtained in Nottinghamshire *[alabaster]*. The fresh, which has been only once calcined, will be the best. For though Mr. Wych below mentions such as has been before employed and several times burnt, yet it is well known, that plaster loses much of its binding or cohesive quality every time it is calcined after the first.

(Use lime found) in and about the county of Nottingham, burnt in the manner there practised. Then beat it, and sift, till it be rendered quite a fine powder. This done, to every eight bushels of the powder, add one bushel of well-calcined ashes of Nottingham-coal, that are perfectly clear of sand or kitchen-dust: the best ashes for this purpose are those of brew-houses, or glass houses, if they can be conveniently procured. When this mixture is made, put it into a trough; and pour water thereon till you make a paste of it, like good mortar. Then cast it in frames on your wall to the thickness of two inches on at each side; and to rise to three inches in the center: after which trowel it. The four sides of the frames are to be made of wood, twelve feet in length, two inches high, and the breadth the thickness of the wall.

When you remove your frame in order to lay another length of coping, you are to leave an interval of two inches between the last and next succeeding length: because *[gypsum]* plaster has the property of extending itself; and that always in a straight line. Therefore, in a few years, those intervals will be filled up. If you find that the intervals fill up too soon, you are then to saw-off a part of it, to give it room to extend: otherwise, it will rise in the middle; and a hollow will be left between the wall and coping. The appearance of this coping at first is in colour like lead, beautiful to look at: and the coping itself is (p18) as durable as free-stone. In Nottinghamshire, free-stone work, thus laid, is computed at two shillings the square-foot: whereas this plaster-coping will not stand you in more than three-half-pence; and answer all the purposes as well.

At Godeby, in the county of Leicester, Mr. Wyche has used this kind of coping prepared exactly as above-mentioned: and the work has stood perfectly sound for upwards of twenty years: and now gathers moss, which is a sure sign of durability.The utility of this coping is much to be esteemed: as, in a little time, a great quantity of work may be done. For what in stone-coping will take up six months, with the like number of hands, will be performed in plaster-coping in one month.

N. B. In the above account, it must be observed, that the proportion of eight bushels of plaster-powder, to one bushel of calcined ashes, is proper, when you use old plaster, that has served for several uses before, and has been often burnt. -- But if you use new plaster dug out of the pit for the purpose of coping, you are then, to every four or five bushels of powder, to add one bushel of ashes.

P. S. When you build your walls for this kind of coping, remember to lay your last course of bricks, so as to project one inch (p19) from the wall. This done, take care to level the top of the wall, with a thin coat of mortar, that the surface of the wall may be perfectly smooth, from one end to the other. When the mortar is quite dry, lay your coping on it, that by having a level foundation, it may extend itself freely. But, if by any hole's being left, in the work, the extension be retarded, its force will greatly damage the wall. December 3rd, I760.

After some years, when the work appears rough, you may spread over it a thin coat of plaster, mixed as above directed; and the whole will appear as new-laid, just as a ceiling appears fresh after white-washing.

P20 ARTICLE III. Account of a Method of making Mortar, which will be impenetrable to Moisture, acquire great Hardness and be exceedingly durable, presumed to be that used by the Antients.

The following method of preparing mortar was communicated, by me, to the Society for the Encouragement of Arts, Manufactures, and Commerce, in the year 1760. The advantages of this method were discovered, after trial of many others, by a gentleman at Neufchatel, in consequence of the following circumstances.

He had a house, the back-part of which being cut out of a rocky hill, the springs of water forced their way through the walls, wainscot, plaster, or whatever he used as a facing to the rock; and rendered the rooms very detrimentally wet. He was necessarily led to endeavour, by the use of all the common compositions, to exclude the moisture: but every thing failed to effect this purpose, till he tried the mortar below described. This he found perfectly answered his end of preventing any transudation of the water: and it grew so tenacious and firm, by time, that he was induced to believe the method of compoſition was the same with that pursued by the antients in (p21) preparing their mortar.

In this light, as a discovery of the mortar of the antients, he communicated it to Lord M____ l, at that time residing at Neufchatel, to whom he shewed the rooms he had rendered dry by means of it; and which had then been plastered with it about eleven years. The plaster appeared as white as marble; and nearly as hard: nor was there the least sign of any moisture's pervading it in the places where, before it was applied, the water from the rock had continually forced its way, in spite of the various other means that had been employed to exclude it.

Lord M_____l believing this discovery to be a matter of utility, gave the recipe, and the particulars of the account, to me, as he had them in writing from this gentleman; in order that I might impart them to the public, in what manner I should think proper, if there were any prospect of their being of advantage. I accordingly delivered a memoir, containing a translation of them, with some additional remarks, to the Society for the Encouragement of Arts, &c. with the view of having them inserted in the Historical Register, which was then proposed to be publiſhed annually by them. But the design of publishing such a Register not taking place, and the memoir having been lost out of the Society's Gard-book, I thought it expedient to make a fresh communication of it in this place: as it may very properly follow (p22) the foregoing valuable article of a method for making coping for walls. –

The manner of preparing this mortar is as follows: **Take of unslacked lime, and of fine sand, in the proportion of one part of the lime to three parts of the sand,** as much as a labourer can well manage at once: and then, **adding water gradually**, mix the whole well-together by means of a trowel, till it be reduced to the consistence of mortar. Apply it immediately, while it is yet hot, to the purpose, either of mortar, as a cement to brick or stone; or of plaster for the surface of any building.

It will then Ferment for some days, in drier places; and afterwards gradually concrete or set; and become hard. But in a moist place it will continue soft for three weeks or more; though it will, at length, attain a firm consistence, even if water have such access to it so as to keep the surface wet the whole time, After this, it will acquire a stone-like hardness; and resist all moisture *[this is very likely a feebly hydraulic lime].*

The perfection of this mortar depends on the ingredients being thoroughly blended together; and the mixture's being applied immediately after to the place where it is wanted. In order to this, about five labourers should be employed for mixing the mortar, to attend one person, who applies it.

P23 Chalk-lime, which is the kind most commonly used in London, is not fit for this purpose, on account of its containing flints; which makes it required to be skreened before it can be tempered with the water and sand. This skreening renders the slacking the lime previously necessary: and the slacking it before it be mixt with the sand **prevents its acting on the sand, so as to produce their incorporation; which power it loses, in a great degree, after its combination with the quantity of water that saturates it.** Lime made of limestone, shells, or marble, must be therefore had for this purpose: and the stronger it is, the better the mortar will be. If such lime be wanted for this end in London, though it is not commonly used there, it may be obtained at some of the wharfs; or at a Work, carrying on for making stone lime, on the banks of the river Thames, above Vauxhall.

Besides this regard to the kind of the lime designed to be employed in making the above mentioned mortar, that which is intended for it should be carefully kept from the access of air or any wet: otherwise it will attract moisture; and, lose proportionably that power of acting on the sand, by which their incorporation is produced. It is proper, also, to exclude the sun and wind from the mortar itself for some days after it is applied: that the drying too fast may not prevent the due (p24) continuance of the fermentation, which is necessary for the action of the lime on the sand.

Over and above the value of a very hard and durable mortar, for general purposes, the property which this kind has in resisting and excluding all moisture, gives it very peculiar advantages in particular cases. For, as it may be used, and will grow perfectly hard, even though moisture have access to it when laid on, and while it is fermenting and setting, it is of very high utility for preventing the ousing of water through the floors or sides of many edifices; as well vaults as others, where mortar prepared in the common method would fail of that effect; and continue wet for any length of time. It is, likewise, of great consequence in the erecting bridges, or in making the foundations, or other parts of buildings raised in Water, or situated in very damp places, or for pointing, or plastering conduits, or reservoirs of water: for which last purpose, it appears to answer the end of tarras, or the gypseous plaster; and may save the expence of those materials; which are generally much dearer than lime. The superiority of this to the common mortar is **owing to the intimate commixture of the lime with the sand, at the same time it is combined with the water**, before its attractive power, be diminished by its combination with water: and **this shews the defect in the common method of making mortar**: where the lime is slacked before it is (p25) commixed with the sand; and where, in part, old mortar, common earth, or other substances, with which lime has no peculiar specific attraction, are generally added, or used wholly in the place of sand.

Such mortar is frequently found, instead of growing harder with time, to appear, as it were, calcined in some years; and to moulder into dust: especially where the air has access.

The slacking the lime before its mixture with the sand is, in a great measure, unavoidable in the case of such as is made of chalk, for the reason above assigned: and other lime bears a higher price in London.

The expence of labour, also, **in mixing the lime and sand with a trowel, as directed in the recipe, instead of beating them together in the common way**, is, perhaps, too great everywhere for preparing mortar for general purposes. But in the extraordinary cases, above enumerated, it will be found to answer: **and in all cases it is proper** to have regard to the principles, on which the goodness of mortar so prepared depends; and **to come as near this method as circumstances will admit.**

When a very great hardness and firmness are required in this mortar, as in several cases where strong cement is wanted for stones; or for projecting parts of buildings, or other purposes; **the using of skimmed milk instead of water**, either wholly or in part, will produce the desired effect; and render the mortar extremely tenacious and durable.

(p26) It is confirmed, by the accounts, we have in Pliny, Vitruvius, &e. of the Roman mortar, that the gentleman, who concluded, from his observations of the similarity of the consistence of the mortar he thus prepared, with what is found in the antient buildings, **the manner of preparing them was the same**, was not mistaken in his conjecture. For it appears, the same method of preparation was followed then in the mortar made in great quantities for common purposes: only there is reason to believe, that milk, also, was used in some particular cases, either wholly or in part, instead of water. The appearance of perpetual durability, and the exceeding great hardness of the mortar now found in the remains of the antient buildings, are proofs of the excellence of this method; and shew, that **it ought to be attended to in all instances, where long duration is of moment**.

The total deviation from it in the preparation of the mortar for many of our buildings, particularly in London, is the occasion of the quick decay of them; or frequently of the immediate fall of houses or parts of houses, even before they are finished; and the means also, of great fraud on the purchasing proprietors of such houses; as well as danger to the tenants, and even passengers. Whence, it calls loudly for the control of the legislature, to punish such as do not use fit materials in the composition of mortar. Robert Dossie.

David H (1771)The Complete English Farmer

Chap. IV. Of Lime. Lime is commonly made of Chalk or of any Sort of Stone that is not sandy or very cold, as Free-stone, &c. All Sorts of soft Stone, especially a grey dirty coloured Stone, that if you break it will yield a white Powder, and all sorts of Marble, Alabaster, Slate, Oyster and all Sorts of Sea-shells, and all Sorts of Flints, will make an extraordinary Lime (but they are hard to burn, except in a Reverberatory Kiln, because they are **apt to run to Glass**, for the harder the Chalk or the Stones are, the better is the Lime; only they require the more Fire to burn them: Both Sorts may be burnt with Wood, Coals, Turf, or Fern which makes a very hot Fire.

The Kilns used for Chalk or Stone they commonly make in a great Pit that is either round or square, according as they have conveniency, and big according to the quantity they burn, which they make wide at the Top, and narrow by degrees, as they come nearer to the Bottom: The In-side of this Pit they line round about with a Wall built of Lime-stone ; at the Outside near the bottom, they have a hole or door by which they take out the Ashes, and above that some have an Iron-grate, which cometh close to the Wall round about but others arch it over with Stone or large Pieces of Chalk; and upon this they lay a Layer of Stone, or of what else they burn in the Kiln, and upon that a Lay of Wood or Coals, which they repeat 'till the Kiln is full, only they observe, that the out most Lay be always of Wood or Coals, or what they burn their Lime with, and not of what they make their Lime, to which they give fire at the hole underneath.

Chalk is commonly burnt in twenty four Hours, but Stone often takes up sixty Hours: Ten Bushels of Sea-coal, or a Hundred of Faggots three Foot long will burn forty Bushels of Chalk, and forty Bushels of Chalk will yield thirty Bushels of unslaked Lime.

When Chalk is scarce, you may take the Chalk-rubbish and mix it with Water, working of it together as you do Clay for Bricks, which put into Brick-moulds, and drying of it, burn it, and it will make as good Lime as other Chalk.

But the Stone-lime is much the best for Land, and indeed for all other Uses; which in many places they carry out Upon the Land, and lay in heaps, allowing a Bushel to a Pole-square, or a hundred and sixty Bushels to an Acre, which they cover with Earth, letting of the Heaps lie 'till the Rain slacks it, and then they spread it:

But they reckon that if 'tis carried out upon the Land hot from the Kiln, that 'tis best; and that it doth best upon light sandy Land, or a mixed Gravel, and that wet or cold Gravel or Clay are not good for it. Dung, Mud, or fresh Earth mixed with it makes an extraordinary Manure, and is the best Way of ordering of it for Land that is sandy or gravelly. I am told that a Parcel of sandy Ground in Westmorland produced an extraordinary Crop of Barley and other Corn, being manured with Stone-lime and Cow-dung mixed together. The Nature of Lime is to work downwards, like Chalk, and therefore it s best laying of it upon a Laye the Year before you design to plow it up. Lime is reckoned to make Corn grow with a thin Husk; but 'tis not a lasting Manure, it seldom holding above five Crops.

To complete this article let us just take notice of the flooring, which it would be a considerable saving to the occupier to be properly secured: a mixture of lime, cut horse-hair, drift-sand, temper'd-clay, and horse-dung laid pretty thick, will make the floor impenetrable to vermin "

Smeaton J (1837) Reports of the Late J Smeaton FRS, made on various occasions in the course of his employment as a civil engineer, Vol II. 2nd Edition, Taylor, London 1837.

It will be advisable to set the whole outside up to high water neap tides with Watchet or Aberthaw lime, and it would, as Plymouth lime is very tender in water, be also very advisable **that a quantity of the aforesaid lime was procured to mix with that of Plymouth for the inside work to high water spring tides: this is the more necessary, as Plymouth lime and marble do not seem disposed to form of themselves a very compact body, when constantly subject to the water.**

Not having a plan of the quay at Stanebotse and housing adjacent, I have drawn the bridge straight but as it may probably be found more suitable and convenient to make the rampart somewhat curved from the arch and termination upon the quay, I leave this to the determination of those concerned in the execution upon the place. The above is, I think, the most-material of such directions as at present occur, and which I hope will be found sufficient for beginning; if any thing is not sufficiently explained, shall be ready to do it by letter. J. SMEATON. London, June 15, 1767.

From design and spec of Storehouse Creek Bridge

Smeaton J (1775) Directions for preparing, making, and using Pozzelana Mortar, by John Smeaton, Engineer, in Reports of the Late J Smeaton FRS, made on various occasions in the course of his employment as a civil engineer, Vol II. 2nd Edition, Taylor, London 1837.

Pp421-423. The first thing that should be done, is to sift it through a coarse wire sieve, separating what will pass through the sieve from what will not, and then to sift what has passed through the first sieve through one of a finer sort. A wire sieve having about seven or eight meshes per inch running, will be of sufficient fineness, and all that will pass the second sieve will be fit for use; what will not pass the second sieve must be reserved for grinding, and what would not pass the first sieve must be broken to a size conformable to what would not pass the second, and then all ground together; but, in breaking the large that would not pass the first sieve, it will be proper to pick out a kind of gray stony matter, as well as other heterogeneous substances that get accidentally mixed therewith, and which will readily discover them selves from the true pozzelana, and which have no cementing quality, and render it more difficult to grind.

The true pozzelana is of a dark brown or dirty red colour, and the larger pieces being broken will readily discover themselves, especially with an ordinary magnifying glass, to be of a spongy substance, with innumerable little cavities, like a cinder, and not much harder. That part of it requiring grinding must first be got perfectly dry, either by the sun or by a drying kiln, otherwise it is apt to clog the mill-stones, and it is done by far the most completely by grinding it upon a pair of corn mill-stones, which will at one operation reduce it to a proper fineness without need of further sifting; French stones answer the purpose best, for, though it may be done by other kinds of mill stones, yet, being mixed with flinty matter, which cannot readily be picked out, no other kind of stones will stand the service, if wanted in any considerable quantity. The millers, however, are not very desirous of meddling with it, on account of its spoiling the colour of their stones. I have, therefore, in the larger kind of works that I have been concerned in, found it worth while to construct a mill on purpose, to go by water, wind, or horse, according to convenience.

In making mortar of it, it must be mixed with lime **in much the same manner and proportion that terras mortar is made**: it must be observed that the better and stronger the lime is, the better and stronger the cement will be; but, like terras, it may be used with any lime, and in making comparative trials with terras**, the same sort of lime should be used with both.**

The best kind of lime for water-works that I know of, is from Watchet, in Somersetshire, Aberthaw, in South Wales, and Barrow, in Leicestershire; and the strongest composition I know, is made **by an equal quantity of lime, striked measure in the dry powder, after being slaked and sifted, and of pozzelana**, ground and prepared as above, and, if put together with as little water as may be, and beaten till it comes to a tough consistence, like paste, it then may be immediately used; but if suffered to set, and it be afterwards beaten up a second time to a considerable degree of toughness as before, using a little moisture, if necessary, **it will set harder, but not so quick.** This composition is of excellent use in jointing the stones that form the lodgment for the heels of dock-gates and sluices, with their thresholds, &c. when of stone.

A second kind of mortar is made by using the same proportion of ingredients as terras mortar, that is, **two measures of lime to one of pozzelana beaten up in the same manner, and which, if used with common lime, will fully answer for the faces of walls either stone or brick that are exposed to water, either**

continually, or subject to be wet and dry; in which last case the pozzelana greatly exceeds the terras, as also in its lying quiet in the joints as the trowel has left them, without growing as terras does.

As a piece of economy, I have found that if the mortar last mentioned is beaten up with a quantity of good sharp sand, it nowise impairs its durability, and increases the quantity. The quantity of sand to be added depends upon the quality of the lime, and is thus determined: if to the pozzelana considered as mortar, you add as much real sand as will make out the whole quantity, such as an experienced work man would allow to his lime to make good common mortar, this will shew the quantity to be added, that is, may be originally beaten up together; thus, **if the lime is of such quality as to take two measures of sand to one of lime, then one measure of pozzelana and three measures of sand will satisfy two measures of lime.**
The compositions above mentioned, are seldom used further than for six inches within the face of the stone, or, at most, for setting the stones and the bricks forming the face of the work, **while the backing is wholly done with common mortar, and which, under water, never comes to the hardness and consistence of stone, or forms that bond of union which would arise from a stony hardness; I have therefore, found it preferable, where pozzelana can be had in plenty, to allow one bushel of pozzelana to eight bushels of the lime composing the mortar for backing**. The first composition will assuredly acquire the hardness of stone under water, and in twelve months will be as hard as Portland.

The hardening of the second and third depends greatly upon the quality of the lime, as also that of the fourth; yet there is scarcely any lime with which the materials, well beaten up, in the proportion specified, will not acquire a very competent degree of hardness under water.

Austhorpe, 23d September, 1775. J. SMEATON.

M. de la Faye (1777) **Recherches sur la préparation que les Romains donnaient à la chaux dont ils se servaient pour la construction et sur la composition et l'emploi de leurs mortiers. 1777. Royal Printers, Paris**

Translation Emma Michel 2016

P4 St Augustin in his fourth chapter of the XXIst 'Livre de la Cité de Dieu' says about lime that: we say the lime is alive ('vive') as if the fire it contains is the invisible soul of a visible body; but what is surprising is, that it warms up when it is slaked, because to remove that hidden fire, we soak the lime or just dip it and, cold as it was before, it becomes warm, whereas all the burning bodies are cooled down by this same method. And when this lime is decomposing, its hidden fire manifests itself by leaving and then, like a body deprived of life, it becomes so cold that water will not bring any more heat and then instead of calling it '*vive*', we call it '*éteinte', turned off,* slaked.

P13 Let's now examine Vitruvius's method of preparing lime.
In the fifth chapter, he indicates the proportions of lime with different sands for construction. He discusses reducing limestone to powder, but unburnt and then mixing it with sand. These materials will not fuse together and would not bond with the masonry. **However, if we soak limestone after it has been burnt in a kiln, it will warm up and its pores will open, facilitating its mixture with the sand and give some solidity…<u>If we mix two parts of sand freshly extracted from the river with one part of powdered quicklime, it will create a very fatty and adherent mortar.</u>**

P24 **We saw previously that Vitruvius, who calls the mortar to build with *calx extinata*, which will heat up once put in water.** In this chapter however, he calls 'fused' lime **calx macerata** in which it has to 'warm up' in water *slaked by the 'ordinary' method).* These two ways have clearly different methods.

From the ancient (Roman) laws, there were 3 types of crafstmen who were producing lime in exchange for land and meadows. The term *alii coquere* meant the 'chaufournier' *(literally, the people looking after the kiln – lime-burners)*, *alii atiam excoquere*, the people who had the task to dissolve the lime *(as putty or dry hydrate)*, and *alii vehere*, the people who had to transport it.

P25 'Fused' lime was, said Pliny, forbidden to be used in ancient laws unless it was at least 3 years old and **that is why the plasters were not cracked.**

<u>Agreement between Vitruve and Pline on the 'fused' lime</u>

In his second chapter, Vitruvius does not indicate any mixing of sand or marble dust with this particular lime, and says that it has to be matured. He adds that the polish of the plasters is destroyed only when the lime is freshly 'fused' and that the grains had not had time to dissolve until later.

It wasn't therefore because of an ill mixed plaster but their size. Thus, this lime, from Pliny and Vitruvius, used after 3 years and with a great deal of work before being employed, **was not for the composition of mortar for building**, <u>but for uses in which ill mixed grains would have caused problems and **was reserved for whitewashing the walls and to give the perfect finish to the plasters,**</u> in other words, for light works that the authors call *'albaria opera'*.

P32 Reasons why it is preferable to use powdered lime to 'fused' lime for building.

Fused lime :
We crush quicklime in a tub by submerging it in water until it has no longer any heat and it is completely soaked. This material turns into a paste after 24 hours, then we add sand without any real proportions and we will add again

some water. This drowned lime produces a mortar that dries up slowly and will never reach a good consistency, **because this drenched lime has lost its aptitude to stick to other materials.**

P34

Method to prepare mortar for construction:

You will have to obtain lime from hard stones freshly cooked; you will cover it until you reach the site to avoid humidity and rain mixing with it. You will put this lime on a dry, covered, swept floor.

In that same place, you will have dry barrels, and a big tub three quarters full of river water or a water which is neither flood- nor mineral water. You will only need two workers for this operation. One will break the limestone with a hatchet until the lumps are the size of an egg. The other will take a shovel and fill a flat basket. He will put the basket in the water until the surface starts to boil, then removing the basket, leaving it for a few moments and then pouring this soaked lime into the barrel. He will do this same operation until all of the lime is in the barrel. This lime will heat up considerably and will give off steam, opens its pores and falls into powder and finally loses its heat. This is the state of the lime that Vitruvius calls *calx extinâla. (extinguished lime)*

The acerbity of the lime requires that the operation is undertaken in a ventilated space in order to not cause a nuisance to the workers.

As soon as the lime stops steaming, the barrels will be covered with a thick cloth or a mat.

We will judge the quality of a freshly burnt lime by the rapidity with which it heats up and turns to powder: if it is not freshly cooked or the kiln wasn't hot enough, the lime will heat up slowly and will not divide properly.

P54 Pure lime skim in India *'aux Indes' plural old term, perhaps not just India itself*

In India, said Thévenot (memoirs of his relations), we coat the walls with a pure lime skim slaked in milk and crushed with sugar, we then polish this skim with an agate stone to be as gleaming as a mirror.

Faujas de Saint-Fond *Recherches sur la pouzzolane, sur la théorie de la chaux et sur la cause de la dureté du mortier*...1778. Cuchet, Grenoble et Nyon, Paris.

p35 Fat lime or common lime is the one made from soft limestones, often a marl, that contains sometimes a lot of marine fossils, or a lime that has a grain close to the best lime stone, that is however charged with fat ingredients or phlogisticated volatile acid in which water dissolves its molecules with difficulty. It would mean that we would have, before using such a lime, to leave it to macerate for a long period of time in water, until this gaseous material is decomposed. *In macerations diuturna* said Vitruve, *liquore defervere coacia*. Moreover, we can see in ancient Roman laws that it was forbidden for craftsmen to use this type of lime that they named *calx macerata,* macerated lime, unless it was 3 years old. However, it exists as an intermediary lime between fat lime *(paste/putty)* and quicklime. We understand how many (types of limes) there are with nuances and different characteristics. There is almost no country where the lime is the same and resembles in every detail another. These different varieties were always the cause for the people to give strict and general procedures in terms of lime proportions in several cement mixes, recently developed.

A good quality quicklime is the only one that can be employed with pozzolan intended to be used in underwater works. If we would use common lime instead, I would not guarantee their success, and would even think it uncertain, but it is always good to conduct tests.

*Phlogistique = refuted chemical theory developed by JJ. Bercher in the 17th C, in which he thought heat was constituted of a fluid that he named 'phlogisque' from ancien greek 'phlox' = flame.'

P55 Conjectures on the theory of the hardness of mortar

The best mortar, the one made from a good quality quicklime has not yet reached its last degree (of hardness) after 30 years, it is often said by stonemasons. They observed this when they had to demolish, more or less, old traditional dwellings in which the most common houses built with common materials and mediocre mortar and friable walls were easy to tear down. But the walls, in these same houses, situated in the foundations, sheltered from air and subjected to constant humidity, **obtained in the long run, a greater hardness,** whereas the walls above ground exposed to the fluctuating action of dried air and humid air, suffered and crumbled into decay.

The transparent white lime spath (= *laminated carbonate of lime)* should be considered as the purest limestone. It entirely dissolves in nitrous acid, when exposed to fire and produces, through calcination, one of the best known limes. The good quality of the lime depends partly on the purity of the stone we burn. The lime we obtain from white and black marbles are preferable than from the common limestone. And the common limestone is better than the one made from chalk *(Smeaton undoes this long-standing notion, but not published until 1791).*
The solidity and hardness of the limestone is presumably attributed to a type of crystallisation. Through a microscope, the hardest marble has lamellas, a vitreous glow that announces a 'spathique' crystallisation.
The burnt limestone loses half of its weight, the water of the crystallisation is removed by the fire, the fat substance is burnt, the stone becomes soft, and acquires a great aptitude to seize humid molecules from the air, water is soon

absorbed, a high heat is given off, the lime expands and falls into powder.
This lime powder, the product of calcination, can only regain a part of its hardness through a new arrangement of its molecules, by a new crystallisation with the employment of a liquid. This liquid is the purest water, the least charged with foreign bodies, the lime becomes soluble, it dissolves itself easily, then this water is covered with laminated crystals that we named inapropriately *crême de chaux*. Those little laminas are the true elements of the limestone, it is a regenerated spath.

Raucourt, Antoine. Traité sur l'art de faire de bons mortiers et d'en bien diriger l'emploi 1778. Malher Paris

P12 Slaking of lime

Between all the known methods, only four should be employed, yet, we think that **in our current knowledge, only the first and fourth method should actually be used.** The first method, because it reduces the limestone to a paste; the last because it also liquifies the limestone, allowing it to mix and to regain its solidity. The second and third methods are costly and are **only used to give an hydraulic characteristic to the lime stone.** *(Or preferred as methods of slaking hydraulic limes?).*

P16 First method: ordinary slaking
We throw an adequate amount of water on the quicklime as soon as it is out of the kiln. It splits, blisters and melts until it becomes a thick mash that we call 'melted lime' or 'flowed lime = coulée.

Second method : slaking by immersion
The limestone is immersed in water and removed before the beginning of its fusion, then it whistles, bursts with noise and falls into powder, radiating scorching vapors. When it is soaked, the heat is quite lowered. The lime gives in volume one and a half slaked lime for one quicklime, measured in powder. The hydraulic lime, that divides well, gives in the same circumstances, two for one *(feebly hydraulic lime).*

Third method : spontaneous slaking
By letting the quicklime slake in a slow and continuous action of the atmosphere, it reduces into powder with no great heat. With this natural slaking, the lime increases two fifths of its weight, five to six times less than with the ordinary method of slaking. The lime and the mortars give in volume from one and two thirds, to two and a half for one and, when reduced into a paste, only 2/3 of its weight.

The first method is the one usually used, the second was employed for diverse works, the third has always been avoided and the lime from that method was

considered wasted.

However experience proved that if we put a fatty lime, as soon as it is out of the kiln, in a shed, exposed to the atmopshere, it will become powder, as explained with the spontaneous method, and by shaking from time to time, we notice after six months to a year, that this lime **has acquired hydraulic properties** that could generate a bit of heat, consequently can still be categorised as a quicklime in opposition of complete slaked lime.

<u>Fourth method : complex slaking</u>

After the slaking with either the second or third method, we can **turn the powdered lime into a paste**, **whereupon it produces another expansion.**
(Footnote - if we throw water into a powdered lime slaked by the second or third method, the volume of the powder diminishes but the particles of which it is made increase in volume long after the making.)

(Sets quicker the less lime there is to sand).

Higgins B (1780), Experiments and Observations Made With the View of Improving the Art of Composing and Applying Calcareous Cements and of Preparing Quick-Lime: Theory of These Arts, quoted in Austin (see also, extensive excerpts in Rees (1812) below.

P58 The…inconvenience arising from the excess of lime cannot easily happen in mortar compressed on all sides in massive buildings, but it manifestly occurs in the exterior parts of the joints in walls, where the mortar visibly swells, and after swelling, crumbles; it is likewise visible in the upper parts of walls of modern construction, where the swelling is not prevented by a superincumbent weight…

The strength and duration of the calcareous incrustations composed of lime and sand will be the greater as we depart further from the proportions of lime and sand **commonly used,** approaching (p59) to that of 1:7, because the stucco which hardens the soonest must be the least injured, whilst it is new, by the beating rains and various accidental impressions, because that which adheres most firmly to the other materials of buildings, and which acquires the greatest degree of induration, must contribute most to the strength of the walls, and best withstand the shocks, attrition, and other trials to which the stucco is exposed…but above all, because the stucco made with one part of lime and about seven of sand, **is not disposed to crack**; for incrustations in this climate perish sooner by reason of the fissures than of any other defect, because the water imbibed into the slenderest of them, as well as into those which appear on a cursory view; swells in the congelation, and dilates them; and frequent alternations of wetting and freezing, gradually widen them, until the stucco is bulged and torn from the walls.

p61…(by analysis and trials) I found that the quantity of lime in old cements made with clean sharp sand, and noted for their hardness, **was much less than is now commonly used in mortar; and that in the hardest, it was very near to that which my experiments indicate to be the best.**

a series of experiments with 1 part slaked lime to 7 sand, by weight

I learned that hasty drying prevents good mortar from ever acquiring the hardness which it otherwise would have; and that the more slowly the proper water of the mortar is exhaled or absorbed from it, in incrustations or brickwork, the more perfect will be the induration of it.

(Also) that mortar which is not suffered to dry, or which is supplied with moisture as fast as its proper water exhales, does not harden, or hardens only to a small degree…

p74 (So, for mortar that sets soonest and to highest degree and makes best cement)…it must be suffered to dry gently and set; the (desiccation) must be effected by temperate air and not accelerated by the heat of the sun or fire; it **must not be wetted soon after it sets**; **and afterwards it ought to be protected from wet as much as possible, until it is completely indurated…and then it must be as freely exposed to the open air as much as the work will permit,** in order to supply acidulous gas….

P75
The mortar made with bad lime and a great excess of it, and debased in watering and long exposure, is used with dry bricks and not infrequently, with warm ones. These immediately imbibe or dissipate the water and not only induce the defect (above) (but make it brittle and liable to loosen as work proceeds, causing shocks and vibrations).

But to make strong work, the bricks ought to be soaked in lime water, and freed from the dust which, in common bricklaying, intercedes the brick and mortar in many parts. By this method, the bricks would be rendered closer and harder; the cement, by setting slowly, would admit the motion which the bricks receive when the workman dresses them without being impaired; and it would adhere and indurate more perfectly….

P76 **In plaistering, the workmen always brush away the dust and wet the wall on which they are to lay the cement, because it will not otherwise adhere…**this ought to be done with lime water, and repeated as long as the wall is thirsty.

Advocates soaking sand for mortars with lime water before mixing, rather than adding water to the drier ingredients.

P86 I next endeavoured to ascertain the mixture of coarse and fine sand, (which most reduces the voids, therefore requiring less lime to fill these and) promises to make the hardest and most durable cement.

Series of experiments with different sands in combination

P90 The mixtures of rubble and mixed in any proportion greater than 5:1 were not fat enough, when fresh, to be conveniently used in building or stuccoing…Those which had the smaller quantities of lime in them were very rough on the surface, coarse in the grain, spongey and easily broken…those which contained more lime were not so bad in these respects. 1:5 optimum with 'rubble'.

P92 I was persuaded that a better cement can be composed with such sand as I call fine, than with a coarser sand whose grains are all larger than all those in my fine sand…

p93 Of the specimens made with rubble and fine sand, that was the best in which the fine sand was twice the quantity of the rubble…(but did not seem better than those made with fine sand alone)

Of the specimens made with coarse sand, fine sand and lime, those were manifestly the best which consisted of 4 parts of coarse sand, 3 of fine and one part or a little more of lime: for, whilst fresh, they were more plastic than the others, and were easily made to acquire a smooth surface; they were not disposed to crack …; they were not at all injured by wet or freezing or thawing; they were pretty close in grain and (p94) they grew so hard, in the course of 9 or 10 months, as to resist the chisel… (the best mortar he had made or tested).

…In stuccoing walls, the rubble promised to be useful in pointing and in the first coat; because a roughness of this coat makes the finer exterior coat adhere more firmly.

(Experiments with fine 'house sand' commonly used in London and much finer than the sharp fine Thames sand).

Mortar containing the quantity of lime necessary to the plasticity and other desirable properties of it, or a greater quantity of lime, is the more liable to crack in drying, as the sand if it is finer.

Mortar made with this finest sand and lime does not grow so hard, or resist fracture so forcibly, as that made with my fine Thames sand and lime. …

P99 Mortar composed of lime, my fine (but sharp) Thames sand and the finest sand is the worse as the quantity of finest sand is greater…

(Notes that the roundness of the grains of the finest sand is the problem).

P109

In great cities, where gravel cannot be procured so cheap as the rubbish of old walls, which the workmen lay in the streets to be ground to powder by the passing carriages, they use this rubbish screened, in the place of sand or gravel, in making mortar. It consists of the gross powder of bricks, and of mortar indurated, as much as bad mortar can be, by time; and some builders affirm that it is (p110) better than sand or gravel for mortar. It is certainly eligible when the price is chiefly considered; in any other view, it is not so.

(So, made some trials….)

I found that less lime was required to make fat lime mortar with this ground rubbish, than with my best mixtures of sand…but the mortar made with this rubbish appeared in every stage of induration, and in every comparison except that of the plasticity, to be greatly inferior to that made with mixed sand and lime in the same proportions.

If the workmen would confine their opinion to the comparison of such rubbish mortar (p111) with that in which clayey gravel is used, or with the cements made with the ashes and ordure of the town, dug out in preparing foundations for houses…they might maintain it on divers grounds…but otherwise it is erroneous.

p117 To guard a recent incrustation from the rain, and to secure it from cracking…I proposed **the expedient of hanging sail cloth on the cornices and scaffolding**; but the expense of this measure, and the danger of it in windy weather, are strong objections.

p124 A mortar made of terras powder and lime was used in water fences by the Romans, and it has been generally employed in such structures ever since…It is preferred before any other, for this use, because it sets quickly, and then is impenetrable to water: **whence some people hastily conclude that it is the best kind of mortar for any purpose**. But by experience I know that mortar made of lime and terras powder, whether coarse or fine, **will not grow so hard as mortar made with lime and sand, nor endure the weather so well; but…is apt to crack and perish quickly in the open air.** The efficacy of it in water fences is experienced only where it is kept **always wet.**

Then

Experiments shewing the effects of Plaister Powder, Alum, Vitriolic Acid, of some metallic and earthy Salts, and of Alkalines, in Mortar, Practical Inferences.

Then

Experiments shewing the Effects of Skimmed Milk, Serum of Ox-Blood, Decoction of Linseed, Mucilage of Linseed, Olive Oil, Linseed Oil and Resin, in Mortar; and the Effect of painting calcareous Incrustations.

P133 (All no less liable to crack; encouraged organic growth and prevent the mortar reaching normal hardness).

P134 Olive oil mixed with good mortar, or substituted in the place of a part of the lime water, (p135) rendered the cement defective, as the quantity of oil was greater. The greatest quantity used as half that of the lime.

Linseed oil…makes the mortar fatter, retards the drying of it and prevents it from acquiring in any way so great a degree of hardness as it otherwise would have….In smaller quantities it was less injurious than olive oil.

I have reason to conclude that no oil ought to be used in a cement which consists chiefly of sand, lime and water

I infer that cow-dung, which I have not tried, would impair good mortar. It makes the common mortar fatter, and in that respect more convenient for the pargeting of the interior surface of chimney flues; it seems likewise to prevent the parget made with bad lime from drying so clearly and cracking so much…the fibrous part of the dung being capable of contributing largely to the latter effect.

Then,
Experiments shewing the Effect of Sulphur, introduced by different Methods, in Mortar.

Then
Experiments shewing the Effects of Crude Antimony, Regulus of Antimony, Lead Matt, Potter's Ore, White lead, Arsenic, Orpiment. Martial Pyrites and slaked Mundic, in Mortar

Then

Experiments shewing the Effects of Iron Scales, washed Colcathar, native Red Ochres, Yellow Ochres, Umber, Powder of coloured Fluor, coloured Mica, Smalt, and other coloured Bodies, in Mortar. Advices concerning coloured Incrustations, Inside-Stucco, and damp Walls.

(Condensation):

The plaisterers, finding their stucco, which is as fine and close as they can make it, to contract these damps, especially on the principal walls of houses, case them with lath-work, on which the incrustation is laid distant from the wall. In this way, (p157) they obviate the appearance of damp; but they at the same time contract the rooms, and narrow passages and staircases sensibly, at a great expense. This is enhanced by the repeated plaistering necessary to fill the slender cracks which disfigure their incrustation during the drying, and by the oiling or painting which is finally required to hide this defect completely, if not to give colour. Thus the work becomes costly, though the plaisterer's profit is moderate.

(then sings the praises in this regard of his coloured patent mortar)

Experiments shewing the Effects of common Wood-ashes, calcined or purer Wood-ashes, elixated Ashes, Charcoal Powder, Sea Coal-ashes, and powdered Coak, in Mortar…

The ashes of wood and sea coal are frequently mixed with water, or used in the place of sand, **in laying tiled floors and even in external incrustations.**

Some workmen say they are used in the former case to save sand; others that **they serve to resist moisture…and that they hasten the drying and induration and prevent the cracking of mortar which is laid very thick** in order to fill the depressions of walls which are to be stucco'd and that they are used in finer incrustations with the sole view of preventing cracks.

P164. After a great number of experiments…with the elixated ashes, I found that they rendered the mortar spongey, disposed it to dry and harden quickly, and prevented it from cracking, more effectively than the like additional quantity of sand would do it.

p168

From these experiments, I conclude that…these powders are eligible in this order: elixated wood-ashes freed from the finest powder in washing, first; powdered coak or sea-coal cinders, next; charcoal powder next; rough wood ashes powdered, last.

Experiments shewing the Effects of white and grey Bone-ashes and the Powder of Charred Bones; and Theory of the Agency of these in the best calcareous Cements.

p180

(Has convinced James and s Samuel Wyatt to use his patent mortar on their buildings).

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The Specification made in Consequence of Letters Patent

Specification,

Lime water used to slake.

Let 56 pounds of…lime be slaked, by gradually sprinkling on it, and especially on the unslaked pieces, the cementing liquor, in a close clean place. Let the slaked part be immediately sifted…let the lime which passes be used instantly or kept in air-tight vessels…This finer, richer part of the lime which passes through the sieve, I call purified lime.

(56 parts of coarse sand: 42 parts fine sand: 14 parts purified lime added to the wetted sand; beat together then add 14 parts fine bone ash. Use as soon as possible after mixing).

This I call the water cement coarse-grained, which is to be applied in building, pointing, plaistering, stuccoing, or other work, as mortar or stucco now are, with this difference chiefly, that, as this mortar is shorter than mortar or common stucco and dries sooner, it ought to be worked expeditiously in all cases…(and all surfaces well-wetted before applying).

p214
The inexperience of the workmen, their obstinate adherence to their own notions, and the opinion which they entertained that some of the rules prescribed to them were insisted on rather through an affectation of mystery than for any useful purpose, operated strongly against the best endeavours of Messieurs Wyatt, in the incrustations first made on a great scale for use or ornament. In consequence…their stucco, although it excels others beyond comparison and is far from being perishable, is not quite so hard as it might have been made….

Bryan Higgins (1780) , quoted in Austin

I am generally disposed to think that there is some good reason for any practice which is common to all men of the same trade, although it may not be easily reconcilable to the notions of others; and seeing that the builders **slake a great quantity of lime at once; more than they can use for some days, and that all those with whom I conversed, esteemed mortar to be the better for being long made before it is used,** and that plasterers in particular follow this opinion in making their fine mortar or stucco for in-door work; I was desirous to discover the grounds of these measures **so repugnant to** the notions gathered from the foregoing experiments, and others.

I therefore made about a peck of mortar with one part of the freshest and best chalk lime, slaked, six parts of sand, and water *quan. suff.;* for in a number of experiments I observed that this proportion of lime was better *[showing no shrinkage in a series of mortar samples]* than any larger which I had tried, **or which the workmen observe in making mortar.** The mortar was formed into an hemispherical heap on the paved floor of a damp cellar, where it remained untouched twenty-four days. At the expiration of which time, it was found hardened at the surface, but moist, and rather friable or 'short' than plastic in the interior parts of it *[carbonation will be underway…]* I beat the whole of it with a little water to its former consistence, and with this mortar and clean new bricks, built a wall 18" square, and half a brick in thickness, in a workmanlike manner. On the same day, I made a mortar of the same kind and quantities *[only very slightly richer than 1:3]* of fresh chalk lime and sand, tempered in the same manner, and built a wall with it, like the former, near it, and equally exposed to the weather. I examined the mortar in the joints of these walls every fortnight, by picking it with a pointed knife, and could perceive **a very considerable difference in the hardness of them, the mortar which was used fresh being invariably the hardest.**

At the expiration of twelve months, in pulling these walls to pieces, and by several trials of the force necessary to break the cement and separate the bricks, **I found the mortar which had been use quite fresh to be harder and to resist fracture and the separation of it from the bricks in a much greater degree than the other experiment….**

I concluded that mortar grows worse every hour that it is kept before it is used in the building, and that we may reckon as another cause of badness of common mortar, that the workmen make too much at once, and falsely imagine that it is not the worse, but better, for being kept.

Semple G (1780) A Treatise on Building in Water in Two Parts. Second Edition. London Longman

Part II Building in Water.

Concerning Lime Mortar and Grout.

I HAVE from my Childhood, been well acquainted with the Nature of Lime and Sand made in Mortar, of all sorts, that have been used in Buildings in these Countries, and tried numerous Experiments with them; on which, together with what I have observed and learned from old experienced Workmen, during the Course of upwards of sixty Years, I think, I can safely affirm, that good Mortar, that is, Mortar made of **pure and well-burnt Limestone**, and properly made up with sharp, clean Sand, free from any sort of Earth, Loam or Mud, will within some considerable Time actually petrify, and as it were, turn to the Consistence of a Stone. I remember I had one of my Remarks from an old Scotch Mason,

which I shall give you in his own identical Words, that is,
"When a hundred Years are past and gane.
Then gude Mortar is grown to a Stain (or a Stone.)"

My Father (who was a Workman about the Year 1675) often told me, and my own repeated Observations convince me, that the Methods Masons practised in former Times, in building Churches. Abbeys, Castles or other sumptuous Edifices in this Country, was to this effect. After they laid the outside Courses with large Stones, laid on the flat in swimming Beds of Mortar, they hearted their Walls with their Spawls and smallest Stones, and as they laid them in, they poured in plenty of **boiling Grout, or hot Lime-liquid** among them, so as to incorporate them together, as if it were with melted Lead, whereby the heat of it exhausted the Moisture of the outside Mortar, and united most firmly both it and the Stones, and filled every Pore (which as the Masons term it) set, that is, grew hard immediately, and this Method was taught to our antient Masons, by the Romish Clergy that came to plant Christianity in these Countries, and I affirm, that in many of such old Buildings, I have seen the Mortar, as it were, run together and harder to break than the Stones were.

But with respect to the Matter in hand, I admit that Mortar will not set or grow so soon hard in Water as upon Land; but I am fully convinced, that good Mortar will in reasonable Time grow as firm and as substantial in Water as upon dry Land; but not dwelling upon mere Reports, I shall come to Facts, and I do also affirm, that in pulling down Essex-bridge, and repairing Ormond-bridge, we found the Mortar of the lower Courses of the Piers better cemented to the Stones, than it was in the upper Works; for a wet Stone or a wet Brick imbibes the Mortar, and holds it faster than a dry Stone or Brick will do; the Dust and Dry- ness of either crusts the Mortar immediately, and the wet Stones or Bricks suck and unite with it, as for instance, take two Bricks equally well burned, wet one of them and lay it on a Bed of Mortar, and at some Distance from that lay on the other dry, let them lie so as long as you please, and then take them up, and you will find the wet Brick will bring up its Bed of Mortar with it, but the dry Brick will separate and leave its Bed of Mortar behind it.

There are several sorts of Limestone, some indeed, set much sooner and harder under Water than others, but any good Lime properly mixed, and tempered with sharp clean Sand, will bind and cement as effectually under Water as above it, as I hinted before. What I mean by good Lime, is that which is made of clean, close-grained Limestone. All Marble is Limestone, but all Limestone is not Marble. All Marble will take a polish, but all Stones that will burn to Lime, will not take a polish. For instance, Chalk will make Lime, but it will neither polish nor make good Lime for any Purpose; therefore, I advise you to choose the closest grained, the hardest, and consequently the heaviest Limestone for any Work, but particularly for Water-works.

I need not explain what I mean by sharp, clean Sand, but I shall give this One Caution, that it is better to put too much Sand in your Mortar than too little. **I**

know Workmen choose to have their Mortar rich, because it works the pleasanter, but rich Mortar will not stand the Weather so well, nor grow so hard as poor Mortar will do; if it was all Lime it would have no more Strength in Comparison, than Clay.

Now let us suppose, that a Peck of Roach-lime was slacked into White-wash, and then mixed with two or three Barrels of sharp Sand, so that , every individual particle of Sand partook, and as it were, got a white Coat of this Liquid-lime, such Mortar, that would only appear to be mere Sand, supposing such could be wrought into Mortar, would sooner harden and petrify, either in or out of Water, than if there had been ten Times that Quantity of Lime made up with it; but nevertheless, observe, that I do not recommend that Proportion for Mortar, though it might answer for our present Purposes extremely well.

It is not within my Province to account for the petrifying Qualities of Limestone, Lime or Lime-water, though I have often heard, seen and read of several very remarkable Instances of each of them, but it is sufficient for my present Purpose, that they have these petrifying Qualities to great Degrees; but all sorts of Limestone have not this Quality in the same Proportion, yet I believe, no Limestone whatever can have more excellent Qualities than such as we have in, perhaps, every County in the Kingdom: And indeed, it has some useful Qualities not much known among the Generality of Workmen, as for instance, our Limestone will make exceeding good Tarrass for Water-works, for which purpose you are to prepare it thus: **Get your Roach-lime brought to you hot from the Kiln, and immediately pound or rather grind it with a Wooden maul, on a smooth large Stone, on a dry boarded Floor, till you make it as fine as Flour**, **then without loss of Time, sift it through a coarse hair or wire Sieve, and to the Quantity of a Hod of your setting Mortar (which on this Account ought to be poorer than ordinary), put in two or three Shovels-full of this fine Flour of the Roach-lime, and let two Men for Expedition sake, beat them together with such Beaters as the Plaisterers make use of, and then use it immediately.** This, I can assure you will not only stand as well, but is really preferable to any Tarrass.

I will give you another Instance which will be hereafter found to come within our Subject, ie. the making Cisterns in which Tarrass is generally used in ordinary Work, build all your outside and inside Rows or Courses with wet Bricks, and with Tarrass- mortar **made as above directed**; observing, that your Mortar is to
be a little too soft for Work, and then the heat of the Lime-flour will bring it to a proper Consistence immediately; but never throw Water upon it when you are beating it, for that will chill and slack your Lime-flour, which you ought most carefully to avoid, but make the Men temper it with the utmost Expedition, and what you want in Water to make it fit for your Work, give it in Elbow-grease; and this Rule ought to be observed in making all sorts of Mortar.

The Grout which you lay your middle Row with, must be thus made (in a Tub or Bucket): pour your Water on the Roach-lime, which must be **pure and well burned,** very leisurely; and when it is boiling, you may strain it through either a wire or hair Sieve, so as it may be tolerably free from Stones, and then let it be used directly, and be sure your Sand is sharp and clean, and when you are using it, do not take the thin that is uppermost, but stir it up and take plenty of the Sand with it; but in Masons Work, when the outside and inside Courses of cut Stone are set, pour in this boiling hot Grout, and instantly lay down your middle Course of wet Bricks between them, in double or single Rows of Stretchers, braking Joints as usual, according as the Largeness or Smallness of the Work may require, and that will press and squeeze the Grout into all the inside Pores that are next to it, and so they will all unite, and by the heat of the Grout and Dryness of the Bricks, they will all set together immediately, and become staunch and solid; but if you were making a Cistern of rough Stone, **mix one fourth of the Powder of Tiles, or well-burned Bricks with your Mortar.**

William Marshall. The Rural Economy of Yorkshire Vol 1 1788

CEMENT. **Formerly, ordinary stone buildings were carried up, entirely, with 'mortar'; that is, common earth beaten up with water, without the smallest admixture of lime** [*but see below for contradiction of this - earth mortar with lime lumps present*]. The stones themselves were depended upon as the bond of union; the use of the 'mortar' being merely that of giving warmth to the building, and a degree of stiffness to the wall [*we would disagree with this assumption].*

The event, however, proves that walls built without lime have, in many instances, stood for ages. Even part of the walls of Pickering Castle, formerly esteemed a fortress of considerable strength, have been carried up with a cement which, *to appearance,* seems little superior to common mortar: nevertheless, such is the effect of time, upon walls which are exposed on every side to the atmosphere, that they now hold together with considerable tenacity…

The citadel, or central stronghold, of the fortress under notice, has been built with better cements; which, however, vary much in outward appearance. One specimen…is a smooth childlike substance; another, a coarse rough mass, composed of sand and gravel, with a smaller proportion of chalk-like matter [….lime].

In the fosse, which surrounds the outer wall, lies a fragment…whose cement has acquired a stone like hardness, especially the part which is exposed on the outer surface.

I have bestowed some attention on the decomposition of these four specimens…

EXP 1 CEMENT OF PICKERING CASTLE: - the coarser specimen, taken from the ruins of the central tower.
In *general appearance* it resembles dirty chalk, thickly interspersed with small gravel; some of the granules as large as peas. Its *tenacity* that of common writing chalk; the asperities easily broken off with the fingers. One hundred grains, pounded, dried, immersed in water, and balanced together with the menstruum lost in solution 25 1/2 grains of air, and yielded by filtration 40 grains of residuum; which afforded…35 grains of gravel and rough sand, and 5 grains of suspendible mudlike matter; the solution yielding, by precipitation, 64 grains of calcareous earth…

From this analysis it appears,

7. that the proportion in this case (supposing crude limestone in lumps fit for burning to be of equal weight with sand and gravel) was three measures of unslaked lime in lumps to two of sand and gravel. *[probably the opposite by volume, since lump lime 40% lighter than unburned limestone].*
8. That the sand and gravel, in this case, has been washed; either by the brook, which runs at the foot of the Castle mound, or more probably, by hand; the proportion of dirt being smaller than that which is generally found among *drift sand*.
9. That the lime had not regained the whole of its fixed air.

EXP 2 - finer specimen of the central tower.

General appearance that of stale lime, run together with water, and baked to a crust; almost a pure white; surface rough; shewing the cells and the unbroken granules of the original lime. *Contexture,* more brittle than common chalk; full of pores; the materials do not seem to have been well incorporated, at the time of preparation.
One hundred grains yield, in decomposition, 21 grains of air; 42 grains of whitish grit, 5 grains of suspendible dust like particles; 56 grains of pure chalk.
OBS. The residuum…is evidently *the powder of free stone*. The particles are small, and of irregular figures, very different in appearance (when magnified) from common sand. I was at a loss to ascertain their nature, until pounding some freestone, and washing it in the manner I had done the residuum, I found it to resemble exactly the 42 grains of washed grit of the experiment. It appears to have been pounded or ground very small, and to have been put through a fine sieve…no fragment so large as a pin's head.

It is observable that the cement of this experiment is *weaker* than that of the last (different aggregate; less lime content)….It is also observable that, in the decomposition of the specimen, a urinous smell rose, during the solution…**It is at present a practice, among some plasterers to make use of urine in the preparation of plaster.**

EXP 3 - taken from the ruins of the old outer wall facing the northwest. Collected in three or four different places; a few feet above the foundation; and mostly from the inner parts of the wall, not from the outer surface.

In appearance that of sandy loam, interspersed with specks of chalk *[quicklime, surely],* some of them larger than peas *[we see this pattern locally where quicklime has been added to earth mortar].* Its fragility similar to that of dried brick earth.

100 grains…yield 13 1/2 grains of air; 30 grains of rough sand, and a few large fragments; 37 grains of silt and fine sand; 36 grains of calcareous earth.

OBS. There are two causes of the *weakness* of this cement: the small proportion of lime, and the impurity of the base…chiefly of mere mud, or of sand so fine as to be impalpable between the fingers. *all consistent with the simple use of locally sourced sub-soil and modest addition of quicklime - the sand and silts being naturally part of the subsoil. Fairly typical of modern disaggregation in this area].*

EXP 4 - taken from a fragment in the northwest corner of the fosse.

The general appearance somewhat resembling the last-noticed specimen; but in *contexture* very different. The crust of the outer surface, which has been exposed to the influence of the atmosphere, probably during many centuries, has acquired almost the hardness of limestone; nor is any part of it to be broken with the fingers; nevertheless, this specimen also, is **full of lumps of unmixed lime;** some of them the size of small hazel nuts, and, at the time I took the specimen (the season wet), as soft almost as butter; when dry, they are of the consistency of very soft chalk.

One hundred grains of this specimen yield 15 grains of air; 8 grains of fragments; 12 of coarse sand; 36 of fine sand; 3 of size-like matter; 45 of chalk. *[linseed oil?].*

…GENERAL OBS:

1. All these cements, whether weak or strong, have laid hold of the stones with a degree of firmness proportioned to their respective strengths. **Every crevice of the wall is filled with cement; whole form one united mass.**

Hence, it is more than probable that these cements have been poured into the walls, in a liquid state, in the state of *puddle*…

2. The subjects of EXP 3 and 4 are strong evidence that, in the preparation of these puddles, the ancient builders were very deficient *[we would probably disagree].* Not more than half of the lime they contain appears to operate *[as* *binder, but will seed carbonation as porous aggregates].* The lumps, whether large or small, are *more* than wasted; weakening, rather than strengthening, the cement *[Marshall is going somewhere with this argument - see below].*

3. From the whole of these experiments, it is evident , that the several cements had acquired the principal part of their fixed air; chiefly, perhaps, after they were deposited in the buildings *[by carbonation].* Hence it is entirely probable that the stonelike tenacity of old cements is chiefly owing to the transmutation of lime and sand to calcareous earth and sand; a substance resembling the original limestone *[the lime cycle].*

On examining a wall, which has been built with loam alone, without any admixture of lime, and which has stood about a century, I find that the loam has laid not hold whatever of the stones, and that time has made no alteration on its contexture. It is still the same friable substance it probably was the day it first became dry in the building; without having the smallest appearance of **acquired tenacity** obtained during the century of time it has been exposed to the influence of the atmosphere.

It is therefore probable that the atmosphere imparts nothing *voluntarily* of a cohesive nature to the mortar of walls which are exposed to it.

But it is more probable that cement, **containing a portion of lime, imbibes from the atmosphere something, which gives it a degree of tenacity, superior to that which it had on its first becoming dry in the wall;** and it is a fact well established, that lime begins to imbibe, the moment it grows cool from the kiln, that which the fire has deprived it of, namely, fixed air; which fixed air being imbibed, after the cement is deposited in the walls, is *probably* a principal cause of tenacity.

[and so begins the run-up to recommend dry-slaking of powdered quicklime…]

This being admitted, it may seem to follow that the more quickly it is transferred from the kiln to the building, the greater proportion of air will be imbibed, after it is laid in the walls, and, of course, the greater effect will *time* have on the tenacity or cohesion of the cement; and hence we might be led to infer that, if the ancients had superior skill in this matter, it consisted in their hastening the lime from the kiln to the building.

But in practice, it is observed, that fresh-made mortar does not *set* so well, does not cohere into a stone like substance so readily, as that which has been prepared some time before it is used.
This fact, perhaps, is accounted for in the lime having had, under this circumstance, time to lay hold of the particles of *sand* with which it is inter-mixed.

But, on the same principle, it seems to follow that, if the preparation be made too long before the mortar be laid into the wall, it will have regained too much of its fixed air to lay hold, sufficiently, of the *stones* or other materials, which it is intended to bind together.

Let this be as it may, **it is common, in practice, when mortar is not used, presently *[shortly]* after making, to cover it up closely from the outward air.** It is the opinion of a person, who has paid this subject considerable attention, that, if **mortar** be buried within the surface of the ground, it may be kept twelve months in perfection.

The same person…**has struck out a <u>*new idea*</u> relative to the *slaking* of lime for mortar:**

Lime, whether it be intended for cement or for manure, ought to be reduced entirely to a *dry powder*. And, for cement, it ought to be mixed, in this state, evenly and intimately with the sand.

It is difficult, if not utterly impossible, to reduce lime entirely to powder, **with water alone;** some part of it will always be supersaturated, and thereby be reduced to a *paste;* while the outsides…will (unless the stone be extremely fine) fall into granules, not into powder.

Every piece of paste, and every granule; though but the size of a pea or a mustard seed, is useless, if not detrimental to cement; for, with these, the grains of sand cannot be intimately mixed; much less be coated with them; as they may, and undoubtedly ought to be, with *lime in powder*.
But if, instead of water, *wet sand* be used in slaking the lime; (piling it with the lime in knobs, layer for layer, and covering up the heap with it;) those evils are avoided: no part is supersaturated, nor are any granules formed by the action of the outward air.

Besides, another great advantage is obtained by slaking the lime, in this manner, with the sand with which it is intended to be incorporated. The two ingredients, by being repeatedly turned over, **and by passing through the sieve together,** necessarily **become intimately blended;** more intimately, perhaps, than they could be mixed by any other process, equally simple.

If the sand be *washed* (and all sand mixed with lime for cement ought to be washed) the labour of preparation is, by this method of slaking the lime, considerably lessened.

But, in the preparation of cement, SLAKING THE LIME makes only one stage of the process; MIXING THE INGREDIENTS intimately and uniting them closely together, into one compact homogenous mass, is an operation which requires the strictest attention….

Much care… is requisite in the preparation of mortar for the TROWEL. Working it, with the spade alone *[what? even with the back of an Irish shovel alone???],* is insufficient. Beating it with the edge of a board, a kind of wooden axe, is more efficacious, but is very tedious. Mills for the grinding of clay are common…but a mill, for the grinding of mortar, I have not yet seen, nor have I ever heard of such a contrivance…..

….MORTAR FLOORS. A new species of cottage flooring has lately been thought of, and is now pretty commonly formed, in this neighbourhood.

The materials are lime and sand; mixed in nearly the same proportion, and prepared in the same manner, as the common mortar of bricklayers; except, that for forming floors with is generally made stronger, and is always made up softer, than it is usually done for laying bricks in.

The *method.* The bed being prepared, the materials are carried on, in pails, **in a state between paste and batter;** laying them on four or five inches thick, and about one inch higher than the intended height of the floor, to allow for the settling, in drying. The whole being well worked over with a spade, the surface is smoothed with a trowel; and as it dries, is beaten, repeatedly, with a flat beater, to prevent cracking; the workman, in this operation, standing on planks. **A fortnight or three weeks dry weather will render it stiff enough to walk upon.** If, after the last beating, cross lines be deeply graven on the surface, a floor of cement has the appearance, as well as the usefulness, of a freestone floor.

LIME

This is at present a favourite manure in the Vale. It is used invariably, I believe, on every species of soil, and *in most cases,* with great success….I am not acquainted with any country in which lime is held in such high repute, **nor where the manufacturing of it is so common a practice among farmers, as it is in this. Almost every principal farmer, upon the margin, burns his own lime. There are, besides, great number of 'sale kilns' for smaller farmers, and for the centre of the Vale, where no materials for burning are to be had.** There is an instance of one man occupying eight or ten kilns; burning two or three chaldrons, yearly.

The LIME HUSBANDRY of the District, therefore, merits particular notice. The subject requires the following division:

1. the materials burnt
2. the method of burning
3. the cost, and the felling price
4. the soils, and the crops to which it is applied
5. the method of applying.

1. MATERIALS. On the NORTHERN MARGIN of the Vale, lime is burnt solely from *stones,* of different colours and contexture. The species most prevalent are - a strong grey LIMESTONE GRANITE; and a species of blue and white MARBLE, the blocks, whether large or small, being blue at the core, and lighter-coloured toward the outer surface.

One hundred grains of the former, taken from a lower stratum of PICKERING-CASTLE-BANK, yield 43 grains of air, and 94 grains of calcareous earth, leaving a residuum of 6 grains, chiefly a brown silt, with a few gypsum-like fragments. One hundred grains of the latter, taken from the lower stratum of a quarry, near KIRKBYMOORSIDE, afford 39 grains of air, 86 1/2 grains of dissoluble matter, and 13 1/2 grains of residuum, fine impalpable silt. *[both of these may be feebly hydraulic - the Kirkby stone the more so].* The lime produced from the former is of a dusky colour, and falls in rough coarse grains; that of the latter, bursts into a white volatile flour-like powder.

The stones of different quarries are different in quality, but none of them differ widely from the specimens above described.

On the SOUTHERN HEIGHTS, the prevailing material is a singular species of SOFT CALCAREOUS GRANITE. its colour a dirty white; its contexture resembling the grains of white mustard-seed, or the roe of fish, run together with a cement of chalk or marl. The hardness of this stone (if it merits the name) increases with the depth of the quarry. The lower blocks are used in building; but the upper stratum, for three or four feet below the soil, is generally a STONE MARL of no mean quality, but varies in different quarries…

100 grains of the MALTON STONE, taken from the middle of the quarry opposite the Lodge at New Malton, yield 44 grains of air, and 97 grains of calcareous earth, leaving 3 grains of residuum, chiefly a brown silt. 100 grains, taken from a newly opened quarry, by the side of the road leading from Malton to Castle Howard, yield only 94 grains of dissoluble matter….

100 grains of WOLD CHALK, taken from a lime quarry near DRIFFIELD, yield 44 grains of air; 3 1/2 grains of a soft mucilaginous residuum; and 96 1/2 grains of calcareous matter.

2.BURNING. In giving the detail of this question, the following subdivisions will be requisite:

1. Building the kiln
2. raising and breaking the stones
3. Coals and their proportion
4. Filling the kiln
5. Drawing the kiln.

1. *The kiln.* The materials are either limestone, entirely, or limestone, lined with bricks on the inside. Neither timber, nor mortar, is here used, in building a lime kiln; the former presently decays, and the latter, by alternately swelling and

shrinking, bursts the walls; besides rendering them, in the first instance, too tight to admit a proper quantity of air: no other air holes, than the 'eyes' at which they are kindled, being made in the kilns of this district.
The *form* of the cavity is an irregular cone inverted. At the bottom are generally two eyes, opposite each other; the cavity being here contracted to a thin point, or narrow trough, the width of the eyes. As the walls are carried up, the cavity takes, by degrees, a circular, or sometimes an oval line; at the same time receiving, as it rises, a conical form; until, having reached somewhat more than half its intended height, the form is changed to *cylindrical,* or is sometimes *contracted* towards the top.
The size varies from 6 to 40 chaldrons

2. *The stones.* The art of *raising* stones can only be learned by experience, in the given quarry in which they are to be raised. They are sometimes raised by the day; sometimes by the load; but, most generally, the entire labour of burning is taken, together, at so much a chaldron of lime.

The *breaking,* of hard strong stones, is a laborious part of the operation of lime burning. On the north side of the Vale, it is done, by men, with large sledge hammers; but, on the Malton side, where the stone is soft, women are frequently employed in the breaking.

The medium *size* is that of the two hands; but men, burning by the chaldron, will not, unless well attended to, break them so small: stones, nearly as big as the head, are sometimes, but very improperly, thrown into the kiln; for unless the proportion of coals be unnecessarily large, the surface, only, is burnt to lime, the core remaining a lump of unburnt stone.

3. *Coals.* The Morelands, for the last fifty years, have furnished the north side of the Vale with coals, for burning lime, and for an inferior species of fuel. The seam of this coal is thin, and the quality, in general, very ordinary.

Before the discovery of these coals, lime was burnt with furze, and other brushwood; but notwithstanding the Morelands are, now, nearly exhausted of coals (unless some fresh discovery should be made), the District is relieved from the apprehension of returning, again, to its ancient mode of burning lime. The Derwent, beside an ample supply of coals for fuel, brings an inferior kind (both of them raised in West Yorkshire) for the purpose of lime burning. The eastern end of the Vale is equally fortunate, in this respect, having the port of Scarborough in its neighbourhood.

The *proportion* of coals and stones varies with the quality of the coals, and likewise, but in less degree, with the quality of the stone: the method of burning, too, varies the proportion. **Three chaldrons of lime from one of coals (the measures equal) may be considered as the mean produce.** From 2 1/2 to 3 1/2 for one, includes the whole extent of produce of well burnt lime.

4. *Filling.* **some kindling being used at the eyes, and an extraordinary proportion of coals at the bottom of the kiln, it is filled up with stones and coals, in thin alternate layers; those of the stones being 5 or 6 inches thick; with coals in proportion; the coals, if not sufficiently small, being previously reduced to a gravel-like state; in order to run down, more freely, between the interstices of the stones and thereby to mix, more evenly, with them.**

The materials are cast into the kiln, with large scuttles, or shallow baskets; which are filled with stones, by means of an iron-toothed rake, composed of four teeth, about 6 inches long, of a head about a foot long, and of a handle about four feet long.

If several men be employed, in filling a kiln, it is common for each man to fill and empty his own scuttle. But this is an uncertain, and therefore improper, way of proceeding. Much depends on the regularity and evenness of the layer; and the due proportion of coals; and to judge of this, with sufficient accuracy, requires some experience, and a steady eye; especially when the kiln is on fire, and the cavity to be filled up is obscured by smoke. If more than one person be employed, in this case, it is highly probable the work will be imperfectly done.

Among the sale kilns, about Malton, there is an excellent regulation, in this respect. The scuttles are all filled, and brought to the top of the kiln, by WOMEN and BOYS, who deliver them to the MASTER, or his foreman, standing there to receive them, *with his eye fixed within the kiln;* by which means he is enabled to distribute the stones and the coals, with the greatest accuracy.

5. *Drawing.* There are two species of kiln; or rather, one species used in two different ways.
A kiln which is filled, fired and suffered to burn out, before any of its contents be drawn, is called a 'STANDING KILN'.
If the contents be drawn out, at the bottom, while the upper part is yet on fire, - the vacancy at the top being repeatedly filled up with stone and coal, as the lime is extracted at the bottom, - the kiln is termed a 'DRAW KILN'.

Since coals have been used in the burning of lime, draw kilns have, until of late years, been most prevalent. But, at present, standing kilns are most in use.

The reasons given, for this change of practice, are these: first, that the lime is burnt, *evener,* in standing than in draw kilns; in the drawing of which, the stones are liable to hang round the sides of the kiln; those in the middle running down, in the form of a tunnel; thereby mixing the raw with the half-burnt stones. The consequence is, the outside stones are burnt too much, the inside ones too little; the stones, too frequently, running down to the eye, in a half-burnt state. Secondly, the unevenness of surface, left by this method, together with the obfuscation caused by the smoke, render the filling difficult; under-burnt stones, or an unnecessary waste of coals, is the inevitable consequence. A third argument in favour of standing kilns is, that a *greater proportion* of well

burnt lime may be produced, from the same quantity of coals. It is allowed that more kindling fuel is requisite; and, at the bottom, a greater proportion of coals, but the fire, by this means, getting a strong head, a less proportion of coals is required, in the body of the kiln; and what, perhaps, is of still more consequence, less heat is lost at the top of this, than of the draw kiln; which is always uncovered, and too frequently hollow and full of cracks, while the top of the standing kiln, being piled up in a conical form, and closely covered with sods or rubbish, collects a greater body of fire, and keeps in the heat more effectually.
One circumstance, however, relative to the standing kilns, requires to be mentioned. The inside should be *lined with brick*. For every time a kiln, which is lined with limestone, is suffered to go out, a shell of lime peels off the inside; by which means the walls are soon impaired.

The lime is drawn out of the eyes with a shovel, and generally carried out in scuttles or in basket measures, to the cart or waggon.

Of a living kiln, the drawing is generally continued, until red ashes begin to make their appearance. But standing kilns are suffered to burn undisturbed, until the fire is rising towards the top, and a fresh supply of air is wanted, a few shovelfuls are drawn at either eye, by which means a degree of hollowness is formed and fresh vigour given to the fire.

From these circumstances, it is plain, that a regular supply of lime cannot be had from less than three standing kilns: one filling; one burning; one drawing. The smaller burners, however, have frequently only two; and for a farmer, one, proportioned to his farm, is sufficient.

Rural Economy of the West of England: Including Devonshire; and Parts of Somersetshire, Dorsetshire, and Cornwell. Together with Minutes in Practice 1791

P56
Descend towards Bideford. - Meet strings of Lime Horses, with pack-saddles and bags of Lime. Also two-horse Carts, with Lime and sea sand,

P58 Bideford and its environs

The tide out: many men employed in leading packhorses, with sand, left in the bed of the river: and, in every vacant corner about the Town, composts of earth, mud, ashes, &c. are seen. Shell sand is said to be plentiful on the coast; but little, if any of it, is brought up this river. On the shore of the estuary, opposite to the Town, are several limekilns, now in full work. Numbers of packhorses, and a few carts, loading, or waiting for loads. The stone, chiefly, and the culm with which it is burnt, wholly, brought across the channel, from the coast of Wales.

The kilns similar to those of West Devonshire. This lime is carried fourteen or fifteen miles- chiefly on horseback.

P230
West Dorsetshire

IX. FOSSILS. The most useful Fossil production, that fell under my notice in this District, is LIMESTONE; which is raised, not in the neighbourhood of Bridport only, but more or less in other parts of it. Beside being burnt into Lime, it is used as a walling material, as well as for paving Slabs, Drains, Bridges, and Stiles - large Slabs of it being not infrequently set on edge for this purpose. It is also used as a road material. It appears as a mass of conglutinated shells resembling much, in general appearance, the Sussex marble: …this is found on the summits of hills. On some of the Northern Heights, detached masses of CHALK are found; fragments, probably, of the neighbouring hills; White Down, between Chard and Crewkerne, appears to be chiefly composed of Chalk; and is the most Western collection of that Fossil, which I have observed; or Which; probably, is found, in this Island.

P295

November 1. The ROUGHCAST work of this District is executed in a superior manner, being not only durable, but pleasing to the eye. Some lately done at Ivybridge is equal, in beauty, to dressed stonework. Mr. Stapleton's house, in this neighbourhood, done in a similar way, has now stood upwards of half a century; and, excepting at the immediate foundation, and beneath some of the windows, where water has been suffered to lodge, the whole remains as firm as when first done; appearing to have acquired a stone-like texture. In both these cases Chrystaline gravel has been used; (p296) and both of them are false-jointed, to resemble dressed stonework. An intelligent workman, whom I accidentally conversed with on this subject, suggested an admirable theory of the operation of 'roughcasting'; making an accurate distinction between this and Stucco work.

Stucco being laid on, *in a state of paste*, more or less air is unavoidably shut up, let it be ever so well worked and the very expansion and contraction of this air, by heat and frost, is sufficient to break the texture of the Stucco. Beside, let the working be done ever so carefully, cracks, though not evident to the eye, will be formed in drying; and if, by means of these microscopic fissures (or of those formed by the expansion and partial escape of the confined air), water take possession of the air cells, the perishing and peeling become natural consequences.

ROUGHCAST, on the contrary, being applied *in a fluid state*, and by little and little, fills up every pore, and cranny in the face of the wall; as well as in the face of (p297) every succeeding coat; which being suffered to dry, before another coat is added, the cracks, if any take place, are filled up; and deep ones, of course, are effectually prevented: whereas, the cracks of Stucco necessarily reach through the coat. Stucco evidently partakes of the **nature of cement used, in a state of paste or mortar**;

LIQUID COATING, of cement poured into the wall, in a state of grout.

Stucco is analogous to the materials of a dam, or the bank of a canal, formed with earth, in a state of paste: ROUGHCOATING, to the puddle of Canal Makers:' to loam intimately mixed with Water, and permitted to subside in a liquid state: thus preventing air cells; and forming a close, homogeneous mass.

Marshall W (1787) The Rural Economy of Norfolk: Comprising the Management of Landed Estates, and the Present Practice of Husbandry in that County. Cadell

1781 p65

NOVEMBER 17. A very secure way of laying pan-tile is sometimes practised in this country. Having nailed on the pantile laths, the tiler distributes reeds, so as just to touch each other, between the pantile laths; and, to keep them in their place, inserts one end of a piece of old plastering lath or other splinter, under the tyling lath; presses it down upon the reed; and inserts the other end under the next lath; - weaving, as it were, these splinters between the pan-tile laths and the reed. Upon the reed he spreads a coat of mortar, and on this lays the tiles.

For dairy or other lean-tos, and for common garrets, the reed is covered on the inside with a coat (p66) of plastering; which, with the spars, &c. being white-washed, gives a neat appearance at a very trifling expence; and keeps the room as free from dust as if it were lathed and ceiled. This is not a common practice; but it is a very good one and is much cheaper than the ordinary practice of "interlathing" with plastering laths.

P84

JANUARY 10. It is economical to lay tile on mortar, or ceil the room they cover; they are otherwise subject to every gust of wind; not from its action upon the outside, but from finding, when pent up on the inside, an easy passage through the covering. An instance occurred the other day: a farm house had two or three yards square of tiling blown off by the late winds; not on the windward, but on the leeward side of the house; and from over the only room about it which is not ceiled.

P266

JUNE 8. It is very dangerous to run up sea-stone wall too quick. Mr. --- had one shot down the other day at Antingham, and nearly killed one of the workmen. The weather was wet, and the bricklayer run up the wall, at once, without stopping, at intervals, to let it settle. The stones, being already saturated with wet, could not absorb the moisture of the mortar - the air being also moist, the mortar, of course, remained pappy; and sea stones, being globular, have no other bond or stay than the mortar; which being unable to hold them together, the super-incumbent weight crushed down the whole. (267) Had the bricklayer proceeded by stages, letting the lower parts get sufficiently firm before the upper parts had been laid on, the mortar would have had time to stiffen, and the wall would have stood. If the stones and air be dry, one halt, when the wall is a few feet above the foundation, is generally found sufficient,

1782

Hog-cisterns in this country, are principally built with bricks and terrace *[trass]*. But this is expensive: yet a hog-cistern is among the first conveniences of a farm-house. Wooden vessels are incommodious, and leaden ones dangerous,

P349
This summer a receptacle for water in a brick-yard being wanted, I had one built of bricks, laid in clay, and surrounded with a coat of the same material: it holds water perfectly. Afterwards, I built a hog-cistern in the same manner.

This morning, on enquiry, I find that not only the tenant, but his wiſe and her maids, are fully satisfied with it. It was built in this manner:- A pit five feet and a half long, by four feet wide, and five feet deep, was sunk in the place most convenient to the dairy, kitchen, and hog-yard jointly. (350) The bottom of the pit was bedded with some extraordinarily fine Clay, fetched from the sea coast for this purpose; moistened and rammed down; and its surface smoothed over with a trowel. On this flooring were laid three courses of bricks, in clay mortar (**the best of the clay being taken for this purpose**), and in such a manner, that the joints of one course fell in the middle of the bricks of the course below; the whole being laid longways; not crossed, in the usual manner. The sides were carried up half a brick thick (that is a brick in width) with mortar of fine Clay: and, in a vacancy left between the brick-work and the sides of the pit, moist Clay was firmly (351) rammed; so as to unite as much as possible the bricks, the clay and the sides of the pit into one solid mass; carrying the brick and clay work up together; and beating back such bricks, in to the clay, as were forced forward by ramming. The cistern when brought up level with the surface of the ground measured three feet long, two and a half feet wide, and three and a half feet deep; consequently the surrounding seam of clay is not more than four inches thick; and the stratum at the bottom is about the same thickness.

352 Above-ground, a nine-inch wall was raised on each side, two feet high, with a gable carried up at one end; and, on these, a span of pitched roof was set, and covered with tyles; the other end being left entirely open as a door way.

Marshall W (1789) The Rural Economy of Gloucestershire; Including Its Dairy: Together with the Dairy Management of North Wiltshire; and the Management of Orchards and Fruit Liquor, in Herefordshire, Volume 1. Gloucester. R. Raikes

P30

FARM BUILDlNGS. IMPROVEMENTS in rural architecture are not to be expected in the district under survey. Nevertheless, the leading facts respecting its FARM BUILDINGS require to be registered; and some peculiarities, as well as some few modern improvements, are entitled to notice.

MATERIALS. Timber appears to have been, formerly, the prevailing building material of the district. Farm buildings, in general, even to this day, are of frame-work; filled up with strong laths, interwoven in a peculiar manner, and covered with plastering; or the studwork is covered with weather-boardery alone; especially outbuildings.

The present WALLING material is Brick. Some few "clay-stones," dug out of the sub soil, are used; and, under the hills, " free stone"--a soft calcarious granate, which is common to the Cotswold hills, is in use.

P31 LIME is here a heavy article of building. From 6d. to 8d. a bushel, of ten gallons level, at the kiln. The stones, from which it is burnt, are brought by water carriage to the towns upon the Severn; either from Bristol, or from Westbury &c at the foot of the Forest of Dean; where the " claystone " of the subsoil is raised for this purpose. The kilns are built on the banks of the Severn; so that no land carriage of the stone is requisite. But the lime, notwithstanding the exorbitant price at the kiln is to be conveyed by land into the area of the district. The margin is supplied with the calcarious granate (which has been mentioned), from the Cotswold cliffs; and from Bredon hill, evidently a fragment of the Cotswolds.

These stones vary much in general appearance and contexture; and the limes produced from them are not less various in their qualities. The " Bristol stone " has a somewhat flint like appearance; is of a close, hard, and uniform contexture; and of a dark reddish colour; sparkling with sparry particles; and flying under the hammer like glass: no marine silt. One hundred grains of it afford forty five grains of air, and ninety seven grains of calcarious matter; leaving three grains of residuum -- a dark-coloured impalpable matter. The lime produced from this stone bursts readily in water; and (like that produced from spars) is, when fallen, of a light floury nature: white as snow: coveted by the plasterer; but is considered by the mason and bricklayer, as being of a weak quality. The Westbury-stone - which is a sufficient specimen of the "claystones " found in the subsoil of most parts of the district is in colour, contexture, and general appearance, very different from the rock of St. Vincent. It resembles, in every respect, the marble-like limestone of the hills of Yorkshire: generally blue at the core with a grey dirty-white crust: the base being of a smooth, even texture. When it is fresh raised out of its watery bed in the area of the vale, it is a soft substance, of a somewhat soap-like appearance but hardens (or falls to pieces) on being exposed to the atmosphere. One hundred grains of this stone throw off forty grains of air and afford ninety one grains of calcarious earth; leaving a residuum of nine grains;- an ash-coloured silt. The lime burnt from it is characterized by strength; and is high in esteem for cement; being found strong enough, in itself, to be used in water work. It falls slowly and is of a somewhat brimstone colour and is distinguished by the name of " brown lime. "

Having observed the reluctance with which the lime of this specimen (fresh from the kiln) imbibes water; while that of the Bristol stone drinks it with singular avidity, I was led to try, by a comparative experiment, whether their powers of imbibing air (that is of regaining their fixed air) were in like proportion. The result is interesting.

One hundred grains of the first (in one knob) suspended in a pair of scales, got full five grains in twenty four hours. In a drawer (which was sometimes open, sometimes shut) they got, in twenty four hours more, the same additional weight. In seven days more (wrapped in paper and lying in a drawer) they got twenty three grains: in all **thirty three**; or about three and a half grains a day: mostly air, with, in all probability, some portion of water.

One hundred grains from the Westbury stone, placed in the drawer increased in twenty four hours not quite one grain. In twenty four hours more, in the scale, they barely made up a grain and a half. In seven days more they gained (in the drawer) exactly nine grains: in all **ten and a half grains**: not a grain and a quarter a day. Hence we may conceive how widely different may be the qualities of lime. Consequently, how dangerous to draw general conclusions from an experiment, or even experiments, made with one particular species). (p34)

The specimen of calcarious granate which I have before me was taken from the middle of a "freestone" quarrey, within the camp, on **Painswick Hill. It is common to the Cotswold and the Lansdown hills and corresponds exactly with the soft limestone granate of Malton in Yorkshire.** It varies in specific quality. The Bathstone is softer and lighter than the specimen under analysis, **one hundred grains of which discharge forty four grains of air; yielding ninety eight grains of soluble matter; and two grains of residuum**, a snuff coloured impalpable matter.

The method of burning lime in this country has nothing which entitles it to notice except (p35) the practice of riddling and hand-picking the lime as it is drawn, to take out the ashes, cinders, and rubbish which may have been thrown into the kiln with the stones or coals. The labour is not great and the work is valuable. **Lime as a building material; especially for the plasterer's use cannot be too pure**. The refuse pays the labourer, and the quantity of stone lime loses nothing by its absence. (Footnote:) The LIME KILN of this district is noticeable, as being frequently furnished with a set upon the walls of the kiln, and contracted in a funnel-like form; the materials being carried in at a door in the side. In one instance, the kiln is built within a cone; in the manner of the brick kilns about London. The principal, if not the sole use of these tops, is to carry up the smoke and prevent its becoming a nuisance to the neighbourhood of the kilns.

TIMBER. The old buildings of this district are full of fine oak; in which the lower lands of Gloucestershire have heretofore, in all probability, been singularly abundant. But at present the vale is entirely stripped, and even the Forest of Dean (some few parts of it excepted) is almost naked of good oak timber. The vale, however, abounds at this time with elm of uncommon size and quality. This and foreign timber are the ordinary materials in (p36) use for farm buildings: oak being used only where durability is more particularly requisite.

COVERING MATERIALS. An ordinary kind of slate, got out of the sides of the hills, has formerly been the prevailing covering of the district. At present knobbed plain tile are principally in use. The knob is an obvious improvement of the hole and pin which are still used about the metropolis.

Thatch is still in use for cottages and farm buildings. A species of thatch new to the rest of the kingdom is here not infrequently made use of; especially near the towns, where wheat straw is permitted to be sold. In these situations, not only ricks; but roofs, are thatched with STUBBLE: a material which is found to last much longer than straw; unless this be "helmed"; that is, have the heads cut off before thrashing, in the Somersetshire manner: a practice which is not common in this country. That stubble should be found to endure is reasonably imagined. It has the advantage of helm (in not being bruised by the flail) and consists of the stoutest part of the stems. In many districts it would be difficult to be used on account of its shortness; but in (p37) this country, where it is cut eighteen inches or perhaps two feet high, and (in the situations where it is more frequently used) has generally a sufficient quantity of long wirey grass among it to hold it together; there is no great difficulty in thatching with it: except in the raking, which requires a tender hand. It is first driven up a little with the teeth of the rake; beaten, and then raked gently downward.

FLOORING MATERIALS. Upper floors have heretofore been laid with oak, which is still common in the floors and stair-cases of all old houses. Elm has, perhaps, been more recently used, and is still in use, for the same purposes. Ground floors are not infrequently of common brick (a vile material for floors) or of 'forest stone --an excellent freestone grit, raised in the forest of Dean.

Vol II 1796 Cotswold Hills

P16
III. FARM BUILDINGS.

MATERIALS. The WALLING MATERIALS are in variably stone. TIMBER, chiefly oak. Covering, slate; Flooring, stone, oak, deal. Rough stones, for ordinary building, are usually raised, by the perch of wall. The price 5d. to 8d. a perch, of 16 ½ square feet, (that is **a perch long and one foot deep**) for a-wall 24 inches thick *[8d the 2012 equivalent in economic power to 266 pounds].* This is an unusual, but an accurate mode of raising them. The variation of price is caused by the nature of the quarry. The price of oak timber, in the stick, is 1s. to 15d. a foot. Plenty to be had at this price. A striking evidence, that a small quantity of woodland is sufficient to supply the inland demand for timber. The carriage, however, is to be added to the above price.

P17 Farm kitchens and lower rooms, in general, are laid with dressed stone. The price, upon the ground complete, 4~8d. a foot.

The slates (of a stone colour) are raised in different parts of these hills. The price upon the roof — **plastering beneath included** — about 26s. a square (of 100 square feet).

CEMENT. Lime is excessively dear; and **sand not to be had**, I believe, at any price; nevertheless, an excellent mortar is here prepared, at a moderate expense. **Invention is seldom more successful, than when necessity prompts it.**

The scrapings of the public roads; namely, levitated lime stone, impregnated more or less with the dung and urine of the animals travelling upon them, are found to be an **excellent basis for cement**. For ordinary walls, the scrapings alone are frequently used. And, from what I can learn, the proportion, for the best building, is **not more than one part lime to three of scrapings.** Nevertheless, I found mortar, which had not lain in the walls more than ten years, of a stone-like tenacity: much firmer than the ordinary stone of this country: probably much harder, than either of the stones, from which the basis of the lime was made. Similar scrapings might be collected, in any district where limestone is used as a material of roads.

The method of PREPARING this CEMENT is, simply, that of **collecting the road-scrapings, slaking the lime, mixing them intimately together, and, as the mass is worked over, carefully picking out the stones** or other foulness, which may have been collected. **This, for stonework, is found sufficient: for brickwork, however, it might be necessary, that the materials should pass through a skreen or sieve; previously to their being made up**. The price of lime, here, is 8d. a bushel of eight gallons, level. The price of coals about 30s. a ton. The kilns small, with funnel tops; to carry off the smoke, and, by breaking off the wind, to give a more regular draught.

P19 BARN floors are of a good size: 12 to 14, by 18 to 20 feet. The best of oak: some of stone: but a species of earthen floor, which is made here, is thought to be superior to floors of stone, or any other material, except (p20) sound oak plank. The superior excellency of these floors is owing, in part, to the materials of which they are made; and, in part, to the method of making.

The materials are the calcareous earth of the subsoil, a kind of ordinary gravel, which is found in different parts of these hills, and the chippings of freestone (calcareous granite) from the freestone quarries, in equal quantities. The method of making is founded on a principle which is peculiar, perhaps, to these hills. Earthen barn-floors are made, in other places, with **wet materials**;—a kind of mortar which, as it dries, is liable to crack; and requires some months, after it is made, to dry it hard enough for use.

On the contrary, the materials, in the practice under notice, **are worked dry: they of course do not crack; and are ready for use as soon as they are finished.**

The materials, mixed together, are sifted twice over. The first time, through a wide sieve, to catch the stones and larger gravel, which are thrown to the bottom of the floor. The next, through a finer sieve, to separate the more earthy parts from the finer gravel, which is spread upon the stones, (p21) and, upon this, the more earthy parts; making the whole about a foot thick; and trimming down the different layers, closely, and firmly, upon each other. The surface being levelled , it is beaten with a flat wooden beetle, made as the gardeners turf beater ; until the surface becomes hard as stone, and rings at every stroke, as metal. If properly made, they are said to last a length of years; being equally proof against the flail and the broom.

Marshall (1790) The Rural Economy of the Midland Counties: Including the Management of Livestock in Leicestershire and Its Environs: Together with Minutes on Agriculture and Planting in the District of the Midland Station

P26
THE FARM BUILDINGS of this district are many of them large, substantial, and commodious; and have several particulars belonging to them, that require attention. The MATERIALS of the district are these:

The walling material almost wholly brick. The timber mostly oak, (with) which the builders are still lavish. The covering material, formerly thatch; now, principally, in this district, knobbed plain tiles; but, in Leicestershire, mostly blue slate (Blue slates. These are raised near Swythland–provincially "Swidland"– on the southern skirts of the Charnwood hills; where an immense excavation has, within the last fifty years, been made. Superficial quarries have been worked, time immemorial; but their produce was of a coarse quality, compared with those which are now raised; some of which are nearly equal to the Westmoreland slate. They are raised in blocks, blasted from an almost seamless rock. The blocks are first cleft into slabs; and the slabs afterward into slates; or, if too strong and coarse for this purpose, are thrown aside, as coarse flags, for various uses. Out of the larger blocks, chimney pieces and tombstones are cut. The same kind of blue rock is found in different parts of the Forest hills; but none, yet, which affords slates equal in quality to the " Swidland slates.").

Ground flooring, mostly paving bricks. Chamber flooring, oak, elm, or plaster: the two last are now most common in farm houses: in this, an inland country, deal has not hitherto been much in use; but even here, it is now becoming the fashionable material.

The CEMENT of this district is entitled to particular notice. In common stucco, plaster floors and water-tight walls the Midland counties excel; but in the last most especially. Water cisterns are frequently formed by a nine inch brick wall, standing naked above ground; yet as tight as a stone trough!

Something depends on management, in forming these walls: but much more on the nature of the LIME with which they are built. There is only one sort with which they can be rendered tight with certainty. **This is the BARROW LIME, which not only sets with extraordinary hardness, but remains invulnerable to the elements; setting water, drought, and frost at defiance** *

(* BARROW L1ME. Barrow, situated on the banks of the Soar, nearly opposite to Mountsoarhill, in Leicestershire, has long been celebrated for its lime, It is an interesting fact, that the stone, from which the Barrow lime is burnt, is, in colour, texture, and quality of component parts, the same as the Claystone of Gloucestershire, from which the strong lime of that distrićt is burnt; and what is still more remarkable, it is found in similar situations and deposited in thin strata divided by thicker seams of calcarious clay, in the very same manner, in which the claystone of Gloucesterſhire is found. See Glo. Econ. vol. 1 p.13, 15 and 32.

One hundred grains of the stone contain eighty-six grains of calcarious matter; affording fourteen grains of an impalpable tenacious silt, which seems to be possessed of some singular properties; forming a subject well entitled to future enquiry.

One hundred grains of the clay contain forty-six grains of calcarious matter, leaving fifty-four grains of residuum, **a fine clay**. Hence this earth, which at present lies an encumbrance in the quarries, is richer in calcariosity than the CLAY MARL of the Fleg hundreds of Norfolk, with which very valuable improvements are made. See Norf. Econ. vol. I p. 22. Since writing this article, I have observed, in the Vale of Belvoir, at the northernmost point of Leicestershire, a similar stone, situated in a similar manner, and producing a similar kind of lime).

The only preparation, of this extraordinary cement, is that of washing the sand, and assimilating it intimately with the lime, by beating; and the only judgement requisite in using it, is **to hurry it into the wall as quickly as possible from the kiln.**

P31 BARN FLOORS. In this district, a peculiar method of laying wooden barn floors is in practice. Instead of the planks being nailed down to sleepers, in the ordinary way, the floor is first laid with bricks, and the planks spread over these, with no other confinement than that of being "dowled" together (that is plowed and tongued) and their ends let into sills or walls, placed in the usual way, on each side the floor. By this method of putting down the planks; provided the brickwork be left truly level, vermin cannot have a hiding place beneath them; and a communication of damp air being effectually prevented, floors thus laid are found to wear better, than those laid upon sleepers. It is observable that the planks, for this method of laying, ought to be thoroughly seasoned.

Marshall W (1794) General View of the Agriculture of the Central Highlands of Scotland: With Observations on the Means of Their Improvement. T. Wright

In burning lime, in the Highlands, the chief fuel in use is peat; a weak ineffectual firing. **It is usual to slake the lime as it is drawn out of the kiln, shake it in a sieve, and return the numerous unreduced cores, to pass through the fire a second time**. (**This practice, when the lime is intended for the use of building, appears to be very wrong; especially when it is suffered to lie in that powdered state several months before it be used).**

Blocks of wood, and especially the large roots of trees, are frequently thrown in with the peats, to strengthen the fire, placing the fuel and the stones layer over layer, as in the use of coals; making the strata of fuel thick, proportionably to its strength. The Highland kiln, too, tends to the inefficacy of the fuel: it is too shallow and spreads too wide at the top; suffering the fire to escape before it has fulfilled its intention. It is sometimes built of sods, set upon the surface of the ground from whence, perhaps, the sods were taken, and. this perhaps the best soiled part of the farm: having, however, performed their office as walls of the kiln, they are themselves carried to the field as manure. From these temporary sod kilns, perhaps, were copied the shallowness and width of the present stone kilns of the district.

MacIntyre M (1992) oral history recording of Domhnall Iain Monk speaking about traditional lime burning and slaking in Benbecula. Comainn Eachdraidh Nan Eilean Mu Dheas (Federation of Southern Isles Historical Societies) Newsletter No4 June 1993 and reprinted in Lime News Vol 2 No.1 (1993)

It was done on the ground, on a dry, flat piece. They used to put slabs down, and they would arrange them like 4 'feadain'. So that the draft would get in under the lime when they began to heat it. They would put big slabs to make these 'feadain'. The place where they would put the lime would be about 6 ft in diameter, and they would put the shells in the middle, and they would buid peat on the outside, and they would put wood amongst the peat, and they would build this up. The shells were built up into a big pile (rughan) and the peat was placed around the base. They would then kindle the fire which would burn right up to the top of the shells, and they maintained the peat on the fire, watching it to see that it was burning properly, and it would be going for a day anyway, starting early in the morning and continuing until the next morning.

They would then take the shells out from amongst the soot…if there was enough wind, the soot would blow off the shells. They would put them on canvas beside the loch until all the soot had gone. They then washed the shells (?) and put them in a bag, took them home and placed them on another slab, a big clean one, and again they used to build up the peat around the shells – right round – leaving a hole at the top through which they poured hot water.

The lime would expand and the water would pulverise the shells. It was white just like flour and they would keep it there and use it when they needed it, taking a piece of peat when they needed it…

The lime had amazing power….Any white shell would do, (including razor fish, but mussels were not used)…7 canvas bags made ½ a barrel of lime for building. When it was set it was hard as anything. It would last for years and years.

Marshall W (1804) On the Landed Property of England: An Elementary and Practical Treatise : Containing the Purchase, the Improvement, and the Management of Landed Estates. London.

P270) **Walls. With respect to their firmness, strength, and duration, much depends on the cement with which they are carried up. In erecting rough stone walls, liquid mortar is most eligible to be used, in the middles, and inner parts, of the walls. If the stones are small, or want length to bind the work firmly together, it should be the common practice of workmen to cover their work, every evening, with an entire sheet of flowing cement; to assist in preventing the wall from bursting, or parting in the middle, the ordinary failure of walls which are built of such materials.**

P271 Every large estate requires… An experienced master workman, as a mason or a carpenter, who is employed upon the estate, is a proper man for this office. His duty is to examine, annually, or from time to time under the direction of, or jointly with, the manager, the state and condition of every building upon the estate: to see that the roofs and timbers are sound, the walls firm and upright, and the foundations able to support them. The only operation of repairs that requires particular notice here, is that of setting up walls, which, for want of the requisite ties, above noticed, have lost their balance, or upright position.

The usual palliatives, in this case, are buttresses, built on the outside of the leaning wall: or this is shored up, and underpinned; or the two side-walls are tied together, with cross beams and anchors. But still the wall remains in a leaning posture. The only remedy of the evil (without rebuilding the wall) is to force up the entire wall, in a body, into its original position. This is to be done, by erecting planks, or strong slabs, a few feet apart, against the wall (the number required being in proportion to its strength and extent); placing the heads of shores, or leaning poles, in notches, against these, and their feet upon inclined planes; upon which the feet of the shores are forced forward, with a lever, working in a notch or open mortice, in the middle of each foot; continuing thus to act upon the shores, one by one, and by little and little, until every part of the wall be found, by the plummet, to have regained its upright posture; and, while it is held in that position, effectually to secure the foundation, so as to keep it in that state: letting the shores remain, until the cement be sufficiently set. This valuable operation, the little known among country workmen, is familiar to the higher order of builders; and may readily be learnt by any ingenious artisan.

Smeaton J (1791) – a Narrative of the building and a description of the construction of the Edystone Lighthouse with stone; to which is subjoined an appendix, giving some account of the lighthouse on the Spurn Point, built upon a sand. London. Nicol *(but recounting works and experiments performed 1756 onwards).*

P102 Book III Chapter IV Containing experiments to ascertain a compleat composition of water cements; with their results.

On this subject, I was already apprized that **two measures of quenched or slaked lime, in the dry powder (***either air-slaked or slaked by immersion, therefore),* **mixed with one measure of Dutch Tarras, and both well beat together to the consistence of a paste, using as little water as possible, was the common composition, generally used in the construction of the best water works both in stone and brick,** and which, after being *once set (footnote: this is the term used in the application of calcareous mortar, which denotes a first step, or degree of hardening, but in this state, though it has lost its ductility, it is a very friable substance),* would afterwards become hard, without ever being completely dry, nay, that it would in time grow hard, even under water. This therefore seemed to be the kind of cement adapted to our use, and what (p103) I had yet to learn was the best materials and mode of treating and using them…. I found it commonly asserted by Masons that the harder or stronger the Limestone was, the stronger would be the Lime, but whether this maxim chiefly regarded the usual composition of lime and sand in common buildings…or whether it also held good in Tarras Mortar, did not appear. It was also generally agreed by masons, that mortar, if mixed up with salt water, would never harden in so great a degree, as the same composition would do if made up with fresh water [*Smeaton will later disprove both of these assertions)….*

169. The first object of enquiry, as I had heard much complaint from the workmen of limes not being well burnt, was, whether good or bad burning affected the quality, or the quantity of the lime produced from a given quantity of stone, or both….

I therefore tried a quantity of powder-lime that had fallen from a stone imperfectly burnt, and an equal quantity of lime from one that was thoroughly burnt, and having in other respects treated them in the same manner, **both with sea water and fresh,** I found the former to work **somewhat more harsh,** but that ultimately **there was no material difference in the quality of the mortar,** and from hence I (concluded)…that the complaints of workmen on this head were rather founded upon the *great waste and small produce* from imperfectly burnt lime, than from a real difference in the quality of what is produced.

P104 (Method in these tests:) I took as much of the ingredients as would ultimately form a ball of about two inches diameter – this ball, lying upon a plate till it was set and would not yield to the pressure of the fingers, was then put into a flat pot filled with water, so as to be covered by the water, and what happened to the ball in this state was the *criterion* by which I judged of the validity of the composition for our purposes. (worked the lime to a 'tough but pretty soft paste', afterwards adding the tarras).

(similar balls of just lime and sand would dissolve under water. Some 2:1 lime: tarras also failed under water. Only 1:1 was entirely reliable in its hardening).

Questions:

Question 1st. What difference in the effect results from lime burnt from stones of different qualities, in point of hardness?

(P105) Chalk lime is generally considered by workmen as the weakest of all, and it is accounted for in general, by its being burnt from one of the softest of all limestones. The marble rocks near Plymouth are of so hard a nature that the stone obtained from them to be burnt to lime (**and which is the common lime of that country)** is…blasted off with gunpowder. From observations of the buildings about Plymouth that had been constructed with this lime, at different periods of time, it appeared to me **to be very nearly of the same nature with chalk lime,** not only being of the brightest white, but of the same weak, crumbly nature. I therefore made a couple of balls of tarras mortar of each sort of lime in the above stated proportions of two to one, and also equal parts, and the result of several trials…was that there **was no apparent difference in the strength thereof for the purpose of water building** (footnote – *confirming Higgins' 1780 conclusions)*. Hence it appeared, as the effect of the two limes was the same, that **the strength of the lime** must **depend upon some other quality than the hardness of the stone.**

Question 2nd. What difference results in the strength of the mortar when made up with *fresh* or with *Sea Water,* the compositions being immersed in the same water?

(Balls as before, immersed in fresh water)…the result was that as to what happened immediately, or within the compass of a few days, **there was no apparent difference,** but of the balls which remained entire, when kept under water for two or three months, **those made up with sea water appeared, if there was any difference to have the preference.** Hence I concluded, there was no need to burden ourselves with carrying out fresh water to the Edystone for making the mortar, and in consequence all future trials, except as otherwise mentioned, were carried out with salt water.

Question 3rd. What difference results from different *Qualities* of Limestone, so far as I could procure the specimens?

Having heard of a lime produced from a stone found at Aberthaw…that had the same qualities of setting in water as Terras…(acquired some and burnt it into lime). I found it to require a good deal of fire to make it, by quenching, fall into a fine powder. This stone, before burning, was of a very even, but dead sky blue…but when burnt and sifted, it was of a bright buff colour. Having made up a couple of balls according to each of the former proportions, and also a couple of balls with common lime (Plymouth lime), the difference of hardness after 24 hours was very remarkable, the composition of two measures of Aberthaw to one of Tarras, considerably exceeded in hardness that of common lime and Tarras, in equal parts; the composition of Aberthaw and Tarras in equal parts was still considerably harder, and this difference was more apparent, the longer the compositions were kept.

(because re-tempering would be desirable out on the rock… and because) of a notion entertained by workmen, respecting Tarras mortar, that the longer it was kept and the oftener it was beaten over, the stronger it would set…

Question 4th Whether Tarras mortar, after having been once well beaten, becomes better by being repeatedly beaten over again?

(p106) …I made up a couple of balls of Abethaw lime (in same proportions as above)…and laid them in a damp place upon a water soaken brick, sprinkled them with water, and covered them up with a wet cloth, so that they might be as slow as possible in setting. These I broke down and beat over again, every morning and night for three days and then prepared a couple of balls of the same materials afresh, and beat them very well. These balls were, when set, put altogether in salt water. Between these, where the composition was equal parts, **there was *no discernable* difference,** but of those in which the lime predominated, the **preference seemed due to such as had had the repeated beatings, though the difference was not very remarkable**. The same experiments being tried with **common lime** the preference was evidently **more**

in favour of repeated beatings in that composition in which the lime predominated than that of equal quantities.
Hence, **though the practice of workmen is very right, where common lime and the smaller quantity of tarras…are used, yet where the tarras is not spared, and the lime is of superior quality, the repetition of beatings appears not to be material.**

(so for Edystone Smeaton chose to go with 1:1 Aberthaw and Tarras to save labour time in re-tempering. NB Smeaton is in pursuit of maximum hardness. He does not enquire if the mortars need to be this hard).

173. I had heard that *Shell Lime*, that is *Cockle* or other shells burnt, set very hard and made an excellent mortar for under-drawing and inside work. It is mentioned in Wren's Parantalia as having been made use of in St Paul's Cathedral for this purpose, and found excellent. On trying some of the mortar I found it to set hard, and readily, without any admixture of sand, tarras or other matter. In short, for water work tarras scarcely appeared to improve its natural quality. On being put into water, **after it was set,** it did not dissolve, but did not acquire an additional hardness, on the contrary, by degrees it macerated and dissolved, not internally, but gradually from the surface inwards, and hence I concluded it totally unfit for our use. I was afterwards informed, that a part of Ramsgate Pier had been done with this kind of lime, but was afterwards obliged to be taken up, on its dissolving quality in sea water being discovered.

174. Having observed how speedily Plaster of Paris, from a semi-fluid state would set into a hard substance, I conceived it might probably be of some use in our work. On making up a ball as I did with the mortars, but without beating, it readily set, and did not dissolve on putting it into water, but I soon found that, whilst in a moist state, it had little firmness, and did not acquire any additional hardness underwater and by continuance it became less firm…(and) re-disolved, either throughout its substance or by maceration of its surface, like the shell lime (footnote: I am lately told that Plaster of Paris is liable to be perfectly dissolved in a large quantity of water, if suffered to remain in it for a length of time, and especially if the water is frequently changed or much agitated).
…However, the great readiness wherewith I observed plaster to set to a moderate degree of firmness, suggested to me this thought, which afterwards proved to be useful, that when there was not time for our cement to set before it was subjected to the violence of the sea, if it was coated over with plaster, it might thereby be defended till it had time to set, and then, if the plaster should be washed off, it would be of no consequence.

175. The last species of lime I had an opportunity of trying…was a kind that was much commended for water works, (from)…Devon, (p107) at a place called Bridistow…its appearance, both before and after burning, was much like that of Aberthaw, and on a similar trial it answered pretty much in the same manner, but the composition formed with it appeared to be somewhat inferior in hardness.

(Asked, if the hardness of the limestone not the cause of harder limes able to set under water, then what was the reason? Took advice on analysing stones. Burned out lime with aqua fortis)

…if from the solution little or no sediment drops, it may be accounted a *pure* limestone…as containing no uncalcareous matter, but if from the solution a quantity of matter is deposited in the form of mud, this indicates a quantity of uncalcareous matter in its composition.

(Both Chalk and Plymouth limestone left no residue)…. On trying Aberthaw lime in this way, it was dissolved in the aqua forte but the solution appeared very dark and muddy and…I found a small quantity of undissolved sandy particles at the bottom, some of them transparent like crystals, but mostly very minute, and of a dirty appearance…(weighing) nearly one-eighth part of the original mass (12.5%).

P108

179. …I was convinced that the most pure a limestone was not the best for making mortar, *especially* for building in water, and this brought to my mind a maxim I had heard from workmen, that the best lime for the *Land* was seldom the best for *Building* purposes, of which the reason now appeared, which was, that the most pure lime afforded the greatest quantity of Lime Salts, or impregnation, would best answer the purposes of *Agriculture,* whereas, for some reason or other, when a limestone is intimately mixed with a proportion of *Clay,* which by burning is converted into *Brick,* it is made to act more strongly as a cement. (footnote: It is not to be wondered at**, that workmen generally prefer the more pure limes for building in the *Air*, because being unmixed with an uncalcareous matter, they fall into the finest powder, and make the finest paste, which will, of course, receive the greatest quantity of sand (generally the cheapest material) into its composition, without losing its toughness beyond a certain degree, and requires the least labour to bring it to the desired consistence, hence mortar made of such lime, is the least expensive, and in *dry work* the difference of hardness, compared with others, is less apparent).**
This suggested to me…that **an admixture of Clay in the composition of limestone…might be the most certain index of the validity of a limestone for *Aquatic Buildings,*** nor has any experience since contradicted it, as all the limestones in repute for waterworks, that I have met with, have afforded this mark, even the Dorking lime much esteemed for these uses in London, and in the country round about, is plainly nothing but a species of chalk, impregnated with clay, of which it makes one full seventeenth (5.8%) part of its original weight.

180. Having thus satisfied myself in repsect to limestone, that, if I had not arrived at the best in the world, I had found one competently good…for the Edystone Lghthouse, I considered that though Tarras was really endowed with

those qualities which had justly obtained it a reputation for water building, yet it was generally admitted to have some properties, that for our use were not quite so eligible – in the first place, **though it will cause most kinds of lime to set and become hard *under* water…yet if the Cement grows dry by a gradual exposure to air, it never sets into a substance so hard as if the same lime had been mixed with good clean common sand, but is very friable and crumbly and if, after it has acquired a considerable degree of hardness by immersion in water, it is then exposed to the air, it *loses* a considerable part of its firmness, and also becomes crumbly…**For this reason, though there is **no necessity for using it where the work will *always* be dry, or subjected only to the rain, and though it may be considered as being always wet, where it is in the joints of a massive work immersed every tide, yet in our case, those parts which were above the ordinary swell of the tide and sea, and liable to be wet only in storms, and hard gales of wind…being wet and dry by intervals, tarras is known not to answer well….**In parts so circumstanced, the mortar is the most liable to fail, and to be affected by the frosts, whatever its composition may be, has put artificers upon trying other mixtures, one of the principal of which was communicated to me by Lord Macclesfield:

(Letter in footnote from Lord Macclesfield: …the lime generally made use of in our neighbourhood is made from chalk…The manner of making (ash) mortar is as follows:

Take of lime that is *very fresh* two bushels and take wood ashes three bushels. Lay the ashes in a round trench, and the lime in the middle of the trench, then slake the lime and mix it well with the ashes. Let it lie until it is cold, and then beat it well together and so beat it for three or four times before it is used….Mortar thus made is reckoned, by our bricklayers, to be much more strong than that prepared with Tarras in places that are at sometimes wet and at others dry, though they acknowledge that the terras mortar is better in work that is constantly under water…

(discusses the tendency for stalactites to grow from Trass mortars, which prompted him to look at alternatives) said to be useful in making calcareous mortar to set in water….Terra Puzzolana (being one)…found in Italy. (he got some imported for Westminster Bridge, where they ended up using Trass).

182. On trial of this I found it to be **in every respect equal to terras**, as far as concerned hardening of water mortar, **if not preferable to it….I perceived it in every state of it (**wet, moist or perfectly dry), if made into a mortar with Aberthaw lime, **it exceeded in hardness any of the compositions commonly used in dry work, and in *wet* or *dry,* or wholly wet, was far superior than any I had ever seen or experienced….**I did not doubt but to make a cement that would equal the best *mechantable Portland Stone* in solidity and durability.

P110 (Turns his thoughts to grout, to fill perpends in the stones of the lighthouse) to consolidate the upright joints by pouring in liquid mortar, commonly called *Grout* in so fluid a state, as to run into every cavity and crevice. **The common way *then in use* of doing this was, by putting as much slaked lime into water, as when stirred would be sufficiently fluid to answer the end, which is called *puttying.* And the best practice was to put the ingredients together according to the due proportion to make the species of mortar intended, and with as much water as would render them fluid, and after *stirring them well together to pour the mixture into the joints.***

(concerned that this allowed no beating of the mortar, shown to make mortars stronger, so)

184. (experiment entailing making of mortar balls, allowing them the set and then beating again with an excess of water. This apparently set hard, setting slower than 'undissolved' liquid mortar allowed to dry and then dissolved, but that it became ultimately harder.

No mention of hot lime grout, commonly recommended in 19th C texts).

…p111. 187. Seeing that both Tarras and puzzolans agreed in two of their obvious properties – **porosity and resistance to the actions of aqua forte, as well as the hardening of calcareous mortar under water,** and also as *volcanic* substances, as having passed the fire, I was induced to try experiments on several porous substances, that appeared to have some similarities to them, such as *Pumice stone, Coal Cinders, Brick and Tile Dust,* and such like. I found them all **possessed of an absorbent property, which caused the mortar made with them to set somewhat more quickly, than when made up with sand alone,** so that where hardness is expected from drying, and time is wanted to produce the effect fully, they may be useful (p112) to this end, as procuring it to be done more speedily. But being, when set, immersed in water, they **did not** appear to possess any powers of resistance to their dissolution, more than the same lime would do with common sand (??), if, by a little more time, the composition was become equally set.

188. Having made up my mind that the proper composition for our mortar was **lime of blue Lyas and Puzzulano, in equal quantities…**

(Lias lime from Watchet, but length of journey made it prudent to import the limestone and to burn it at Mill Bay, Plymouth).

P114. …As nothing could succeed, or be more satisfactory, than the mortar I used…I wished to examine all those limes which discovered any degree of fitness for *Water Building,* and more especially, if possible, to find out a substitute for Tarras and Puzzulano in this kingdom, that we might be in possession of all the best materials for water building within ourselves…

The Limes that I have since examined are as follows:

193. That of *Barrow in Leicestershire*, of which we used considerable quantities in the *Calder Navigation*. I was never at the quarries, but having procured some of the unburnt stone, I found it had the appearance of blue Lyas, only somewhat of a more yellow tinge, and more of the slate kind, it **burns to a buff coloured lime,** like that of Aberthaw and Watchet , and on dissolution affords nearly 1/14th (7.2%) of its original weight of blue clay, with a minute quantity of dirty grey sand, so I have no doubt of its being the true *Lyas*, though perhaps of a less perfect composition than that bordering the Bristol Channel. It contains more clay, can be carried further and remains longer without injury, but in the actual use thereof as mortar, it does not appear to me to acquire quite so firm and stony a hardness as the blue lias of Somersetshire. **It makes, however, excellent water mortar,** if properly treated, and will very well serve in those parts of the kingdom that are more accessible to the Trent navigation, than that of the Bristol Channel.

In fact, in travelling from Glamorganshire through Monmouthshire, Gloucestershire and Warwickshire, into Leicestershire, I found such frequent instances of ordinary walls and cottages, built with stone that appeared to me to be blue Lias, the mortar also being of the same hue, that I have not a doubt, but that the curious naturalist…may be able to trace it from Aberthaw and Watchet quite to Barrow….In Bath they pave the streets with a species of Lias…and joint the paving with a mortar of the same kind of stone.

The Bath freestone is of the pure calcareous kind, and it is remarked that when it is walled with this kind of mortar, which is *frequently,* if not generally, used for the purpose, **the joints are more permanent, and resist the weather better, than the stone itself…**

From Leicestershire it appears to pass by the Vale of Belvoir into Nottinghamshire and Lincolnshire, for a species of this kind of lime is used in some of the buildings of Newark, and the Great North Road is repaired with the blue lias stone for a considerable length in the post stage between Newark and Grantham…I have not yet seen it further north than this.

194. Perhaps nothing will show that the qualities of lime for water mortar do not depend on hardness or colour, than a comparison of the white Lyas of Somerset (which though approaching a flinty hardness, has yet a chalky appearance) with what is called near Lewes, in Sussex, the *Clunch Lime*, a kind of lime in great repute for there for water works, and indeed deservedly so. This is no other than a species of chalk…it is considerably harder than common chalk…(and) heavier, and is not near so white, inclining towards a yellowish colour….(contains a yellowish clay with a small quantity of sand). Hence **the fitness of lime for water building seems neither to depend upon the hardness of the stone, the thickness of the stratum, nor the bed or matrix in which it is found, nor merely on the quantity of clay it contains, but in burning and falling down into a powder of *buff* coloured tinge, and in containing a considerable quantity of clay. I have found all the water limes to agree.** Of this kind I esteem

the lime from *Dorking in Surrey* to be; which is brought to London under the idea of its being burnt from a *stone* and in consequence of that, of its being *stronger* than **the chalk lime in common use there,** though in fact it is a chalk, and **not much harder than common chalk**…

195. There is in *Lancashire* a lime famous for water building, called *Sutton* lime…The stone itself is of a deep brown colour or hue (the lime is buff)…the goodness of the quality as water lime does not therefore consist in the colour before it is burnt…but they all agree in the colour or hue, *after* they are burnt and quenched…(on analysis 6 ¼ % brown or red clay)…so that in reality **I have seen no lime yet, proved to be good for water building, but that…(its stone) contained clay….**

P116
196. Since the above was written, I have had the opportunity of examining others of the *Water Limestones*. I find a species of lime that has been used in some of the works about *Portsmouth,* and recommended as very good for water building, **where the expence of Tarras mortar made with chalk lime could not be *afforded*.** It is called *Grey Lime*, as having been burnt from a…stone called *Grey Chalk*. This…(agreed) so nearly to the *Clunch* lime (of Lewes)…This Grey Lime goes by land carriage from the parish of *Berryton* near *Petersfield in Hampshire* to *Portsmouth*. (Similar in its character to both the Clunch and the Dorking stones and limes; less clay on analysis than the clunch, but more than the Dorking and a good water lime)

(Blue Lias from Lyme (Regis) used in the 'King's Works at Plymouth and at Ramsgate Harbour on Smeaton's recommendation)

p117.

Table (fractions changed to percentages):

Species of Limestone	Proportion of clay	Colour of this
1. Aberthaw	13%	lead colour
2. Watchet	12%	the same
3. Barrow	21%	the same
4. Long Bennington	12%	
5. Sussex Clunch	18.75%	ash colour
6. Darking	5.8%	
7. Berryton Grey Lime	8.3%	
8. Guildford	22%	
9. Sutton	18.75%	

(Tested blacksmith's scales 1:1 with lime to good effect; also iron ore 'after it had passed the fire' …) this being powdered, I found had a very good effect in water mortar, in causing it to set speedily, in preventing cracks, and finally, in hardening it. On this account it was used in the Calder Navigation, for the inside mortars of the best work, and for the face work of the subordinate parts, but its strength in hardening lime was far inferior to that of Puzzulano or of Forge Scales.

198. MINION, or iron stone burnt where it can be had in plenty, is a good succedaneum for puzzulana and tarras, and if it is made up with lias, or other proper water lime, in equal quantities, **will make a mortar more firm and hard than common lime,** made up with the common quantity of tarras or puzzolana (and so may save cost).

199. I come now to shew the means I have used to make a given quantity of tarras, or puzzulano, produces a greater quantity of good *water mortar*, than either the composition, **where the material is sparingly used,** or that I used at the Edystone, **where nothing was spared,** that had the appearance of being of service….

Limestone …upon quenching, when fully burnt, falls freely, and will produce somewhat better than double the quantity of powder or slaked lime , in point of measure, that the burnt limestone consisted of, and this will be nearly the case, whether it is common lime or water lime. (Will reduce to half this volume when made to a paste with water).

200. The use of sand in mortar…is two-fold, 1st **to render the composition harder**, and 2ndly **to increase it in quantity,** by a material that in most situations is of far less expence, bulk for bulk than lime.
Ration has never been agreed in, yet from common experience
P119
201. The experience of ages has shewn that a considerable quantity of sand and other matter may be introduced with advantage in the making of mortar, but the proportion has never been agreed in, yet from **common experience it appears that there is scarcely any lime, but what, if well burnt, well beaten, a load, or measure of lime, will take two loads, or measures, of sand, that is, the quantity of sand that can be introduced into its composition may be equal to the lime in powder** (and one trass to two also best),,,to make the composition acquire the proposed degree of hardness *under water*.

(Then experiments with increased volumes of sand) …I found that (lime) with good beating, would take in for every two measures of slaked lime, one measure of trass, and three of clean sand (2:1:3)…

p122.

Table of mortars, most of which (Smeaton has) used in different situations and for different circumstances.

(NB Smeaton is using quicklime already slaked to a powder, either by air or by immersion).

Water Lime with Puzzolana	lime powder	puzzolana	common sand
1. Edystone Mortar	2	2	-
2. Stone mortar	2	1	1
3. ditto, 2nd sort	2	1	2
4. Face mortar	2	1	3
5. ditto, 2nd sort	2	½	3
6. Backing mortar	2	¼	3
Water Lime with Minion		minion	
7. Face mortar	2	2	1
8. ditto, Calder composition	2	1	3
9. Backing mortar	2	½	3
10. ditto, 2nd sort	2	¾	3
Common Lime with Tarras		tarras	
11. Tarras mortar	2	1	
12. ditto, increased	2	1	1
13. ditto, increased further	2	1	2
14. ditto, increased still further	2	1	3
15. Tarras backing mortar	2	¾	3
16. 2nd sort	2	½	3
Common lime with minion		minion	
17. Ordinary face mortar	2	2	2
18. 2nd sort	2	1	3
19. ordinary backing mortar	2	½	3
20. 2nd sort	2	¼ or ¾	3

Observations on the preceding table

1st…the materials are all supposed to be in a dry state when measured
2nd That the lime is supposed to be thrown into the measure with a shovel, with some degree of force, for to put it in as light as possible, in the way to make the most measure of it, there will be want of the real quantity, and if pressed down, the measure will contain considerably more than what can be expected in purchasing the material, and the same may be said of the puzzolana, the tars and the minion.
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3rd Respecting sand, it is particularly to be noted that if in a moist state, the real quantity is considerably less under the same measure, than if dry…and as moist sand is most frequently brought for use, it is advisable that the operator should take a means of finding the difference of proportion, and allowing accordingly in measure.

4th …If the sand is not naturally a composition of fine and coarse, it should be rendered so by an admixture of different sorts….
5th the due beating of the mortar is, however, of *great* consequence…a degree of beating sufficient to give it all *possible* consistence and toughness before it is used, is in reality *indispensible* and the method I have found to answer the end in the most satisfactory way is, **to mix the due proportion of lime and the puzzolana, the tarras or the minion, together in the dry powder…put as much water to the lime as that with a shovel or beater you can bring it to a paste of moderate consistence, but rather more wet than to be properly used as a mortar in that state, then by degrees, beat in the moist sand and afterwards the dry, bringing it to a consistence by beating after every addition.** The dry sand is intended to take up the superfluous moisture, **so as to render the mortar immediately fit for use,** and if this has not brought it to a sufficient stiffness, you may let it lie till it inclines to set, and then beat it up to the due consistence, or, if immediately wanted, you may beat in a little dry lime powder to drink up superfluous moisture (but not to neglect the beating)…

6th The customary allowance for tarras mortar beating, first and last, **is a day's work of a man for every bushel of tarras, that is, for two bushels of lime powder with one bushel of tarras….**

(Table of comparative costs of materials:)

water lime per bushel in the dry powder	0s 9d
common lime ditto	0s 4d
puzzolana in powder, prepared	3s 0d
tarras ditto	4s 0d
minion ditto	1s 0d
coarse or fine sand, or mixed	0s 2d
The labour of beating 2 bushels of common lime to terras mortar, is supposed	2s 0d
the labour of beating 2 bushels of water lime	1s 0d

Book IV Chap 1. (account of construction process)

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221. The mortar, which was compounded as shown (above)…was prepared for use by being beat in a very strong wooden bucket made for the purpose, each mortar-beater had his own bucket, which he placed upon any level part of the work, and with a kind of rammer or wooden pestle, **first beat the lime alone, about a quarter of a peck at a time, to which, when formed into a compleat, but rather thin paste with sea-water, he then gradually added the other ingredient, keeping it constantly in a degree of toughness by continuance of beating.** When a stone had been fitted and ready for setting, he whose mortar had been longest in beating came first, and the rest in order; the mason took the

mortar out of the bucket, and if any was spared, he still kept on beating; if the whole was exhausted, he began upon a fresh batch…

Pratt Manuscripts, Kent Archives U840.

"Although it is desirable the ruins be preserved from further injury, yet, they should not wear the appearance of being recently repaired….

"In preserving the Ruins of Bayham Abbey the following Mortar Cement is Recommended.

Stone lime – well burnt and new from the Kiln every two or three days – The lime to be slaked with but little water and no more mortar to be made up than can be used in the Day. To half a Bushel of slaked lime mix a Bushel of clean sharp road or wash(ed) sand which will be quantity sufficient for a Days use, this must be beaten in small quantities by two Labourers for three hours at Least & they must keep on beating it – in the same way that Tarriss (trass) is prepared for water; a small quantity of smiths ashes should likewise be added to give it the color of the old mortar – and if any remains to be used when the Days work is nearly over, some of the larger stones may be laid with it when a greater quantity of cement may be used in a short time, because I consider the mortar as of no use the day after it is made – The grout which is designed for pouring into the loose walls should also be prepared in the same manner – that is: the same proportions of lime, sand & smiths ashes to be made of, consistence thin enough for running into & filling up the Interstices – the work as I have before observed should be previously pointed to prevent the Grout from running through & Smearing the face of the walls."

William Wilkins Architect 1799

The original is in the **Pratt Manuscripts, in the Kent Archives U840.**

(Bayham Abbey is in Lamberhurst, Kent)

Sir Humphrey Davy (1836) Elements of Agricultural Chemistry, in a Course of Lectures for the Board of Agriculture, Delivered between 1802-1812. London Longman, Rees, Orme, Brown, Green & Longman.

The basis of all cements that are used for works which are to be covered with water must be formed from hydrate of lime; and the lime made from impure limestones answers this purpose very well.

Puzzolana is composed principally of silica, alumina, and oxide of iron; and it is used mixed with lime, to form cements intended to be employed under water. Mr. Smeaton, in the construction of the Eddystone lighthouse, **used a cement composed of equal parts by weight of slacked lime and puzzolana**. Puzzolana is a decomposed lava.

Tarras, which was formerly imported in considerable quantities from Holland, is a mere decomposed basalt: two parts of slacked lime and one part of tarras form the principal part of the mortar used in the great dykes of Holland.

Substances which will answer all the ends of puzzolana and tarras are (p303) abundant in the British islands. An excellent red tarras may be procured in any quantities from the Giants' Causeway in the north of Ireland; and decomposing basalt is abundant in many parts of Scotland, and in the northern districts of England in which coal is found. Parker's cement, and cements of the same kind made at the alum works of Lord Dundas and Lord Mulgrave, are mixtures of calcined ferruginous, siliceous, and aluminous matter, with hydrate of lime.

The cements which act by combining with carbonic acid, or the common mortars, are made by mixing together slacked lime and sand. These mortars at first solidify as hydrates, and are slowly converted into carbonate of lime by the action of the carbonic acid of the air.
Mr. Tennant found that a mortar of this kind **in three years and a quarter had regained 63 per cent, of the quantity of carbonic acid gas which constitutes the definite proportion in carbonate of lime.**

The rubbish of mortar from houses owes its power to benefit lands principally to the carbonate of lime it contains, and the sand in it; and its state of cohesion renders it particularly fitted to improve clayey soils. The hardness of the mortar in very old buildings depends upon the perfect conversion of all its parts into carbonate of lime. The purest lime stones are the best adapted for making this kind of mortar; the magnesian limestones make excellent water cements, but act with too little energy upon carbonic acid gas to make good common mortar.

(p304) The Romans, according to Pliny, made their best mortar a year before it was used; so that it was partially combined with carbonic acid gas be fore it was employed. In burning lime there are some particular precautions required for the different kinds of lime stones. In general, one bushel of coal is sufficient to make four or five bushels of lime. The magnesian limestone requires less fuel than the common limestone. **In all cases in which a limestone containing much aluminous or siliceous earth is burnt, great care should be taken to prevent the fire from becoming too intense; for such lime easily vitrifies, in consequence of the affinity of lime for silica and alumina.** And as in some places there are no other limestones than such as contain other earths, it is important to attend to this circumstance. **A moderately good lime may be made at a low red heat; but it will melt into a glass at a white heat. In limekilns for burning such lime, there should be always a damper.**

In general, when limestones are not magnesian, **their purity will be indicated by their loss of weight in burning;** the more they lose, the larger is the quantity of calcareous matter they contain. The magnesian limestones contain more carbonic acid than the common limestones; and I have found all of them lose more than half their weight by calcination.

Rondelet (1803) Theoretical and Practical Treatise on the Art of Building.

P251 **Observations on the methods of burning lime stones.**

To turn lime stones (into lime), we need to make sure to heat the kiln gradually 1° because if the stones are surprised by a high fire, they will break […], 2° because it is feared that stones burnt too quickly cannot be turned into lime: instead, begin with a moderate fire, making the stones slowly sweat and lose their humidity without incident. The degree of heat has always to increase without interruption. It is believed by the workers, which is repeated in several books, that when the fire (heat) is stopped before the stone has reached the right degree of burning, a whole wood would not be enough to reduce it into lime.

We need to make sure that for each batch, only one type of stone, from the same quarry, if possible *(should be used),* in order **to obtain a lime with the consistent quality**. When we are forced to fill the kiln with different types of stone or from different quarries, we need not to stack them haphazardly, but to stack them on account of their quality and in a way of being able to separate them once reduced to lime. And be sure to know which degree of heat they require. The biggest and heaviest have to be placed in the centre and the smallest or less heavy on the circumference.

Most authors, among them Alberti and Palladio say it needs at least 70 hours of high heat - violent and continuous - to reduce the stones to lime. According to Scamozzi, it needs 100 hours or 4 to 5 days, which is about the time we presently burn it for. It is not possible to indicate a precise time for it because it depends on 1° the quality of the stones, 2° the fuel we use and 3° the way the kiln is built and various other circumstances.
We know the lime is ready when a cone of high heat rises above the kiln at the mouth of the platform, without any smoke and when, on examining the stones, they are of a bright whiteness.

M. de Buffon has discovered, by experiment on the obscure heat, a new method of making lime with less expense, that is to say, by using less wood or whatever other combustible. This method consists of using a closed, instead of an open kiln. He asserts that with a small quantity of coal we could in less than 15 hours, convert all the lime stones into very good lime.
It results from his observations, 1° the lime made with a slow and concentrated heat is heavier that the ordinary lime which is reduced to less than half of the weight of the stone it is made from, while this particular one loses only about $3/8^{th}$.
2° that this lime does not absorb water with such vivacity when thrown. It does not give any sign of heat not ebullition, but slowly swells and divides in such way we do not need to stir it like ordinary lime.

3° this lime has a more acrid smell compared to the common lime.
4° it is infinitely better, more binding and stronger than the other lime. We noticed we only need to use half as much as of common lime to make an excellent mortar.
5° this lime slakes in the air after a very long time, at least a month or 5 weeks, while it only often needs one day to reduce it to powder quicklime.
6° Instead of reducing in flour or dried dust as the ordinary lime, it conserves its volumes and when it is crushed, all the mass seems malleable and penetrated of a fat and binding humidity which can only come from the humidity in the air it has absorbed for these 5 weeks.

(Quotes Vitruvius on mortar proportions)

Most authors who have written on the art of building since Vitruvius have copied what he said on sand. Most of them confirm what he said, such as Leon-Baptiste, Alberti, Palladio, Daniel Barbaro, Philibert Delorme, Scamozzi, Savot, the great Blondel. They think the sand found when digging - pit-sand - is usually the best to make mortar with, especially when it is used freshly extracted, because it loses its quality after long exposure to the air. There are others, however, such as Bullet and Belidor, who think river sand is better and according to the second Blondel and Patte, they think the most arid sand is the most preferable. Belidor even says, against everyone else's opinion, that the colour of the sand has nothing to do with its good or bad quality and that white sand can be used the more safely because it is naturally the one with the least earth.

Wishing to possess more certain notions on this important topic, I tried with the same lime, several different types of sand, cements, stone dusts, and pozzolans. The results were : 1°the sands purely vitreous or quartz form with three lime, a mortar less hard than the mixed sands, and this mortar takes longer to dry out.
2° the dug sand produces a better mortar than the one made from a river sand of about the same grain. Some of the dug sand can make a mortar as hard as cement. I also experimented and found out that arid (dried) sand does not make the best mortar and we must prefer, of that type, the sand of the darkest colour, except for the yellows. The best ones are the ones between the sands too fat and the ones too dry.
[…]. Mortar made with a too fine a sand does not acquire the consistency of the one made with a moderately coarse sand.

Of all what has been said about sands, we cannot, however, conclude that the pit sands are (always) the best because, as Alberti correctly observed, it is not the location from which the sand acquires its goodness, but from the quality of the elements of which it is composed. […].
Thus, the most reasonable conclusion would be to examine the sands independent of their locations but if they appear to be of the same quality, the ones from digging are preferred for masonry to the ones from rivers, but the latter has always to be used for renders, according to Vitruvius.

P 282 Article IV : Mortar

P283 *he thinks that the method used by the Romans to mix mortar is the same as the one they do during his time, having compared mortar from Roman buildings with that from buildings from his time, concluding them to be of similar hardness. He doesn't detail how he compared the mortars)*.

The excellent reputation we give to the mortars of the ancient Romans comes not only from the good quality of the lime and sand used, but also from the carefulness of compounding it in order to facilitate the union of these materials. I discovered by several experiments that the more the mortar is pounded and ground, the more it acquires tenacity and the quicker it hardens.

Then talks about the Loriot method, which was to make a mortar of
slaked lime with sand, water, pozzolan then add quicklime just before use.
(A few pages describing this until to finally saying, **page 292**: as for the method of making this mortar, I discovered that **we can leave out the fused lime or slaked lime in water by mixing powdered quicklime with the sand and the crushed tile damp enough to slake the quicklime. We also can add the water only after mixing dry together the (quick)lime and the other materials.**

Then the M. de la Faye method

p298 It is probable that had the ancient Romans used two types of limes in their mortar composition, Pliny and Vitruvius would have mentioned it, particularly concerning the powdered lime, which requires a specific preparation. But instead of debating on passages which can receive various interpretations, it is best to indicate ways to rectify the abuses that the negligence of the workers, their ignorance, or cupidity, have introduced into the way of making mortar, by showing what is good in the methods offered by different authors. *(Then the author examines Loriot and de la Faye again, nothing interesting)*.

In the ordinary method of making mortar, especially in Paris, the first abuse comes from the fact that the lime is never burnt enough, because those who sell it have to keep it for some time, in order to always have a stock and would not be preserved had they had the appropriate degree of burn **to be used right away**. **The second vice is to slake the lime with too big a quantity of water, under the pretext of running it from the basin in which it is slaked to the one in which it is being conserved.** But this method tends to reduce its quality and expand more. Instead of crushing these materials with iron tools made for this purpose, like the ones used in Italy and in all places where the method of the Romans is conserved, we stir with wooden paddle at the end of a stick. **This method requires more water, produces an imperfect mix, is long to dry out and offers only a weak consistency**.

It is essential to note that **a good mortar depends as much on the way it is made than on the quality of the materials used.** So that, with good materials, one can make a mediocre mortar. I am certain that the excellence of Roman mortars is due to the precautions they took to make it right. After having selected and gathered their materials, **they burnt their lime themselves to use it immediately.** This is why in all the countries they built, their mortar is equally good.

In all the regions of France and Italy I have traveled to study the way of building, I questioned workers, the ones who seemed the smartest. I found that their knowledge came, from a practical side, from use and experience. There are many differences in materials; it is not possible to prescribe specific methods, because every rule requires uniform qualities and proprieties in the materials, which does not happen. **A worker of long experience knows how to judge if the mortar is fat enough, beaten enough, if it has the right consistency - he almost never makes a mistake; he crushes and mixes the different materials until it feels right**. This is why it is not enough to propose methods, we need to train workers to understand and modify them on account of the materials and buildings intended to be built. There is an infinity of things that cannot be said nor prescribed in advance. **We can only indicate the general precautions to take for the most important operations, which are the method of slaking lime and the method of mixing it with sand and cement *(eg when he's talking about the crushed tile mix)* to make a good mortar.**

Article V Plaster (of Paris)
Plaster can be considered a type of lime which does not need any other material apart from water to form a solid body of a medium hardness. For this reason alone, plaster would be preferable to mortar if it could resist for a longer time the bad weather and humidity. Despite this inconvenience, plaster is a useful material in all of Paris where it is of good quality and when it is used appropriately. As this material sticks equally to stones and wood, we may use it with advantage for the construction of vault walls and renders. We coat walls, timber frames, floors etc in such ways that from the floor of the ground floor to the roof, a house can be covered in plaster and seem of one piece of the same material.
[…] gâché plaster (mixed in water) increases in volume upon drying.

Plaster […] varies according to the region and the type of stone or gypsum of which it is made.
The best method of burning the plaster stone is to give it a moderate heat to dry out the humidity. Then we gradually increase the heat to give it the appropriate degree for about 24 hours. When the plaster is not enough burnt, it is too dry, and does not form a body solid enough; when it is overburnt, when mixed with water, we find that there is no more what the workers in Paris call 'd'amour', that is to say it is not fat enough. When the plaster is rightly burnt, the worker feels it to be soft, attaching to the fingers. It is this quality the workers say makes the best plaster.
The plaster has to be reduced into powder as soon as it is burnt, whether by

beating it or by crushing it with grindstones or cylindrical stones, because it loses its quality when exposed to the air. The sun, by warming it up, ferments it, the humidity diminishes its strength and the air takes away the biggest part of its salts. It then loses its creamy texture and the facililty to harden quickly and to form a solid body. This plaster would only weakly stick to materials and if we use it to render, to coat, it will crack.
[…]
To mix plaster of Paris, it needs about as much water as plaster. We begin by putting the water in the trough, then we add the plaster by sprinkling, until it almost reaches the surface of the water. Then we stir it with a trowel to form a paste of a smooth consistency.
We put more or less water to mix the plaster, depending on the work needed. If we need all plaster's strength, we only put the necessary amount of water and then use it right away - this is what the masons call gâcher serré (tight mixed). When we put more water, they call it gâcher clair (clear mixed), and there is more time to use it. There are some works for which it needs to be mixed with even more water when it comes to spreading it onto large surfaces, such as renders. Lastly, for filling voids where the trowel nor the hand cannot reach, we make what we call a coulis (grout). This plaster is very clear and is poured from buckets positioned to be able to fill the cavities. We cannot expect that this grout can form a solid body. We only use it in areas where there is no weight to support such as the vertical joints, and never on the horizontal beds. This method is one of the abuses it is essential to reform when laying ashlars.

Article V Comparison of constructions made in plaster with ones made in mortar.

In Paris, where plaster is very strong, the masons do not expend much care. They don’t even dress the beds of rubble stones, laying the stones how they find them. It does not matter to them, because they know that the plaster, sticking right away, would hide it. Seeing the walls they are building before being covered up by plasters, one cannot conceive that they are still standing. There exist facades, built in this way, not half a meter or 18 inches of thickness, all pierced with croisées (he means windows I think), and support six or seven levels of floors and the attic. The precarious solidity of these walls only depends on the strength of the plaster which unites the stones and the renders.

Plaster is more convenient for the construction of ordinary houses than mortar because it immediately acquires solidity, whereas mortar needs several years. **We observe that the solidity of mortar constructions always increases but that it decreases with plaster**. When the latter are exposed to humidity and to the air, they need to be renewed in between 15 and 20 years.

The works in mortar settle to a more solid consistency…, whereas the works made with plaster change form by increasing in volume, torment themselves, warp under the effect of a bulge. It is for this reason that in the cities where

we build with mortar, the buildings have an air of solidity which we do not see in the ones built with plaster.

Malcolm J (1805), Land Surveyor to their Royal Highnesses the Prince of Wales, and the Dukes of York and Clarence.
A COMPENDIUM OF MODERN HUSBANDRY, PRINCIPALLY WRITTEN DURING A SURVEY OF SURREY Made at the desire of the Board of Agriculture; Illustrative also of the best practices in the neighbouring Counties, KENT, SUSSEX, Etc. London

P54 It has been proved by Dr. Higgins that the best lime is that which is made with the hardest and most compact stone, broken into small pieces, and heated slowly until the furnace is become of a white heat. This heat must be kept up uniform and regular (which is best ascertained by a thermometer) until the stone is no longer capable of effervescing with acids. The lime becomes over-burned, if the ignition be carried to a greater degree, and the produce is then called frit, which is properly ashes; and this frit is no longer capable of being divided in water, or of resuming with avidity the principles it had lost. When pieces of calcareous stone of different sizes are calcined, the lime will not be all of equal good ness; the small pieces will consist of over-burned lime, while the larger pieces are scarcely altered in their central parts.

The best lime is that which is most quickly divided by immersion in water, and affords the greatest quantity of heat in this process, which causes it to fall into the finest powder. Good lime should likewise dissolve in the acetous acid, without effervescence, and leave the least possible quantity of residue. Lime continually endeavours to resume the acid and the water of which the stone was deprived by calcination : consequently when it is left exposed to the air, it cracks, becomes heated, falls into powder with an increase of bulk, and resumes the property of effervescing. It is therefore of importance to use lime that is newly (p55) made, if the mason or builder is desirous of possessing its whole force.

Having given this description of lime, it may not be unimportant here to say a word or two upon mortar, without which many of our farming buildings would be of much less value than they are, and many may be made better.

Mortar is made simply by working sand or other bodies insoluble in water, together with slaked lime, and is used for the purpose of joining bricks or stone together. The sorts of sand generally used are pit sand, river sand, and road sand. The former is almost always altered by admixtures of vegetables and calcareous earth, which weaken its efficacy; the second is purer and better suited for the purpose; and the last being generally the fragments of pulverized flints, or the gravel of flints, is by much the best. The angles which these fragments present, and the roughness of their surface, contribute to give a consistence to the mortar. The hardening of mortar appears to be merely the progressive regeneration of limestone.

It does not obtain the greatest degree of hardness of which it is susceptible, until it has resumed all the carbonic acid of which the stone was deprived; and this operation is very slow, unless the combustion be facilitated by well known methods, which consist in mixing with the mortar substances which contain either the carbonic acid, or a principle analogous to it, such as vinegar. It is this regeneration of limestone, which is effected by the lapse of time, that explains to us, why the hardest stones afford the best lime, and why old mortars are found to possess a degree of hardness which modern artists have no (p56) hopes of attaining. This circumstance has arrested the notice and attention of many of our best chymists, as well as architects, and the effect of some of their researches has been to propose, that the lime should be put into a basket, and suffered to slake in the air, as it is thought by this means that it would preserve a greater degree of force, and be less weakened than by the usual processes.

Loriot, in the treatise which he has written upon the subject, has attributed the superiority of the mortars of the antients to the means which they used to dry them speedily; and in consequence of these principles, he mixes powdered bricks with flints, works the whole together with slaked lime, and dries the mass with one fourth part of quick lime. Care must be taken to use only lime which is finely pulverized and sifted; for otherwise, the mortar would crack, and be very imperfect.

Before the mortar is thoroughly dry, we often see how easily it is injured by frost, and thereby we are made sensible of the impropriety of doing such work as requires mortar at the latter end of the season, but especially in the winter. Note, as the lime produced by the Earl of Stanhope is considered to be much superior to that in general met with, it may arise from the following circumstance :

The burning of lime in the large way depends on the disengagement of the carbonic acid by heat; and, as lime is infusible in our furnaces, there would be no danger from too violent a heat, if the native carbonate of lime were perfectly pure; but **as this is seldom the case, an extreme degree of heat produces a commencement of vitrification in the mixt (p57) stone**, **and enables it to preserve its solidity, and it no longer retains the qualities of lime, for it is covered with a sort of crust which prevents the absorption of the water when it is attempted to be slaked.** This is called also over-burnt lime. It is therefore principally by attending to the disengaging the carbonic acid by a regular and uniform heat from the native carbonate of lime that we can produce lime in any tolerable state of purity.

Dr. Bryan Higgins has found that burnt bones improve the common mortar very much; and as the mortar prepared according to his direction is certainly the best that can be proposed, we shall shortly notice the composition of it. Take 56 parts of washed coarse sand, whose single grains do not exceed one sixteenth part of an inch in diameter, and 42 of fine sand. Mix and wet them with lime-water, add gradually 14 parts of slaked lime, beat it well together, and lastly, add a like quantity of powdered bone-ashes.

Water cement, or mortar, which has the property of hardening under water, may be prepared, according to Guyton, by mixing together **four parts of blue clay, six of black acid of manganese, and nine of carbonate of lime; this mixture is to he heated to a white heat, in order to decompose the carbonate of lime. It is then mixed with 60 parts of sand, and formed into mortar with a sufficient quantity of water.**

CHALK-STONE. * The chalk-stone quarries are at Godstone, Catterham, Reigate, Merstham, Buckland, Beachworth, Epsom, Leatherhead, Bookham, Effingham, West Horsley, Clandon, Stoke near Guildford, Guildford, and Puttenham; at each of these places chalk is dug in greater or less quantities, not because the one may (p58) be better in quality than another, but according as the farmers are more or less intelligent, according to the system of farming pursued by them, and according to the qualities of the soil in each of those neighbourhoods, and the difficulty or facility of getting at it, or of procuring other sorts of manures.

…(p59) The kilns employed for agricultural purposes are all of the common kind, neither elliptical nor circular, but something between both; they are built with brick, but sometimes with brick and stone, and in a few instances entirely with stone; they are generally placed against a high bank for the greater convenience of charging it, or they are sometimes found upon the commons and wastes sunk in a natural or artificial rise of the ground. The walls are carried up something out of the perpendicular, both without and within to an even height, from whence a sort of dome springs with a large opening at top. The fireplace and the opening where the lime is drawn out are one and the same place. These sort of kilns are only used where wood or faggots are burnt, and they have the insuperable objection of letting a great part of the beat be lost,

Cleland J (1810) Specification of the Manner of Building and Finishing a Set of Public Offices and a Prison, with Court-Yards etc for the City of Glasgow. Glasgow Hedderwick & Co

MASON AND BRICKLAYER

Morter, how to be prepared.

The mortar to be used in these buildings, is to be made of lime from Netherwood, Campsie, or Kilbride quarries, mixed in the proportion of twelve bolls of shells to forty five cubic feet of sharp river-sand.

PLASTERER.

One Coat of Plaster on Walls.

The bossings of the windows, which are described to be lined with wood, and the face of the walls where vents are to be carried up, are to have one coat of plaster put on them before they are lined or lathed, so as to prevent the cold air or the smoke from coming through the walls.

Two Coats of Plaster on Walls.

The walls and ceilings of every apartment in these buildings, (except where formerly described to be made of ashler, or lined with iron or wood,) are to be covered with two coats of plaster, well straighted and smoothed; the lime for which may be taken from any of the quarries quoted in the Mason's Specification, and is to be mixed with a due proportion of clean river sand, and long fresh hair; it is then to be beat and well soured, so as to prevent blisters.

Three Coats of Plaster on Walls.

The walls of all the apartments in the public offices, justiciary-hall, turnkey's lodge, jailor's house, and chapel, are to have a third coat of plaster, made of Irish lime, and properly mixed with fine riddlings from the shivers of white stones. Three Coats of Plaster on Ceilings. The ceilings of all those last mentioned apartments, are to be gauged with stucco *(gypsum)* of the first quality.

Deafening.

Deafening, one inch and a half thick, is to be prepared with equal proportions of lime, smithy ashes, and river sand, and one stone of long fresh hair to every cart-load of the above, it is then to be properly mixed, and spread on the deafening boards, which are formerly described in the Joiner Work. The cracks which may appear in the deafening, before it is thoroughly dry, are to be filled up and smoothed over.

SLATER.

The roofs are to be covered with the best full sized slates from Esdale or Ballachoilish quarries, and put on with wrought-iron nails, at least twelve pounds to the thousand, which are to be boiled in linseed oil, so as to prevent corroding: The slates are to be dressed square up to the nail-holes, and sized both in length and thickness. When the first course has been laid, the shoulders of the slates, and the joints of the sarking, are to be filled up and smoothed with hair-lime, so as to prevent drift; the next and succeeding courses are to be done in the same way, having at least two-thirds cover.

Rees A (1819) The Cyclopedia or Universal Dictionary of Arts Sciences and Literature. Vol 29.

QUICK-LIME, in Rural Economy, such lime as is in the caustic or most active state, and which possesses the greatest power of operating upon different substances with which it may come in contact. It is quite the opposite in its qualities and properties, to that which has fallen down into a powdery state, in consequence of being saturated with water and carbonic acid gas, or fixed air, or which is slaked and become effete. Its powers, when applied upon land in this condition, have already been noticed in speaking of lime. See LIME. .

But it possesses qualities and properties in the way of a cement, the utility of which for building, for various domestic purposes, properly belong to this place.

According to Dr. Anderson, lime is in the best and most fit estate for this use when the most perfectly caustic, or in the most crystallizing condition.

It is remarked, that the powder of lime, when reduced by means of water into a thin or fluid sort of paste-like form, and then suffered to become dry, concretes into a coherent mass, which fixes to stones and other rough bodies in a very firm manner, and in this way becomes a proper cement for building any sort of walls. And that, after this pasty material has once become firmly dry, it is quite indissoluble in water, and incapable of ever being softened again by the moisture of the atmosphere or other similar causes.

Hence it excels many other sorts of cements. When composed for the purpose of building walls, &c. it is usually denominated mortar; but when formed as an application in the way of a smooth coating upon any plain surface without intermixture with stony matters, it is commonly here termed plaster. _

When made from the lime of the purer sort of lime-stone, it is found to be more soft and crumbly, and to acquire a less degree of hardness, and to be broken with much less force, than where the lime-stone from which it is made contains a large proportion of sand, in which case it becomes much more hard, firm, and durable.

It has, however, been discovered that the purest lime may be rendered a firm cement by adding a proper proportion of clean hard sand to it; hence the practice of blending sand with lime, when intended for mortar, has become so universal.

This is fully shewn to have been very early the case, by the oldest lime-built walls which are now to be met with. It nevertheless still remains a desideratum to ascertain the due proportion of sand which is necessary, **as both writers and practical masons greatly disagree in opinion on this matter, as well in their directions about the mode of mixing the materials,** as of applying the cement; some of the more modern, especially, **ascribing extraordinary effects to a small variation in these particulars, while others deny that these circumstances have any sensible effect on the durability and firmness of the cement**. It is conceived that these different and contradictory opinions arise from an imperfect knowledge of the nature of quick-lime, and the variations it may admit of; for these variations are so very great, as to render it impossible to afford any general rules that can possibly apply in all cases. It is, therefore, conceived to behove those who are desirous of acquiring any consistent and satisfactory knowledge on this head, to endeavour to ascertain, in the first place, the circumstances which render calcareous substances at all capable of becoming a cement, and then to trace the several changes that may be produced upon it by other extraneous causes.

Having explained the circumstances which cause the differences in lime-stone, and pointed out the different constituent principles of it, as well as various other peculiarities; **it is stated that lime, which has in any way absorbed its full quantity of air from the atmosphere and become mild, is altogether unfit for becoming a cement, and that, of course, it is evident, that a great change may be produced upon the quality of any lime, by having allowed less or more of it to be in this state before it is worked up into mortar.** And further, that if a large quantity of water be put to fresh slaked quick-lime, and beat up with it into a thin sort of paste, the water dissolves a small portion of the lime, which as it gradually absorbs its air, is converted into crystals; between the Particles of which crystals, that part of the lime which was not dissolved, and the other extraneous matters which may have been mixed with it, are entangled, so as to form a firm coherent mass of the whole. And that the pasty substance formed in this manner, **is the well-known article mortar**; and this heterogeneous, imperfectly semi-crystallized mass, constitutes the common cement employed in building ordinary walls or other erections.

These circumstances, therefore, being known, it is thought that it will not be difficult to comprehend what are the particulars that are necessary to form the most perfect cement of this nature.

That since lime becomes a cement only in consequence of a certain degree of crystallization taking place in the whole mass, it is sufficiently obvious that the firmness and perfection of that cement must depend upon the perfection of the crystals; and the hardness of the matters that are entangled among them; **for if the crystals are ever so perfect and hard of themselves, if they be separated from one another by any brittle incoherent medium, it is evident that the whole mass must remain in some degree brittle and incoherent.** That as water can only dissolve a very small proportion of lime, even when in its most perfect saline or caustic state, or while it remains deprived of its carbonic acid gas, and as happens in other similar cases, no more of the lime can be reduced to a crystalline mass than has been actually dissolved in the water; it happens of course, that if mortar be made of pure lime and water alone, a very small proportion only can be diſſolved by that small quantity of water that is added to it: and as this small proportion alone can afterwards be crystallized, all the remaining undissolved Particles of the lime will be entangled among the few cryſstals that are formed. And as the undissolved lime in this mass will in time absorb its air, and be converted into mild calcareous earth **without having had a**

sufficiency of water to allow it to crystallize, it must concrete into a friable mass exactly resembling chalk; it follows, that this kind of mortar, when and as it can be made, and in its highest degree of perfection, will always be soft, and easily crumbled into powder. **But that, if, instead of forming the mortar of pure lime alone, a large proportion of sand be added to it,** the water will in this case dissolve as much of the lime as in the former; and the Particles of hard sand, like sticks or threads, when making ſugar-candy or other Crystals, while rounded by the watery solution, will help to forward the crystallization, and render it more perfect than it other wise would have been, **so as firmly to cement the Particles of sand to one another.** And as the granules of sand are perfectly hard, of themselves, so as not to admit of being broken down like the Particles of chalk, it necessarily follows, that the cement made of these materials must be much more perfect in every respect than the former.

After considering a variety of circumstances in regard to the solubility of lime in water, and its crystallization, it is remarked, that when a large quantity of sand is mixed in the mortar, that sand will of course bear a great proportion to the whole mass; so that the water that may be mixed with the mortar will be much greater in proportion to the quantity of lime contained in this mortar, than if the Whole had consisted of pure calcareous matter. And that, as the sand absorbs none of that water, that water, now pure, is at liberty to act once more upon those few particles of Caustic lime that may still remain in the mortar, which will be dissolved and converted into crystals in their turn. In this way it may happen, in some circumstances, that a very large proportion of the lime may become crystallized; so that **the mortar will consist almost entirely of sand enveloped in Crystalline matter, and become in due time as hard as stone itself; whereas mortar, consisting of pure lime, without sand, can hardly ever be much harder than chalk.**

It is not, however, to be supposed, that in any case this dried mortar will assume that transparent Crystalline form, or the compact firmness of some ſorts of calcareous matters, such as marble and lime-stone. In mortar, in spite of the utmost care that can ever be taken, **a very considerable quantity of the lime must remain undissolved; which undissolved lime, although it may be so much separated by the sand and crystalline lime-stone as not much to affect the hardness of the mortar, yet it must still retain its white chalk-like appearance**. As marble and lime-stone are, however, always formed by those Particles of lime that have been wholly dissolved in water, and from which they have been gradually separated by a more slow and more perfect mode of Crystallization, they have nothing of that opaque Calx-like appearance, but assume other colours, and appear more firm, uniform, and compact; the sand and other matters that may be enveloped in them being entirely surrounded with a pure crystalline matter.

But to obtain the most perfect kind of mortar, it is not, however, enough that a large proportion of sand should be employed, and that the sand should be intimately mixed with the lime; it is also of the utmost importance that a large proportion of water be added; for without this it is impossible that a large proportion of the lime can be Crystallized: and the mortar, in that case, would consist only of a mixture of chalky matter and sand, which could hardly be made to unite at all, and would be little more coherent than sand by itself, and less so than pure Chalk. In that case, pure lime alone must afford rather a firmer cement than lime with sand.

It is also of very great importance that the water be retained as long in the mortar as possible: for if it be suddenly evaporated, it will not only be prevented from acting a second time upon the lime, after a part of what was first dissolved has been crystalized, but even the few crystals that would be formed when the water was suddenly evaporating, would be of themselves much more imperfect than they otherwise most certainly would have been. In proof of which, instances of the Crystallization of common salt, lump sugar, and sugar candy, are adduced; after which it is noticed, that every one knows what a difference there is between the firmness of the different substances; and that as great must be the difference between the firmness of that cement which has been slowly dried, and that which has been hastily hardened by the powerful action of a warm air.

It is contended, that it is owing to this Circumstance that the lime, which remains all winter in a mortar tub filled with water, is always ſound to be much firmer and more Coherent than the mortar that was taken from the same tub and used in any work of masonry, although in this case the materials were exactly the same.

From the same cause, any work cemented with lime underwater, if it has been allowed to remain undisturbed and uninjured until it has once become hard, is always much firmer than that which is above the ſurface of the water. . - In order to render the force of the above reasoning more strong and convincing, lime cement or mortar is compared to a mass of matter consisting of a Congeries of stones closely compacted together, and united by a strong cementing matter that had, while in a fluid state, pervaded all the interstices between the stones, and afterwards become a solid indissoluble substance. If the cementing matter be exceedingly hard and Coherent, and if the stones bedded among it be also very hard and firm, the whole mass will become like a solid rock, without fissures, that can hardly be broken to pieces by the power of man. But, although the cement should be equally firm, if the stone, of which it consists, be of a soft and friable nature, suppoſe chalk or sand-stone, the whole mass will never be capable of attaining such a degree of firmness as in the former case; for when any force is applied to break it in pieces, although the cement should keep its hold, the solid matter cemented by it would give way, and the whole would be easily broken to pieces.

Whereas in mortar, the sand that is added to it represents the stones of a solid matter in the Composition, the particles of which are united together by the lime which had been formerly dissolved, and now crystallized, which becomes an exceedingly solid and indissoluble Concretion. And as the Particles of sand are of themselves exceedingly hard, and the cement by which they are united equally so, it is plain that the whole Concretion must be extremely firm, so as to require very great force to disunite any particle of it from the whole mass. Failing sand, the only solid body that is entangled among the Cementing matter should be chalk, (as in all Cases where the mortar consists of pure lime alone,) or any other slightly Cohering substance, let the Cementing Particles of that Composition be ever so perfect, it is impossible that the whole can ever attain a great degree of firmness, as these Chalky matters will be easily broken asunder.

It is remarked, in addition, that a variety of conjectures have been made about the nature of the lime cement employed by the ancients. It has been thought that they possessed an art of making mortar, which has been long since entirely lost; as the cement in the walls which have been built by them, appears to be, in many cases, much firmer than that which had been made in modern times. Yet, when the mortar of these old buildings is analysed, **it is found to consist of the same materials, and nearly in the same proportions, in which they are now made use of.** And it is thought probable, that their **only secret consisted in mixing the materials more perfectly than the rapidity or avarice of modern builders will permit, in employing their mortar in a much more fluid state than is done now, and in allowing it to dry more slowly, which the immoderate thickness of many of their walls would naturally produce, without any pre concerted design on their part.** Tradition has even handed down to the present times the memory of the most essential of these particulars; as the lower class of people, in every part of the nation, at this moment invariably suppose and believe **that these old walls were composed of a mortar so very thin, as to admit of its being poured, like a fluid, between the stones, after they were laid in the wall:** and the appearance of these old walls, when taken down, seems to favour this popular tradition. *[very effective, if done whilst the lime still slaking].* Nor is it doubted but that this may have been the case. **The stones in the outer part of the wall, it is thought, were probably bedded in mortar nearly as is practised at present; and the heart, after being packed well with irregular stones, might have the interstices between them entirely filled up with fluid mortar, which would insinuate itſelf into every cranny, and in time adhere as firmly as the stones themselves, or even more so, if the stones were of a sandy friable nature.** And that, as these walls were usually of very great thickness, it might often happen, that the water in this mortar, by acting successively upon different Particles of caustic lime, would at length be entirely absorbed by successsive crystallizations, so as to become perfectly dry, without any evaporation at all; in which case, a very large proportion of the original lime must have been regularly crystallized in a slow and tolerably perfect manner, so as to attain a firmness little inferior to lime stone or marble itself. It is supposed that, upon these principles it is easy to account for the superior hardness of some old cements, when compared with that of modern times, in which a practice very different is usually followed, without having recourse to any wonderful arcana whatever.

Monsieur Loriot, a late French writer, imagined that he had made a perfect discovery of the way in which the ancients employed their quick-lime, so as to obtain such an extraordinary firm cement; from which discovery, he conceived, very important benefits might be derived to society. According to his opinion, **the ancient cement consisted of lime and sand nearly in the same proportions as are commonly employed for that purpose at present.** But instead of making it of slaked lime entirely, as is done now, he contends that they **employed a certain proportion of their lime unslaked, which they mixed with their mortar immediately before it was used.**

And it is further noticed, that this newly discovered cement dries and hardens almost under the hand of the Operator, without cracks or flaws of any sort; that it neither expands nor contracts with the air;--that it is impervious to moisture, and may not only be employed for making roofs of houses that are subjected to the continual dropping of water, basons, aqueducts, canals, &e. which will instantly contain water in any quantities, but even finer works of the pottery kind; that it perfectly resists frosts, and has a variety of other interesting **qualities** *[This will have been a feebly hydraulic lime].*

The trials of Dr. Anderson with the same sort of materials do not, however, confirm the great certainty and utility of this discovery *[presumably because done with pure lime/.*

That **such effects as the writer describes, says the doctor, will invariably be produced, merely by adding a certain proportion of unslaked lime in powder to mortar, <u>or even by making the mortar entirely with powdered quick-lime</u>, I may without hesitation venture to deny,** not only from the reasoning that has been given, but from actual experiment, again and again repeated by myself and which is likewise, in some measure, corroborated by the experience of Mr. Dossie. On these accounts, it is supposed, that if Monsieur Loriot, has really experienced these uncommon effects from the mortar he has tried, **it must have been occasioned by some other unobserved peculiarity, and not merely by the circumstance to which he seems to ascribe it.** *[Rees seems entirely unaware of Smeaton's work, identifying clay as a natural pozzalan, as well as of feebly hydraulic stone lime].*

Possibly the doctor supposes the lime he employed may have been impregnated with a gypſum, or the sulphate of lime, as is probable, for many reasons. The effects and qualities of which, as to becoming a fine powder, and of suddenly setting, are well known, but it never acquires the stony hardness that lime cement is sometimes endowed with, although it takes the smoothest poliſh of any cement we know: on which account, it has long been employed as a plaister where fine Ornaments are required.

There are unquestionably, however, many doubtful and mysterious circumstances connected with this matter, which require the aid of further trials and experience in their full explanation. There are still further a few other circumstances that may influence the quality of common lime-mortar. If lime-stone be sufficiently Calcined, it is deprived of all its moisture, and of all its carbonic acid gas, or fixed air. But experience shews, that lime-stone will fall to powder on the effusion of water upon it, when it is much less perfectly Calcined, and while it still retains almost the whole of its fixed air. And that as masons have hardly any other rule for judging whether lime-stone be sufficiently Calcined, except this single Circumstance of its falling to a powder when water is poured upon it, it may thus eafily be perceived, that the same lime may be more or less fitted for making good mortar, according to a Circumstance that, in a great measure, eludes the Observation of operative masons ; for if it should happen that all the pieces of lime drawn from a kiln at one time, were just sufficiently Calcined to make it fall to a powder with water and no more, that powder would be altogether unfit for making mortar of any kind. This is a case that can seldom happen: but as there are a great many intermediate degrees between that state and perfect calcination, it must often happen that the stone will approach nearer to one of these extremes at one time than at another; so that the mortar may be much more perfect at one time than at another, owing to a variation in this particular.

All those who have written on the subject of lime as a cement, have endeavoured to ascertain what is the due proportion of sand for making the most perfect cement. But a little attention to the matter will shew, that all rules, which could be prescribed as to this particular, must be so vague and uncertain, as to be of little utility to the practical mason ; as, besides the variation which may arise from a more or less perfect degree of calcination as above, it is a certain fact, that **some kinds of lime-stones are much more pure, and contain a much smaller proportion of sand than others do; some being found almost perfectly pure, while others contain eleven-twelfths of sand and all the intermediate proportions of it….**

It is conceived, that **it is impossible to prescribe any determinate proportion of sand to lime, as that must vary according to the nature of the lime and other incidental circumstances,** which would form any general rule. But **it would seem that it might be safely inferred that the moderns in general rather err in giving too little sand, than in giving too much**.

It deserves, however, to be noticed, that the sand, when naturally in the lime-stone, is more intimately blended with the lime than can possibly be ever effected by any mechanical operation; so that it would be in vain to hope to make good mortar artificially from pure lime, with such a small proportion of caustic calcareous matter as may some times be effected when the lime naturally contains a very large proportion of sand. But there seems to be no doubt, that if a much larger proportion of sand were employed, and if that were more carefully blended and expeditiously worked than is common, the mortar would be much more perfect than is usual in modern times, as has been proved by actual trials.

It is stated by Sir Humphrey Davy, in his work on Agricultural Chemistry, that there are two modes in which lime acts as a cement; in its combination with water, and in its combination with carbonic acid. When quick-lime is rapidly made into a paste with water, it soon loses its softness, and the water and the lime form together a solid coherent mass, which consists of seventeen parts of water, to fifty-five parts of lime. **When this hydrate of lime, while it is consolidating, is mixed with red oxyd of iron, alumina, or silica, the mixture becomes harder and more coherent than when lime alone is used**; and it appears that this is owing to **a certain degree of chemical attraction** between hydrate of lime and these bodies; and they render it less liable to decompose by the action of the carbonic acid in the air, and less soluble in water. **It is thought that the basis of all cements that are used for works which are to be covered with water must be formed from hydrate of lime; and that the lime made from impure lime-stones answers this purpoſe very well.**

Puzzolana, it is said, is composed principally of silica, alumina, and oxyd of iron ; and it is used mixed with lime, to form cements intended to be employed under water. It is stated that Mr. Smeaton, in the construction of the Eddystone lighthouse, used a cement composed of equal parts, by weight, of slaked lime and puzzolana. Puzzolana, it is said, is a decomposed lava. Tarras, which was formerly imported in considerable quantities from Holland, is found to be a mere decompoſed basalt: **two parts of slaked lime and one part oſ tarras form the principal part of the mortar used in the great dykes of Holland.**

It is supposed that substances which will answer all the ends of puzzolana and tarras, are abundant in the British islands. An excellent red tarras may be procured in any quantities from the Giant's Causeway, in the north of Ireland : and decomposing basalt is abundant in many parts of Scotland, and in the northern districts of England in which coal is found.

It is observed that Parker's cement, and cements of the same kind made at the alum-works of lords Dundas and Mulgrave, are mixtures of Calcined, ferruginous, siliceous and aluminous matter, with hydrate of lime. **It is noticed, that the cements which act by combining with carbonic acid, or the common mortars, are made by mixing together slaked lime and sand.**

These mortars at first solidify as hydrates, and are slowly converted into carbonate of lime by the action of the carbonic acid of the air. It was found by Mr. Tennant, that a mortar of this kind, in three years and a quarter, had regained sixty-three per cent. of the quantity of carbonic acid gas, which constitutes the delinite proportion in carbonate of lime. The hardness of the mortar in very old buildings is also thought to depend upon the perfect conversion of all its parts into carbonate of lime. **The purest lime-stones are the best adapted, it is said, for making this kind of mortar. The magnesian lime-stones make excellent water cements, but act with too little energy upon carbonic acid gas to make good common mortar.** The Romans, on Pliny' s authority, made their best mortar a year before it was used ; so that it was partially combined with carbonic acid gas before it was employed, it is supposed *[not really – kept moist in pits or casks]*.

When for plaister, it is of great importance to have every particle of the lime-stone slaked before it is worked up; for, as smoothness of the surface is the most material point, if any particles of lime should be beaten up in it, and employed in work before sufficiently fallen, the water, still continuing to act on them after it was worked up, would infallibly slake such particles, which forcibly expanding themselves, would produce those excrescences on the surface of the plaister commonly termed blisters.

Consequently, in order to obtain a perfect kind of plaister that will remain smooth on the surface and free of Blisters, there is an absolute necessity to allow the lime to lie for a considerable time macerating or souring in water, before it is worked up. And the same sort of process is necessary for the lime when intended for use as mortar, <u>though not so absolutely.</u>

Great care is, however, required in the management in this respect; the principal **things being the getting of well-burnt lime, and the allowing it to macerate or sour with the water for only a very short time before it is used; but that which is the best burnt will require the maceration of some days in the water before it is sufficiently slaked in the whole for this purpose.** See SOURING

Lime for Mortar and Plaister. It has been almost univerſally admitted, that the hardest lime-stone affords a lime that will consolidate into the firmest cement, and hence generally concluded, that lime made of chalk, produces a much weaker cement than what is made of marble or lime-stone. It would seem, however, that if ever this be the case, it is only incidentally, and not necessarily ſo. As from the nature of calcareous matter, **every kind of lime is equally fit for becoming a firm cement, if it be first reduced to a proper degree of causticity, and has afterwards a due proportion of sand properly mixed with it, before it be employed in work.**

Different sorts of lime, without doubt, differ much from each other in the proportion of sand they naturally contain, and, of course, require very different proportions of sand to be added to them before they can be made equally perfect as a cement, which is an economical consideration, of no small moment in some cases, as it may make one sort of lime a great deal cheaper than another on some occasions, and, of course, deserves the attention of builders in general. See LIME.

The excellencies and defects of other substances that may be occasionally mixed with lime in making cement may be just noticed. **Those commonly used as an addition to mortar, besides sand of various denominations, are powdered sand-stone, brick-dust, and sea-shells**.

And for forming plaister, where closeness rather than hardness is required, they are lime that has been slaked and kept long in a dry place, till it has become nearly effete, powdered chalk or whiting, and gypsum in various proportions; besides hair and other materials of that nature. But some others have been more lately advised, such as earthy balls, slightly burnt and pounded, powdered and sifted old mortar rubbish, and others of a similar kind. All of which substances are found objectionable in some respect or other for this use, sand being the only perfectly suitable material that can be easily met with; on which account it has been always justly preferred.

Pure firm crystallized sand is the best, but all pure sands are not equally proper in this intention. See theſe substances respectively. See also CEMENT and SAND MORTAR

MORTAR, a composition of lime, sand, &c. mixed up with water: serving as a cement to bind the stones, &e. of a building. The ancients had a kind of mortar so very hard and binding, that after so long a duration as to this time, it is next to impossible to separate the parts of some of their buildings; though there are some who ascribe that excessive strength to time, and the influence of certain properties in the air, which is, indeed, found to harden some bodies very surprisingly. The lime used in the ancient mortar, is said to have been burnt from the hardest stones, or often from fragments of marble. De Lorme observes, that the best mortar is that made of pozzolana for sand; adding, that this penetrates black flint, and turns them white. See POZZOLANA.

Mr. Worledge observes, that fine sand makes weak mortar, and that the larger the sand the stronger the mortar *[later writers, such as Treussart and Totten would differ, preferring a combination of both].* He therefore adviſes, that the ſand be washed before it is mixed and adds, that dirty water weakens the mortar considerably. Wolfius observes, that the sand should be dry and sharp, so as to prick the hands when rubbed; yet not earthy, so as to foul the water in which it is washed. Vitruvius observes, that fossile sands dry sooner than those taken out of rivers. Hence, he adds, the latter is fitted for the insides, the former for the outsides of a building. He subjoins, that fossile sand, lying long in the air, becomes earthy. Palladio takes notice, that of all sands white ones are the worst; and the reason is owing to their want of asperity. . **The proportion of lime and sand in our common mortar is extremely variable**: Vitruvius prescribes three parts of pit-sand, and two of river-sand, to one of lime; but the quantity of sand here seems to be too great. *[this is taken directly from Moxon].*

The proportion most commonly used in the mixing of lime and sand is, to a bushel of lime a bushel and a half of sand, i.e. two parts of lime and three of sand; though the common mortar, in and about London, has more sand in it than according to this proportion. The improvement of mortar is certainly an object of real importance: and different schemes have been suggested for giving it that degree of durability for which the mortar used by the ancients is so justly celebrated.

With respect to this method, Dr. Higgins observes, that M. Loriot corrects the bad quality of the old and effete lime, which constitutes the basis of his mortar, and which has regained apart of the fixed air that had been expelled from it, by the addition of fresh and non-effervescent lime, hastily added to it, at the time of using the composition, which must undoubtedly improve the imperfect mass. And he adds, that when an ignorant artist makes mortar with whiting instead of lime, he can mend it considerably by adding lime to it; but his mortar will still be defective, in compariſon with the best that may be made, by reason of the old slaked lime or whiting; this on repeated trials he has found to be the true state of the case.

Dr. Higgins has made a variety of experiments, in consequence of the modern discoveries relating to fixed air, for the purpose of improving the mortar used in our buildings. According to this author, the perfection of lime, prepared for the purpose of making mortar, consists chiefly in its being totally deprived of its fixed air. On examining several specimens of the lime commonly used in building, he found that it is seldom or never sufficiently burned for they all effervesced, and yielded more or less fixed air, on the addition of an acid, and it slaked slowly, in compariſon with well burned lime*[calcium carbonate would, of course, effervesce]*. Dr. Higgins also relates some experiments, which shew how very quickly lime imbibes fixed air from the atmosphere ; on its exposure to which it by degrees soon loses those characters which chiefly distinguish it from mere lime stone or powdered chalk: by soon attracting from thence that very principle, to the absence of which it qives its useful quality as a cement, and which had before been expelled from it in the burning. Hence he concludes, that, as lime owes its excellence to the expulsion of fixed air from it in the burning, **it should be used as soon as possible after it is made, and guarded from exposure to the air, as much as possible, before it is used.** It is no wonder, therefore, he says, that the London mortar is bad, if the imperfection of it depended solely upon the badness of the lime, since the lime employed in it is not only bad when it comes fresh from the kiln, because it is insufficiently burned, and the air has access to it, but becomes Worse before it is used, by the distance and mode of its conveyance, and when slaked, is as widely different from good lime, as it is from powdered chalk.

For a similar reason, every other cause, which tends to restore to the lime the fixed air, of which it had been deprived in the burning, must deprave it. It must receive this kind of injury, for instance, from the water, so largely used, first in slaking the lime, and afterwards in making it into mortar; if that water contains fixed air, from which few waters are perfectly free, and which will greedily be attracted by the lime. The injury arising from this cause is prevented by the substitution of lime-water, so far as may be practicable or convenient. _ _ _ From other experiments, made with the view of ascertaining the best relative proportions of lime, sand and water, in the making of mortar, it appeared that those specimens were the best which contained one part of lime in seven of the sand; for those which contained less lime, and were too short whilst fresh, were more easily cut and broke, and were pervious to water; and those which contained more lime, although they were closer in grain, did not harden so soon or to so great a degree, even when they escaped cracking by lying in the shade to dry slowly. It appeared farther, that mortar, which is to be used where it must dry quickly, ought to be made as stiff as the purpose will admit, or, with the smallest practicable quantity of water, and that mortar will not crack, although the lime be used in excessive quantity, provided it be made stiffer, or to a thicker consistence than mortar usually is. –

Dr. Higgins has also shewn, that though the setting of mortar, as it is called by the workmen, chiefly depends on the desiccation of it, yet its induration, or its acquirng a stony hardneſs, **is not caused by its drying, as has been supposed, but is principally owing to its absorption of fixed air from the atmosphere,** and is promoted in proportion as it acquires this principle ; the accretion of which is indispensibly necessary to the induration of calcareous cementa. **In order to the greatest induration of mortar, therefore, it must be suffered to dry gently and set; the deſiccation must be effected by temperate air, and not accelerated by the heat of the sun or fire; it must not be wetted soon after it sets; and afterwards it ought to be protected from wet as much as possible, until it is completely indurated;** the entry of acidulous gas must be prevented as much as possible, until the mortar is finally placed and quiescent; and then it must be as freely exposed to the open air as the work will admit, in order to supply acidulous gain, and enable it sooner to sustain the trials to which mortar is exposed in cementitious buildings, and incrustations.

Dr. Higgins has also enquired into the nature of the best sand or gravel for mortar, and into the effects produced by bone-ashes, plaster powder, charcoal, sulphur, &c. and he deduces great advantages from the addition of bone-ashes, in various proportions, according to the nature of the work for which the compoſition is intended. _

This author describes a water-cement or stucco, of his own invention, ſor incrustations internal and external, exceeding, as he says,' Portland stone in hardness, for which he obtained his majesty's letters patent in 1779. As for the materials of which this is made; drift sand, or quarry sand, or, as it is commonly called, pit sand, consisting chiefly of hard quartose flat-faced grains, with sharp angles, the most free from clay, salts, and calcareous, gypseous, or other grains, less durable than quartz, containing the smallest quantity of pyrites, or heavy metallic matter, inseparable by washing, and admitting the least diminution in bulk by washing, is to be preferred to any other. The sand is to be sifted in streaming clear water, through a sieve which shall give passage to all such grains as do not exceed one sixteenth of an inch in diameter; and the stream of wash and sifting are to be so regulated, that all the sand, which is much finer than the Lynn sand, together with clay and other matter, specifically lighter than sand, may be washed away with the stream; whilst the purer and coarser sand, which passes through the sieve, subsides in a Convenient receptacle; and whilst the coarse rubbish and shingle remain on the sieve to be rejected. The subsiding sand is then washed in clean streaming water, through a finer sieve, so as to be farther cleansed and sorted into two parcels, a -coarser, which will remain in the sieve which is to give passage to such grains of sand only as are less than one thirtieth of an inch in diameter, and which is to be saved apart under the name of coarse sand; and a finer, which will pass through the sieve and subside in the water, and which is to be saved apart under the name of ſine sand. These are to be dried separately, either in the sun, or on a clean iron plate set on a convenient surface, in the manner of a sand heat. Let the lime be chosen, which is **stone-lime, which heats the most in slaking, and slakes the quickest when duly watered; which is the freshest made and most closely kept;** which dissolves in distilled Vinegar with the least effervescence, **and leaves the smallest residue insoluble**, and in this residue **the smallest quantity of clay, gypsum, or martial matter**. Let this lime be put in a brass-wind fine sieve, to the quantity of fourteen pounds. Let the lime be slaked by plunging it in a butt, filled with soft water, and raising it out quickly and suffering it to heat and fume, and by repeating this plunging and raising alternately and agitating the lime, until it be made to pass through the sieve into the water and reject the part of the lime that does not easily pass through the sieve; and use fresh portions of lime, till as many ounces oſ lime have passed through the sieve as there are quarts of water in the butt.

Let- the water, thus impregnated, stand in the butt, close covered, until it becomes clear; and, through Wooden cocks placed at different heights in the butt, draw off the clear liquor, as fast and as low as the lime subsides, for use. This clear liquor is called the cementing liquor.

Let fifty ſix pounds of the foresaid chosen lime be slaked, by gradually sprinkling on it, and especially on the unslaked pieces, the cementing liquor, in a close clean plate. Let the slaked part be immediately sifted through the ſine brass wired sieve. Let the lime which passes be used instantly; or kept in air-tight vessels, and let the part of the lime which does not pass through the sieve be rejected: the other part is called purified lime. Let bone-ash be prepared in the usual manner by grinding the whitest burnt bones; but let it be siſted to be much finer than the bone aſh commonly sold for making cupels.

Having thus prepared the materials, take fifty-ſix pounds of the coarse sand, and forty-two pounds of the ſine sand: mix them on a large plank of hard wood placed horizontally: then spread the sand so that it may stand to the height oſ six inches, with a flat ſurface on the plank; wet it with the cementing liquor; to the wetted sand add fourteen pounds of the purified lime, in several successive portions, mixing and beating them up together; then add fourteen pounds of the bone ash in succssive portions, mixing and beating all together. This Dr. Higgins calls the water-cement: coarse-grained, which is to be applied in building, pointing, plastering stuccoing, &c. observing to work it expeditiouſly in all cases, and in stuccoing to lay it on by sliding the trowel upwards upon it; to well wet the materials used with it, or the ground on which it is laid, with the cementing liquor, at the time of laying it on; and to use the cementing liquor for moistening the cement and facilitating the floating of it. If a cement of a finer texture be required, take ninety eight pounds of the fine sand, wet it with the cementing liquor, and mix it with the purified lime and the bone-ash as above, with this difference, that fifteen pounds of lime are to be used instead of fourteen pounds, iſ the greater part of the sand be as fine as Lynn sand. This is called water-cement fine-grained; and is used in giving the last coating or the finish to any work, intended to imitate the finer grained stones or stucco.

For a cheaper and coarser cement, take of coarse sand or shingle fifty-fix pounds, of the foregoing coarse sand twenty-eight pounds, and of the finer sand fourteen pounds; and after mixing and wetting these with the cementing liquor, add fourteen pounds, or somewhat less, of the purified lime, and then as much of the bone-ash, mixing them together. When the cement is required to be white, white sand, white lime, and the whitest bone-ash are to be chosen. Grey sand, and greybone-ash, formed of half-burnt bones, are to be chosen to make the cement grey and any other colour is obtained, either by chusing coloured sand, or by the admixture of the necessary quantity of coloured talc in powder, or of coloured vitreous or metallic powders, or other durable colouring ingredients, commonly used in paint. The water-cement above described is applicable to forming artificial stone; by making alternate layers of the cement and of flint, hard stone, or brick, in moulds of the figure of the intended stone, and by expoſing the masses so formed to the open air to harden. When it is required for water fences, two-thirds of the bone-ashes are to be omitted, and in its stead an equal measure oſ powdered terras is to be used. When the cement is required of the finest grain, or in a fluid form, so that it may be applied with a brush, flint powder, or the powder of any quartose or hard earthy substance, may be used in the place oſ sand, so that the powder shall not be more than six times the weight of the lime, nor less than four times its weight. For inside work, the admixture of hair with the cement is useful. (Higgins's Exp. and Obs. on Calcareous Cements, &e. 8vo. 1780, passim). See Stucco.

Mortar in Building

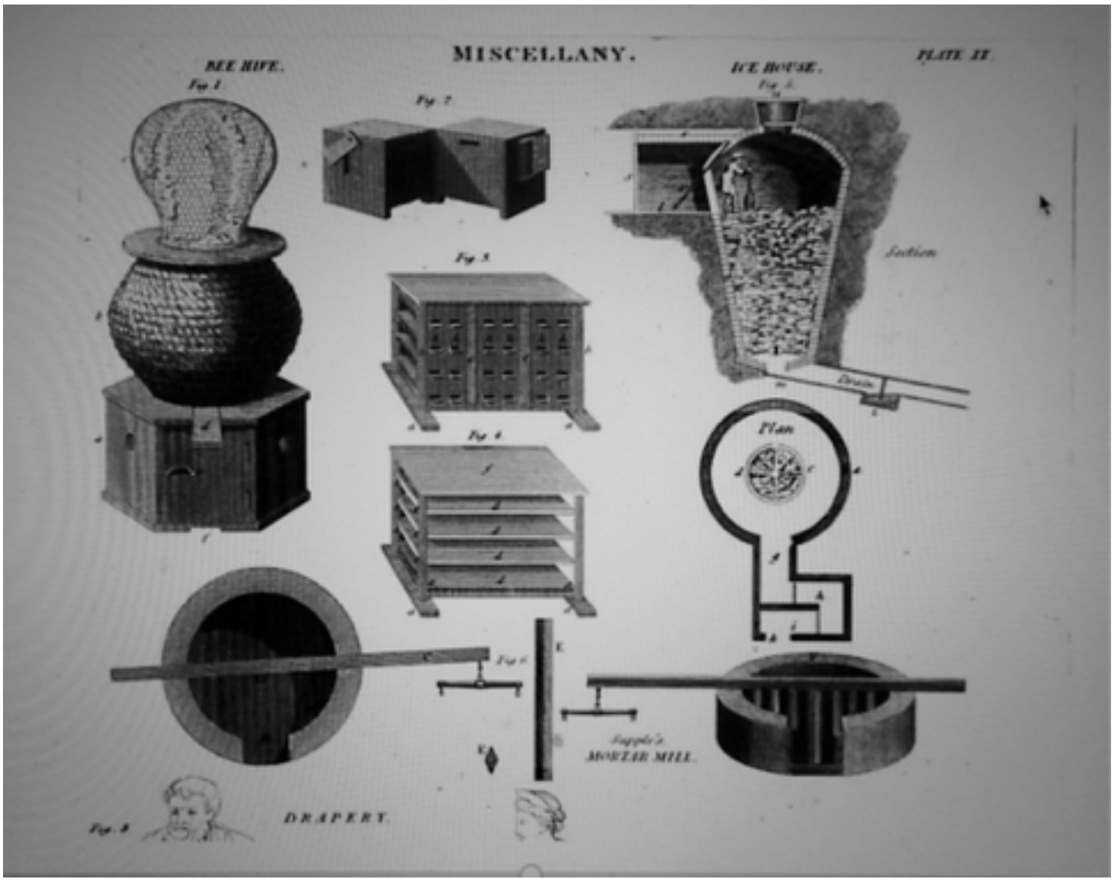
M. Felibien observes, that the ancient masons were so very scrupulous in this process, that the Greeks kept ten men constantly employed, for a long space of time, to each bason; this rendered the mortar of such prodigious hardness, that Vitruvius tells us the pieces of plaster falling off from old walls served to make tables. The same Felibien adds, it is a maxim among old masons to their labourers, **that they should dilute with the sweat of their brow, i.e. labour it a long time, instead of drowning it with water to have it done the sooner.**

MORTAR-Mill, a machine contrived by Mr. Supple, for the purpose of saving labour in the making up of mortar, as well as doing the business more effectually and at a trifling expence. It may also be useful in working clay, &e.

And the mode of doing it is thus described: **A pit is dug in the ground, which is bricked at the bottom and sides, into which the operator puts the lime. He has**

the command of a small stream of water, which is conveyed at pleasure into the pit, and in a few days the lime is sufficiently slaked; he then puts the lime and sand, or gravel, into the mill, which not only mixes both together, but incorporates them in a very effectual manner; and, as the lime is sufficiently moist when taken out of the pit, no more water is required for the mortar. If for present use, the quantity he makes at a time is six bushels, as he finds when more is put in, it is apt to strain the cogs, iſ not made very strong. If the mortar is made with sand alone, the space between the cogs need not be made so wide as three inches. He has a second shaft, with closer cogs, in order to give the mortar another working; the space between these is but two inches; but it does not answer well till after the first shaft has been used, nor is it necessary, unless for very nice work. He adds, that he made 200 barrels of lime into mortar last summer, and has now the like quantity of lime in the pit for the same purpose. He made six barrels of mortar in a day with ease; a boy of seven years old drives the horse, and the most indifferent one is good enough for the purpose, the draught being so easy. This machine may be wrought by any other power, as water, wind, or steam.

The nature, plan, and construction of the machine are seen at flg. 4, in Plate XXIV in which A is the plan of the boarded floor, raised eight inches from the ground, four feet two inches in diameter, and surrounded by a fourteen inch wall, whose outſide height is five-feet. B, a sliding door, two feet wide. C, plan of the shaft, with its cogs, or teeth; its length eleven feet eight inches, breadth eight inches, depth five inches. D, plan of the post, or axis, on which the shaft turns round; diameter seven inches, height twenty inches. E E, plan and upright of one of the cogs as it stands in the mill. The plan is a rhombus, the longest diagonal is three inches, the shortest but two, in order to make the angles of the cogs more acute, by which means they will pan through the mortar with the greater ease. F, elevation and section of the mill in perspective.



The inventor states, that the space between the cogs is three inches, except the first to the left of the post, which is but half an inch distant from it, in order to give the cogs to the left a different direction from those on the right; and its use will, by inspection, readily appear. There must be a space of two inches between the end of the cogs and the floor, in order to give the gravel a free passage, which would otherwise strain the cogs, and stop the course of the mill."

Besides the common mortar used in laying of stone, bricks, &c. there are several other kinds: as, Monran, used in plastering the walls and ceilings; made of ox or cow's hair mixed with lime and water, **without any sand.** The common method of making this mortar is one bushel of hair to six bushels of lime.

MORTAR (that) is very hard and durable, being made of lime and hogs-grease, sometimes mixed with the juice of figs, and sometimes with liquid pitch; and, after application, is washed over with linseed-oil. See BETON. For this purpose, mortar made of terras, pozzolana, tile dust, or cinders, is mixed and prepared in the same manner as common mortar: only that these ingredients are mixed with lime, instead of sand, in a due proportion, which is about half and half. The lime should be made of shells or marble; and in works which are sometimes dry and some times wet, instead of terras, which is very dear, tile-dust or cinder-dust may be used.

MORTAR for Sun-Dial: on walls may be made of lime and sand, tempered With linseed-oii; or, for want of that, with skimmed milk. This will grow to the hardneſs of a stone. For buildings, one part of washed soap-ashes, mixed with another of lime and sand, make a very durable mortar.

Rees A (1829)The Cyclopedia or Universal Dictionary of Arts, Sciences and Literature Vol XXXIII. London Longman, Hurst, Rees, Orme & Brown

SOURING Lime for Mortar and Plaster, in Rural Economy, the practice of macerating and rendering it proper for these uses. It has been stated by the writer of an Essay on Quicklime as a Cement, that when lime is to be employed for making plaster, **it is of great importance that every particle of the limestone be slaked before it is worked up**; for, as the smoothness of the surface is the circumstance most wished for in plaster, if any particles of lime should be beaten up in it, and employed in work before they have had sufficient time to fall, the water still continuing to act upon them after the materials have been worked up, will infallibly slake such particles, which will then expand themselves in a forcible manner, and be productive of those excrescences upon the surface of the plaster, which are commonly known by the name of **blisters.**

Consequently, if it be intended to have a perfect kind of plaster, which is capable of remaining smooth on the surface and free from blisters, **there is an absolute necessity for allowing the lime of which it is composed, to lie for a considerable length of time in maceration with water, before it is wrought up into plaster, which is a process or operation that is here termed souring.**

Where the limestone is of a pure quality, and has been very perfectly calcined or burnt, there will seldom be any danger of the whole of the lime falling at first; but where it has been less perfectly burnt, there will be many particles, which will require to lie a long time before they will be completely reduced into powder. This macerating process or operation is consequently **more necessary with impure than pure lime**; but still it ought on no occasion to be omitted or neglected, as there is not the smallest probability, but that some blisters would appear on the surface of plasters made with even the purest lime, **when worked up and applied immediately after being slaked, without undergoing this souring process in some degree.** The practice is also common of souring the lime when it is intended for being used in mortar; but although it is not so indispensably necessary in this case, as in that where it is designed for plaster, yet, when properly performed, it is evident, it is said, that it must even in this instance too be of utility; as any dry knots of lime that may fall after the mortar is used, must have a tendency to disunite the parts of it, which have already been united, and to render the mortar or cement much less perfect than if the whole had been properly mixed up with the materials and allowed to sour before using. More circumspection is, however, requisite, it is said, in souring lime for mortar than for plaster; for, as it is not necessary that plaster should be endowed with a stony degree of hardness, there is no loss sustained by allowing a great proportion of the lime which is designed for that purpose to absorb its air before it be used; for a very small quantity of caustic or quicklime will be sufficient to unite the whole into one slightly coherent mass. Consequently, the only circumstance which is necessary to be attended to in souring lime for plaster is, that it be allowed to macerate long enough, as there is no danger of ever erring on the opposite extreme. It is indeed necessary, it is said, on some occasions, it should lie a very long time, before any certainty can be had, that all the particles are thoroughly slaked, as pieces of lime-shells have been known to lie upwards of six months exposed to all the changes of the winter weather, and fall after that period. . Such slightly burnt stones are indeed, it is said, usually separated **in sifting the lime for plaster;** but as some small chips may escape, it is **always the safest way to allow lime to lie in the sour a very considerable length of time.** Another advantage of some consequence likewise, it is said, attends this practice; as, if by such means a large proportion of the lime be allowed to absorb its air, and become in the mild or effete state, when it is wrought or beaten up for use, the water can have no sensible effect upon this mild lime; it will only separate the particles of the caustic lime more perfectly from each other, so as to permit it to dry without cracks of any kind, and render the surface of the plaster a great deal more smooth and entire, than could have been the case, if the whole had been made use of while in the perfectly caustic state. By this means too, those crystalline exudations, which are so common on walls newly plastered, will be the best and most effectually prevented. **On all which accounts, the practice of suffering lime, which is designed for plaster, to macerate or sour a long time with water, should never, it is said, except in cases of necessity, be neglected or overlooked.**

However, as lime, from the moment of its being fully slaked, begins to absorb air, and continues to take up more and more every minute from that time until it becomes perfectly mild or effete, so as to be rendered **gradually less and less proper for forming mortar of any kind,** it necessarily follows, that where lime designed for this purpose is permitted to lie long in the sour, a great part of it will be converted into chalky matter, or uncrystallized mild or effete lime, in which state it will be (in)capable of having so much sand added to it, or of forming so good a mortar as would have been the case**, if a larger proportion of the sandy material had been made use of in the first place, and been wrought up as speedily as possible, without so much souring, into mortar,** and immediately made use of. The evil will also be increased where the lime has been but slightly burnt, consequently the best burned lime should always be preferred for this use, which, **when carefully sifted after slaking**, will soon fall sufficiently for this purpose; as the main point here is to have the mortar firm and binding; and the falling or bursting of very small unslaked particles of lime in the mortar afterwards, will not be productive of such evident inconvenience as is the case in the making and using of plaster.

In the making of good mortar, it will consequently be necessary to get the best burnt lime, and to only suffer it to macerate or sour with water a very short time before it is wrought and applied. The best burnt lime, however, mostly requires some days to macerate and sour with water, before the whole becomes fully slaked and fallen for this use.

(souring as described was setting aside slaked lime mixed or unmixed with sand to allow time for late-slaking to occur. A slight excess of water would have been added to produce a mix dry enough to allow screening but not so dry as to prevent slaking of then unslaked lime, being later knocked up with more water to form a workable mortar. Alternatively, a wetter hot mixed sand and lime mortar might be set aside and knocked up prior to use with a minimal addition of water. The period of souring would depend upon the lime used and local practice. Millar says this was typically 2 weeks in Yorkshire and Scotland; up to 3 months elsewhere. There is ample evidence in both old texts and material science to indicate that it was common for plaster to be applied sooner than this, and often whilst still hot, however. The debate about how soon to use mortar or how long to lay it down before use goes on throughout history. Prompt use seems to have been the most common response by craftsmen on site).

This doctrine of the nature and utility of the souring process in the making of these substances is supposed to receive additional proof and support from the practice which was followed by the ancients, which is very similar to this, if the accounts given of it by Vitruvius and Pliny can be depended on. The former, it is said, expressly recommends that the lime should be macerated or soured in water, for exactly the same reasons that have been already seen, as it is only by that means, he asserts, that the plaster can be prevented from blistering. His words are theſe: " tunc de albariis operibus eſt explicandum. Id autem erit recte, ſi glebae calcis optime, ante multo tempore quam opus fuerit, macerabuntur. Numque cum non penitus macerata, Jed recens ſumitur—habens latentes crudos cuculos, puſtulas omittit. Qui calculi diſſolvunt et diſpant tederii politiones." Wit. lib. vii. c. 2. t –

The latter points out, it is said, in a still more clear manner, the difference between the quality of the lime, which is necessary for making mortar and plaster:—a certain proof, it is conceived, that the ancients had been very accurate in the observing of facts, as they could have no idea of the reasoning by which those facts might have been corroborated or explained.

furto, calcis fine ferrumine ſuo camenta componuntur.. In trita quoque quo vetuſitor, eo melier. In antiquarum (anti quis) ardumligibus invenitur, ne recentiore trima uteretur redempter; idionulla (nullae) te&toriaeorum rimae faedavere." Plin. Hiſt. lib. xxxvi. c. 23. –

In this passage, the writer strongly contrasts, it is said, mortar (cementa) with plaster (intrita). The first, he contends, by implication, ought always to be composed of lime cum ferrumine ſuo; that is, lime which still retains its gluten, cementing or adhering principle; lime that still keeps or possesses that quality, by which it is enabled to unite detached matters into a solid body, and glue them, as it were, together. In other places of the same work, the author, it is said, describes it as calcis quam vehementiſſima,; lime in its most acrid state; that is, perfectly caustic lime. And this quality he plainly hints, it gradually loses by time, so as to come at length to be sine ferrumine suo: in which state, as it is impossible to become a good firm mortar or cement for building with, those who make use of it as such are severely reprehended. But although the practice of **using old and inert lime for mortar is condemned**, it is immediately added, as has been seen above, that for plaster it is better than new, because it is not so subject to crack in the work. Thus it would seem, that the importance of the souring operation or process, for these different purposes, was well known at an early period, though the principles on which its utility depended, were probably far from being understood.

Thomas Kelly The New Practical Builder and Workman's Companion (1823) Paternoster Row, London

P306 Masonry

Walls… are formed of very small pieces, that they may have a sufficient quantity of, or be saturated with, mortar, which adds greatly to their solidity. **To saturate, or fill up, a wall with mortar, is a practice which ought to be had recourse to in every case, where small stones, or bricks, admit of it. It consists in mixing fresh lime with water, and pouring it, while hot, among the masonry in the body of the wall.**

Bricklaying

WALLS, &c.—The foundation being properly prepared, the choice of materials is to be considered. In places much exposed to the weather, the hardest and best bricks must be used, and the softer reserved for in-door work, or for situations less exposed. **In slaking lime, use as much water only as will reduce it to a powder, and only about a bushel of lime at a time, covering it over with sand, in order to prevent the gas, or virtue of the lime, from escaping. This is a better mode than slaking the whole at one time, there being less surface exposed to the air. Before the mortar is used, it should be beaten three or four times over, so as to incorporate the lime and sand, and to reduce all knobs or knots of lime that may have passed the seive.** This very much improves the smoothness of the lime, and, by driving air into its pores, will make the mortar stronger: as little water is to be used in this process as possible. Whenever mortar is suffered to stand any time before used, it should be beaten again, so as to give it tenacity, and prevent labour to the bricklayer. **In dry hot summer-weather use your mortar soft; in winter, rather stiff**. If laying bricks in dry weather, and the work is required to be firm, wet your bricks by dipping them in water, or by causing water to be thrown over them before they are used, and your mortar should be prepared in the best way. Few workmen are sufficiently aware of the advantage of wetting bricks before they are used; but experience has shown that works in which this practice has been followed have been much stronger than others wherein (p355) it has been neglected. It is particularly serviceable where work is carried up thin, and in putting in grates, furnaces, &c. In the winter season, **so soon as frosty and stormy weather set in,** cover your wall with straw or boards; the first is best, if well secured; as it protects the top of the wall, in some measure, from frost, which is very prejudicial, particularly when it succeeds much rain; for the rain penetrates to the heart of the wall, and the frost, by converting the water into ice, expands it, and causes the mortar to assume a short and crumbly nature, and altogether destroys its tenacity.

P369 Plastering

LIME forms an essential ingredient in all the operations of this trade. This useful article is vended at the wharfs about London in bags, and varies in its price from thirteen shillings to fifteen shillings per hundred pecks —-Most of the lime made use of in London is prepared from chalk, and the greater portion comes from Purfleet, in Kent; but, for stuccoing, and other work, in which strength and durability is required, the lime made at Dorking, in Surrey, is preferred.

The composition, known as PLASTER or PARIS, is one on which the Plasterer very much depends for giving the precise form and finish to all the better parts of his work; with it he makes all his ornaments and cornices, besides mixing it in his lime to fill up the finishing coat to the walls and ceilings of rooms….

The plaster commonly made use of in London is prepared from a sulphate of lime, produced in Derbyshire, and called alabaster. Eight hundred tons are said to be annually raised there. It is brought to London in a crude state, and afterwards calcined, and ground in a mill for use, and vended in brown paper bags, each containing about half a peck; the coarser sort is about fourteen pence per bag, and the finest from eighteen to twenty-pence. The figure-makers use it for their casts of anatomical and other figures; and it is of the greatest importance not only to the plasterer, but to the sculptor, mason, &c.

P371 The Cements made use of, for the interior work, are of two or three sorts. The first is called lime and hair, or coarse stuff; this is prepared in a similar way to common mortar, with the addition of hair, from the tan-yards, mixed in it. The mortar used for lime and hair is previously mixed with the sand, and the hair added afterward. The latter is incorporated by the labourers with a three-pronged rake…

FINE-STUFF, is pure lime, slaked with a small portion of water, and **afterwards well saturated**, and put into tubs in a semi-fluid state, where it is allowed to settle, and the water to evaporate. A small proportion of hair is sometimes added to the fine-stuff. Stucco, for inside walls, called trowelled or bastard stucco, is composed of the fine-stuff above described, and very fine washed sand, in the proportion of one of the latter to three of the former. All walls, intended to be painted, are finished with this stucco.

MORTAR, called gauge-stay; consists of about three-fifths of fine-stuff and one of Plaster of Paris, mixed together with water, in small quantities at a time: this renders it more susceptible of fixing or setting. This cement is used for forming all the cornices and mouldings, which are made with wooden moulds. When great expedition is required, the plasterers gauge all their mortar with Plaster of Paris. This enables them to hasten the work, as the mortar will then set as soon as laid on.

C. F. PARTINGTON, Author of an Historical and Descriptive Account of the Steam Engine; and one of the Lecturers at the London, Russell, Metropolitan, and Surrey Institutions, Mechanics' Institution, &c. &c.

MECHANIC'S COMPANION, OR, THE ELEMENTS AND PRACTICE of CARPENTRY, MASONRY, PAINTING, JOINERY, SLATING, SMITHING, & BRICKLAYING, PLASTERING, TURNING, CONTAINING A FULL DESCRIPTION OF THE TOOLS BELONGING TO EACH BRANCH of BUSINESS; AND copious directions for their Use, with an explanation of The TERMS USED IN EACH ART; and an Introduction to Practical Geometry. Author of The Carpenter's Guide, Joiners' Assistant, &c. PRINTED AND PUBLISHED BY BARTLETT AND HINTON, and sold AT THEIR WAREHOUSE, 17, WARWICK SQUARE, LONDON. 1825

§32. Of Cements. Calcareous cements may be classed according to the three following divisions: namely, simple calcareous cement, water cement, masticks, or maltha

1. Simple calcareous cement includes those kinds of mortar which are employed in land building, and consists of lime, sand, and fresh water. Calcareous earths are converted into quick lime by burning, which being wetted with water, falls into an impalpable powder, with great heat; and if in this state it is beat with sand and water, the mass will concrete and become a stony substance, which will be **more or less perfect according to its treatment, or to the quality and quantities of ingredients**. When carbonated lime has been thoroughly burnt, it is deprived of its water, and all or nearly all of its carbonic acid, much of the water, during the process of calcination, being carried off in the form of Steam.

Limestone loses about four-ninths of its weight by burning, and when fully burnt it falls freely, and will produce something more than double the quantity of powder or slacked lime in measure, that the burnt limestone consisted of. Quicklime, by being exposed to the air, absorbs carbonic acid with less or greater rapidity, as its texture is more or less hard; and this by continued exposure, becomes unfit for the composition of mortar: and hence it is that quick lime made of chalk, cannot be kept for the same length of time between the burning and slacking, as that made from stone.

Marble, chalk, and limestone, with respect to their use in cements, may be divided into two kinds, simple limestone, or pure carbonate of lime, and argillo-ferruginous lime, **which contains from one-twentieth to one-twelfth of clay and oxide of iron, previous to calcination**: there are no external marks by which these can be distinguished from each other, but whatever may have been the colour in the crude state, the former, when calcined, becomes white, and the latter more or less of an ochery tinge.

The white kinds are more abundant, and when made into mortar, **will admit of a greater portion of sand than the brown; consequently, are more generally employed in the composition of mortar**; **but the brown lime is by far the best for all kinds of cement**.
If white, brown, and shell lime recently slacked, be separately beat up with a little water into a stiff paste; it will be found that the white lime, whether made from chalk, limestone, or marble, will not acquire any degree of hardness; the brown lime will become considerably indurated, and the **shell lime will be concreted into a firm cement, which, though it will fall to pieces in water,** is well qualified for interior finishings, where it can be kept dry.

It was the opinion of the ancients, and is still received among our modern builders, that the hardest limestone furnishes the best lime for mortar; but the experiments of Dr. Higgins and Mr. Smeaton, **have proved this to be a mistake**; **and that the softest chalk lime, if thoroughly burnt, is equally durable with the hardest stone-lime, or even marble: but though stone and chalk lime are equally good,** under this condition, there is a very important practical difference between them, as the chalk lime absorbs carbonic acid with much greater avidity: and if it is only partially calcined, on the application of water it will fall into a coarse powder, which stone lime will not do.

For making mortar, the lime should be immediately used from the kiln, and in slacking it, no more water should be allowed than what is just sufficient: and for this purpose. Dr. Higgins recommends lime water. The sand made use of, should be perfectly clean; if there is any mixture of clay or mud, it should be divested, of either or both, by washing it in running water. Mr. Smeaton has fully shown by experiment, that mortar, though of the best quality, when mixed with a small proportion of unburnt clay, **never acquires that hardness**, which without this addition, **it speedily would have attained**. If sea sand is used, it requires to be well washed with fresh water, to dissolve the salt with which it is mixed, otherwise the cement into which it enters, **never becomes thoroughly dry and hard**: the sharper and coarser the sand is, the stronger is the mortar, also a less proportion of lime is necessary. It is therefore more profitable to use the largest proportion of sand, as this ingredient is the cheapest in the composition.

The best proportion of lime and sand in the composition of mortar, is yet a desideratum. - It may be affirmed in general, that no more lime is required to a given quantity of sand, than what is just sufficient to surround the particles *[Gilmore disputed this and most military engineers during 19thC offered mix proportions that did more than this, whilst sometimes paying lip service to the* *principle],* or to use the least lime so as to preserve the necessary degree of plasticity *[this was generally in the hands of masons and bricklayers on site, who tended to want more lime than was simply sufficient to fill the voids in the sand].*

Mortar in which sand predominates, requires less water in preparing, and therefore sets sooner; it is harder and less liable to crack in drying, for this reason, that lime shrinks greatly in drying, while sand retains its original magnitude. We are informed by Vitruvius, lib. 2. c. 5. that the Roman builders allowed three parts of pit sand, or two of river or sea sand, to one of lime; but by Pliny, (Hist. Nat, lib. xxxvi.) four parts of coarse sharp pit sand, and only one of lime *[both may have been counting the lime proportion before slaking, as Pasley (below, 1826) says should be always the case, though Vitruvius explicitly says 1 part of the slaked lime, perhaps as intended, perhaps because of the assumptions of translators. Pit sand was assumed to contain clay and loam, which would react with the lime].*

The general proportion given by our London builders, is one hundred weight and a half, or thirty-seven bushels of lime and two loads and a half of sand; but if proper caution were taken in the burning the lime, the quality of the sand, and in tempering the mortar be admitted. Mr. Smeaton observes, that there is scarcely any mortar, that if the lime be well burnt, and the composition well beat in the making, but **what will require two measures of sand, to one of unslacked lime**; and it is singular, that **the more the mortar is wrought or beat, a greater proportion of sand may be admitted.** He found that by good beating, the same quantity of lime would take in one measure of tarras, and three of clean sand, which seems to be **the greatest useful proportion**. *[Smeaton suggesting this whilst usng Blue Lias lime; the relative leaneness of the lime:sand proportion is rendered successful by the addition of trass pozzalan]*. **Dr. Higgins found that a certain proportion of coarse and fine sand, improved the composition of mortar;** the best proportion of ingredients, according to experiment made by him, are as follow, by measure:

(Higgins proposed 1:7, or even 1:8, but by weight. He also promoted the addition of a high proportion of ground bone).

…The mortar should be made under ground, then covered up and kept there for a considerable length of time, the longer the better *[Higgins, Treussart and others asserted the opposite]*; and when it is used, it should be beat up afresh *{this is coarse stuff, not simply slaked lime].* This makes it set sooner, renders it less liable to crack, and more hard when dry.

The stony consistence which it acquires in drying, is owing to the absorption of carbonic acid, and a combination of part of the water with the lime: and hence it is that lime that has been long kept after burning, is unfit for the purpose of mortar; for in the course of keeping, so much carbonic acid has been imbibed, as to have little better effect in a composition of sand and water, than chalk or lime-stone reduced to a powder from the crude state would have in place of it.

Grout is mortar containing a larger proportion of water than is employed in common mortar, so as to make it sufficiently fluid to penetrate the narrow irregular interstices of rough stone walls.

Grout should be made of mortar that has been long kept and thoroughly beat; as it will then concrete in the space of a day: whereas if this precaution is neglected, it will be a. long time before it set, and may even never set *[others indicate that it should be made fresh and as a 'hot mix', poured whilst still slaking, see below].*

Mortar made of pure lime sand and water, may be employed in the linings of reservoirs, and aqueducts, provided that it has sufficient time to dry; but if the water be put in while it is wet, it will fall to pieces in a short time, and consequently, if the circumstances of the building are such as render it impracticable to keep out the water, it should not be used; there are, however, certain ingredients put into common mortar, by which it is made to set immediately under water, or if the quick lime contain in itself a certain portion of burnt clay, it will possess this property. This is all that is necessary to say under this head; what relates to mortars employed in aquatic buildings will be treated of under Water cements.

From the friable and crumbling nature of our mortar, a notion has been entertained by many persons, that the ancients possessed a process in making their mortar, which has been lost at the present day; but the experiments of Mr. Smeaton, Dr. Higgins, and others, have shown this notion to be unfounded: and that nothing more is wanting, than that **the chalk, lime-stone, or marble, be well burnt and thoroughly slacked immediately, and to mix it up with a certain proportion of clean, large-grained, sharp sand, and as small a quantity of water as will be sufficient for working it; to keep it a considerable time from the external air, and to beat it over again before it is used: the cement thus made will be sufficiently hard.**

The practice of our modern builders is to spare their labour, and to increase the quantity of materials they produce, without any regard to its goodness; **the badness of our modern mortar, is to be attributed both to the faulty nature of the materials, and to the slovenly and hasty methods of using it.** This is remarkably instanced in London, where the lime employed is chalk lime, indifferently burnt, conveyed from Essex or Kent, a distance of ten or twenty miles, then kept many days without any precaution to prevent the access of external air: now in the course of this time, it has absorbed so much carbonic acid as nearly to lose its cementing properties; and though chalk lime is equally good with the hardest lime-stone, when thoroughly burnt, yet by this treatment, when it is slacked, it falls into a thin powder, and the core or unburnt lumps are ground down, and mixed up in the mortar, and not rejected as they ought to be. The sand is equally defective, consisting of small globular grains, containing a large proportion of clay, which prevents it from drying, and attaining the necessary degree of hardness. **These materials being compounded in the most hasty manner, and beat up with water in this imperfect state, cannot fail of producing a crumbling and bad mortar** *[Does he mean hot-mixed?].* To complete the hasty hash, screened rubbish, and the scrapings of roads, also are used as substitutes for pure sand.

How very different was the practice of the Romans! The lime which they employed, was perfectly burnt, the sand sharp, cleaned, and large grained: these ingredients were mixed in due proportion with a small quantity of water, the mass was put into a wooden mortar, and beat with a heavy wooden or iron pestle, till the composition adhered to the mortar; being thus far prepared, they kept it till it was at least three years old. *[Did they really? For other than fine stuccos?].* **The beating of mortar is of the utmost consequence to its durability,** and it would appear that the effect produced by it, is owing to something more than a mere mechanical mixture.

Water cements are those which are impervious to water, **generally made of common mortar, or of pure lime and water, with the addition of some other ingredient which gives it the property of hardening under Water.** For this purpose, there are several kinds of ingredients that may be used. That known by the name of pozzolana, which is supposed to consist of volcanic ashes thrown out of Vesuvius, has been long celebrated, from the early ages of the Romans, to the present day. It seems to consist of a ferruginous clay, baked and calcined by the force of volcanic fire; it is a light, porus, friable mineral, of a red colour. The cement employed by Mr. Smeaton, in the construction of the Eddystone light-house, was composed of equal parts by measure, of slacked aberthaw lime and pozzolana; this proportion was thought advisable, as this building was exposed to the utmost violence of the sea; but for other aquatic works, as locks, basins, canals, &c. a composition made of lime, pozzolana, sand, and water, in the following proportion: viz. **two bushels of slacked aberthaw lime, one bushel of pozzolana, and three of clean sand, has been found very effectual.**

Mr. Dossie, in the second volume of the Memoirs of Agriculture, gives the following method of making mortar impenetrable to moisture, acquiring great hardness, and exceedingly durable, similar to that used by the ancients, which was discovered by a gentleman of Neufchatel: take of unslaked lime and of fine sand, in proportion of one part of the lime to three parts of the sand, as much as a labourer can well manage at once, and then adding water gradually, mix the whole well together with a trowel till it be reduced to the consistence of mortar. Apply it immediately, while it is hot, to the purpose, either of mortar, as a cement to brick or stone, or of plaster to the surface of any building. It will then ferment for some days in dry places, and afterwards gradually concrete, or set, and become hard: but in a moist place it will continue soft for three weeks or more; though it will at length attain a firm consistence, even if water have such access to it, so as to keep the surface wet the whole time. After this, it will acquire a stone-like hardness, and resist all moisture.

The perfection of this mortar depends on the ingredients being thoroughly blended together, and the mixture being applied immediately after to the place where it is wanted. The lime for this mortar must be made of lime-stone, shells, or marl; and the stronger it is, the better the mortar will be; besides, the lime should be care fully kept from the access of air or wet, otherwise, by attracting moisture, it will lose proportionably that power of acting on the sand, by which the incorporation is produced. It is proper also to exclude the sun and wind from the mortar for some days after it is applied, that the drying too fast may not prevent the due continuance of the fermentation, which is necessary for the action of the lime on the sand.

When a very great hardness and firmness are required in this mortar, the use of skimmed milk instead of water, either wholly or in part, will produce the desired effect, and render the mortar extremely tenacious and durable.

M. Loriot's mortar, the making of which was announced by order of His Majesty at Paris in 1774, is made in the following manner: take one part of brick-dust finely sifted, two parts of fine river-sand skreened, and as much old slaked lime as may be sufficient to form mortar with water in the usual method, but **so wet as to serve for the slaking of as much powdered quick-lime, as amounts to one-fourth of the whole quantity of brick-dust and sand. When the materials are well mixed, employ the composition quickly,** as the least delay may render the application of it imperfect or impossible.

Another method of making this composition is, to **make a mixture of the dry materials; i.e. of the sand, brick-dust, and powdered quick-lime, in the prescribed proportion, which mixture may be put in sacks, each containing a quantity sufficient for one or two troughs of mortar. The above mentioned old slaked-lime and water being prepared apart, the mixture is to be made in the manner of plaster, at the instant when it is wanted, and is to be well chafed with the trowel.** With respect to this method, Dr. Higgins observes, that M. Loriot corrects the bad quality of the old and effete lime, which constitutes the basis of his mortar, and which has regained a part of the fixed air that had been expelled from it, by the addition of fresh and non-effervescent lime, hastily added to it at the time of using the composition, which must undoubtedly improve the imperfect mass. And he adds, that when an ignorant artist makes mortar with whiting instead of lime, he can mend inconsiderably by adding lime to it; but his mortar will still be defective in comparison with the best that can be made, by reason of the old slaked-lime or whiting; this, on repeated trials, he has found to be the true state of the case.

Dr. Higgins has made a variety of experiments in consequence of the modern discoveries relating to carbonic acid or fixed air, for the purpose of improving the mortar used in our buildings. According to this author, the perfection of lime prepared for the purpose of making mortar, consists chiefly in its being totally deprived of its fixed air. On examining several specimens of the lime commonly used in building, he found that it was seldom or never sufficiently burned, for they all effervesced, and yielded more or less fixed air, on the addition of an acid, and slaked slowly in comparison with well burned lime. Dr. Higgins also relates some experiments, which shew how very quickly lime imbibes fixed air from the atmosphere, on its exposure to which it by degrees soon loses those characters which chiefly distinguish it from mere lime-stone or powdered chalk, by soon attracting from thence that very principle, to the absence of which it owes its useful quality as a cement, and which had before been expelled from it in the burning. Hence he concludes, **that as lime owes its excellence to the expulsion of fixed air from it in the burning, it should be used as soon as possible after it is made, and guarded from exposure to the air as much as possible before it is used**. It is no wonder, therefore, he says, that London mortar is bad, if the imperfection of it depended solely on the badness of the lime; since the lime employed in it is not only bad when it comes fresh from the kiln, because it is insufficiently burned, and the air has access to it, but **becomes worse before it is used, by the distance and mode of its conveyance**, and when slaked, is as widely different from good lime as it is from powdered chalk.

For a similar reason, every other cause which tends to restore to the lime, the fixed air of which it had been deprived in the burning, must depreciate it. It must receive this kind of injury, for instance, from the water, so largely used, first, in slaking the lime, and afterwards in making it into mortar, if that water contains fixed air, from which few waters are perfectly free, and which will "greedily be attracted by the lime *[but not if the slaked lime or coarse stuff is protected from the air]*. The injury arising from this cause is prevented by the substitution of lime-water, so far as it may be practicable or convenient. From other experiments, made with the view of ascertaining the best relative proportions of lime, sand, and water, in the making of mortar, it appeared that those specimens were the best that contained **one part of lime in seven of the sand** *[by weight, not volume]*; for those which contained less lime, and were too short whilst fresh, were more easily cut and broke, and were pervious to water; and those which contained more lime, although they were closer in grain, did not harden so soon, or to so great a degree, even when they escaped cracking by lying in the shade to dry slowly. It appeared farther, that mortar, which is to be used where it must dry quickly, ought to be made as stiff as the purpose will admit, or with the smallest practicable quantity of water, and that mortar will not crack, although the lime be used in excessive quantity, provided it be made stiffer, or to a thicker consistence than mortar usually is. Dr. Higgins has also shewn, that though the setting of mortar, as it is called by the workmen, chiefly depends on the desiccation of it, yet its induration, or its acquiring a stony hardness, is not caused by its drying, as has been supposed, but is principally owing to its absorption of fixed air from the atmosphere, and is promoted in proportion as it acquires this principle, the accession of which is indispensably necessary to the induration of calcareous cements. **In order to the greatest induration of mortar, therefore, it must be suffered to dry gently and set; the exsiccation must be effected by a temperate air, and not accelerated by the heat of the sun or fire; it must not be wetted soon after it sets; and afterwards it ought to be protected from wet as much as possible, until the mortar is**

finally placed and quiescent; and then it must be as freely exposed to the open air as the work will admit, in order to supply acidulous gas, and enable it sooner to sustain the trials to which mortar is exposed in cementing buildings, and other incrustations.

Dr. Higgins has also inquired into the nature of the best sand or gravel for mortar, and into the effects of bone-ashes, plaster, powder, charcoal, sulphur, &c, and he **deduces great advantages from the addition of bone-ashes**, in various proportions, according to the nature of the work for which the composition is intended.

This author describes a water cement or stucco, of his own invention, for incrustations internal and external, exceeding, as he says, Portland stone in hardness, **for which he obtained His Majesty's letters patent**. As for the materials of which this is made; drift sand or quarry sand, or, as it is commonly called, pit sand, consisting chiefly of hard quartose flat-faced grains, with sharp angles, the most free from clay, salts, and calcareous, gypseous, or other grains less durable than quartz, containing the smallest quantity of heavy metallic matter, and admitting the least diminution in bulk by washing, it is to be preferred to any other. ….

Fresh made mortar, if kept from the air underground in considerable masses, may be preserved a great length of time without injury, and the older it is before it is used, the better, the builder taking the precaution to beat it up afresh previous to using it, for it not only sets sooner, but acquires a greater degree of hardness, and is less apt to crack. A fact related by Mr. Smeaton, remarkably illustrates these points. Having had occasion to take up a large flat stone of a close grain, of about five feet square, that had probably lain above a century at the bottom of a malt cistern, he found that it had been well bedded in mortar, which had become coagulated to the consistence of cheese; but having never come to a perfect dryness, it so far retained its natural humidity, that he found it might, with some pains, be beaten up to mortar without any addition of water; and afterwards, being suffered to dry in the air, it set to a stony hardness, and appeared as good mortar as any which that part of the country could produce.

Pliny informs us, that the ancient Roman laws prohibited builders from using **mortar** that was less than three years old; and to this circumstance he expressly attributes the remarkable firmness of the oldest buildings in the city.

A similar custom prevailed, and indeed still prevails in Vienna, requiring the **mortar** to be a year old before it is employed. But there is nothing which shews, in so striking a point of view, the advantage and necessity of beating mortar, and the effect produced is owing to something more than a mere mechanical mixture of ingredients, as the preparation of grout, or liquid mortar.

This differs from common mortar, only in containing a larger quantity of water, so as to be sufficiently fluid to penetrate the narrow irregular interstices of rough stone walls, and is generally made by diluting common mortar with water, either cold or hot. It not unfrequently happens, that this refuses to set, and at all times it is a long while in acquiring the proper hardness; but if, instead of common mortar, that which has been long and thoroughly beaten is employed, the grout will set in the space of a day, and soon after acquires a degree of hardness much superior to what is made in the common manner. Mortar which sets without cracking, whether this be owing to the due proportion of sand, or to the slow exhalation of the water from mortar containing less sand, never cracks afterwards, whatever its faults, in other respects, may be. As it is the lime paste, and not the sand, which contracts and produces fissures in drying, so the more sand there is in the composition, the less the cracks will be seen. Mortar which is liable to crack, becomes irreparably injured by frequent alternations of wetting and freezing ; for the water imbibed by the smallest fissures, dilating as it congeals, loosens its whole texture. Where, however, it is composed of seven parts of sorted sand, to one of lime, it is not disposed to crack.

Plasterers, who use a finer kind of mortar, made of sand and lime, observe that their stucco blisters, if it contain small bits of unslaked lime, and **as smoothness of surface is with them of more consequence than excessive hardness,** they take care to secure the perfect slaking of their lime by allowing sufficient time for the imperfect parts to be penetrated by the moisture. The **bricklayers, trusting, perhaps, more to the judgment of the plasterers, in this respect, than to their own, and considering it very convenient to slake a large quantity of lime at once, follow the same practice, without caring for or apprehending the real fact, that mortar, when exposed to the air, is worse for every hour it is kept, and that they are taking such measures as will prevent it from ever acquiring that degree of hardness in which its perfection consists**. Among the circumstances which contribute to the speedy ruin of modern buildings, it may also be observed, that mortar made with bad lime, and a great excess of it, is used with dry bricks, and not unfrequently with warm ones. These immediately imbibe or dissipate much of the water, and as the cement approaches nearer to be dry, whilst it is still liable to be displaced by the percussions of the workmen, render it **little better than equivalent to a mixture of sand and powdered chalk.** To make strong work, the bricks ought to be soaked in lime-water, and freed from the dust with which they are commonly covered. By this means the bricks are rendered closer and harder, the cement, by setting slowly, admits the motion which the bricks receive when the workman dresses them, without being impaired, and it adheres and indurates more perfectly. This steeping of the bricks is an imitation of the practice of the plasterers, who always wet the wall before they commence their work, because they know the cement will not otherwise adhere. This ought to be done as long as the wall is thirsty, and lime-water is the most proper liquid they can use. **The same advantage that attends the soaking of bricks, would attend the soaking of bibulous stones in lime-water**. Mortar made with sand containing one-seventh or one-eighth of fat clay, moulders in winter like marl; a circumstance which proves the propriety of freeing from clay the sand used in mortar. The washing performed for this purpose, would be found a very cheap operation, even in cities, if the water which carries off the clay be directed into a receptacle where it may be depurated by subsidence for repeated use.

Chalk lime may be easily prepared, so as to be fully equal if not superior to stone lime. The reason why this is not generally thought to be the case, probably is, that not being of so close a texture, it is sooner spoiled by the absorption of carbonic acid, when exposed to the atmosphere after it is made. A cask of chalk lime should therefore never be opened till the moment it is to be slaked, and the greatest expedition should be used in the slaking, and in the making and applying the mortar to use. In the quiescent air of a room, a pound avoirdupois, of chalk lime, becomes two ounces and a half heavier in two days ; and nearly the whole of this increase of weight, consists of the carbonic acid which it has imbibed from the atmosphere. **The fittest water for making mortar, is rainwater; river water holds the next place; land water the next; spring water the last; sea water and all waters noticed medicinally or otherwise, for their saline contents, ought never to be used for this purpose *[this probably he first mention of the contribution of water source to mortar quality in any hierarchical order of preference].***

Masonry

The chief business of a mason is, **to make the mortar**; raise the walls from the foundation to the top, with the necessary retreats and perpendiculars; to form the vaults, and employ the stones as delivered to him. When the stones are large, the business of chewing or cutting them belongs to the stone-cutters, though these are frequently confounded with masons: the ornaments of sculpture are performed by carvers in stone, or sculptors.

L J Vicat Recherches Experimentales sur Les Chaux de Construction, les Betons et les Mortiers Ordinaires 1818 Goujon Paris. Translation Emma Michel 2016.

p1 Different types of limes in construction

p1 We can distinguish the different limes in construction between fat limes and lean limes. There are some in which the volume measured in unslaked powder can triple with ordinary slaking and others which can only expand to one and one fifth. However in between those extremes there are numerous other 'average' limes that when mixed, expand to two, sometimes more than two and less than three times for one. We are aware of the difficulty of tracing a line to separate the fat limes from the lean ones.

(footnote) M. Faujas de Saint-Fond (Recherches sur les pouzzolanes, la chaux et les mortiers) uses the term 'quicklime' for the lime we have been calling 'lean' lime. This denomination is inappropriate because we mean by quicklime, a lime that has not yet been slaked, whatever its nature.

P 5- 6
(…) Hydraulic limes are not only precious for the making of concretes but also because they can be – when mixed with ordinary sand – excellent mortars in construction above ground despite the opinion of Mr. Sage **who thinks they should be banned for the particular reason that we do not know the quality nor the quantity of the ingredients they are composed of.**

P10-11 **Chapter 2 : des pierres à chaux : literally, stones that can be made into limes.**

Most of the treatises on the art of building offer incorrect or sometimes completely wrong notions on the stones (to make lime). Vitruvius differentiates two types of stones, the white and hard stone, to make the proper lime for construction and the others, porous, for plastering.
Belidor repeats from Vitruvius that to obtain good limes, we need to use hard, heavy and white stones and the best stone to use is marble.
M. Faujas de St-Fond separates two types of limes, quicklime and fat lime. The first one, he says, comes from a pure, healthy limestone, crystalline when it breaks and which is very close to spath. Fat or common limes are made with soft stones, often marled.
M. Sage states that the good quality of lime depends partly on the purity of the stone we burn and that the lime we obtain from marble is preferable to the lime we obtain from other common stones.
M. Rondelet says the best lime is made from the hardest, heavier stones, the ones with fine grains, homogenous and of very compact density.
The English engineer Smeaton and Dr. Higgins state however that from chalk to marble, the two extremes of stones (to make lime) in terms of hardness gives each one as good a lime for the making of mortar. Smeaton makes experiments with trass and Higgins with common limes.

Most of these opinions seem contradictory only because they are presented without restrictions. Some of them are completely opposed to indisputable facts. It is certain that neither the colour, the texture, the hardness nor the specific weight are sufficient indications on the quality of limestones

P12 In what we call purity of the stone, M. Rondelet has contradicted himself after having said that in all Italy, the lime was very good because almost always made from a pure marble but he also states the Cretage lime was excellent and contains, he adds, a lot of iron and manganese (…).

P15 Chapter 3 <u>Nature of lime, the action of fire on limestone.</u>
Limestone changes colour while it is burning, the fire develops from within a

dark shade, sometimes black, sometimes grey, bluish or greenish until it becomes white or orange which are the normal colours of lime when cooked at this temperature. The lime to be burnt has to fuse promptly and completely with the water. When we exceed the calcination time (*I'm not sure of this translation Lorsqu'on outre—passe le terme ordinaire de la calcination*), lime becomes lazy, meaning, it acquires the property of remaining from a few hours to several days in water, without slaking. *(It is overburnt)*.

P16 Chapter 4 : Three ways to slake lime and resulted phenomena
First method: **lime out of the kiln is thrown in a suitable amount of water**, cracks with noise, swells, produces a great amount of scorched vapour, is slightly caustic and melts into a thick gruel. In this state, we call it *chaux fondue* (melted lime) or *chaux coulée* (flowed lime, idea of liquid). This method is widely used, **but the stonemasons abuse it, they drown the lime in great amount of water until the lime is reduced to a milky consistency and then pour it into permeable pits where it dries up and loses its qualities.**
Common, very fatty limes, slaked into a thick gruel, give in volume up to 3 and one tenth for one; there are hydraulic limes that can only give one and one fifth. (…) M. Sage says if we throw water a second time right after the lime has reacted to the first amount of water with noise, it will create a noise similar to a hot iron soaked in water. This fact is true, but this alchimist doesn't seem to have noticed the consequences that are important and known to the masons. **The hot bits, non-fused and touched by the water will divide badly and the gruel will have grains.** The cooler the water is, the more sensitive it is on lime, especially the fat limes. **When we want to obtain a perfectly melted lime, we have to throw the water in one go, or add some more when the lime has cooled down.**

Second method :

Quicklime immersed in water for a few seconds and then removed before the beginning of the fusion, bursts with noise, diffuses scorched vapours and becomes powder. We call it, lime slaked by immersion. **It can be kept a long time if protected from humidity.** This lime does not get warm again when it is wetted. (…) Common fat limes are reduced with difficulty into fine powder with Lafaye's method (1777 – *recommending this method for slaking lime for construction mortars*) if we only break the limestones in the size of an egg before immersion as some authors state and let them fuse. **More than half fall into peas size fragments, and these fragments once cooled down, can retain water for a long time without turning into a paste** (mortars made this way always seems badly crushed and are subjected to cracking). But we resolve this problem in breaking the limetone into nut size before the immersion and putting them right after into boxes, the heat is then trapped, a great amount of evaporated water goes then back to the lime which can then dissolve better.

(footnote : it is a mistake to think that Lafaye's method is inconvenient and difficult to achieve. To tell the truth, you will need sheds and boxes to receive the powdered lime but the cost of the slaking is much less than we'd think. On the work on the bridge de Souillac, we only needed 168 days to slake by immersion 128m3 of quicklime. Water was taken from a well on site by the use of a powerful pomp.)

<u>Third method :</u>
Quicklime submitted to the action of the atmosphere falls into a very fine powder, with a slight emanation of heat but without any visible vapour.

These are the three methods, the first one is widely used, the second was only tried as an experiment on diverse works and the third was banned due to the loss of energy when mixed.

Hassenfratz M (1825) Traité théorique et pratique de l'art de calciner la pierre calcaire et de fabriquer toutes sortes de mortiers. Translation, E Michel 2016.

SECOND PART: USE OF LIME

Preliminary stages we subject the lime to and the differences of various limes

p129 There exist, in many countries, monuments which have resisted the destructive action of time. The mortars in almost all these antique ruins have acquired such hardness that sometimes the stones themselves break before the mortars do. Observers believe this hardness in the mortars is the result of the way they were made and particularly of how the lime was slaked.

So everyone rushed to consult the works of the Ancients, in which a few details were given, whether on lime slaking or on the preparation of mortars. We noticed, attentively, the small differences in the description of these preparations and we may think these differences explain the (good) quality we observe in those mortars and the hardness they attained.

Pliny, Vitruvius, Saint Augustin and others reported two methods of slaking, the first, by immersion, fusion and marceration and the second by aspersion, imbibition, air slaking and natural pulverisation. We thought to attribute to this second method to prepare lime, which is not usually (p131) employed, the good quality mortar we obtain, and Loriot expressly recommends this method of slaking in his mortar compositions.

(A paragraph on what Vicat says are the three ways to slake lime then talks about Ancient buildings erected without mortar).

Some observers doubt, with reason, the superiority we attribute to the Roman mortars over the ones we employ today. They notice that the constructions we focus on as those of good quality Ancient mortars are, in some ways, anomalies, exceptions to the ordinary constructions. Only a few survived; how many disappeared (p131) from the surface of the earth! The buildings which survived were, probably, made with mortars that consolidated and of which the hardness increased with time. The other constructions could have been built with 'light' mortars, soft and less resistant. We are led to believe that their short lives were mostly due to the bad quality and poor solidity of the mortars. *[by Vicat]* Pliny even complains in the book XXXVI of the bad quality of mortars, which cause houses to collapse.

This variation in the hardness in mortars, built from unchanging principles and methods can still be observed today. We could still wonder what is this good quality and hardness in the mortar we observe in several antique monuments.

It would be easy to say that the cause of the three ways of lime slaking - indicated by Pliny, Vitruvius, St Augustin etc – is exclusively related to the nature of the lime itself. That several limes, slaked by immersion, fusion and maceration can be conserved a long time in pits; that many of them get better with time and should be used after a few years. However, we should not conclude this method of slaking can be applied to all limes.

Grignon states, page 351 of his *Mémoires de Physique*,

p132 that a 'procuror' of the Bourbonne Benedictines, melted and marcerated a big quantity of lime several months before starting to build. But was quite surprised when he discovered that the melted lime - destined for the mortar - was in the state of a solid and hard mass, good to use as rubble.

In this country (he probably means region, not country), as well as in the vicinity of Metz, where the lime has similar properties, we are accustomed to employ fresh lime just made and to slake it by aspersion or instantaneous imbibition. It falls into dust and we make a mortar by adding water to the powdered slaked lime to reduce it to a paste. When slaked by immersion and maceration, the lime should be used in the following eight days of its slaking otherwise it hardens and loses its property to bond, gather, attach and adhere stones together.

In the areas of Padua and Montélimart, the stone we burn produces a lime, in a very short time, which hardens quickly. This lime therefore could not be slaked by immersion or maceration in mass. We need, if we wish to conserve it, to only slake it by aspersion and imbibition. *[to a dry powder]*

The three methods to slake lime, mentioned by P, V and A etc are necessarily inherent to the nature of the lime and that not all lime stones can be slaked by immersion and maceration to be conserved. Some of them can conserve their properties by only slaking by aspersion, imbibition or by letting them fall into dust naturally. This method of slaking is still used today, in the Indies, in Europe and in the countries where lime hardens (p133) quickly. It seems we should consider this particular method to slake lime, that Loriot, Delafaye and others, indicate as a way to obtain a better mortar and that we should consider this method for the limes that require it. However, each method of slaking can be more or less beneficial when applied to each type of lime according to the purpose and the use we wish to make them.

(…) The Romans were so convinced of the enhancement of the macerated lime, acquired by time in the pits, that Pliny states Ancient laws forbade the people from using the lime unless it was three years of old. And that is the reason why the coatings and daubs (enduits) were not damaged with cracks and crevices. *[for plaster finishes and limewash only].*

P 134 Fat lime can be easily conserved after being slaked by immersion and maceration and improves by being conserved in a state of paste; it also acquires in many circumstances, great advantages by being slaked spontaneously and conserved in barrels. Thus, made into mortar mixed with quartz sand, lime can reach a greater hardness by being slaked spontaneously instead of fusion in water whether the mortars were placed in a humid area, in a covered place, or on a roof. Spontaneous slaking is (p135) also advantageous when employed for the making of 'béton,' meaning mortars that harden under water.

P137

We saw previously lime can be slaked in three methods, 1. by natural efflorescence (falling into powder), 2. by aspersion (p138) 3. by immersion, fusion and maceration. In the first two cases, some humidity in the air and water penetrate into the stone, combine with the lime, solidify and let escape all the heat liquid water and solid water have. Each particle of water, by coming between the lime particles, to unite intimately with each other, pushes the lime molecules from each other, destroys their cohesion, making them detach and separate themselves from the mass. It is how a piece of solid lime becomes a powdery substance.

In the third case, the first molecules of water, after unified and solidified with lime molecules, attract in return new molecules of water that gather to the first ones. The mass then takes the consistency of a paste and the excess of water dissolved from the lime allows it to turn into a liquid state.

In the slaking by immersion, fusion and maceration, two successive operations must be distinguished. The first how lime reacts to water and by the action of the mass, forces the water to solidify with lime. The second, the action of water on the lime hydrate, increased by the water mass, transforms the hydrate into a liquid. In the first case, we have a dry hydrate lime and in the second water lime or a dissolution, a mix in a pasty state, of lime hydrate in water. The pasty state that lime acquires in the maceration can be seen as an 'in-between' state from the two extremes of water combined with dry lime and liquid lime dissolved in water. It is, if you like, lime hydrate combined with lime water.

P144 Talks how Delafaye explains slaking lime.

P150
We can use several methods to slake lime - by dissolving in water (délaiement), immersion and maceration. The most employed method consists in digging in the ground a receiving basin and to form on top of the first one, a second basin destined for the slaking. We link the two basins with a canal that we can open and close at will. The bottom of the slaking basin is solid built with planks or stones, bricks or tiles. The quicklime is placed in it, covered by water, it heats up and dissolves. We stir with wooden tools (rabots = can't find any translation) to facilitate the fusion, break up the big lumps and dissolve it completely.

A few builders add water incrementally to maintain the lime in a liquid paste. Several advise to be careful in adding too little or too much water. They say that too much water drowns the lime and that too little burns it, dissolves its particles and reduces it to ashes. It is difficult to know in advance or without previous experience on the exact quantity of water needed, because this quantity depends on the nature of the lime. The purer , the fatter it is, the more water it needs. The more foreign substances it contains, the less it needs. Usually, the necessary quantity of water varies from one to three parts (of water) for one of lime.

P151 It is essential to deliver all at once the quantity of water necessary to slake lime because cold water reaching non-fused parts, delays and stops the fusion. After being certain that the lime is dissolved, the connection between the two basins is opened. In order to pour into the lower basin, we continue to stir until the slaking basin is completely empty, after which, the passage is closed. The same operation is repeated until the receiving basin is full or we have slaked all the lime we needed. During the discharge from one basin to another, all lumps and foreign bodies are kept in the slaking basin, as they will damage the quality of the lime, by placing a grid in the canal.

P152
Some builders advise to use fresh lime right after its slaking, others recommend that the lime rests a few years in a receiving basin. Vitruvius and Palladio share this view, the latter, though, does not mention anything about basins. The lime of Padua, he states, should be used right after its fusion, otherwise if kept, the lime burns, consumes and hardens and would be unusable.

If several limes, as for example the ones with pure calcareous carbonates, can be conserved in basins and improved with time as Vitruvius, Palladio, Philibert Delorme believe, it would be dangerous to recommend this conservation (p153) as a general method because several limes, such as the ones from Padua, Montélimart, Bourbonne etc would harden in a basin and could therefore not be used.

(…) Philibert Delorme proposed, in imitation of the Ancients, to dig a hole and to place the lime out from the kiln in this basin, covering it with a layer of sand thick enough to prevent the escape of steam and to throw on water in great quantities lime to dissolve the lime and not burn it. Seal the cracks at the surface of the sand to prevent the escape of 'smoke'. . Because it is essential that the sand should not be mixed with the lime, we place in between them withy panels *(claies d'osier)* or straw or cane mats. When we wish to use it, we uncover it and (p154) take the quantity needed and cover it back up immediately. The rest under the sand is conserved as long as needed and without being altered. However, this lime needs to have at least fifteen days of fusion before use, the older it is, the better the quality.

(…) Paris builders usually count two parts of slaked lime paste for one part of quicklime. This proportion is variable, there are light and impure limes which make barely one part slaked lime paste for one part quicklime. Some others, such as fat limes, produce three parts and a half of pasty lime for one of quicklime.

(…) dry lime fused by immersion, as practiced in Padua, Montélimart etc gives no inconvenience to this process. However, this slaking method, or dry fusion, is related to the burning of the lime. As to what we call 'drowning', which is another way of slaking, in a bigger quantity of water needed to conserve it, after (p 155) being slaked. This (excessive) quantity does not at all prevent complete fusion of the lime
But, because the temperature is not as high, the slaking is slower and this excess of water will soon slowly drain into the ground in which the basin was dug, and the lime will reach the degree of humidity and stiffness at which it should to be used.

If slaked with too little water, the temperature becomes too high, lime flows with more difficulty into the second basin and we have to add more water to facilitate the flow, which delays and stops the fusion. It is better, then, to add a bit too much water rather than less. However, the best would be to use the necessary amount of water.

We find in the Encyclopedia another method to slake lime by immersion and maceration which is based on a prejudice. It needs two basins placed and prepared just as described previously, the lime run into the lower basin. When all the lime is received, we will throw as much water again as we used to slake it and will stir it and let it rest for 24 hours, which will give it time to settle *(Arts et Métiers de l'Encyclométhodique, tome 1 p 462*),
(p156) after which we will find the lime covered in a greenish water which will contain all its salts and we will put this into barrels. After this, we will get rid of the lime at the bottom of the basin, which would have became unusable, and will slake some new lime with this water saved in the barrels. This preparation makes the lime better, perhaps, because it contains twice as much salt. This is where we end the description.

This process is based on the idea that lime has salt, and that it is those salts which convey the good quality and efficacy. It is also on the same idea, that we mix a quantity of water with the lime for it cannot be burnt or drowned because in the first case, salts decompose and disappear and in the second case, salts, dissolved by the abundant amount of water infiltrate with the water through the basin walls *(into the ground)*.

Even if this supposition should not be taken seriously by educated men, we ought, however, to discuss it for a moment as a favor to the numerous entrepreneurs who truly believe in the existence of these salts.
But we have to repeat ourselves in saying we should always employ in one go, all the necessary water needed for the slaking and only this quantity. All the analysis of pure limes, made until now by Vauquelin, Thenard, Klaporth and other distinguished chemists, only found one result which is one only substance: lime without mixtures (p157) or combinations of any types of salt.

The water that dissolved the lime and which we collected in a basin were analyzed and only gave water and lime. At last, the vapour which escapes from the lime when it fuses was also analyzed and only resulted in water and lime content. This vapour is exactly the same as the water on top of the lime.

We do not know in which circumstances the author of the article from the Encyclopedia perceived green water on the surface of the lime. We can assure you that in similar circumstances, we did not obtain green water. At last, to complete our researches, after having removed the water on the surface of the lime, which the author says cannot be used, we compared it with mortar slaked with the floating water from the first basin. We did not see any difference.

Despite the advantage Vitruvius, Palladio, Delorme, etc, find in employing lime only after it has been kept a few years in a basin, we think fresh made lime and used straight out of the kiln, whatever the nature of the lime, should produce a good mortar and this, because this freshly lime undergoes fewer alterations and contains less carbonic acid. The builders are so convinced of this truth that, in many circumstances, they slake the *(right amount of)* lime as needed (p158) to make mortars by the ordinary method. The rest of them, as there exist infinite varieties of lime, could some of them acquire improvement by staying longer in basin.

Some shape a basin with sand or cement with which the mortar will be made. They place the quantity of lime needed and slake it by adding all the necessary water. When slaked, they mix in the sand or cement and prepare the mortar to be used immediately. Others place the lime in a small sandy bassin, shape a heap and cover it with sand, then slake it by aspersion under the sand, as the same method of the Ancients and Delorme. When the lime has slaked, they mix it with the sand and prepare their mortar by adding the necessary amount of water.

This second method of slaking under the sand that we execute still today in many places, has the intent of stopping the evaporation of salts and obtaining a better mortar. We already know what we think about the evaporation of salts, however this method is favorable because the lime is slaked by aspersion. M. Vicat found this method preferable to the ordinary method and that the sand heap stops the evaporation of saturated lime which would inconvenience the workforce in charge of the slaking. This method with these two real advantages should be advised and even prefered to the ordinary method. This method can also (p159) be applied to any type of lime. But we have to repeat that in many circumstances, slaked lime conserved, improved and should be naturally preferred.

P 160 Chapter II : *On the division of lime*

They gave the name of fat lime to any kind of lime the volume of which increases considerably upon slaking, and can conserve for a long period this unctuousness, this binder allows a considerable amount of sand to be added for the fabrication of mortars.
They gave by opposition, the name of lean lime to any kind of lime the volume of which increases only slightly on slaking, that is rough at the touch, presents little untuousness or binding, in which only a small quantity of sand can be mixed when preparing mortars.

Soon we noticed that several lean limes hardened quickly and the mortar made from them even hardened underwater. From this, we concluded that this type of lime could be used in all hydraulic constructions in all places, in foundations exposed to humidity and we gave the name of lean lime (chaux maigre) to the ones we can use underwater.

As not all lean lime hardens underwater, we think it is appropriate to divide lean limes in two categories, lean limes - that do not have any particular properties and which are only distinguished from fat limes (p161) by its increasing only slightly when slaked and does not take as much sand when making mortar - and lime that hardens underwater, which can be used on hydraulic constructions.

In respect to the various properties of limes, we believe we should divide them into five types : 1° fat lime, 2° lean limes, 3° limes that harden in the air, 4° limes that harden in water, 5° lime that harden in the air and underwater.

(p271) Preparations we make to the slaked lime destined for buildings.
There exist two types of construction, 1° the ones which are exposed continually to the action of air and the ones exposed to the action of water. For each type of construction, we need a different lime or a particular preparation for the same lime.

P368 In the ordinary constructions, we prefer to employ fat limes and sand to gather stones and to build walls because this mortar is abundant and cheaper. In humid places, in particular underwater, wherever we wish to stop the action and infiltration of water we use a mortar that hardens underwater or we use some 'béton'.

Depending on the nature and the size of the stones we want to bind together, the mortar requires different preparation. To bind ashlars together, that we place beforehand, the mortar should be very fine and very liquid in order to flow easily and to enter and fill in the narrow space. *[grout?]*

P400 As to the stucco, meaning the coating we put on the last coat, we take the best limestone we can obtain. It needs to be white and well slaked, it is slaked with great care by first dipping it in water before putting it (p401) in a basin and giving it water only when it starts to smoke. We need to pour the water progressively when lime starts to dissolve and to stir it constantly to facilitate its fusion. After the lime is slaked, some plasterers dilute it with water to pass it through a sieve to remove any bits. Others grind it on a marble slab. Rondelet believes the latter is the preferable method because it does not weaken it. What would be best is to slake lime by immersion and to let it through a fine sieve. We could also slake it into a mush and pass this mush into a sieve before letting it rest in order for the lime to reject the excess of water. This sieved lime should rest four or five months and sometimes more because the longer, the better for the stucco for the ease of work and the economy of it.

Freshly slaked lime is not the best option, unless it has been crushed several times to facilitate its dissolution. We can, thanks to this method, accelerate the process. The lime used for the stuccos should be fat limes because the other limes would harden while resting in the basin.

Pasley C W (1826). Practical Architecture. Reprinted 1862 by Royal Engineer Establishment, Chatham. Reprinted Donhead Publishing 2001)..

[These are Pasley's earliest published thoughts on mortars, and other things, and are somewhat more referential to existing craft practice. He engages critically with the experiments and subsequent conclusions made by Dr Bryan Higgins, particularly with the fact that Higgins proportioned his experimental and recommended lime: aggregate proportions by weight, primarily on the basis that different quicklimes had different bulk densities. That said, Higgins mixes, proportioned by weight will usually have reflected the proportions by volume subsequently discussed as appropriate by Pasley – between 1:2 and 1:4, depending upon the lime and the proposed use of the mortar. Did Higgins understand that on site practice will have been to mix by volume, not weight?

*Importantly, Pasley makes clear that, whether mixed at 1:2; 1:3 or 1:4, the lime proportion was measured in the form of quicklime, **whatever** the specific method of slaking this quicklime, so that, whatever the specified proportion, this would be similar or the greater according to which quicklime was used, with fat* *and feebly hydraulic limes at least doubling in volume; the more energetically hydraulic quicklimes not increasing in volume anything like as much, if at all, upon slaking. 1:2 would be the common specification for hydraulic lime, therefore, whilst 1:3 or 1:4 would be most commonly specified for fat and feebly hydraulic limes.*

In discussing general practice, Pasley implicitly – sometimes explicitly – indicates that quicklime was slaked whilst mixed with the (wetted) sand of the intended mortar and was generally used immediately, or very soon after being mixed.

As in later works, many of his examples (and, in later works, his practical trials) were taken from buildings and practice at Chatham Naval Dockyard. Many of these mortars will remain in situ, and Pasleys attention to detail would suggest that these might be usefully analysed in the future, to inform on-going mortar research.

Excerpts:

P 2: *Of Lime*

Lime is obtained by breaking any calcareous stone…into fragments of a convenient size, and burning it in a kiln, and afterwards pouring water upon it, which causes it to effervesce and fall into a fine white powder, in which state it is said to be slaked.

(summary of Smeaton's conclusions):

The goodness of lime the same whether made from hard or soft stone;
Distinguished between Water Lime and Common Lime.
The presence of clay gives lime the capacity to set under water;
Blue Lias the best water lime; impure chalks, containing clay also serve as water limes; as do Sussex clunch, grey lime from Berryton, near Petersfield (Hampshire) and Dorking lime, (p4) much used in and around London, called 'stone lime'.
Whatever the colour of the original limestone, all water limes assumed a buff colour after calcination.
Blue Lias lime has about 1/8 clay *[12.5 %];* Dorking lime about 1/17 *[5.8%]*.
That slaked lime powder typically has twice the volume of the unslaked material but that when mixed with just enough water to form it into a paste, its volume will diminish to that much the same as before slaking.
That Plymouth limestone and common chalk – both very pure – yielded lime of similar quality, but neither delivered a water lime, though their lime was '**good enough for the common purposes of building, and for inside work'** *[not just for interior work, therefore, which became a common assertion by mid-19th C]*.
Cockleshell lime was similar to the above, although it enjoyed an accelerated set, and not suitable for underwater use *[Smeaton had taken his lead on this from Wren, who had asserted in his memoirs that plasters at St Paul's, made of cockleshell lime, were as 'hard as' Portland stone]*).

It is essential that burned limestone should be carefully preserved from the air, for which purpose it should either be used **as soon as it comes from the kiln,** or it should be **kept in water-proof casks,** which precaution is necessary in moving it any distance. *[This, much easier today than in the past, with plastic tubs].* **The same rule** should be followed in regard to **slaked lime, which should be used the moment it is slaked.** If that is not convenient, the workmen cover it over with sand, to save it from the air as much as possible.

It is essential that lime should be well burned, and capable of slaking the moment that water is applied to it *[not necessarily the case with hydraulic limes – Pasley's main experience at this time is with fat and feebly hydraulic limes, therefore]*

Of Mortar

P4)

The **common mortar used for the walls of buildings** is composed of slaked lime and sand, which have been beaten up together, and intimately mixed, with no more water than is necessary to give them a proper consistency *[see above for **when**].*

The goodness of the mortar depends partly on upon the quality of the lime and sand…and partly on the **care with which it is mixed.** Too much pains can scarcely be taken in this operation which, in great works, is often done by a mortar mill, in preference to manual labour.

(P5)

The sand used for mortar should be sharp (not round or smooth), and free from earthy particles, for which reason it should be washed…This should always be done in using sand from the sea-shore…for mortar containing salt will never dry properly…sea-water should never be used for the walls of buildings, nor even sea sand, unless no other can be had; but there is **no objection** to the use of sea water for wharf walls, or other revetments exposed to the action of the tides *[on experiment, Smeaton had found little difference in the performance of mortars made with fresh, or with sea water, and used the latter for the mortars of the Eddystone Lighthouse].*

…According to Dr Higgins (1780, who)…laid down many useful rules, **since acted upon by the most eminent architects and engineers, but contrary to the received opinions of the period at which he wrote,** it is better to use two kinds of sand mixed…(coarse, that which passes through a 1/16th of an inch sieve; and fine, passing through 1/30th of an inch sieve – 4 coarse: 3 fine: 1 'of lime powder of the purest quality, that is of common lime').

Dr Higgins recommends that, in making mortar, the sand shall always be wetted first, and then the lime added, and mixed up with it, without any further addition of water, and he was the first to recommend *[followed also by General Treussart in France]* that **mortar should be used as soon as made, contrary to**

the former practices of the times *[though Moxon had suggested this in 1703]*….Dr Higgins discovered that, by exposure to the air, burnt lime will absorb the same (carbonic acid) gas by degrees, and becomes no better, as an ingredient for cement, than the dust of the same quality of limestone in its original state *[if not protected from the air, it will begin to carbonate]*. If, on the contrary, **it be intimately incorporated with sand, so as to form mortar, and used in building as soon as it is made,** in joints of moderate thickness, the absorption of carbonic acid gas, by gradually restoring to the lime its original chemical properties, produces an intimate union of the whole mass of solid substances with which it is incorporated, or to which it is attached, and the mortar hardening by degrees will become stronger than brickwork.

(Smeaton agreed that mixture of coarse and fine sand the best, but without fixed relative proportion). His rule is to **mix the water and lime first** *[before quickly mixing this with the sand, implicitly]*.

In respect to the proper proportion of lime and sand which ought to be used in mortar, it is known that when the lime is **in excess** the mortar may be plastic **and convenient to use,** but that it never hardens properly. If, (p6) on the contrary, the sand be in excess, the mortar becomes too short, as the workmen style it – that is to say, not sufficiently plastic at first, and may eventually crumble to pieces. It is agreed, however, that all the particles of sand should be just separated, and, consequently, cemented together, by the smallest quantity of lime capable of effecting this object, **which can only be judged by experiment** *[but see Gillmore (1861) for why more than this should be allowed, and which most craftsmen sought to allow]*.

(Bemoans Higgins's use of weight when poorest burned limes are the heaviest and when building sands vary significantly in bulk density *[he does not use this term]…[Implies that Higgins's proportions are too lean – 1:8 by weight might be 1:4 or 1:5, the lime being already slaked])* .In order to judge of the proper proportions of lime and sand, the state of the lime, and of the sand, at the period of mixture, must be accurately defined.

The prejudices of common workmen are all in favour of using an excess of lime, upon which they consider the whole essence of good mortar to depend. In public works, it therefore becomes necessary for the Engineer to guard against this propensity *[but see below for what he considers appropriate proportions],* as they imagine that they are doing a service to Government by wasting the more expensive material; and, if they are not strictly looked after, **they will make the mortar according to their own judgment, in spite of general directions to the contrary.** *[This may be seen to be confirmed by Neve's(1726) relation of preferred mortar mixes volunteered by masons in London and elsewhere, some of which had more lime in them than sand, and most of which were richer in lime than even 2:3].*

It must, therefore, be understood that, in estimating the comparative proportions of lime and sand, for making mortar, **unslaked lime – as it comes from the kiln – and dry sand, are generally implied,** unless the contrary should be expressed; and, in making a contract, or in giving directions, in respect to mortar, these particulars should always be stated beyond the possibility of a mistake.

In making enquiry into this subject, whether personally or by reference to books, equal care must be taken to obtain, if possible, a correct specification **of the state of the lime at the period of its being mixed.**

When lime is of inferior quality, or there are not the means for mixing the mortar well, it is considered that **one part of unslaked lime to two parts of sand** is the proportion **necessary for obtaining a compound of proper tenacity.**

If the lime be of good quality, and dependence can be placed upon the diligence of the persons employed making the mortar, one part of unslaked lime to three of sand, has been held as a better proportion than the above, and has very often been used in Government works.

It appears to me that, **for common mortar *[which is to say, fat or feebly hydraulic lime mortar]* for the walls of buildings, the former *[1:2, quicklime:sand]* may be considered the maximum, the latter *[1:3, quicklime:sand]* the minimum, proportion of lime that ought to be used.**

…When mortar cannot be expended **as soon as it is made,** the remainder of it should be carefully covered from exposure to the air, which is sure to deteriorate its quality; and it should be beat up again when about to be used, **but without adding water,** unless absolutely necessary.

In Government works in the Ordnance department, it has always been the custom to measure lime and sand by the cubic yard, which is the simplest method. *[NB powdered quicklime has nearly twice the bulk density as dry hydrated lime and one comparable to dry sand].*

P 7 It ought to have been observed that Dr Higgins recommends mortar to be made with lime water, not with common water, but **I am not aware that this nicety has ever been attended to by practical builders.**

Recently, a custom has been introduced of grinding, or pounding, the lime about to be made into mortar or grout, previously to slaking it; it has been stated that this practice is chiefly advantageous when the **water limes** are used, which do not slake so quickly as common lime.

…It appears from Vitruvius that the Romans considered one part of lime mixed with three parts of sand as the best proportion for common mortar *[Pasley assumes the one part lime to be quicklime, as stated above],* **and this agrees nearly with the practice of the most eminent engineers and architects of our**

own times; and if that quality of lime, termed by Smeaton water lime, be mixed with Thames sand…I believe that no better proportion, or ingredients, can be adopted for buildings of any importance.

The objection to using common lime in such buildings is that the surface more immediately exposed to the air is apt to decay, which, after some time, requires all the joints to be pointed with fresh mortar.

At the new British Museum…the brickwork was laid in mortar composed of one part of Dorking lime, mixed with three parts of Thames sand *[Dorking lime feebly hydraulic and expansive on slaking]*.

(comments on the hardness of the mortar within, as observed during alterations after one year, comparing this to a soft, friable mortar found upon demolition of 100 year old buildings near Westminster Abbey)

I ascribe the comparative inferiority of the older mortar, in this case, to a practice which seems to have prevailed in London in the last century, of **building with mortar composed of about equal parts of lime and sand for inside work, but of no less than two parts of lime to one of sand for outside work (references Batty Langley book from 1729).** *[This is confirmed by reference to Neve, 1726]*.

In the new works in Sheerness and in Chatham Dockyards, Mr Rennie directed the mortar to be made with one part of Dorking lime to three parts of Thames sand; but the backing mortar to be made with one part of Dorking lime to four parts of sand. The lime was ground in a mortar mill previously to its being used.

Of Grout

Grout is mortar or cement in a liquid state, which being poured into the joints of rough masonry, or brickwork, such as foundations, etc fills up all the crevices and hardens by degrees, though not so speedily as the same quality of mortar or cement when worked up stiff in the usual manner.

In the new docks in Her Majesty's yards at Sheerness and Chatham, grout was used for all the rough parts of the foundations and walls. It was composed of Dorking lime ground in the mortar mill, but not slaked, and of the proportion used for the lower part of the foundation…one part of lime to four parts of sand. These ingredients, mixed together dry, were wheeled to the walls, and made into grout…and pouring it **instantly** into all the vertical joints of each course of the brickwork. (later inspection during an alteration showed a)…very intimate cohesion of the parts.

Mr Smirke, the architect, has recently made great use of grouted gravel for the sub-foundation of considerable buildings. One measure of pounded Dorking lime, **not slaked,** and five measures (in some cases, but more usually seven measures) of clean gravel are mixed together with water, and poured into the trench or excavation…

Hot lime grout has also frequently been used in rough work. This is made by stirring up slaked lime in water, without any other ingredient, and pouring it into the joints of each successive course…
P9

Lime Putty

The term putty, better known as the cement for fixing glass in windows, is applied in brickwork to a very different substance, which is nearly the same as hot lime grout, It is made by **dissolving in a small quantity of water, as much hot lime as, when slaked,** and continually stirred up with a stick**, will assume the consistency of mud**…It is then sifted, in order to remove the unburnt parts of the lime, and **should be used without delay.**

It is only proper for gauged brickwork, or for the ornamental outside work of brick walls….

…*Of Water Cements in general*

(In the light of Smeaton's experiments and conclusions)…it…appears proper, **in buildings exposed to the action of water,** either to use water lime, as defined by Mr Smeaton, which is in itself a water cement, if common sand only be employed; or, if common lime be used at all, it must be mixed with some efficient kind of water cement, such as Puzzolana, Tarras, and other substances (to be dealt with later)…

As proof of the efficacy of good water lime, may be mentioned a fact communicated to me by Mr Telford, the eminent civil engineer, (who)…observed a pier-building at Watchet, **by the common masons of the country,** who used no other material than bolder stones, or round pebbles, found on the beach, which they **cemented together with hot lime grout** of the Blue Lias stone of that country. Thus, a wall was formed, which resisted the tides of that coast…

A curious incident…occurred at Waterloo Bridge. In driving piles for one of the coffer dams, the workmen, most unexpectedly, encountered what appeared to be a stratum of rock. This, on examination, was found to be the common gravel at the bottom of the river, which had been indurated by a large load of Dorking lime, previously sunk over that spot by accident. This circumstance being mentioned by Mr Rennie to Mr Smirke, induced the latter to adopt the grouted gravel before alluded to, for the foundations of several important edifices.

…(discussion of Pozzalan and Trass)

Of Roman Cement

Roman cement is the name given to a powerful water cement, discovered in this country subsequently to the publication of Mr Smeaton's work, and which recently, in a great measure, superseded the foreign water cements *[made with Puzzolana or Trass]*, unless in works of great importance. It is used not only as a water cement, but for pointing, and plastering the walls of brick buildings, which, in the new streets of London, have thereby been rendered susceptible to those architectural decorations hitherto confined to buildings of fine stone.

Recently, it has also been employed for forming artificial stones of considerable size for drains, copings, chimney pieces, etc. …

Of Tile-Dust Cement

The practice of using pounded tiles or bricks as an ingredient for water cement is very ancient, and has been general in almost every part of the world…and would seem to be founded upon just principles. (Dr Higgins was against it, but has not been proved right)….

Mr Batty Langley asserts that a mixture of powdered brickdust and lime yields an excellent mortar for tile pavements in situations generally damp, and that it is superior to Tarras in situations alternately wet and dry. M Rondelet…speaks in favour of it as making an efficient water cement, when mixed with lime; and states that tiles well-burnt should always be selected, and that **old tiles which have been used on roofs are better than new tiles or bricks.**

…Mr Smirke…(specified for rebuilt parts of the New Custom House in London…) a mortar consisting of **one part pounded Dorking lime, one and a half parts of pounded clinkers, or bricks nearly in a state of vitrification, and one and a half parts of Thames sand.**

Here it may be remarked, that, for common walls of brick buildings, it seems **quite unnecessary to use any other cement than common mortar,** made with water lime and sand, which, in the process of time, will become equally strong with the bricks themselves, **or perhaps rather stronger,** for, according to the **common but obvious adage, no compound substance can possibly be stronger than its weakest part** *[Hurrah!].*

Transcribed 20.12.2015.

Fourmy Jean *Essai sur les chaux à bâtir et sur les mortiers calcaires* 1827. Janet et Cotelle Paris Translated Emma Michel 2016.

p4 A lime that had been reduced into a paste when slaked, can acquire in our constructions a solid consistency that ordinary liquids do not destroy. That is the reason why the calcareous mortars were preferred to the ones that can be dissolved *(earth mortars?)*

The degree of solidity that a pasty lime can acquire in our constructions depends upon (p5) the process of solidification[1] **; the slower the process is, the more solid the lime becomes and vice versa.**

[1] (I find it unnecessary to insist on this point. It has been cleverly discussed in a thesis/dissertation published from 1780 to 1790. Even though I forget the title of this book and the name of its authors, I still remember the main ideas it contains, and particularly this one [above] of which I have had numerous opportunities to demonstrate the accuracy.)

Solidification of limestone in our buildings is too slow for this oxide only, and even mixes that do not contain a certain proportion of heterogeneous substances, can be subjected to a commercial lime manufacturing process. This is why we will advocate more or less complicated mixes as suitable materials for large projects (…).

The caloric action on these mixes results in two types of products. One consists of simple oxide mixes more or less modified by this action, when it is weak. **The other is in more or less intimate combination that develops only with the help of this same action pushed to a certain degree of intensity.** Whatever the chemical composition of a calciferous mix is, **it only turns to lime by the action of heat** (caloric action) *(or – mixing gets the best out of the lime when the mortars are mixed hot?)*

P7 The return of pasty lime to a solid consistency has been attributed to different causes; no one offers a reason for the difference that exists between the types of lime (…). What we know is that, once abandoned on its own and deprived, whether of the mix, or of contact of with certain substances, calcium (oxide) which has lost its solid consistency by **the dry process,** does regain [its solid consistency] by humid process, **only with extreme slowness. And numerous substances put in contact with this oxide, whether intrinsically in the lime composition or externally in the preparation of mortars, have, in different degrees, the facility to accelerate the solidification process.**

Vicat 1828 Résumé des connaissances positives actuelles sur les qualités, le choix et la convenance réciproque des matériaux propres à la fabrication des mortiers et des ciments calcaires...Translation, Emma Michel 2016.

P8 Chapter II
<u>Grand scale burning of limestones.</u>

Limestone becomes lime when it is deprived of the carbonic acid and water that is contained whether hygrometrically (hydrométriquement) or in combination(<=?) within it. The agency of this effect is fire.

In steady heat, the burning works all the better and more quickly due to the fact the limestone does not have a tight composition that can be reduced to a smaller volume and that it contains a certain humidity

Contact with air is not essential but it manifests towards particularly argillaceous limestone a useful influence. No stone can be transformed into lime in a sealed container due to the fact the emanation of carbonic acid gas would be impossible.
Pure limestone just about tolerates white fire without inconvenience. On the contrary, limestone mixed in the required proportions to obtain hydraulic lime or eminently hydraulic crumbles easily.

Its burning requires a few precautions:
The fire should only be of an ordinary red, except on occasion to compensate the intensity by the duration.
The mixed limestone, overburnt, is heavy, compact, blackish, coated with a sort of enamel, particularly on the angular parts. It slakes with great difficulty and produces a charred lime with no energy. Sometimes it does not even slake at all but turns, after a few days exposed to air, into an inert rough powder.
Pure limestone and mixed limestone, imperfectly burnt, or those that did not slake, or only partially, leave a solid kernel, a type of subcarbonate (*'avec excès de base' = with an excess of base)* possess properties that will be explained later on.
The burning of limestone is the art of the 'chaufournier' = the lime burner.

P9 We use as a fuel, depending on the places, cordwood, faggots, heather, peat and coal. It would be tedious and useless to describe every lime kiln proposed or designed in the last few years. We will only tell the ones usually adopted by their shapes; rectangular prism (pl. I, fig. i); cylindrical (pl. I , fig. 2).; cylinder topped with a slightly truncated cone (pl, I. fig. 3); truncated inverted cone (pl. I, fig. 4); ellipsoid of revolution '*diversement renflé = no idea'* or ovoid (fig. 4, 7 et 8, pl i).
Rectangular kilns are used in the Nirvernais *(former province of France, actually la Nièvre)* and in the South of France, in which we burn limestone and brick at the same time. Limestone occupies about half of the capacity at the bottom and the top is filled with bricks or tiles packed tightly together.
Cylindrical kilns are mainly used on site for the production of large quantities of lime in a limited amount of time. We call them *'les fours de campagne'* kilns of the countryside.' Their construction is very quick and cheap but precarious: we raise a large quantity of limestone in the shape of a tower, on an ogival vault or semi dome, that **we cover with a beaten envelope of earth** and maintained externally by a rough wattle (*clayonnage = made of branches*) where we previously created an opening to introduce the fire under the vaulting.
The kilns of the third type are more robust and durable, like the quadrangular

kilns, we do not burn bricks, the biggest stones occupy the cylindrical bottom space, the chips and others bits are placed in the cone above.
The kilns of the fourth and fifth types are particularly adapted to the burning of coal. The internal wall of a lime kiln is ordinarily built in bricks or other materials undisturbed by fire, cimented (P10) by a thick layer from 32 to 42 cm of wetted refractory mixed sand and clay.
In the high flame kilns supplied by wood or heather, the load always rests on one or two vaults built dry with the same materials as the load. We light a small fire at the bottom of the vaults that we gradually increase in stepping back as the fire settles and grows stronger. Once outside, we make sure to create an opening that we constantly feed with fuel. The engulfed air carries the flame to every part in the vault, it penetrates in the joints and does not take long to turn incandescent even in the higher parts of the kiln.
There exist certain types of stone that the fire bursts with noise, we will not use them for the construction of the vaulting or the jambs without risking to damage the kiln. We choose instead materials that do not have this inconvenience.

Habit (*meaning experience*) is the only thing that indicates the appropriate duration of burning. It varies under a lot of circumstances, such as the quality of the wood, more or less green, more or less dry. Also the direction of the wind, which helps or prevents the draft etc. The master lime burners usually adjust it on the basis of the general compacting of the load which varies from 1/5 (one fifth) to 1/6. In a kiln of a capacity from 60 to 75 cubic metres, the fire lasts from 100 to 150 hours, each meter cube of lime consumes (in general terms) in woodcord 1st 66^{e} *(st = stère =one meter cube and 66 something?)*, 22st00^{e} in fagot, and 30st for heathers and others.
In the coal kilns, in steady heat, the stone and the coal are mixed. Of all the burning methods, this is certainly the most capricious and difficult one, especialy when burning argillaceous limestone. A simple change whether in the direction or intensity of the wind, a few degradations on the inner wall of the kiln, a too great inequality in the size of the fragments are the causes (P11) that slow down or accelerate the draft. It produces irregular movements in the descent of the materials, which eventually form a vault and precipitate at times the coal or at other times the stone in a same area which creates an excess or a defect in the burning.

Sometimes, a kiln functions perfectly for many weeks then is being disturbed without any visible cause, a simple alteration in the quality of the coal suffices to give trouble to the most experienced lime burners. In another word, the coal burning in steady fire is an affair of **trial, error and experience.**
The capacity of a kiln is as important as its shape and proper burning. They are limits when we cannot put out the fire without serious inconveniences illustrated in (pl. I, fig. 5, 6, 7 et 8) (…).
The volume of coal to make one meter cube of lime varies necessarily with the hardness of the stone used. But between these limits, as long as it is not chalk or crumbly marl, we determine in average 3 meter cube of lime for each meter cube of coal.

P48 Chapter XI

Des mortiers constanment exposés à l'air et à toutes les intempéries (of mortars constantly exposed to the air and in all weathers)

We have said in the chapter IX, that **the only mortars able to defy the vicissitudes of the atmosphere and to acquire at the same time a great hardness, are the ones made exclusively of pure quartz *(<=silica ?)*, granite or calcareous sand and hydraulic or eminently hydraulic limes.** If then, we discuss, in what follows, the ordinary mortars or mixtures of sands and fat limes, it is only because it is required in to order to obtain a complete picture of the phenonema that we exposed earlier. **Because it is our opinion that we should always prohibit its use *(of ordinary mortars)*, at least on the works of importance.**

P64 Chapter XVI

Antique mortars compared to the Middle-Age mortars and modern mortars.

The monuments in Egypt are without doubt the most ancient examples that we can cite on the employment of lime in building. The mortar that joints the stones in pyramids particularly those in Cheops are exactly similar to our mortars in Europe. The mortar we see between the joints in decayed edifices in Ombos, Edfou, on the isle of Philae and in other places detects by its colour and grain, a very fine reddish sand, mixed with lime in common proportions. The use of mortar was then known more than 2000 years before our era.
Perhaps, it would be easy to go into earlier times, and consult the old monuments of India and its Sanskrit books if they talk about their former relations with Egypt, but it would be a research led by curiosity rather than usefulness.
By only using the mortar for very fine/narrow joints that separate huge blocks, the Egyptians, (p65) by assigning this almost insignificant role of the use of mortar, seemed to have sensed the *(bad)* influence a scorched and dry climate could exert on the curing and the lasting of that mortar.
Time has proved their caution because the works of Romans on the edge of the Nile do no longer exist whereas after **40 (20 in the 1856 publication)** centuries, a few Egyptian temples present still intact to our admiration.
Masonry built with small materials could not be suited to a people that sculpted on the façades of their monuments the history of their customs, arts, wars and conquests. Unbaked brick, *('la brique crue' = literally, raw brick) adobe*, cemented with clay was enough for simple dwellings and under a constant cloudless sky, this way of building was as safe as quick and economic.
It was in the country of Fine Arts, in this Greece so fertile in ingenious inventions that the industry, stimulated by a very different climate, succeeded to vary the employment of lime and to slake it for various purposes unknown in Egypt.

At the time, in Athens, as a curious antiquity, was displaying on the roof of the Areopagus built in earth, coats *(sheltercoat ?)* similar to the Paros marble for its whiteness, hardness and polish, that ornamented the houses of the simple citizens. The flat roofs resisted severe weather. We were building walls with rubble or other hard stones of small dimensions which did not offer the solidity that ashlar stones offered. The artificial paving was so perfected they absorbed in a few moments all the water we were using to wash them. The slaves were walking on them barefeet without being incommoded by the humidity or the cold (…).

The practices of the East soon arrived in Italy: Greek workers as well came in mass. Romans had the opportunity (P66) to learn about the writings of Anaxagore, Agatarchus, Metagenes, Phytheus, Theocides and others. Fussitius published the first book of architecture in Rome, after him, Terentius Varron, Publius Septimius and finally Vitruvius who was the architect of Augustus. His book is the only one that survived to us and is all the more precious because it contains, from the admission of the author himself, everything the Greeks knew on the art of building. Pliny the Elder, in his *Natural History* and Palladius in his treatise de *Re rusticâ* **did not add anything new from what Vitruvius said before them. We would be tempted to think that they plainly copied it.**

Therefore, we do need to consult Vitruvius when some controversial explanations are required on the architecture of the Greeks and Romans. The monuments erected by these people speak even more clearly than their books, and what remains is enough to solve every difficulty raised.

Romans, as we noticed before, were referring to the best lime made from the hardest and purest marble. Hydraulic lime, judging by the silence of Vitruve, was totally unknown to them, or, at least, its properties were. That is why they could not do without pozzolan when they worked on hydraulic works of great importance (...). They knew well enough that ordinary lime and sand could never bond in water (…).

They used crushed brick, employed as a pozzolan, only for structures that did not need great solidity. Their mortars exposed to the air, are usually all similar to each other, we can recognise them thanks to the presence of sand mixed with gravel, (P67) and **the lime lumps are sometimes so numerous that it is impossible to think it is a defect of grinding.** The slaking of fat lime by immersion is the only way to explain this *(hot mixing explains it better)*.

Roman hydraulic mortars are remarkable and are essentially different from ours. They are made, apart from a few exceptions, of pure lime, mixed in great proportions with fragments of roughly crushed bricks. However, as the brick cannot be crushed without freeing small quantities of fine dust, it means the lime cannot be white, but is, on the contrary, slightly red or yellow depending on the colour of the brick used.

This mortar was usually intended to avoid water infiltration. We were coating the bottom and sides of tanks, pools, aqueducts, etc. (…).

p 68 There is a belief, rather widespread in France, that Romans had a secret in the making of their mortars. Some say it is in the choice of their materials, others in the way they used them. The obvious consequence of these two opinions is that Roman mortars should be equally hard in all parts (…). It is certain that the ingredients, lime, sand and bricks always present in mortars are absolutely the same in the country where the monuments are and Vitruve concurred in this observation (book I, chap. V), 'I do not determine what should be the materials of the walls, because we do not find everything that we desire, **but we need to use everything that we find, etc**.'

We thought to have answered triumphantly to everything by saying, in surviving for 18 centuries and beyond, the antique mortars are infinitely superior to the modern mortars the inadequacy of which is proved by the deplorable state of most buildings.
For this to be true, we should have compared great monuments to other great monuments and precarious constructions to constructions of the same type. We could have then opposed, even with advantage, the antique mortars to our old walls and in general to the great buildings of the Middle Ages.

As to the fragile walls of our houses, (P69) they could have been featured next to the one of Pliny (book. XXXVI) when he says « *Ruinarum urbis ea maximè causa, quod furto calcis, sine ferrumine suo caementa componuntur.* » (translated from google : The main cause of the ruin of the City is the theft of the lime, and cement without ferrumine *(iron from the word ferrum)* it is composed).

Biston M (1828) Manuel Théorique et Pratique du Chaufournier. Paris, Roret. Practical and Theroretical Manual on Lime-burning.

Section I : the slaking of lime

Lime is slaked by three methods 1° From the fusion of the water, 2° By immersion, 3° spontaneously from the only action of the atmosphere.

P 196 <u>Art. I Slaking by fusion</u>

Slaking by fusion, also called ordinary slaking, has to be done in impermeable basins with only the necessary quantity of water to reduce the lime to a thick mush. We will be careful to give all the water it needs in the first instance, only coming back to it at the moment of the effervescence (to add more) or else, wait for it to cool and then add some more water. **We will forbid in all cases, the method followed by some masons of drowning the lime in a large quantity of water, reducing it to a milky consistency before pouring it into permeable pits where it dries out and loses its qualities.** When we need to keep the lime after it has been run, we will cover it with earth or sand.

<u>Art. II Slaking by immersion</u>

We will reduce the lime stones to the size of a walnut before putting them into an open-weave basket. We will immerse this basket into water until the surface starts to slighty bubble. Then we will then retrieve it; let it drain a bit and then pour the lime into boxes or barrels in which the concentrated heat, unable to escape, will be absorbed by the lime, which will turn into powder.

P197 To conserve this lime in this state, we are sure to cover the boxes or barrels with straw and keep it in a location away from humidity.

Art. III Spontaneous slaking

This is done by submitting the quicklime to the slow and continuous action of the atmosphere. It will then turn into a very fine powder with a slight emission of heat but with no visible steam. We should be sure not to practice this method in a humid atmosphere and we will only stop its operation when the reduction is complete. The spontaneous slaked lime should be preserved with the same care as the lime slaked by immersion.

Art. IV Slaking in general

Every experiment shows that the method of slaking has a great influence on the quality of the mortar, although less on the ordinary mortar than on the hydraulic one. However M. Vicat found out that we can still double the resistance of an ordinary mortar when it is properly selected.
Here are the results of the experiments of this engineer. They are not prescribed here as absolute principles but only as facts to support what we have just said on the influence that slaking methods can have on the quality of mortars.

P 199 ordinary slaking does not present any difficulty, it is essential only to give the strictly necessary amount of water.

P 200 **With care, we will need to put the quicklime into a basin, to put a quantity such it will not spill out during slaking. We will then throw the water on the lime, wait a bit and when the bubbling begins to decrease, we will stir the gruel in such way as to be sure that all parts of the limes are dissolved. When the gruel is homogenous, it will be run through a grid opening into an earth pit to conserve the lime until it is used. It is essential to throw right into the basin all the water necessary for the slaking. If there is not enough, we will have to wait until the gruel has coolled down before adding any more water, otherwise, the lime will become lazy, will remain grainy and resistant to mixing.**

P203-204 We should particularly distrust, for the choice of slaking methods, the ignorance and the routine of the masons, who often reject the best method of slaking only because it produces less expansion than the other.

P204 Sometimes, the workers reject, with the same reasoning, types of lime which would be preferable to the ones they are used to use. Thus, in the region of Calvados *(← YAY! Home!)*, **half of the limekilns produce hydraulic lime for the consumption of farmers to enrich their fields whereas this same lime is not at all used by the masons,** because it does not expand as much as the others and because it hardens quickly, therefore the workers would have to change how they work *(Or they just knew better than you, ah! Calvados masons rock!) (Biston pp203-204)*

During the works, the type of slaking will always have to be decided by the architect or the engineer. To this effect, we will determine by experience and for each type of mortar, the slaking method which will offer the best mortar and this method will be used exclusively during the entirety of a same works. Moreover, we observe it is best to slake the lime near where it is needed, especially if the works are of some importance.

P206 The mode of slaking used in Lille and in other cities can be linked with the one we just mentioned from M. de Lafaye (immersion). Described in a note of Monsieur, the captain of engineering, JB Bergère on the coatings *(revêtement, very general term, like enduits)* on bricks. We throw quicklime with enough water to be turned into a very fine powder, after which we cover it with the necessary quantity of sand to make a mortar. This sand keeps the heat in the heap and accelerates the reduction of the lime into an impalpable powder. But this method (as de Lafaye's) requires close attention from the workers so that there will be no unslaked bits of lime left in the mix. M. J.-B Bergère thinks *(this method is)* partially, the reason for the degradation occurring to the exterior walls of the fortifications on Lille square.

P207 (And here how he explains the cause of the accidents). When a wall is raised, the *(exterior part of the)* wall dries quicker than the centre. Later the excess of water will be rejected through the mortar […] and when it finds quicklime bits, with which it will combine and solidify and increase in volume, this lime then would produce a similar effect to the *gâché* (mixed with water) plaster resulting in puffiness on the walls and then cracking.

Martin M E (1829) The Art of the Mason L'encyclopédie populaire ou les sciences, les arts et les métiers, Paris, Audot éditeur.

(Martin was professor of science and physics)

From the chapter, Study of Materials

p38 <u>Quality and of use of plaster (plâtre)</u>

We mentioned the plaster stone *(alabaster)* used sometimes for rubble, or ashlar in constructions but this habit is not widespread and is always in poor taste. The main characteristic of this stone is to acquire, from a slight slaking, the property of becoming a paste with water and to quickly solidify a large volume of liquid.

They are several grades of *plâtre:* The finer one, remarkable for its finesse, its gloss and its creamy texture, is reserved for sculptural ornament. The one less soft and less white is used for inside plaster, and the rougher one is used for partitions and walls. […]. In the same kiln, we can obtain, if desired, different qualities of plaster. In all cases, we reduce it to powder before using it and the more delicate the work, the finer the powder should be.

P39 […] Plaster should be stored away from moisture and from contact with the air when stored. Otherwise, it will become air slaked, meaning it will absorb slowly the biggest quantity of water it can absorb and then will be useless, lest we burn it once more. This material offers great disadvantages when used for wall constructions. It falls apart rather quickly with the humidity it absorbs – indeed, we should never use it in humid areas. Moreover, the property the plaster has to expand and bulge when it is still fresh, requires caution in the working method.

P40 The best for construction is the plaster that contains some lime.

p 40 Quality and Use of Lime
Nothing is more important than builders being able to recognize the qualities of the lime and to know what they have to do to it on different occasions. […]

p 40-41 Limes can come from pure limestones, are called fat and, as those stones are usually heavy, it is natural that fat lime |[...] has the property of absorbing a lot of water during the slake and thus expanding significantly.

P41 These limes mixed with common sand make mortars that dissolve underwater and are unsuitable for works in humid places. If we would want to make mortars capable of hardening underwater, **the sand would need to be replaced by clay, sandstones, pulverised and burnt slates or by fragments of tiles and pottery and ashes of earth coal.** These substances, associated with a certain quantity of common sand, form with fat lime, cements of good quality, perfectly resistant to humid and underwater locations.

We recognise pure limestones capable of producing a fat lime when, reduced into powder, they dissolve entirely in strong vinegar, hydrochloric acid or salt. There are impure and potentially hydraulic lean limes (p 42) which may harden underwater and expand only a little. When treated with one of the above-mentioned acids, they leave a considerable residue. The nature of this residue can vary depending on the region the stone is extracted). But we observe that, no matter its nature, the limestone it comes from always produces hydraulic limes, although to varying degrees.
These types of lime do not need to be mixed with a pozzolan to produce hydraulic mortars, concretes or cements. They need only to be mixed with common sand and we always obtain good results, whether for works underwater or in the air, which former is more difficult to achieve using fat limes.

Qualities and use of sand

When we use the term 'common sand', we mean siliceous sand, with the grains more or less big, but completely cleaned of earthy elements, and which could be washed with a great amount of water without really changing the colour of this water. (P43) We frequently see this type of sand in rivers or in the ground. We choose sand with rough and angular grains, as it binds better with the lime and we sieve it when it contains larger gravel. Sand of this type is excellent for most constructions. **However, when the limes are very fat, we prefer a sand containing clay.**

<u>Composition of mortars and cements</u>
As introduction to the principle is rarely sufficient to guide the application, we will go into a few details on the compositions of these various mortars and cements which the mason has the opportunity to use.

<u>Ordinary mortars</u>

We make this mortar by mixing 3, 4 or 5 parts of sand to 1 part of quicklime. The lime has to be of good quality and not be air slaked. After being slaked in water and turned to a buttery paste, we mix it with the sand.

The sand can be more or less big but it should be cleaned of loamy/silty parts. We have to incorporate it into the lime by long and continuous work and, as the ancients would say, 'in order to have a good mortar, it needs to be watered by the sweat of the brow'
When we mix powdered quicklime and sand in the proportions of one part of lime to 2 of sand and we moderately wet the mix while kneading it, we obtain a mortar which sets quicker than the first one and hardens better. But we should avoid letting it dry too quickly.

Equal parts of fine sand and sharp sand, a sixth part of quicklime and 1/12th of burnt bones, make a good quality mortar, which hardens quickly when mixed right before using it, with another quantity of powdered quicklime. The use of quicklime, advised for the first time by M. Loriot, gives to the mortar the property of setting up immediately, like (gypsum) plaster…

P45 <u>Mortars, cements, concrete of different composition</u>

Ordinary mortar is of better quality when we replace one part of the sand with fragments of tile or powdered pottery. This is only if it is a fat lime; if it was hydraulic lime, any such addition would seem pointless.

In Africa, we sometimes use a cement made of one part of sand, 2 parts of ashes and 3 parts of quicklime, sieved together, mixed and kneaded with water 3 consecutive times and wetted alternatively with linseed oil and water. This cement acquires a particular hardness.

Hydraulic mortars, or concretes, are made from fat limes and pulverised pozzolan or, in the absence of it, sandstones, slates or burnt, pulverised clays, or simply from coal ashes.
Hydraulic limes do not need to be mixed with common sand to produce good concretes. […].
We prepare a cheap cement mortar by kneading 2 parts of lime, 1 part of coal *(houille),* well sieved and half a part of clay. This mortar is damped slowly and well stirred. Then it is left in a heap for several days after which it is beaten and stretched; it is then left to rest once more until it is flexible and pliable. This mortar can be used to create floors in attics. We apply it by layer, and when it is almost dry, we cover it in a light coat of good quicklime mixed in butter milk.

In Italy, we make surfaces in the ancient way which is worth knowing.

P47 We lay a first coat of cement made of 3 parts of tiles and 1 of lime. We spread the cement well, we let it rest for a day or two depending on the season. After that, we beat it with force with an angled-iron-bar and we repeat this operation each day until the bar does not produce any impression on the layer. On this layer, we then spread another thinner one in which the lime is in equal proportion to the tiles and we sprinkle on this, still fresh coat, small pieces of marble by pressing them with a cylinder. When done, we beat the layer again and when it is perfectly resistant and dried, we polish the surface with sandstones and water. We work it after that with pumice. The last task is to give two layers of hot linseed oil and rub it to a polish.

p100 **Enduits (coatings)**

Coatings/plasters are an essential part of the art of the mason to which we will give details to its importance.

P 101 <u>Coatings/plasters of common mortar or crépis</u>

Mortar coatings are usually called *crépi* (plaster, render) when it is made of only one coat and the method is slightly rough. **In all cases, the first coat should contain more lime than the ordinary mortar and should be made preferably from old slaked lime.** It needs to be well beaten and softened. And if it is made from recently slaked lime, it should be left in a heap for a long time and then moistened and beaten once more. To the first coat, once well dried, we add a thinner coat made with finer sand and in more quantity, applied with not only a trowel, but also a small wooden ruler with a handle that we run along the wall by damping it. Once this work is done, we limewash the wall with a lime milk. If we would have wanted a better looking plaster, the lime would have been very fine, slaked for a long time and conserved in sand - grind it with chalk and then apply a layer upon the second coat with the trowel and the ruler as we just mentioned. This third coat would be capable of taking a polish. When the 'crépi' has to be applied on a smooth surface such as wood, it is good to nail lathes and hatch them.

In regions where we lack (gypsum) plaster *(I assume it's gypsum plaster)* and where lime is abundant, **we can compose a mortar to replace the gypsum plaster in the construction of cornices and other ornaments, by adding 3 parts of quicklime in powder to a liquid mortar made of 2 parts of fine sand and one part of pulverised tiles slurried into clear gruel with a sufficient quantity of old slaked lime to bind everything together. The addition of the powdered quicklime is done in the trough where the mortar has been previously poured and we briskly mix the ingredients together to use it right away.**

P 103 <u>(Gypsum) Plaster</u>
(Gypsum) Plaster is almost always used in the regions where the substance is not too expensive. We start by wetting the wall well, then we throw with a brush, some very clear plaster and then we cover this layer which is full of asperities with another coat applied with the trowel which we do not try to smooth over. We then add a third coat of fine plaster with the trowel and we smooth it as much as possible. When it is done, we scratch the protruding bits with a sort of toothed copper rake on one side and smooth on the other *(coxcomb, mason's drag.*

Batifodage

We often substitute for the plaster, for economy, or for obtaining a lighter and warmer plaster *(enduit),* **heavy soil, kneaded with care, mixed with a certain quantity of hair *(bourre)* and if we want, a fifth of old slaked lime.**

P 104 This mix, which we call batifodage, can be used as a plaster for walls and ceilings, we give a white colour with white of Spain (fine crushed chalk) wetted with strong size. (eau de colle forte).

Stuccoes

We give the name of stuccoes to the plasters capable of being polished. The best ones are made from well selected lime, slaked with care, well beaten and then conserved for several months in the sand. To make the stucco, we mix with this lime, an equal quantity of white marble or any types of heavy stone or even chalk. We crush it in such way to form a pliable paste. We apply it on a moist, slightly rough surface in layers of about two lines (millimetres?). When it is dry, we polish it with a moist cloth and with pumice.

P105 We continue to rub it with the palm of a hand and we finish by polishing it with a very small quantity of linseed oil but not so much as to form stains. The polishing is very precise, requiring great experience to be done well and for which time and patience should not be spared.

When the stucco has to be applied to interior surfaces, protected from the weather, we can apply a (common) mortar plaster (un enduit de mortier) made of lime and sand with gypsum. But when it is meant for exterior surfaces, we should give it a better resistance and thus put it only on a good cement, made from lime, pulverised tiles or pozzolan, and scoria […].

P113 **Rammed earth construction**

The construction of rammed earth being of the greatest importance in some regions, we believe it useful to understand the method, particularly today, with woods becoming rare and stone and brick often being materials too expensive in certain areas and particularly for rural construction.

If the art of rammed earth construction was practiced with the same care as in Lyon and in the Dauphiné, we would not doubt the number of healthy and suitable dwellings would multiply more quickly and the working classes would find it a great benefit.

This method of building was introduced into areas lacking in stone where previously we were using wood instead, and this circumstance hopefully would permit that such a useful way to build be introduced in other regions, where, due to the scarcity and the high price of materials, the poor citizen has to live in unhealthy and poorly roofed cottages.

We give the name of rammed earth to a construction in which masses of natural soil, made compact and hard through particular handling, are placed one along the other and one on top of the other to form the entire thickness of the walls as stones do. These masses are worked where they are placed in a type of movable mould that we remove only when the layer we have just finished has acquired all its necessary hardness.

Here how it is done: when the mould, which is a type of deep frame made of timbers, distanced by transoms, is placed where the wall has to be continued, we throw loose earth, about a foot square each time and then beat this soil very well before anymore is added.

P 115 In order that no soil will escape from the boards of the mould at the bottom, **we apply a bead of good mortar made of sand and lime, mixed**. These beads, also called *moraine* by the workers, can thus be used to see, once the wall is done, the given height of each course, or *banchée*. When raising the work, we will make sure to give the exterior side of the mould a batter, in such ways it results in a diminution of an inch for about every *toise* (old unit of measure for length = 2 m). We are certain to build rammed earth constructions on good foundations, 2 or 3 feet high to protect the rammed earth from the moisture of the ground and from the splashing of rainwater. The roof also has to be very well cared for because water would cause great damage in little time. As for the walls, we protect them with a good coating of lime and sand that we renew when necessary. With these precautions, buildings of this type have a lifespan as long as the ones in wood or rubble.

P116 In the Lyonnais and the Dauphiné, where this method of construction is very common, we see an infinity of these houses built 150 years ago that have not needed more significant nor more frequent repairs than if they would have been built in stone.
The height we can build the rammed earth without compromising its solidity is 20 feet above the foundation, and this height of two stories is enough for every need. Even though it is not usual in this construction to build the quoins in brick or ashlar, we suggest it only offers advantages and we advise this practice in every region where we would look to introduce the use of rammed earth, where it would not have been known from experience
Of the rest, the doors' openings and apertures should always be built in bricks, ashlar or wood. Bricks or ashlars are preferable as they bind perfectly with the rammed earth.

P117 The wood however, always detaches slightly and even though we paint it with oil, we obtain window frames of poor taste. The best is, when plaster is not too scarce, to lath the wood and to cover the jambs and lintels with plaster.
When we build in rammed earth, we usually do not tend to leave voids for every aperture of the building. Sometimes even, we do not put any and we simply carve them out, once the building is done, to accommodate the frames. When we have opened the space this way and we have placed masonry or wooden jambs, we wait until the building has dried well before putting a coat of plaster (enduit). Indeed, we should be careful not to trap humidity inside the walls because then, they could be susceptible to be damage by frost. Moreover the wall shrinking in its dimensions, the dried plaster would be lifted in plaques and would fall.

P118 **Thus, the construction of rammed earth should always be done early *(in the year)* in order for it to have time to dry before the cold weather, and we should never plaster them before the moisture has come out. The plaster (crépi) with which we coat the rammed earth wall is done with a mortar of lime and sand that we prepare with care and where we only use good angular sand in the proportion of 3 parts of sand for 1 part of lime. This mortar should not be spread in water but it requires to be kneaded for a long time and be softened.**
When […] we reach the level of a floor, we need to stop the building if this floor is

only made of joists, whereas it can continue if these floor joists are carried by beams. In the latter case, after the building is done, we open the rammed earth for the spans of each beam and we install in these openings timbers 2 feet long and 1 foot wide, laid in mortar of lime and sand if it is fir tree and of plaster or earth mortar if it is oak.

P 119 The beams are then placed on pads (coussinets). We fill with bricks the part of the wall that corresponds to the extremity of the beams and the exterior part of the pad and we continue the rammed earth after that.

[…] p 120 The soil we can use for the construction of the walls is a mix of clay and sand in which the sand seems to be in greater quantity at first glance but which is, however, capable of being kneaded and moulded. Even if it is not usual to work it as the earth brick/adobe *(la terre à brique,* it needs, however, to be mixed well, because it only gets its good qualities from this method. It also needs to be rather moist to bind when it is beaten in the mould. We can make sure if a soil is good for rammed earth by packing a flared bucket with it. If it is good *(quality)*, the heap once removed from the bucket will stand the weather without crumbling *(loosing its shape)*.

Del Rio M (1830) Memoria sobre los conocimientos actuals de las materias propias para la formación de los morteros y argamasas calcáreas que se emplean en la construcción de las obras civiles e hidráulicas. 1830 Madrid Real Academia de San Fernando. Translation NC.

Del Rio references a number of engineers and their writings upon lime mortars – Vitruvius, Berthier, Bruyere, Caudemberg, Raucourt, Petot and De La Faye. The text makes clear that he was heavily influenced by Vicat – with whole passages from Vicat delivered almost verbatim. He shares similar prejudice against pure limes and is in general pursuit of the hardest possible mortar, favouring the use of hydraulic limes in the air, as well as underwater and underground.

P12
Seccion II

(*Five categories of lime):*

1) Las cales grasas; 2) las cales aridas o secas; 3) las cales medianamente hidráulicas; 4) las cales hidráulicas; 5) las cales eminentemente hidráulicas.

1. Fat limes; 2} arid or dry limes - lean limes; 3) moderately hydraulic limes; hydraulic limes; eminently hydraulic limes. *(Moderately denotes feebly in this hierarchy)*.

Las cales grasas son aquellas que adquieren por la extinction ordinaria un doble volume, que su consistencia después de muchos anos de inmersión continua en el agua pura, es aun la misma o casi la misma que en el primer día, y que se disuelven hasta la ultima particular en un agua frecuentemente removida.

Fat limes are those which acquire upon ordinary slaking twice their volume;

their consistency after many years of continual immersion in clean water, and remains the same , or almost the same, as on the first day, and it will dissolve completely in frequently changed water.

Las cales secas son aquellas cuyo volumen aumenta muy poco por la extinción; por lo demás se conducen en el agua poco mas o menos como las cales grasa, con solo diferencia que no se disuelven en ella sino parcialmente dejando un residuo sin consistencia.

The dry (lean) limes are those the volume of which increases very little on slaking, otherwise they behave in water more or less the same way as fat limes, with one difference - that they don not dissolve in water without leaving an inconsistent residue.

Las cales medianamente hidráulicas fraguan a los quince o veinte días de inmersión y continuar endureciéndose…al cabo de un ano su consistencia es igual a la del jabon duro.

Moderately hydraulic limes set on the 15th or 20th day after immersion and continue to harden…after one year their consistency is like hard soap.

(Hydraulic limes, set up in 6 to 8 days; eminently hydraulic 2 to 4 days. This is directly from Vicat. Chapter on artificial hydraulic limes, including discussion of Vicat factory on outskirts of Paris).

p20 Seccion V De la estincion de la cal.

La cal viva se apaga por tres metodos o procederes diferentes:

10. **por aspersion que es el modo ordinario**
11. por inmersión; y
12. espontaneamente

Quicklime is slaked by three different methods or procedures:

6. **by aspersion - which is the ordinary method**
7. **by immersion**
8. **spontaneously.**

p21. Se toma la cal viva al salir del horno y se echa sobre ella una cantidad de agua conveniente…la cal se hunde y abre desde luego con ruido, se llena de grietas por todas partes, despide un humo acuoso y muy caliente, ligeramente cáustico, y en muy poco tiempo la cal se halla reducida a moléculas tan finas que forman un polvo impalpable: acompaña a estos efectos un calor muy grande. La cal apagada de este modo la llaman indiferentemente *cal fundida,* cal precipitada, y mas generalmente *cal apagada o cal muerta*.

One takes the quicklime as it leaves the kiln and one throws upon it a

convenient quantity of water…The lime sinks and opens after a time with noise, and entirely cracks, gives off steam and becomes very hot and slightly caustic, and in very little time it is reduced to molecules so fine they form an impalpable powder; as well as producing great heat. Lime slaked in this manner is called, variously *molten lime; precipitated lime and most commonly slaked (switched off; extinguished) lime or dead lime*.

Este proceder es el mas generalmente seguido, mas se abusa de el extraordinariamente, pues la reducen a consistencia de lechada en una alberca de donde la pasan a otra para hacer las mezclas, resultando entonces una pasta blanca, que aunque muy fina y pegajosa hasta cierto punto, sin embargo, no tiene la misma especie de ductilidad que las arcillas. La cal apagada así pierde la mayor parte de sus cualidades ferruginosas.

This procedure is the most commonly followed, moreover, they abuse it extraordinarily, reducing it to the consistency of grout in a tank (or pit) from where they pass it to someone else with which to make the mortars, resulting in a white paste which, although very fine and sticky up to a point, nevertheless, it has not the same kind of ductility (workability) as the clays. Lime slaked in this way loses the majority of its ferruginous qualities.

Las cales grasas apagadas en polvo producen de dos a tres volumenes por uno. Las cales secas, la mayor parte de las hidráulicas, y todas las eminentemente hidráulicas, no producen en las mismas circunstancias sino a uno y medio cuando mas.

Fat limes slaked as powder produce between 2 and 3 volumes to one. The lean limes, most of the hydraulic limes and all of the eminently hydraulic limes, in the same circumstances, from no to 1 1/2 times increase.

La cal grasa al momento de la extinción con mucha agua se funde algunas veces en seco en cierto puntos de la alberca, en donde el agua no ha podido llegar sino en pequeña cantidad: si se le echa de pronto mas agua sobre las partes que se funden así, produce un silbido semejante al de un hierro hecho ascua que se templa; y es cosa de notar que la cal asombrada, digámoslo así, por esta aspersion subida se divide en (p22) seguida muy mal, y permanece granujienta: cuanto mas fría es el agua que se echa, mas sensible es el efecto, particularmente en las cales muy grasa: cuando se quiera obtener una cal en pasta muy fina para blanquear las paredes, es preciso **echar desde el principio bastante agua para no verse precisados a tener que hacerlo de nuevo en el momento de la efervescencia,** o bien conducirla insensiblemente al rededor de las partes secas que se la absorben espontáneamente por aspiración.

During slaking with a surplus of water, fat lime sometimes melts to dryness in parts of the tank or pit, where the water has not run or has not been sufficient; if one throws more water too quickly upon these parts, it hisses like the

quenching of a hot iron, indicating the burning the lime, and they tell us, that this lime will then divide very poorly and remain permanently grainy. The colder is the water when you throw it, the more pronounced will the effect, particularly the fattier limes; when you want to obtain a very fine lime in paste to lime wash walls, it is essential to throw enough water at the beginning to effect the slake without the need to add more water during slaking.

Toda cal se hace perezosa o lenta a apartarse cuando ha sido antes aventada: este efecto es mas notable en las cales hidráulicas, que terminan entonces por disolverse en el agua sin manifestar otra cosa que un ligero desprendimiento de calor.

All lime is lazy or slow to move away (?) before sifting: this effect is more pronounced in the hydraulic limes, which finally dissolves in water without showing any but a slight heat.

Segundo proceder

Second Procedure.

La cal viva sumergida en el agua durante algunos segundos, y retirada antes de empezar la fusion, silva, astilla con ruido, estarse vapor ardiente y se deslace en polvo (estos fenómenos pueden ser mas o menos manifiestos); en este estado se la llama *cal apagada por inmersión*. Se la puede conservar mucho tiempo en este estado con tal que se ponga al abrigo de la humedad; y no se recalienta cuando se la deslíe.

(Notes that de la Faye promoted this method for building mortars in 1777)….

Quicklime plunged into water for some seconds, and withdrawn before the onset of the effusion (or slake), *silva (?),* splinters with noise, emits a steam, and breaks to powder (these phenomena could be more or less manifest): in this state it is called 'switched off' or extinguished lime - *cal apagada-* by immersion. One can conserve it a long time in this state, so long as it is protected from humidity/moisture. It does not become hot again when later dissolved (made into a paste).

p23 Cien partes de cal grasa apagada por inmersión no retienen regularmente mas que diez y ocho partes de agua, mientras que las cales hidráulicas contienen de veinte a treinta y cinco: este sucede en un sentido inverso con la extinción ordinaria.

Ten parts of fat lime slaked by immersion do not usually retain more than 18 parts of water, whilst the hydraulic limes contain from 20 to 35: this happens in an inverse relationship with the ordinary method of slaking.

Las cales muy grasas si solo se las quebranta groseramente antes de la inmersión, y se las deja en seguida de ella, fundir sobre el terreno, se dividen difícilmente en polvo muy fino; **mas de la mitad se queda en pequeños fragmentos sonidos del tamaño de un garbanzo,** y estos fragmentos, una vez enfriados pueden estar mucho tiempo en el agua sin desleírse. **Se vence esta dificultad reduciendo primero las piedras de cal viva antes de sumergirlas al tamaño de un huevo, y sobre todo acumulándolas inmediatamente después de la inmersión en gran pipas, toneles o cajones; entonces el calor se halla concentrado, y una gran parte del agua evaporada en el principio, no pudiendo escapar, es absorbida por la misma cal, que por este medio llega a dividirse de una manera satisfactoria.**

Very fat limes only will break coarsely before immersion, and if they are left will divide on the ground but with difficulty to a fine powder: more than half remains in small fragments the size of a chickpea, and these fragments, once chilled, will remain for a long time without dissolving. To overcome this difficulty first reduce the lump lime to the size of an egg and, above all, collect it immediately after the immersion in large pipes, barrels or troughs, as a result of which the heat will be concentrated and a large part of the water evaporates at the start and cannot escape but is absorbed by the same lime, and hereby it is divided (reduced) in a satisfactory manner.

Un volumen de cal viva grasa medida en polvo no produce mas que 1.5 a 1.7 en polvo apagado.

One volume of fat quicklime measured in powder does not produce more than 1.5 to 1.7 in slaked powder.

Las cales hidraulicas producen en las mismas circunstancias de 1.8 a 2.8.

Hydraulic limes produce in the same circumstances from 1.8 to 2.8.

Tercer proceder

Third procedure.

La cal viva sometida a la acción lenta y continuada de la atmosfera se reduce a polvo **muy fino.** Durante esta extinción natural hay ligero desprendimiento de calor, mas sin vapores sensibles.

The quicklime is submitted to the slow and continuous action of the atmosphere and reduces to a very fine powder. During this natural slaking there is a slight release of heat, but without perceptible vapour.

Las cales grasas aumentan 2/5 de su peso y producen (p24) en volumen hasta 3.52 por uno (medida en polvo). Las cales hidráulicas no absorben regularmente mas que 1/8 de agua.
Para obtener estos resultados es preciso esperar a que se haya completado la reducción, y **no operar en una atmósfera cargada de humedad.**

The weight of fat limes augments by 2/5 and increases by volume up to 3.52 times for one (in powder). The hydraulic limes don't usually absorb more than 1/8 of water and will be inert in a damp atmosphere.

La extinción ordinaria es de las tres la que mejor divide las cales grasas y las cales hidráulicas de todos los grados, por consiguiente lleva la fusion al mas alto termino: en segundo lugar, y bajo las mismas relaciones, la extinción espontánea conviene mejor a las cales grasas que a las cales hidráulicas y eminentemente hidráulicas, y vice-versa en la extinción por inmersión.

Ordinary slaking is the one of the three that most divides the fat limes and the hydraulic limes of all kinds, due to its bringing the fusion to its highest degree; in second place and under the same conditions, spontaneous slaking is better for fat limes than for hydraulic and eminently hydraulic limes, and conversely in slaking by immersion.

Toda cal respuesta viva al contacto de aire en un lugar abrigado, recupera insensiblemente el acido carbónico que es necesario a su saturación. El tiempo necesario para esto vaya según la naturaleza y **el volumen de la cal** : si es grasa bastan diez meses cuando se ha apagado en capas o tongas de una pulgada de espesor reduces to a solamente.

All reactive limes placed in contact with the air in a sheltered place, imperceptibly regain the carbonic acid necessary for their saturation. The time necessary for this depends upon the nature and the volume of the lime: if it is fat, it takes 10 months when it has been slaked in layers of an inch thickness.

p35

Las arcillas.

Clays

Las arcillas son unas sustancias terrosas diversamente coloreadas, finas, suaves al tacto, que se deslicen en el agua con bastante facilidad; y se reducen a una papilla que conducida a cierta consistencia es untuosa, tenaz, y se deja alargar y comprimir sin quebrarse. La pasta arcillosa desecada conserva cierta tenacidad y se endurece al fuego, etc…

The clays are earthy substances variously coloured, fine, soft to the touch, that dissolve in water with relative ease: and reduce to an unctuous, tenacious

paste which can be extended or compressed without breaking. A drier clayey paste retains tenacity and endures in the fire.

p36 Las arcillas se distinguen en cuatro clases, que son 1. las arcillas aspires, que resisten sin fundirse el calor de los hornos de porcelanas; 2. las arcillas fósiles; 3. las arcillas efervescentes, o margas arcillosas; y 4. en fin las arcillas ocreosas coloreadas de rojo, o amarillo puro por el oxido de hierro.

Clays are divided into four classes, which are, 1. aspiring clays, which resist without disintegrating in the heat of a pottery kiln; 2. fossiliferous clays: 3. effervescent clays, or clayey marls and 4. finally, ocherous red or yellow clays coloured by iron oxides.

p38…Las Puzzolanas artificiales

Artificial pozzalans

Bajo de esta denominación comprenderemos las arcillas, las arenas, las sammitas y los chistes convenientemente calcinados; las escorias de las herrerías, las cenizas de la combustion de las turbas y del carbon de piedra, en fin los desperdicios de los tejares y alfarerías.

Under this heading we understand clays, sands, the sammites and wastes conveniently calcined: iron scales, peat and coal ash and lastly the waste from potteries and brickworks.

Tal es el cuadro sucinto de las sustancias que concurren con la cal para la formación de las argamasas calcáreas; mas estas sustancias, aunque generalmente compuestas de sílice y de alumina, no se conducen todas de la misma manera: las unas se unen bien con las cales grasas, las otras con las cales medianamente, o eminentemente hidráulicas, y entre estas dos diferentes aleaciones las unas resisten bien al aire, a las intemperie y a la acción de las aguas; las otras no se mantienen sino por una inmersión continua en el agua, aquellas en fin pierden toda su adherencia desde que se las sumerge etc etc.

Such is the summary of the substances which concur (agree) with lime in the formation of calcareous mortars; moreover, these substances are generally composed of silice and alumina, but don't all behave in the same way: some unite well with fat limes, others with moderately or eminently hydraulic limes, and between these two 'alloys' some offer good resistance in the air, outdoors as well as to the action of water; some will at last lose all adhesion when submerged in water.

p39. Section VIII *De las cualidades de las diversa materias que concurren con la cal para la formación de los morteros y argamasas.*

p43 Section IX
De la fabrication de las puzzolanas artificiales.

Entre las rocas o tierras esencialmente compuestas de silice y de alumina, las que se eligen porque se presentan mas fácilmente a esta transformación, son 1. las arcillas; 2. las sammitas schistoides, pardas y amarillas, que forman pasta arcillosa con el agua; 3. las arenas abundantes en arcilla; 4. en fin algunas especies de chistes.
Among the rocks or earths essentially composed of silica and alumina, those are chosen which most easily transform: 1. clays; 2, brown or yellow schist sammites, which will form a clayey paste with water; 3. sands rich in clay; 4. various types of waste.

El fuego es el agente que se emplea y las condiciones de la transformación son: 1. que la materia puede adquirir bastante cohesion para no formar pasta con el agua; 2. que tenga el mínimo de pesadez especifica y el máximo de facultad absorbente; 3. que se haga mas accesible a los agentes químicos, tales es como los ácidos debilitados que lo eran anteriormente.

Fire is the agency employed and the conditions of transformation are: 1. that the material acquires enough cohesion without forming a paste with water; 2. that has the minimum specific gravity and the maximum porosity; 3. that which is most accesible to chemical agents, such as weak acids.

Se llenan estas condiciones por medio de una cocción muy moderada, dirigida de manera que el aire pueda (p44) alcanzar a todas las partes de la materia en escandescencia.

These minimum conditions are met by way of a moderate heat, directed in a manner by which air can bring all parts of the burn to incandescence.

El primero y el mejor método consiste em pulverizar primero la arcilla, la sammita o la arena que se ha elegido, estendiendola en seguida en una capa o tonga de cinco a seis lineas de espesor sobre unas planchas de hierro hecho ascua, se deja enrojecer la materia al mismo grado durante un tiempo que varia en cada una de veinte a veinte y cinco minutos. Se tiene cuidado de remover continuamente el polvo con una espátula, a fin de que todas las partes sean uniformemente calcinadas. Las arcillas o sammitas ocreosas de un rojo obscuro o anaranjado que tira a sanguíneo muy pronunciado, exigen un fuego mayor y mas durable que las otras; veinte minutos y una escandescencia mas inmediata del rojo a estirar que del rojo cereza son los términos que la conviene. Este método de cocción no ha sido aun ejecutado en grande por las muchas dificultades que presenta.

The first and best method is to first pulverise the chosen clay, sammite or sand, laying it out in a container or pit in 5 or 6 lines of thickness over red hot iron grilles, leaving it for from 20 to 25 minutes, depending upon its nature, taking care to continually stir and agitate the powder with a spatula, until all parts are evenly calcined. Clays or dark red or orange ocherous sammites require a hotter fire for longer than the others; 20 minutes and a strong red incandescence tending to cherry red is the minimum required. This cooking method cannot be performed on a large scale due the its many difficulties.

El segundo metodo consiste en hacer la materia extremamente porosa y penetrable al aire, si no los es ya, y en cocerla en seguida como el ladrillo; mas en la parte mas elevada del horno, en donde el calor no es nunca bastante fuerte, no solo para vitrificar, mas ni aun para dar al ladrillo fusible el grado de cocción que se exige en el comercio.

The second method consists in making extremely porous materials and cooking them like bricks; moreover, in the highest parts of the kiln, where the heat is never so strong, not only to vitrify, but also to give to the brick the extent of cooking which is necessary for commerce.

Se hace la materia porosa amasando con igual volumen de sílice cuarzosa, después de lo cual se divide en panes o prismas que se dejan secar y endurecer convenientemente….

The porous material is kneaded in equal volumes with quartz sand, after which the mixture is formed into briquettes or prisms which are left to dry and harden.

p45 Los hornos de cal que sirven al mismo tiempo para la cocción del ladrillo, facilitan bastante el paso del aire, y por lo tanto convienen perfectamente para la cocción de las puzzolanas artificiales.

Lime kilns which also serve as brick kilns, allow the passage of sufficient air, and serve very well for the calcination of artificial pozzalans.

Toda arcilla, principalmente compuesta de sílice y de alumina fina y suave al tacto, que tiene poco o mucho oxido de hierro, y poco o nada de carbonate de cal, dará una puzzolana **muy enérgica,** si es cocida por uno de los métodos primeros.

All clay, principally composed of silica and alumina, fine and soft to the touch, which contain a little or a lot of iron oxide, and little or no calcium carbonate, will give a very energetic pozzalan, if it is cooked by one of the first methods.

p47 De la combinación de las diversas cales con los materiales propios para la formación de los morteros y argamasas.

Caso Primero.
Para obtener los morteros o argamasas capaces de adquirir una gran

consistencia y dureza en el agua, or bajo de tierra, o en lugares constantemente húmedos, es necesario combinar:

First case.
To obtain mortars or plasters capable of acquiring a good consistency and hardness in water, or below ground, or in constantly wet places, it is necessary to combine:

Con las cales grasas
Las puzzolanas naturales o artificiales muy enérgicas

With fat limes

Very energetic natural or artificial pozzalans

Con las cales medianamente hidráulicas

Las puzzolanas naturales o artificiales simplemente enérgicas o las puzzolanas naturales o artificiales muy enérgicas, templadas por una mezcla próximamente de la mitad (p48) de slice u otras materias inertes; o las arenas y las semitas enérgicas.
With moderately hydraulic limes

Simply energetic natural or artificial pozzalans or very energetic natural or artificial pozzalans mixed in equal parts with sand or other inert materials; or with sands or energetic sammites.

Con las cales hidráulicas

Las puzzolanas naturales o artificiales poco enérgicas o las puzzolanas naturales o artificiales enérgicas, templadas por una mezcla de la mitad próximamente de silice o las arenas y las sammitas poco enérgicas

With hydraulic limes

Little energetic or energetic natural or artificial pozzalans, tempered into a mixture with an equal measure of silica sand or sand and slightly energetic sammites.

Con las cales eminentemente hidráulicas
Las materias inertes, tales como los silices cuarzosos o calcáreos o forge scales.

With eminently hydraulic limes

Inert materials, such as quartz or calcareous sands or forge scales.

Caso Segundo.

Second case.

Para obtener los morteros o argamasas capaces de adquirir una gran dureza al aire libre, y de resistir a las lluvias, a los calores y a las fuertes heladas, es necesario combinar

To obtain mortars or plasters capable of acquiring a great hardness in the air and to resist rains, heat and freezing, it is necessary to combine:

Con las cales grasas
Ningun ingrediente puede llenar el objeto.

With fat limes

No ingredient can achieve this objective *(repeating Vicat)*

Con las cales medianamente hidráulicas
Ningun ingrediente puede llenar completamente el objeto.

With moderately (feebly) hydraulic limes

No ingredient can achieve this objective.

p49 *Con las cales hidráulicas*
Los slices cualquiera bien puros o los polvos cuarzosas o los polvos que provienen de las piedras calcáreas duros o de otros materias inertes.

With hydraulic limes

Pure silica sands or quartz powders or the powders that come from hard calcareous stones or other inert materials.

Con las cales eminentemente hidráulicas.

Los silices cualquiera bien puros o los polvos cuarzosos o los polvos que provienen de las piedras calcáreas duras y de otra materias inertes.

With eminently hydraulic limes

(as for hydraulic limes).

p51 *Eleccion de los procederes de extinción.*

Choosing the method of slaking.

La naturaleza de las cales y de los ingredientes empleados, regla la elección del proceder de extinción. Los hechos nos conducen a esta observación general.

2. Que para todas las argamasas posibles de cales grasas…el orden de preferencia de los tres procederes de extinción es i) la extinción espontánea; ii) la extinción por inmersión; iii) la extinción ordinaria.
3. Para todas las argamasas y morteros posibles de cales hidráulicas y eminentemente hidráulicas, es i) la estación ordinaria; ii) la extinción por inmersión; iii) la estación espontánea….

The nature of the lime and the ingredients employed determines the choice of slaking procedure. The facts lead us to these general observations:

6. That for all fat lime plasters, the order of preference of the three procedures is i) spontaneous slaking; ii) slaking by immersion; iii) ordinary extinction.
7. For all hydraulic or eminently hydraulic plasters and mortars, i) ordinary slaking; ii) immersion; iii) spontaneous extinction.

La diferencias de dureza que resultan de emplear tal o cual proceder de extinción son muy variables: llegan al máximo en las cales grasas mezcladas con materias inertes, y son casi insensibles cuando se mezclan con puzzolanas muy enérgicas. Entre estos limites estas diferencias están sometidas a una marcha progresiva que se arregla sobre la energía variable de los ingredientes.

The difference in hardness which results from the employment of this or that slaking procedure is very variable; it arrives at its maximum with the fat limes mixed with inert materials, and is almost imperceptible when these are mixed with very energetic pozzalans. Between these boundaries, the differences are subject to progressive variation according to the energy of the ingredients.

Este gran cuestión del mejor medio de extinción ha sido agitada hace mucho tiempo entre los Arquitectos, no siendo extraño que haya sido resuelta por los unos en favor de la inmersión, y por otros en favor del proceder ordinario; cada uno se ha servido para ello de los materiales que ha tenido mas a mano, sin conocer que el resultado que se iba a obtener solo convenio a aquella materia. Faujas es el único que previo (p52) que la cal según su naturaleza se prestaba con preferencia a tal proceder de extinción, mejor que a tal otro, según puede verse en una de las notas de su Memoria sobre la inmersión.

This big question of which method of slaking is the best has preoccupied architects for a long time, not surprisingly leading to some in favour of immersion, others in favour of the ordinary method, each one having served for the materials to hand, without knowledge of the result from the use of these materials….

Las cales hidraulicas o eminentemente hidráulicas, pueden apagarse por inmersión o por el proceder ordinario, sin que resulte grandes diferencias en los morteros o argamasas en que intervengan estas cales; mas no sucederá lo mismo con la extinción espontánea, cuya influencia sera tanto mas perjudicial, cuanto las cualidades de las cales a que se aplique sean mas eminentemente hidráulicas.

The hydraulic or eminently hydraulic limes can be slaked by immersion or by the ordinary method without showing great difference in the mortars or plasters; but the same is not so of spontaneous slaking, the effect of which will be much more harmful, and the more so the more eminently hydraulic they are.

Nos hemos limitado en la sección segunda a solo dar una definición de la cal árida y seca (lean limes?), y después no hemos vuelto a hablar de ella: la razón es muy sencilla, **porque esta cal no se emplea sino rara vez en falta de otras,** porque **tiene todas las cualidades negativas de las cales grasas,** para ello es preciso modificar las proporciones de los ingredientes teniendo presente que estas cales contienen mas oxido terroso o metálico que las cales medianamente hidráulicas, a quien se asemejan. En las experiencias que se han hecho en Brest con estas cales por el Ingeniero De-Laroche se ha hallado que el precepto de *vale mas pecar por defecto que por esceso de cal,* no se verifica en estas cales.

We have limited ourselves in the second section to just giving a definition of the lean limes, and we will talk no more of them: the reason is very simple - for this lime is only used when no others are available, because they have all the negative qualities of fat limes…

De la manipulation o fabricacion.

La fabricación comprende la extinción de la cal y su mezcla con los ingredientes que se unen con ella para la composición del mortero o argamasa.

De cualquiera manera que la cal haya sido apagada es necesario reducirla al estado de pasta homogénea (p53) para que pueda recibir en seguida los ingredientes con que ha se mezclarse.

By ‘Manufacturing’ is understood, the slaking of the lime and its mixture with the ingredients with which it will unite to make a mortar or plaster

Esta pasta debe ser tan dura como sea posible, siempre que haya de construirse como ganga entre granos duros y palpables, que conservan entre si una cierta distancia apreciable, o al lo menos sensible. En este caso se hallan los morteros o mezclas de cal y sílice.

La fuerza de los morteros considerada como agregados, reside exclusivamente en la de los hidrates de cal o ganga, que envuelve los granos de sílice, siendo evidente que cuanto mas densidad tenga el hidrate, tanta mayor sera la resistencia de la mezcla.

La pasta podrá tener una consistencia mas o menos blanda, cuando haya de formar con una materia pulverulenta de granos impalpables y absorbentes un todo en apariencia homogéneo, donde la simple vista no pueda discernir ninguno de los elementos constitutivos. En este caso se hallan las argamasas calcáreas o mezclas de cal, puzzolanas, arenas, arcillas o sammitas. Mas en todos los casos posibles el resultado de la mezcla debe presentarse bajo de una buena consistencia arcillosa, igual a la que digamos al tratar de los hidrates.

La cal apagada por inmersión o espontáneamente, se puede reducir al estado de pasta dura o de puchada cuando se la toma en un estado pulverulento; mas esto no es posible cuando se trata de cal apagada por el proceder ordinario, si esta ha sido ahogada desde el principio en una gran cantidad de agua; por eso es preciso no emplear en este método de extinción sino es el agua absolutamente necesaria para que puede pasar la cal del estado de piedra viva al estado de pasta dura. Hay siempre tiempo de anadirla agua si fuese necesario en el momento de usarla.

Las cales hidraulicas….(p54) ofrecen con respecto a esto algunas dificultades. Vamos a exponer detalladamente el proceder que debe seguirse cuando se aplique la extinción ordinaria.

La cal viva en piedra se echa con la pala en una alberca impenetrable al agua, hecha para el efecto, en la que se extiende por capas iguales de tres a cuatro pulgadas de grueso; sobre esta capa se echa agua de tal manera que puede circular y penetrar con facilidad en los vacíos que dejan entre si los pedazos de la cal viva. La efervescencia no tarda casi nada en manifestarse, se continua echando alternativamente la cal y el agua, cuidando de no remover la materia ni de reducirla a lechada (**segun la costumbre de los albañiles);** solamente cuando por casualidad algunos pedazos de cal se funden en seco, se dirige el agua hacia aquella parte por unas regatas que se hacen ligeramente en la pasta, y de tiempo en tiempo se introduce una vara puntiaguda en los puntos donde se sospeche que el agua no ha podido llegar; si el palo o vara al sacarle sale cubierto de una cal glutinosa la extinción es buena, mas si solo se levanta un humo farinoso es una prueba de que la cal se funde en seco, entonces se agranda el agujero, o se hacen otros al lado, y se dirige allí el agua.

No se debe apagar así mas que la cantidad de cal que se necesite para el consumo de uno u dos días a lo mas. Dos albercas separadas, o dos de capacidades en la misma son indispensable. Se empieza a llenar la una cuando la otra esta próxima a vaciarse; por este medio la cal tiene a lo menos veinte y cuatro horas para trabajar, y los fragmentos perezosas se dividen todos igualmente.

La cal apagada de este modo es ya bastante dura al día siguiente, es necesario cavarla, o a lo menos cortarla con una pala de hierro para estraella. En este estado parece que no puede ser ya reducida al de pasta (p55) blanda sin mas adición de agua; mas esto es un error, se la hace fácilmente blanda por medio de unas mazas de hierro con su mango de madera. La rastra o batidera jamas podrá trabarla, pero si se la golpea y comprime con las mazas, no tarda casi nada en regoldar el agua que conserva empapada y formar una pasta suficientemente blanda para recibir el sílice.

P59 *Influencia del tiempo.*

p60 El tiempo del fraguado al principio no puede ser un pronostico exacto de la dureza futura, sino cuando se comparan dos argamasas o morteros de una misma especie. …

Las observaciones siguientes se deducen de los resultados obtenidos hasta el día:

1. El excess de cal grasa o medianamente hidráulica en una argamasa retarda el fraguado; las proporciones mas favorable a este son las que le dan mayor dureza.
2. El segundo y tercer proceder de extinción parecen generalmente mas propios para acelerar el fraguado que el primero.
3. Los progresos de las argamasas de cales grasas y puzzolanas enérgicas o muy enérgicas, son aun sensibles durante el tercer ano que sigue a la inmersión.

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4. Los progresos de los morteros de cales hidraulicas, o eminentemente hidráulicas, y de silices cuarzosos o calcáreos, no son mas sensibles después del segundo ano de inmersión.
5. El tiempo modifica, mas no destruye las relaciones de dureza que derivan de la comparación de los tres procederes de extinción, esto es, que el orden de preeminencia observado al fin del primer ano es el mismo al fin de tercero, y así sucesivamente.

(Then whole sections almost verbatim from Vicat about sands and limes)

p63 *Influencia del tamaño de los sillines.*

…Los silices cuarzosas o calcáreos guardan, con respecto a cada especie de cal, el orden de superioridad siguiente:

Para las cales eminentemente hidráulicas, y simplemente hidráulicas: 1. los silices finos; 2. los silices de grano desigual, que resultan de la mezcla del silice grueso con el fino; el silice grueso.

Para las cales medianamente hidráulicas: 1. los silbes de granos desigual mezclado como arriba; los sillines finos; 3. los silices gruesos.

Para las cales grasas: 1. los silices gruesos; 2. los silices de grano desigual; 3. los silices finos.

(To some extent based on investigation of Roman mortars in Spain).

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La resistencia de los morteros de cales muy grasas apagadas por el proceder ordinario
crece desde 50 hasta 240 partes de sílice por 100 de cal en pasta dura, y después decrece indefinidamente.
La resistencia de los mismos morteros, cuando la cal ha sido apagada por inmersión o espontáneamente, crece desde 50 hasta 220 partes de sílice por 100 de cal en el pasta dura, y después decrece indefinidamente.

La resistencia de los morteros de cales hidráulicas apagadas por el proceder ordinario crece desde cero hasta 180 partes de sílice por 100 de cal en pasta dura, y después, etc
La resistencia de los mismos morteros cuando la cal ha sido apagada por inmersión o espontáneamente crece desde cero hasta 170 partes de sílice por 100 de cal en pasta dura…

Estos resultados bastan para establecer que las mejores proporciones están subordinadas, no solamente a la naturaleza de la cal empleada, sino también al proceder de extinción a que la cal ha sido sometida: se vera después que aun hay otras consideraciones de que dependen también.

p66 Ya hemos dicho, hablando de las argamasas y morteros sumergidos, que la manera de apagar la cal ejercía sobre su dureza una influencia muy notable: esta influencia de la extinción no es con mucho tan pronunciada en los morteros expuestos a la intemperie.

De la formación o manipulación

Hay varios autores que aseguran que los morteros ganan mucho con estar amasados largo tiempo; mas esta opinion carece de fundamento.

Las sustancias cuarzosas y calcáreos se conducen generalmente mejor en el estado de sílice, que en el estado de polvo con toda especie de cal; el efecto mecánico de una trituración laboriosa, y sostenida mas allá del tiempo necesario para su perfecta mezcla, no puede menos de ser danosa; mas hay otro punto de vista bajo del cual la cosa debe mirarse, este es la influencia atmosférica sobre los principios de los morteros y favorece por la frecuente renovación de los contactos.

Se ha visto que las cales hidráulicas y eminentemente hidráulicas, **respuestas al aire pierden una parte (p67) de sus calidades, mientras que las calas grasas adquieren nuevas:** de aquí resulta que el mortero de cal grasa es el único que tiene que ganar alguna cosa con estar largo tiempo amasado, y esto es también lo que prueban las experiencias que se han hecho: en efecto ellas han hecho ver que una mezcla de 150 partes de sílice y de 100 partes de esta cal apagada por inmersión y medida en pasta, habiendo sido amasada y vuelta a amasar con adición de agua de ocho en ocho días durante cinco meses seguidos, llego un ano después a adquirir un resistencia representada por 5.43, mientras que en el caso de una manipulación ordinaria esta misma mezcla no pudo llegar mas que a 4.14; mas aunque sensible esta diferencia no corresponde con mucho al trabajo que costo; así pues solo a los morteros de cal grasa podrá ser util este método, con lo que en cierto modo se halla justificado el sistema Leones…

Todo lo que hemos dicho sobre la extinción de la cal y la consistencia de la mezcla con respecto a las argamasas y morteros sumergidos, se aplica exactamente a los morteros expuestos al aire: sin embargo hay 4/10 de perdida sobre la resistencia ulterior que pueden adquirir los morteros de cal hidráulica, cuando en lugar de la fuerte consistencia de que hemos hablado se atiende a la generalmente adoptada por los albañiles por efecto du una practica rutinaria, y sin examen ni conocimiento.

El mortero en todas la estaciones debe estar fabricado (p68) en cuanto sea posible a cubierto, ya para evitar la desecación rápida del estío, ya para obviar los inconvenientes aun mas graves de la estación de las lluvias. En este ultimo caso es preciso separarse un poco de los principios establecidos, y preferir la cal hidráulica apagada por inmersión a la que resulta de la extinción ordinaria, para por este medio poder absorber el agua que el sílice mojado puede contener, sin lo que no es posible obtener un buen mortero.

En el estio, al contrario, la cal en pasta no es siempre suficiente para remojar el sílice que algunas veces esta, digamoslo así, hirviendo y es indispensable andar agua, mas gradualmente y con la mayor precaución. No se podrá creer sin haberlo visto cuan poco se necesita para ahogar la mezcla,

Empleo de los morteros

Es de toda evidencia, que un mortero duro no puede ser empleado con materiales secos y absorbentes. Cuando hay semejantes materiales es preciso mojarlos sin cesar para tenerlos siempre en un estado de humedad: el secreto de una buena manipulación consiste enteramente en este precepto, 'mortero duro y materiales mojadas', mas nuestros albañiles al contrario parece han tomado por divisa *materiales secos y mortero anegado.*

Las manos del operario no hay duda que con este método no tardaran en hacerse una llaga, si no toma al mismo tiempo algunas precauciones para defenderse de la acción de la cal. El alquitrán liquido es un remedio eficaz; para esto basta frotarse los dedos con el varias veces al día; la ligera capa que queda adherida a la piel equivale a un guante impenetrable.

p69 *Precauciones*

Los morteros se hacen generalmente pulverulentos cuando son expuestos después de empleados a una desecación rápida: la influencia se semejante desecación se hace **tanto mas funesta cuanto las cales empleadas en ellos son mas eminentemente hidráulica:** los morteros pueden entonces perder los 4/5 de la fuerza que habrían adquirido por una desecación lenta. Así conviene regar la fabrica cuando se hace durante la estación del estío o de los grandes calores, y de tal manera que el mortero no pueda perder el agua necesaria a su solidificación.

La influencia de la desecación lenta sobre la bondad de los morteros hace mucho tiempo que es conocida en Italia…(for bridges in various places there) emplean una cal hidráulica sacada de las cercanías de Casal, que apagan según el proceder ordinario, y cuando tiene de cinco a seis días de apagada se la coloca en el centro de una fosa (pit) de sílice de granos desiguales, desde el grueso de sílice ordinaria hasta el de la grava gruesa. Este sílice es eminentemente cuarzoso y contiene algunos residuos de cal, se hace en seguida la mezcla, en la cual se pone mucho cuidado: se prepara antes de emplearla un foso prismático triangular de una longitud arbitraria en un terreno de nivel, y al abrigo de las inundaciones: se igualan las paredes con la llana y el agua, y se forman los prismas (breakwaters?) por capas sucesivas, introduciendo en el mortero guijarros (pebbles) de igual tamaño distribuidos con igualdad.

p70 *Influencia del tiempo.*

'Un mortero de cien anos es aun niño' dicen los albañiles con frecuencia, como resultado de las observaciones diarias que están a su alcance hacer sobre las demoliciones: efectivamente solo en los fundamentos o macizos de edificios de 400 a 500 anos es en donde se encuentran buenos morteros de cales grasas….que es muy fácil de concebir es que un mortero que no esta duro hasta después de cien anos, es **para nosotros como si no lo fuese jamas.**

En cuanto a los morteros de cales hidráulicas, o eminentemente hidráulicas, las numerosas experiencias que se han hecho y hemos reunido prueban que expuestos al aire bajo un pequeño volumen llegan en muy poco tiempo (de 18 a 20 meses) si no al ultimo grado de dureza; de que son susceptibles, a lo menos a un termino que difiere muy poco para que se pueda conocer con certeza lo que llegara a ser en lo sucesivo.

(Section XIV - mostly Vicat's observations on curing time and frost resistance).

p75 En las partes cubiertas de los edificios los morteros de cales grasas no tienen que sufrir todas estas vicisitudes, mas no se hacen mejores por eso. Los limites máximos de las proporciones del sílice que les conviene entonces son de 55, 125 o 175 partes por 100 de cal en pasta según provenga de la extinción ordinaria, la extinción por inmersión, o la extinción espontánea.

Acordandonos de los limites maximos que se han asignado para los casos de las intemperie, concluiremos facilmente que estas mismas intemperie favorecen los morteros cargados de sílice, y al contrario perjudican a aquellos en que domina la cal.

Shaw E (1832) Operative Masonry; or, A theoretical and practical treatise of building; containing a scientific account of stones, clays, bricks, mortars, cements, &c.; a description of their component parts, with the manner of preparing and using them. The fundamental rules in geometry, on masonry and stone-cutting, with their application to practice. Illustrated with forty copper-plate engravings. Boston; Marsh, Capen & Lyon.

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SECTION VII. The Burning of Lime.

… The calcination of lime-stone may be effected by wood, coal, or peat, as fuel; but the heat should **not much exceed a red heat, unless the stone employed be nearly a pure carbonate.** The fuel is placed in layers, alternately with those of the stones, or calcareous materials in the kilns, and the process of burning continued for any length of time, by repeated applications of fuel and the calcare ous materials at the top ; the lime being drawn out occasionally from below, as it is burnt. Fossil, or mineral coal, are supposed to be the most convenient and suitable materials for effecting this business, where they can be pro cured plentifully, and at a sufficiently cheap rate ; as they burn the stone, or other calcareous matter more perfectly, and, of course, leave fewer cores in the calcined pieces, than when other sorts of fuel are employed for the purpose.

P53 Peat, also, is highly recommended for its cheapness and uniformity of heat. When coal is used, the lime-stones are liable, from excessive heat, to run into solid lumps; which may be avoided by the use of peat, as it keeps them in an open state, and admits the air freely.

Count Rumford, with his usual attention to economy in fuel, and in the expense of caloric, has invented an oven for preparing lime. It has the form of a high cylinder with a hearth at the side, and at some distance above the base. The combustible is placed on the hearth, and burns with an inverted or reflected flame. The lime is taken out at the bottom, while fresh additions of lime-stone are made at the top; and thus the oven is preserved constantly hot.

Lime-stone recently dug, and of course moist, calcines more easily than that which has become dry by exposure to the air: in the latter case it is found convenient even to moisten the stone, before putting it into the kiln. Lime-stone loses about four-ninths of its weight by burning ; but is nearly of the same bulk. Lime thus obtained, is called quick-lime. If it be wet with water, it instantly swells and cracks, becomes exceedingly hot, and **at length falls into a white, soft, impalpable powder.** This process is denominated the slaking of lime. The compound formed is called the hydrate of lime, and consists of about three parts of lime to one of water. **When intended for mortar, it should immediately lie incorporated with sand, and be used without delay, before it imbibes carbonic acid anew from the atmosphere.** Lime doubles its bulk by slaking.
SECTION VIII.

Common Mortar and Cement.

These are the substances generally made use of, for the uniting medium between bricks, or stones, in forming them into buildings. Though many experiments have been made to ascertain the best materials for these compounds, and the mode of mixing them, and not without a degree of success, still, **much yet seems to remain to be discovered.** A composition of lime, sand and water, in consequence of the facility, with which they pass from a soft state to a stony hardness, has, in common uses, superseded all other ingredients *[earths and earth mortars, he presumably means]*.

But in order that the mortar should be of a good quality, great care and skill are requisite, in the selection of the materials, and the proportioning of them; and much depends on the degree of labor bestowed on the mixing and incorporation. The lime should be well burnt, and free from fixed air and carbonic acid. Hence, lime that has become effete from exposure to the atmosphere, is impaired in its quality. The sand most proper for mortar is that which is wholly siliceous, and which is sharp, that is, not having its particles rounded by attrition. Fresh sand is to be preferred to that taken from the vicinity of the sea-shore, the salt of which is liable to deliquesce and weaken the strength of the mortar: (p54) it should be clean, rather coarse, and free from dirt and all perishable ingredients. The water should be pure, fresh, and, if possible, free from fixed air. **The proportions of lime and sand to each other, are varied in different places; the amount of sand, however, always exceeds that of lime. The more sand that can be incorporated with the lime, the better, provided the necessary degree of plasticity is preserved;** for the mortar becomes stronger, and it also sets, or consolidates more quickly, when the lime and water are less in quantity and more subdivided. **From two to four parts of sand are commonly used to one of lime, according to the quality of the lime, and the labor bestowed upon it.** The more pure the lime is, and the more thoroughly it is beaten, or worked over, the more sand it will take up, and the more firm and durable does it become.

SECTION IX.

The ancient masons were so very scrupulous in the process of mixing their mortar, that it is said the Greeks kept ten men constantly employed for a long space of time, to each bason; this rendered their mortar of such prodigious hardness, that Vitruvius tells us, the pieces of plaster falling off from old walls, served to make tables. *{This is taken directly from Rees (see above)].* It was a maxim among the old masons to their laborers, that they should dilute the mortar with the sweat of their brows, that is, labor a long time, instead of drowning it with water to have it done the sooner.

The weakness of modern mortar, compared to the ancient, is a common subject of regret; and many ingenious men take it for granted, that the process used by the Roman architects in preparing their mortar, is one of those arts which is now lost, and have employed themselves in making experiments for its recovery. **But the characteristics of all modern artists, builders among the rest, seems to be, to spare their time and labor as much as possible, and to increase the quantity of the article they produce, without much regard to goodness; and perhaps there is no manufacture, in which it is so remarkably exemplified, as in the preparation of common mortar.**

SECTION X.

[included once more to illustrate the speed with which Partington's observations crossed to the USA].

Mr. Dossie gives the following method of making mortar impenetrable to moisture, acquiring great hardness, and exceedingly durable, which was discovered by a gentleman of Neufchatel. Take of unslacked lime, and of fine sand, in the proportion of one part of lime to three of sand, as much as a laborer can well manage at once; and then, adding water gradually, mix the whole well together with (p55) a trowel, till it be rendered to the consistency of mortar. Apply it immediately, while it is hot, to the purpose, either of mortar, as a cement to brick or stone, or of plaster, to the surface of any building. It will then ferment for some days in drier places, and after wards gradually concrete, or set, and become hard; but in a moist place, it will continue soft for three weeks, or more ; though it will at length obtain a firm consistence, even if water have such access to it as to keep the surface wet the whole time. After this it will acquire a stone-like hardness, and resist all moisture. The perfection of this mortar depends on the ingredients being thoroughly blended together; and the mixture being applied immediately after, to the place where it is wanted. The lime for this mortar must be made of hard lime-stone, shells or marl; and the stronger it is, the better the mortar will be. When a very great hardness and firmness are requisite in this mortar, the using of skimmed milk, instead of water, either wholly or in part, will produce the desired effect.

SECTION XI.

Monsieur Loriat's Mortar. *[Similarly].*

Monsieur Loriat's Mortar, — The method of making which, was announced by order of his majesty, at Paris, in 1774: it is made in the following manner: — Take one part of brick dust, finely sifted, two parts of fine river sand, screened, and as much old slaked lime as may be sufficient to form mortar with water, **in the usual method**, but so wet as to serve for the slaking of as much **powdered** quick lime as amounts to one fourth of the whole quantity of Brick-dust and sand.

[This allows the use of lump lime slaked to a thick paste mixed to a wetter mortar than it would be possible to use straight away, but facilitating good mixture of the sand, lime and brickdust, before adding quicklime in powder, which would avoid the hazard of late-slaking, the slaking of which would bring the wetness back down to an immediately useful mortar, with added plasticity and good initial set. This method comparable to the use of quicklime in earth mortars previously mixed beyond the liquid limit to maximise the engagement of the clays, the quicklime addition bringing the earth mortar back beneath the liquid limit].

When the materials are well mixed, employ the composition quickly, as the least delay may render the application imperfect, or impossible *[the slaking quicklime would enhance the reactivity of the brickdust, leading to an accelerated initial set].*

Another method of making this compound is, to make a mixture of the dry materials; that is, of the sand, brick- dust, and powdered quick-lime, in the prescribed proportion; which mixture may be put into sacks, each containing a quantity sufficient for one or two troughs of mortar. The above-mentioned old slaked lime and water being prepared apart, the mixture is to be made in the manner of plaster, at the instant when it is wanted, and is to be well chafed with the trowel.

SECTION XII. Dr. Higgins *[see above – these sections lifted directly from Partington (1825).*

P58 SECTION XIII.

Although a well made mortar, composed merely of sand and lime, allowed to dry, becomes impervious to water, so as to serve for the lining of reservoirs and aqueducts; yet if the circumstances of the building are such as to render it impracticable to keep out the water, whether fresh or salt, a sufficient length of time, **the use of common mortar must be abandoned**. Among the nations of antiquity, the Romans appear to have been the only people, who have practised building in water, and especially in the sea, to any extent. The bays of Baiae, of Pozzuoli and of Cumae, from their coolness and salubrity of situation, were the fashionable resorts of the wealthier Romans, during the summer months; who not only erected their villas and baths as near the shore as possible, but constructed moles, and formed small islands, in the more sheltered parts of these bays; on which, for the sake of the grateful coolness, they built their summer houses and pavilions. They were enabled to build thus securely, by the discovery, at the town of Puteoli, of an earthy substance, which was called pulvti pulcolanus, Puteolan powder, or as it is now called, puzzolana.

The only preparation, which this substance undergoes, is that of pounding and sifting, by which it is reduced to a coarse powder; in this state, being thoroughly beaten up with lime, either with or without sand, it forms a mass of remarkable tenacity, which speedily sets under water, and becomes, at least, as hard as good free-stone.

Limes, which contain a portion of clay, or argillaceous matter, have also the property of forming a mortar, which hardens under water. A composition, formed of two bushels of clayey lime, one bushel of puzzolana, and three of clean sand, the whole being well beaten together, make a good water cement *[again, from Partington].*

P59
The Terras, which is so much used in Holland, is a preparation of a species of basalt by calcination. It possesses the property, when mixed with lime, of forming a water cement, not inferior to puzzolana. Perhaps common green-stone and other sub stances may be found to answer the same purposes. The materials of terras mortar, generally used in the construction of the best water work, are **one measure of quick-lime, or two measures of slaked lime, in the dry powder, mixed with one measure of terras, well beaten together to the consistency of paste, using as little water as possible.** Another kind, almost equally good, and considerably cheaper, is made of two measures of slaked lime, one of terras, and three of coarse sand; **it requires to be beaten longer than the foregoing,** and produces three measures and a half of excellent mortar.

When the building is constructed of rough, irregular stones, where cavities and large joints are to be filled up with cement, the pebble, or coarse sand mortar, may be most advantageously applied; this was a favorite mode of constructing among the Romans, and has been much used since. Pebble mortar will be found of a sufficient compactness, if composed of two measures of slaked, argillaceous lime, half a measure of terras, or puzzolana, and one measure of coarse sand, one of fine sand, and four of small pebbles, screened and washed. It is only under water, that the terras mortar sets well.

The scales produced by hammering a red-hot iron, which may be procured at the forges and blacksmith's shops, have been long known as an excellent material in water cements. The scales being pulverized and sifted, and incorporated with lime, are found to produce a cement equally powerful with puzzolana mortar, if employed in the same quantity.

Fresh made mortar, if kept under ground, in considerable masses, may be preserved for a great length of time, and the older it is before it is used, the better it has been thought to be. Pliny informs us, that the ancient Roman laws prohibited builders from using mortar that was less than three years old; and a similar law prevails in Vienna *[This should not be here, as it is not true of pozzalanic mortars, illustrating, perhaps, the general eclecticism of Shaw's sections on mortar; or, at least, his urge to relate recent European insight to an American audience].*

SECTION XIV. Stucco. This is a composition of white marble, pulverized, and mixed with plaster, or lime; the whole sifted and wrought up with water; to be used like common plaster. Of this are made statues, busts, basso-relievos and other ornaments of architecture.

A stucco, for walls, &c. may be formed of the grout, or putty, made of good stone-lime, or the lime of cockle shells, which is better, properly tempered and sufficiently beat, mixed with sharp grit sand, in a proportion which depends on the strength of the lime. Drift-sand is best for this purpose, and it will derive advantage from (p60) being dried on an iron plate or kiln, so as not to burn, thus the mortar would be discolored. When this is properly compounded, it should be put in small parcels against walls, or otherwise to mellow, as the workmen term it; reduced again to soft putty, or paste, and spread thin on the walls without any under coat, and well trowelled.

A succeeding coat should be laid on, before the first is quite dry, which will prevent points of brickwork appearing through it. Much depends on the workman giving sufficient labor, and trowelling it down. If this stucco, when dry, be laid over with boiling linseed oil, it will last a long time, and not be liable, when once hardened, to the accidents to which common stucco is liable.

P129 CHAPTER V. SECTION I.

The ancients used several kinds of walls, in which more or less masonry was always introduced. They had their incertain, or inserted walls — and also their reticulated walls. The uncertain or irregular walls are those where the stones are laid with their natural dimensions, and their figure and size of course uncertain…The materials rest firmly one upon another, and are interwoven together, so that they are much stronger, than the reticulated, though not so handsome. In this kind of wall, the courses were always level; but the upright joints were not ranged regularly or perpendicularly to each other in alternate courses, nor in any other respect correspondent; but uncertainly according to the size of the bricks or stones employed. Thus our bricks are arranged in ordinary walls in which all that is regarded is, that the upright joints, in two adjoining courses, do not coincide. Walls, of both sorts, are formed of very small pieces, that they may have a sufficient of, or be saturated with mortar, which adds greatly to their solidity.

To saturate, or fill up a wall with mortar, is a practice which ought to be had recourse to in every case, where small stones, or bricks, admit of it. It consists in mixing fresh lime with water, and pouring it, while hot, among the masonry in the body of the wall.

The walls called by the Greeks Isidomum are those in which all the courses are of equal thickness; and Pseudo-isidomum, or false, when the courses are unequal. *[Vitruvius is the source for much of this section, though not for the hot core-filling, necessarily]/* Both these walls are firm, in proportion to the compactness of the mass, and the solid nature of the stones, so that they do not absorb the moistness of the mortar; and being situated in regular and level courses, the mortar is prevented from falling, and thus the whole thickness of the wall is united. In the wall called complecton, the faces of the stones are smooth; the other sides being left as they came from the quarry, and are secured with alternate joints and. mortar, the face of this wall was often covered with a coat of plaster. This kind of building called Diamixton, admits of great expedition, as the artificer can easily raise a case or shell for the two faces of the work, and fill the intermediate space with rubble-work and mortar.

Walls of this kind, consequently, consist of three coats; two being the faces and (p130) one the rubble core, which is the middle; but the great works of the Greeks were not thus built, for in them, the whole intermediate space between the two faces, was constructed in the same manner as the faces themselves: and they besides occasionally introduced diatonost or single pieces, extending from one face to the other, to strengthen and bind the wall. These different methods of uniting the several parts of the masonry of a wall, should be well considered by all persons, who are entrusted with works requiring great strength and durability.

If the walls are Isidomoi, and fastened together with iron, they are properly called cramped *[see Vitruvius, above]*. The network structure, was much used in ancient Rome, and is beautiful to the sight, but is liable to crack, wherefore no ancient specimens of this kind remain.

Plate XXXV. fig. 1, exhibits a species of ancient walls which may be seen at Naples. There are two walls A. A. of square stones, four feet thick; their distance six feet. They are bound together by the transverse walls B. B. at the same distance. The cavity C C. left between, is six feet square, and is **filled up with rubble stones and earth.**

…. The thickness of walls should be regulated according to the nature of the materials, and the magnitude of the edifice. Walls of stone may be made one fifth thinner than those of brick; and brick (p131) walls, in the basement and ground stories of buildings of the first rate, should be reticulated with stones, to prevent their splitting; a circumstance which has been two much disregarded by our builders.

BRICKLAYING

P136… SECTION V.— Walls, &c. The foundation being properly prepared, the choice of materials is to be considered. In places much exposed to the weather, the hardest and best bricks must be used, and the softer reserved for in door work, or for situations less exposed. If laying bricks in dry weather, and the work is required to be firm, wet your bricks by dipping them in water, or by causing water to be thrown over them before they are used. Few workmen are sufficiently aware of the advantage of wetting bricks; but experience has shown, that works in which this practice has been followed, have been much stronger than others, wherein it has been neglected. It is particularly serviceable, where work is carried up thin, and putting in grates, furnaces, &c. In the winter season, so soon as frosty and stormy weather set in, cover your wall with straw or boards; the first is the best, if well secured, as it protects the top of the wall, in some measure, from frost, which is very prejudicial, particularly when it succeeds much rain; for the rain penetrates to the heart of the wall, and the frost, by converting the water into ice, expands it, and causes the mortar to assume a short and crumbly nature, and altogether destroys its tenacity. In working up a wall, it is proper not to work more than four or five feet at a time ; for, as all walls shrink immediately after building (p137) the part which is first brought up will remain stationary ; and when the adjoining part is raised to the same height, a shrinking or setting will take place, and separate the former from the latter, causing a crack, which will become more and more evident, as the work proceeds. In carrying up any particular part, each side should be sloped off, to receive the bond of the adjoining work on the right and left. Nothing but absolute necessity can justify carrying the work higher in any particular part, than one scaffold; for, wherever it is so done, the workmen should be answerable for all the evil that may arise from it.

Smith G (1834) Essay on the Construction of Cottages suited for the Dwellings of the Labouring Classes for which the Premium was voted by the Highland Society of Scotland. Glasgow

Whatever roofing is adopted, whether slate or tile, it is of the utmost consequence that the lime used for pointing should be properly prepared. The slater's lime ought to be mixed up with pure sea or river sand, all the clay or earthy particles completely washed out; the coarser the sand, the more durable will the lime be; care should be taken not to mix up too much hair with it, as it soon rots, and makes the lime porous, and prevents it from taking a fine surface. All lime composition for outside work, ought to be so prepared as to take on a fine close surface, and to be impervious to water and able to resist the winter's frost.

Design 1

The roof to be formed of dram battens covered with 3 inch deal sarking, and slated the same as the others. The walls to be plastered inside with one good coat of lime.

The floors to be elevated above the surface of the ground, as shown from the section, to be formed of a composition of lime, earth, and engine ashes, mixed up in equal proportions; this to be laid over to the thickness of 3 inches above a level stratum of dry stone shivers well beat down.

GENERAL HEADS OF A SPECIFICATION for the Construction of Cottages.

Mason Work. The foundation course to be laid with large flat-bedded stones, to the breadth of 3 feet, and the walls to be brought into the thickness of 2 feet, by an offset at each side, as is shown in the sections. The whole walls to be built of the best rubble stones found in the district, all laid on their natural bed, with properly prepared mortar. The division walls of the double cottages to be carried close up to the slates….

Plaster Work. All the walls, ceilings, and partitions, to be finished with two coats of good plaster lime, hard finished.

Vicat L J (1837) *Practical and Scientific Treatise on Calcareous Mortars and Cements, Artificial and Natural. Translated by Capt JT Smith, Madras Engineers.* London. John Weale. Donhead Reprint 1997.

Vicat's opinions have exercised more influence than most in the UK and within the Lime Revival. Wingate, in his 1997 introduction to the Donhead edition calls it 'perhaps the most important text ever published on limes' as assertion that must be seriously doubted, but which illustrates its influence in the UK. Vicat was much criticised by contemporaries such as Treussart, whose insights and conclusions, frequently at odds with those of Vicat, had more influence with US military engineers during the 19th C, particularly Totten and Gillmore. As was even accepted by Smith, who replicated some of Vicat's experiments with very different outcomes, many of Vicat's conclusions were flawed. Vicat was entirely dismissive of the value of fat limes and very keen to promote an artificial hydraulic lime of his own concoction which was commercially produced in Paris. This commercial interest must be taken to have influenced his conclusions. His primary practical interest was in hydraulic engineering, where fat limes alone would have been of minimal utility. However, he 'protests too much' about the uselessness of rich limes, always favouring hydraulic and eminently hydraulic limes. The majority of his experiments and methodology goes largely unexplained; those that may be deduced are clearly 'abstract' laboratory experiments, yet these are quoted to make bald assertions that few others of his ilk were prepared to make. Many of the 'rules' and assertions of the Lime Revival may be found in Vicat, indicating his disproportionate and clearly *biased influence. Publication of his text by Donhead coincided with the growing introduction of imported NHLs and growing frustrations with the performance of lime-lean putty lime mortars. Vicat – who had no concept of compatibility, sacrificial behaviour of mortars, etc – seemed to offer the embrace of NHLs harder than any previously used in the UK legitimacy. It gave expediency an excuse. Whilst generally condemning – and calling for the 'prohibition' of rich lime mortars, some of his more practical observations, about frost resistance of rich lime mortars, for example, were simply overlooked or lost in the rush to routine NHL-use. Vicat effectively condemned the use of all rich limes and feebly hydraulic limes as deployed historically in the UK, and this was the message taken and generally accepted by the Lime Revival, itself based upon materials with a similar lack of historic precedent.*

P26

Chapter IV

The Slaking of Lime

First Method

56. Quicklime, taken as it leaves the kiln, and thrown into a proper quantity of water *[Vicat the only author before the 20th C to advocate the addition of quicklime to water, rather than the other way around],* splits with noise, puffs up, produces a large disengagement of hot, slightly caustic vapour, and falls into a thick paste.
57. This method is generally adopted, but they abuse it strangely. They reduce the lime to a milky consistency in a separate basin, whence it runs off into a large trench. Thus drowned, it loses the greater part of its binding qualities *[Vicat does not say who 'they' are, but must be plasterers, not masons].*
58. The rich limes, when slaked and brought to a very thick pulp, give from 2 to 3 volumes for 1. The poor limes, most of the hydraulic limes, (p27) and all the eminently hydraulic limes, do not give…more than from 1 to 1 1/4, or 1 ½ at most.
59. Rich lime, at the moment of being quenched with much water, sometimes slakes to dryness in certain parts of the vessel…**If we now suddenly throw a fresh supply of water upon the parts which slake in this manner, it causes a hissing resembling the immersion of a red hot iron in water;** and what is remarkable, the lime **being numbed by this sudden aspersion, afterwards falls to powder very imperfectly, and continues gritty.** The colder the water thrown upon it, the more marked is the effect, more especially with the rich limes *[on the face of it, this is exactly what happens during a two-stage slake of sand and powdered quicklime, with the slake commencing with the moisture in the sand; reaching a high temperature and then having water added to bring it to a mortar].* When we wish to procure a slaked lime of great fineness (for whitewashing walls eg) we should have a sufficient quantity of water at first, to avoid the necessity of replenishing it at the moment of effervescence…

60. All lime becomes effete, or difficult to slake, after it has been acted upon by the air…(more especially the hydraulic limes…

Second Method

61. Quicklime, plunged into water for a few seconds, and withdrawn before it commences to slake, hisses, (p28) splits with noise, gives out hot vapours…and falls to powder. It is then called slaked lime by *immersion.* It may be kept for a long time in this state, provided that we shelter it from moisture. It does not again become heated on tempering it.

(p29)

Third Method

66. Quicklime, subjected to the slow and continued action of the atmosphere, is reduced to a very fine powder.

…68. Of the three processes, the ordinary mode of extinction is that which most perfectly divides the rich limes, and the hydraulic limes of all degrees, and…which raises their expansion to the highest limit. (p30) Next…the spontaneous mode…(is) more suitable to the rich than the hydraulic, and eminently hydraulic limes, but vice versa in slaking by immersion.
69. From these differences it ensues, that three equal volumes of lime, in paste of the same consistency, but slaked by different processes, contain neither the same quantity of lime, nor the same quantity of water. *[the quantities of lime differ in the original lime stone and quicklime].*

(It will take 10 months for rich lime to air-slake spread in ¾ inch beds; (p31) hydraulic will take 7-8 months).

P32

76. **In the work-yards, rich limes slaked by the ordinary process, are preserved by placing them in trenches nearly impermeable, and covering them over with 30 or 40 cm of sand or fresh earth.** When slaked by immersion, or spontaneously, they may be kept without change for a tolerably long time, either in casks or under sheds, in large bins covered with cloths, or with straw.

77. The hydraulic limes harden in a short time in a trench: they cannot be kept long, nor especially be much carried about…unless they be slaked by immersion, and then secured in that state in casks, or sacks of cloth…

p34

Chapter V

The Hydrates of Lime, or the Solids Resulting from the Simple Combination of Water and Lime.

(a series of experiments carried out with limes slaked to the consistency of clay 'in a state of readiness for the manufacture of pottery'. Conclusions:

1) limes carbonate from the outside in…after a year, no more than 6mm for hydraulic limes; 2 or 3 mm for rich limes. The process slows over time.
2) The hardness of the hydrates varies according to mode of slaking. In order of hardness: For fat limes: 1) ordinary extinction; 2) air-slaking; 3 by immersion. For hydraulic limes: 1) ordinary; 2) by immersion; 3) air slaking.

P37…we see that the order of relative hardness is absolutely the same as that of their expansion (on slaking).

Chapter IX – recommended mortars for particular uses. (This a précis)

1) to obtain mortars or cements capable of acquiring a great hardness in water, or underground, or in situations constantly damp, we must combine:

With the rich limes – the 'very energetic' pouzzolanas, natural or artificial

With slightly hydraulic limes – the 'simply energetic' pozzalans; the very energetic, but also with inert sand; the energetic arenes.

With the hydraulic limes: feebly energetic pozzalans; energetic pozzalans plus one half of sand; feebly energetic arenes

With the eminently hydraulic limes – inert materials – sands.

2) To obtain mortars or cements capable of acquiring great hardness in the open air, and of resisting rain, heat, and severe frosts, we must combine:

With the rich limes – no ingredient will effect this *[this is clearly nonsense]*;

With the slightly hydraulic limes – no ingredient will completely effect this *[likewise]*.

With the hydraulic limes – any very pure sands; quartose powders; powders of hard, calcareous (and inert) minerals.

With the eminently hydraulic limes – any very pure sands; as above.

[and so, were both fat limes and feebly hydraulic limes substantially condemned].

Chapter X

Of Calcareous Mortars or Cements Intended for Immersion (beton)

P71…*Of the Manipulation or Manufacture*

178. The manufacture includes the slaking of the lime, and its mixture with the ingredients which unite with it in the composition of the mortar or cement.
179. In whatsoever way it may have been slaked, the lime ought to be first brought to the condition of a thoroughly homogenous paste, and then to be mixed with the ingredients…for it.
180. This paste ought to be as stiff as possible, whenever it is intended to act the part of a matrix amongst hard and palpable grains…(p72) such is the case with mortars, or mixtures of lime and sand.
181. It may have a more or less thin consistency, when, with a pulverulent substance, whose grains are impalpable, and at the same time absorbent, we would form a whole of homogenous appearance…This is the case with the calcareous cements, or the mixture of lime with the pozzalans, arenes, clays or psammites.
182. *But in every possible case, the resulting mixture, be it mortar, or cement, must exhibit a* ***good, clayey consistency…***
183. We may…bring lime which has been slaked by immersion or spontaneously, to the condition of a stiff paste or pulp, when we take it in the pulverulent state; but this is no longer possible when we have to deal with lime slaked by the ordinary process, if it has been drowned at first in too much water. To avoid (this)…we ought to employ, at the moment of slaking by that process, no more than the water rigorously required…to cause the lime to pass from the (lump)…to that of a stiff paste.

(Long description of special method for slaking hydraulic limes to a thick paste).

P74
186. We ought not in this way to slake more lime than is required for…one or two days' work at the most…(giving) the lime at least 24 hours to sour, and the sluggish lumps become all reduced.

187. The lime (thus slaked)…is already very stiff the next day; it is necessary either to pick it, or at least to cut it with a spade, in order to remove it. …(however) it is easily rendered ductile by means of the pestle…it then forms a paste sufficiently thin to receive the sand.
188. The materials which combine in the formation of calcareous cements, are worked up and mixed together with the more facility, the greater the quantity of water with which they have been diluted…(so that) the same workmen will take four times as much time to prepare a stiff mortar, as would be required to prepare the same quantity of **that degree of softness adopted by masons….**

…p75. …the most exact and varied experiments show, that every mortar or cement destined for immediate immersion, ought…to be worked to a stiff, clayey consistency, or lose ½ to 2/3, and sometimes 4/5, of the strength it would have acquired if properly treated.

(mortar beaten and battered in the beton before rubble is added, rammed in).

p82

Chapter XI

Of mortars constantly exposed to the air and weather.

We have already said in Chapter IX, that **the only mortars capable of standing the vicissitudes of the atmosphere, and of acquiring at the same time great hardness, were those composed exclusively of the pure quartzose, granitic, or calcareous sands, and of the hydraulic, or powerfully hydraulic limes.** If then, in what follows, we treat of the ordinary mortars, or the mixtures of sand and rich limes, it is because we are compelled to do so to complete the history of the phenomena which we have to describe. **For it is our most decided opinion, that their use ought forever to be prohibited, at least in works of any importance.** *[As a position statement, this has much informed the later phases of the lime revival. It has no foundation in terms of like-for-like or compatible repair or in the observed durability of air limes in exterior use across the world].*

[Continuing the esoteric theme, based upon the performance of pastes]..

p85

(Results of experiments with lime pastes:)

1) that the hydrates of lime which in the open air attain the greatest hardness, are those whose mixtures with pure sands, on the contrary, produce the weakest mortars
2) The intervention of pure sand does not tend…to augment the cohesion…but is injurious to rich limes, very serviceable to the hydraulic and the eminently hydraulic limes, and is neither (good or bad) to the intermediate kinds.

P86
(after bemoaning the inadequate scientific basis of Roman assertions about mortars)
…One thing which we know to be quite certain, and which we ought never to lose sight of, is this – **that there is no sand whatever, be it red or yellow, grey or white, with round grains or angular ones, etc, which can, if it be inert, form a good mortar with rich lime.** Whilst, on the other hand, **all possible kinds of sand,** provided they be pure, that their grains be hard, and do not exceed a certain size, **give excellent mortars with the hydraulic and eminently hydraulic limes.**

Influence of the size of sand

P87
211. (best sands) for the eminently hydraulic, and simply hydraulic: 1st. fine sand; 2nd. Irregular-grained sand, resulting from the mixture of coarse and fine; 3rd. coarse sand.

P88
212. For the slightly hydraulic limes: 1st. irregular-grained sand, mixed as above; 2nd. Fine sand; 3rd. coarse sand.
For rich limes, 1st. coarse sand; 2nd mixed sand; 3rd. fine sand.

213. (depending on the sand, the hardness of the mortars differs by 1/5 for the rich limes; but by more than 1/3 for hydraulic and eminently hydraulic.

P89 *Choice of Proportions*

(Cannot generalise – will vary according to lime and sand used. But ‘certain limits’ may be set out):

p90

Case of the Rich Limes

216. 1st. The resistance of mortars made from very rich limes slaked **by the ordinary process**, increases from 50 up to 240 parts of sand to 100 of lime in stiff paste, and beyond that decreases indefinitely. *[2:1 to 1:2.4 slaked lime:sand].*

217. The resistance of the same mortars, when the lime has been slaked by immersion, or spontaneously, increases from 50 to 220 parts of sand to 100 of lime in stiff paste, and then diminishes.

Case of the Simply Hydraulic Limes

218. Resistance increases from 0 to 180 parts of sand to 100 of lime in a stiff paste. *[should be no leaner than 1:1.8 lime: sand].*

219. Resistance when slaked by immersion or spontaneously – 0 – 170 parts sand to 100 of lime.

P91. 220. (nature of lime and mode of slaking have an effect, as well as sand:lime proportion).

Choice of Mode of Slaking.

221. (The influence of manner of slaking significant when mortar is immersed; much less so when in the air).

The Manufacture or Manipulation.

223. Many authors assert, that mortars are very much benefited by being soured a long time, but without precisely fixing anything. (So experiments done to decide).

225. Now we have seen, that the hydraulic limes, when exposed to the air, lose in it a part of their qualities, while the rich limes acquire new ones from it; hence it follows, that a mortar of rich lime is the only one which can gain anything by being a long time soured, and this is also proved by our more recent experiments.

(A mixture of 1:1.5 lime:sand, slaked by immersion and being kneaded and reworked every 8 days for five months, was nearly 20% stronger than one made with lime slaked by the ordinary method. But Vicat acknowledges insignificant compared to the extra cost).

P93.

226. It is therefore only by means of renewing the contacts, and favouring the action of the atmosphere, that a long-contained trituration can become favourable to mortars of rich lime; **and this furnishes a complete vindication of the Lyonese method,** which consists, as is well known, in **preparing large heaps of mortar beforehand, from which they take successively as much as is wanted for the day's consumption, rendering it ductile by adding water.** *[This method may very well be hot mixing to coarse stuff, laid down in heaps to 'sour'].*

227. (But, of course, wouldn't work for hydraulic lime mortars).

228. Everything which has been said of the slaking of lime, and the consistency of the mixtures, in treating of mortars exposed to the air. The mortars of hydraulic lime may lose 4/10 of the ultimate hardness of which they are capable, when, instead of that stiff consistency…, we make use of **that adopted by the masons.**

229. Mortar in every season ought to be prepared as much as possible under cover…to avoid rapid dessication…in summer, or to obviate the still more serious inconvenience in the rainy season.

P94
230. In summer…the lime in paste is not always sufficient to moisten the sand, which is sometimes hot. It then becomes dispensable to add water, but gradually, and with the greatest caution.

Application.

231. It is quite evident, that a very stiff mortar cannot be used with dry and absorbant materials. When we have materials of this kind, they must be watered without ceasing…The whole secret of good manipulation and right employ, is condensed in following precept: *"Stiff mortar, and materials soaked"*. Our bricklayers, on the contrary, seem to have taken for their motto, *"dry bricks, and drowned mortar"*
[exhaustive experiment by Totten (1886) demonstrated that the bricklayers were probably right; or were not necessarily wrong, when a rich fat lime was used].

232. It is true, that to build in the way here understood, we must change certain habits; as, for example, never after the first supply have to introduce mortar between the stones too close to one another, but to lay under each one, in the first instance, a sufficient (p95) quantity to allow those at the side to supply themselves from it when it is battered down in bedding it.

233. The mason's hands will soon be covered with sores, if he do not at the same time take some precaution to guard himself from the action of the lime. Liquid tar remedies this very effectively; it is sufficient to rub the hand with it frequently during the day; the thin coating which remains sticking to the skin acts as an impermeable glove.

Precautions to be taken after Application.

234. In general, all mortars become pulverulent when, after being applied, they are exposed to a rapid desiccation. **The influence of such a desiccation becomes the more fatal, the more eminently hydraulic the mortars are.** They may lose 4/5 of the strength which they would have acquired by drying slowly. It is therefore **proper to <u>water the masonry</u> when we build during the hot season; and this in such a way, as never to permit the mortar to whiten, and thus part with the water necessary for its solidification.**

P96.

Influence of Time

235. *Mortar a hundred years old is still in its infancy.* This saying of the masons is the result of the daily observations which they have the opportunity of making in demolitions. It is **seldom** in fact that we meet with good mortars of rich lime, except in the foundations or masonry of buildings of four or five hundred years old *[or are they earth mortars or lime stabilised earth mortars, in fact]*. (Difficult to explain, but) one thing which it is not at all difficult to apprehend, (is) that a mortar which does not harden for four or five hundred years, is to us much the same as if it never hardened at all *[self-serving, once more, and so -]*

236. As regards hydraulic, or eminently hydraulic mortars, numerous experiments…prove, that when exposed to air in small bulk, they in a very short time (18 to 20 months) attain, if not the ultimate degree of hardness (p97) of which they are susceptible, yet at least a condition differing so little from it, that we are enabled to predict with certainty what they will ultimately become.

237. Thus the influence of ages may modify, but not overturn, the relations in respect to durability **established by our observations.**

P102. Chapter XIII

Of the vicissitudes to which cements and mortars may be exposed, and of the consequences.

243. Some mortars and cements which solidify tolerably in water, **lose part or the whole** of their cohesion when exposed to a dry and warm air. This happens generally with those whose elements do not suit one another perfectly; for instance, the cements of rich limes and feebly energetic substances, such as the arenes, the psammites, clays etc; the mixtures of feebly hydraulic limes with inert materials etc *[thus contradicting the majority of previous building practice by untested assertion].* The deterioration id more particularly marked in respect to the exterior surface…these parts lose all their consistency.

244. Mortars formed from the hydraulic or eminently hydraulic limes, whose solidification takes place in a damp soil, behave equally well in the open air, and in the water.

245. In general, most kinds of cement which have well hardened under a damp soil, stand equally in the water, but they behave variously in the open air; some resist, others are altered by it. We are unable to say to the presence of what principles these differences are to be attributed.

P103

…248. In general, **all cements of rich limes resist frosts but imperfectly; they give way like hard stones by irregular cleavage.** This action of the frost is considerably weakened, **and may even be entirely avoided, by mixing a certain quantity of pure sand with the powdery ingredients which are employed in their composition.** *[does Vicat mean lime stone dust of same geology from which the lime was made? Or earth?].*

249. All mortars of rich limes, and coarse and (p104) very pure sand, resist the winters of our climate when they have attained a certain degree of solidification…Experience furnishes the following indications on this subject:

1) Every mortar prepared in the month of April, with rich lime slaked by the ordinary process, is attacked (by frost) the following winter, when it

contains less than 220 parts of sand to 100 of lime in paste (1:2.2; lime:sand). *[Rich lime mortars should be leaner than this, therefore, although most surviving in situ(and therefore successful) rich lime mortars in the UK and Ireland were richer in lime than this].*

2) It is attacked in the same way, when it contains less than 160 parts of sand to 100 (1:1.6) of the same lime, in paste obtained by immersion.
3) (Likewise)…when it contains less than 240 parts of sand to 100 (1:2.4) of the same lime in paste, slaked spontaneously.

250. After two years the danger is past, and after six years the most severe frosts are powerless…

[the early frost vulnerability of air lime mortars Vicat identifies is actually (and in our experience) unlikely unless the fabric is especially saturated and has very poor architectural detailing].

251. With regard to hydraulic and eminently hydraulic mortars, **six to seven months' age is sufficient** to place them beyond its reach (p105)…but they resist nonetheless in proportion to the quantity of sand they contain. That is to say, **the 'poorest' are attacked the last, if any can be.** *{Again, Vicat's conclusions contradict those of numerous others during the 19th C, particularly those of American military engineers, who generally concluded the opposite. 1:1 or 1:2 were their offered mixes which balanced economy with durability most effectively for hydraulic cements).*

252. In the covered parts of buildings, the mortars of rich limes have not to undergo these vicissitudes, but **they do not become better on that account** *[Once more, Vicat is alone before the 20th C in indicating that rich limes should not be used internally].* The maximum limit of sand proper for them in that case is from (1:0.55; 1:1.25; or 1:1.75, lime:sand)…according as it is obtained by the ordinary extinction, by immersion, or spontaneously.

(referring to limits laid down in Chapter XI)…we shall easily deduce therefrom, that the same atmospheric changes are favourable to mortars loaded with sand, and on the other hand, are injurious to those in which the lime predominates.

Chapter XV.

(Discussion of natural cements; doubting their utility and certainly doubting any superiority over hydraulic and eminently hydraulic limes).

P114 Chapter XVI. The antique mortars compared with those of medium age and modern mortars.

(Vicat asserts that the mortar of the pyramids are) 'exactly similar to our mortars in Europe…(p115) of a reddish very fine sand mixed with the lime in the ordinary proportions'. (Smith, analysing samples of the same mortar identifies them as being, in fact, common lime with coarse gypsum addition and no sand at all, containing a significant proportion of lime lumps, and an 'aggegate' of ocherous clay, but no silica, probably included by accident amidst the gypsum. He concluded that 'the mortar is a composition of rich lime and coarsely powdered gypsum, which has been used as a substitute for sand, in the proportion of about 1 (of rich lime) to 5 (of gypsum) by weight'

p119. (Discussing Rome)…in general, all their mortars which are exposed to the air are alike; we recognise them by the presence of coarse sand mixed with gravel; the **lumps of lime in it are sometimes so multiplied, that it is impossible to attribute them to defective manipulation.** The extinction by immersion, as applied to a very rich lime, can alone account for it.

P120…It is evident that the Romans employed lime in paste in the way of lining, and that the spongey, dry substances (such as brick) which they introduced into it, **were for no other object but to hasten the solidification, by exhausting its superabundant water.**

P123 – (on the average compressive strength of mortars exposed to the weather, one year old, in kilogrammes per cm square – Smiths equivalent in lbs per square inch in brackets):

Of the eminently hydraulic mortars	12.00 (170.8)
With common hydraulic mortars	10.00 (142.34)
With hydraulic lime mortars of medium quality	7.00 (99.64)
With rich limes	3.00 (42.7)
The bad mortars which our builders manufacture do not give more than	0.75 (10.67).

p124

Chapter XVIII

(Vicat 'disproves' the conclusions of Black, Higgins, Achard and others that lime sets by carbonation, examining the theories of the 'interlacement' of aggregates; the cohesion'adherence of the lime and aggregates, both of which were based on an assumption that the sands and aggregates were 'inert' and non-reactive. He excludes this as a reason for the setting of hydraulic and eminently hydraulic limes

For Vicat, hydraulic limes setting was promoted by chemical reactions between lime and silica within the kiln, or between lime and calcined clays within the mortar). He was correct in this, but distracted by hydraulic limes, denied carbonation as a factor in rich or other limes).

Pasley(1838) Observations on Limes, Calcareous Cements, Mortars, Stuccos and Concrete, and on Puzzolanas, Natural and Artificial. Cambridge University Press.

"I have ascertained, by repeated experiments, that one cubic foot of well burned chalk lime fresh from the kiln…, when well mixed with 3 1/2 cubic feet of good river sand and about 1 1/2 cubic feet of water, produced about 3 1/4 cubic feet of as good a mortar as this kind of lime is capable of forming [*he doesn't much rate air limes*].

A smaller proportion of sand such as 2 parts to 1 of lime is however often used, which the workmen generally prefer, although it does not by any means make such good mortar, because it requires less time and labour in mixing, which saves trouble to the labourers, and it also suits the convenience of the masons and bricklayers better, being what is termed *tougher,* that is more easily worked. If on the other hand, the sand be increased to more than the above proportion of 3 1/2, it renders the mortar *too short,* that is not plastic enough for use, and causes it also to be too friable, for excess of sand prevents mortar from setting into a compact adhesive mass. In short, there is a a certain just proportion between these two ingredients, which produces the best mortar, which I should say *ought not to be less than 3 nor more than 3 1/2 parts of sand to 1 of lime,* that is when common chalk lime or other pure limes are used, for different limes require different proportions.

When the proportion of sand to lime is stated in the above manner, which is done by Architects as part of their specification or general directions for the execution of a building, it is always understood, when nothing is expressed to the contrary, that the parts stated are by fair level measure for the lime, and by stricken measure for the sand, and that the lime is to be measured in lumps, in the same state in which it comes from the kiln, without slaking or even breaking into smaller pieces…

Without occasionally having recourse to actual measurements such as the above, it is impossible to form any just estimate of the proper proportions of lime and sand for mortar; **but no such measurements are usual or necessary in practice, because the expert labourer employed in this operation, on receiving general directions to use as much sand as possible without making the mortar too short, will from habit serve out the proper proportions of lime and sand with all necessary accuracy, without measuring them.**

The pure carbonates of lime form a good mortar for all dry situations, and for inside work, but not for building in damp or wet situations, in which they never *set,* as the process of induration is technically termed by workmen, but always remain in a soft pulpy state…. Pure lime is so little capable of resisting the action of water, that it is unfit even for the external joints of walls exposed to the common vicissitudes of the atmosphere…

The *Water Limes* or *Hydraulic Limes* recomposed of carbonate of lime, generally mixed with silica, and alumina, and the oxide of iron…They all have more or less the property of setting in watery or damp situations, and therefore are exceedingly useful for the purposes of hydraulic architecture, and nothing can be better for the foundations and backings of wharf walls; but even these limes when exposed to running water are partially soluble, and therefore, it is desirable to protect the external joints of wharf walls, built with mortar made of these limes, by some superior kind of water cement. For this purpose Puzzolana from Italy and *Trass* from the Rhine usually termed *Dutch Terrace* were formerly used. Recently, these two…have been superseded by the water cements of England, misnamed *Roman Cements,* for the purpose of mystery or for enhancing their value…

The blue Lias limestones are considered the strongest water limes in this country, and are found on opposite sides of the Bristol Channel near Watchet in Somersetshire and Aberthaw in Glamorganshire, and also at Lyme Regis in Dorsetshire…The Dorking or Merstham lime, and the Halling lime so termed from a village on the left bank of the Medway above Rochester…are also much esteemed; and these two limes, the former of which is considered rather the best, are more used in the metropolis than the blue Lias…

All the water lime stones are of a bluish grey or brown colour…they are usually termed *Stone Lime* by the Builders of the Metropolis, to distinguish them from common chalk, but so far improperly, that the Dorking lime stone is not much harder than pure chalk, and the Halling lime stone is actually a chalk and not harder than the pure chalk of the same neighbourhood, from which it is only distinguished in appearance by being a little darker.

In fact all the coloured chalks found in various parts of England, commonly termed *Grey Chalks,* which are the Lower Chalks of the the Geologists, and generally free from flints, are possessed of hydraulic properties more or less powerful….

All of these limes slake with heat by the addition of water, and most of them also in process of time by exposure to air, but not so readily nor so soon as chalk lime or other pure limes…

…the hydraulic limes ought not to admit of so much sand as chalk, but that they will bear more than cement (roman cement), without being injured…Accordingly, I conceive that three cubic feet of sand to one of Dorking or of Halling lime, will be a good proportion for making mortar with those limes….But the blue Lias lime will not make good mortar if mixed with more than two cubic feet of sand to one of lime….(this being) entirely conformable to the masons of Lyme Regis. But Captain Savage of the Royal Engineers, who was employed professionally some years ago in improving the Cobb or Pier of that little seaport, which was done by tide work, and in which no other kind of lime was used, assured me that he found that a smaller proportion of sand than 2 to 1 made still better mortar. We have since ascertained by repeated experiments at Chatham, that 1 cubic foot of blue Lias lime from the kiln…, mixed with 2 cubic feet of sand, and about 3/4 of a cubic foot of water, made mortar fit for use, but which could not have borne more sand without it becoming too short….

Concrete is formed by mixing lime, coarse gravel and sand together, with a moderate quantity of water, which is usually done on a large square board, having a margin raised a little above it on three sides only. The lime used for this purpose has usually been reduced to fine powder by pounding or grinding it, whilst fresh from the kiln; and it is generally considered of so much importance not to slake it until ready for use, that it has been customary to mix it with the gravel and sand in a dry state for a little while, before the water was added; after which the whole of these ingredients have been intimately mixed, with as much expedition as possible, by employing two labourers to work together at each of the mixing boards, which being always placed as near to the spot previously prepared for the foundation as possible, the concrete is either thrown down at once or wheeled a little way and dropped down from a temporary scaffold with moveable planks…into the excavation, where it is spread and leveled, and trodden down or sometimes rammed by other labourers below….Concrete made in this manner, according to the system first introduced by Sir Robert Smirke, throws out a moderate heat on the slaking of the lime, and soon begins to set, forming in time a kind of artificial rock….

Appendix, Journal of the House of Assembly of Upper Canada (1837-38). Toronto.

Minutes of the St Lawrence Canal Commission.

St Lawrence Canal Office Cornwall 30th May 1837

…I have visited Kingston for the purpose of making enquiry respecting the cement used in the public works there, and (consulted) Captain Baddely, Royal Engineers, who has given much attention to the subject of the water cements of this country. …from the information…received from Captain Baddely, I find that a very important property (is)….that though many of them may set so very slowly as to be quite unfit for tide work, and though they may even go to pieces under water, unless they are kept several days in the air previous to immersion, yet if allowed sufficient time to set in the air before they are immersed, they will become very good, and will not afterwards dissolve under water….so that it is not an indispensable test of the goodness of a cement that it should set underwater unless it be required for tide work, or works of a similar kind. …I would beg leave to refer to a report made by Colonel Pasley, Royal Engineer, about two years ago on some cement submitted to him by Captain Baddely prepared from the Black Rock of Quebec….

Kingston 8th May 1837.

Dear Phillpotts

…There is great uncertainty even among the best cements in this country, whether they will or will not set under water from a plastic state, the greater portion of them will not, **nor do I think the fact of their not doing so, any proof of their badness for many kinds of work;** on the contrary, I have often noticed that cements which refused to set underwater would, after hardening in air, become (as) capable of resisting the action of water etc as the best water limes. In corroboration of this opinion, I appeal to the well-known practical and scientific skill of Colonel Pasley…who has recently stated in a manuscript report on specimens of Quebec cement …that although they will not set under water, and are consequently unfit for tide work, yet after six weeks exposure to the air, some of them attain an inconceivable degree of hardness, and a greater degree of indissolubility in water than any European cements with which he is acquainted. There is uncertainty also in the time which good cements will take to harden, some acquire hardness rapidly – others very slowly;…I do not think that the fact of a cement being sufficiently soft to yield to the pressure of the nail after one week's exposure to the air any proof of unsoundness, for I would trust **more to the circumstance of an observed increase in the hardness, when examined from time to time, than to the quantity of that increase**; and it is always, in my opinion, **a safe sign when the hardness slowly but certainly increases**. I adduce the Hull (Ottawa) cement as an instance of this, also many of the Quebec and Kingston limes. The Hull cement will not set under water; but when set in air it gradually acquires induration and insolubility; inasmuch as it is not known to what cause is owing the peculiar properties of these cements, whether to the presence of iron, manganese, silex, aluminae or magnesia….

It has been asserted that the cements of Europe and of this country differ in respect to the power they exhibit in resisting the action of water while in a plastic state – that those from Europe set readily in water – while those of this country do not. If any difference in this respect exists (which I doubt), it is more probably owing to a geological than to a geographical cause.

The fact is, we have in this country, and in Europe also, good cements which both fail and set in water, there is one thing certain, that as we approach the upper formations of limestones they become generally too calcareous to form cements, whereas the lower series or those in contact, or nearly so, with the primary rocks, are often poor in lime and rich in silex, and probably more likely to yield them. The best cements heretofore manufactured in this country, whatever may be the original colour of the rock they are derived from, assume, when properly set, a deep yellow colour, and throw out a white effervescence in dry weather; and the same we learn by reading is the case with the best European cements. To my knowledge no cement has been met with in Canada, or even in the United States, which, in colour, resembles the dark brown umber-tinted Harwich and Roman cements – these it must also be observed, are drawn from ferro-calcareous clays of the tertiary order…I have not noticed in this country any portion of its cement which will set under water with the rapidity of the Harwich cement; still many ultimately in that fluid acquire an equal and even superior degree of hardness.

The following characters in rocks often indicate their convertibility into water cement, and are set down according to the order of their conceived importance.
1st a feeble effervescence in muriatic acid before calcination, and after refusing to slack (essential)
2nd A yellow colour when calcined (very general)
3rd A silicious or cherry aspect, with a conchoidale fracture, often sharp-edged, and having flat wedge shaped scales upon it; fragments frequently hollowed on the surface like trenches, free from fossil organic remains.

Yours truly, F H Baddely Captain RE

(then conclusion and signed by Geo Phillpotts).

Cuming Mr. Clerk of Works, R.E.D. (1837) Memorandum with reference to the accompanying Sketches of the Officers' Barracks erected at George Town, Demerara. Cork. Papers on Subjects Connected with the Duties of the Corps of Royal Engineers. Vol II London. J Barker.

The trenches for the foundations were excavated to a depth of about 5 inches; and where found softer than usual, or where intersected by old trenches, deeper excavations were made, filled in with broken stones, and grouted.

Sleepers of Wallaba timber, 6 by 6 inches, and from 2 to 3 inches apart, were laid transversely, the spaces between them filled with broken stones, and grouted; 2 inch Greenheart planks were spiked to the timbers; the pillars built thereon, and the ground formed around them, to the depth of about 2 inches. The pillars are 8 feet in height, built of malm pavior-bricks, having two off-sets, the first of two courses, and the second of four courses in height, and capped with Yorkshire paving-stones, neatly squared; **the mortar was composed of slaked lime from England, and sand obtained from the beach in front of the Ordnance lands, in the proportion of about 20 bushels of sand to 1 hogshead, or about 24 bushes of slaked lime**; **the outer faces of the brick-work being pointed with Harwich cement.**

Christopher Davy (1839) The architect, engineer, and operative builder's constructive manual; or, A practical and scientific treatise on the construction of artificial foundations for buildings, railways, &c: with a comparative view of the application of piling and concreting to such purpose ...2nd Edition London John Williams

(Begins with an important inventory of limestone, building stones and other relevant mineral deposits (such as coal), by county, with an assessment of their properties and usefulness).

Yorkshire.

Yorkshire contains, I.Coal. 2. Millstone grit. 3. Carboniferous limestone. 4. Trap. 5. Mountain and magnesian limestones. 6. Clays and crag. Building materials may be obtained as follows. Quarries of freestone and millstone grit are to be found at and near Gatherley Moor, near Richmond, Renton near Boroughbridge, west of Sheffield, Penistone, Huddersfield, Bradford, Otley, Harrowgate, Ripley, Masham, Rainton quarry, Pateley quarry, Moorstone quarry, all within a few miles of Ripon. Quarries at Bramley, Mexborough, Holton, Kirby, Leeds, Idle, and Sheffield; all these are quartzose grits. Magnesian limestone quarries, Brodsworth, Quarry Moor, Ripon, and at Doncaster. Mountain limestone quarries — Roach Abbey and near Richmond, &c.* Limestone and marble are also found in the Western Moorlands. A roofing flag slate (siliceous) is dug near Wensleydale. Lias is sufficiently near to be procured for lime.

… These rocks are not generally suitable for building materials, and being sparingly exhibited in England, do not demand the attention of the engineer; we may, however, remark, that an assemblage of grains consisting of quartz, schist, felspar, and particles of mica, &c., agglutinated with a variable cement, form the "psammites" of Mr. Vicat. Those, he observes (p. 46, Treatise on Cements), are the most important which are slatey, of a yellow, (xix) red, or brown colour, fine grained, unctuous to the touch, producing a clayey paste with water. These belong to the primitive schistose formations, and cannot exist except in situ, being found in " beds or veins, forming part of the schist of which they are merely a decomposition." In the composition of mortar, the schistose sands or "psammites" are feebly energetic, namely, causing the mortar to set from the tenth to the twentieth day, and that acquires the hardness of dry soap after a year's immersion.

xxvi

Mr. Farey, in his " Agricultural Survey of Derbyshire," enumerates forty-six limestone quarries in this county, and sixty-three lime kilns, from whence great quantities are conveyed and sold in this and some of the neighbouring counties. The largest quarries are at Ashover, Buxton, Crich, and Calver, near Barslow. A considerable quantity is sent from Calver into Yorkshire, and from Buxton into Cheshire and Staffordshire. The marble quarries are nineteen in number, and are situated near Bakewell and Matlock. The number of stone quarries are one hundred and thirty-eight, in some of which an excellent building stone may be obtained.

P94 The extraordinary phenomena exhibited by the combination of lime with siliceous matters, and the variable results that are effected by modifying the proportions of the component parts in the composition of cements and mortars, for building purposes, are of the utmost importance to the practical builder.

P95 Limestone, when burned, is deprived of its carbonic acid, &c., and becomes converted into lime, its chief constituents being a metallic oxide combined with oxygen. For the manufacture of mortar, lime requires slacking, which is accomplished by wetting it with a certain proportion of water, a compound is thus formed, bearing the chemical name of " hydrate of lime."

Lime may be obtained from an immense variety of stones; indeed, any stone exhibiting the indications mentioned above, will burn to lime; varying in quality in proportion as it is more or less impregnated with silex, alumina, iron, &c., the pure lime stones furnishing the weakest lime (quotes Vicat). Chalk is the most common variety of calcareous mineral from which lime is obtained; its physical character is so well known as to need no remark. We shall merely observe, that when quarried, **the less exposure it (p97) has received from the atmosphere, the better will be the quality of the lime.** Most of the lime used in the neighbourhood of London and its suburbs is procured from Dorking, in Surrey. This lime is produced by burning masses of indurated chalk, or chalk marle. Chalk forms an extensive and conspicuous geological feature in this island; its great abundance, and the ease with which it is obtained, renders it **a most available medium for the manufacture of lime.**

Chalk may with propriety be considered as a "tender earthy limestone," the second in the scale of materials from which lime is made. Thus we consider lime made from the varieties of argillaceous limestones, 1st; chalk, 2nd; that made from shells, the 3rd. near Dorking is one of the escarpments of the chalk range, and at two-thirds or three-fourths of the depth (P98) of the chalk strata, a very hard chalk is obtained, **having a brownish tinge**; this is quarried, broken, and burned, and forms the substance so well known by the name of Dorking lime. In proportion to the depth at which the chalk is obtained, so is its state of induration, — in this respect not differing from other strata. It has been remarked, that within a few yards of the bottom of the chalk formation, there are one or more beds of it so hard as to be nearly equal to the best Portland stone. In many places its induration is so great, that it has been quarried for the purposes of masonry; the following may be cited as instances of its employment as a building stone: — The abbey of Sturley, and its parish church, Berkshire: abbey of St. Omer's; mullions and arches of St. Catherine's chapel near Guildford, Surrey, &c. A lime obtained from Merstham in the same county (Surrey), is also extensively used; it is obtained from an indurated chalk marle (clay and chalk), the kilns used for burning it into lime are distributed (p98) in various parts of the county ; those at Merstham are situated at the lowest level at which the marle is fit for the kiln, beneath which it becomes much harder and partakes of the nature of stone. The more argillaceous forms of chalk marle, according to the analysis of Mr. Phillips, indicate carbonate of lime nearly 30 per cent.; and the more cretaceous varieties 82 per cent, carbonate of lime, 18 silex and (p99) alumine, chiefly the former, and a trace of the oxide of iron.

… Oolitic series. 1. Portland. — The summit of the Portland beds, called the cap, is only burned for lime. The cap is No. 4 of the layers of the quarries; it is a cream-coloured stone in three layers, with partings of clay, and so hard as to turn the steel points of chisels and pickaxes. 2. Cornbrash. — A loose rabbly limestone, affords lime of tolerable quality. 3. Forest marble, a very shelly limestone. 4. Bath stone. — Now extensively worked for the purposes of masonry: it is a tolerably pure carbonate of lime, but as a lime, possesses no remarkable features.

P101 For the manufacture of cement, the lias lime stone must be allowed to hold the most prominent place in the above series. In the recent alterations at Heywood House, at Westbury, and at other extensive works in Wiltshire, **the lias lime has been used as a cement <u>in all under ground or damp situations</u>:…**

P102 In the immediate neighbourhood, it is known among masons by the name of Bath brown lime, and when prepared for cementing, or in combination with the patent metallic cement, is what is locally termed **" wind slacked-" namely — after having been burned, it is placed in covered sheds, but open at the sides, the atmosphere being allowed to operate upon it; should the slacking proceed too slowly, a small quantity of water may be sprinkled upon it to stimulate the process, but on no account should water in a considerable quantity be added; it is therefore much, better (if possible) to allow the atmosphere to act for this purpose. The lime, when thus slacked, is converted into fine granulated particles, and is among workmen said to be " alive," as it will run from an iron shovel similar to quicksilver. The colour of the lias, previous to burning, is blue; when it has passed the kiln, it is brown.**

(Discussion of magnesian lime in Northumberland and Durham)

p109 The quantity of magnesia contained in lime stone does not appear to operate injuriously upon lime employed for building purposes, although its presence, when used for agricultural purposes, is anything but favourable to vegetation. The presence of magnesia in limestone used for building produces scarcely any other effect than to render the proportion of clay greater in relation to the (p110) proportion of carbonate of lime.

P111 Carboniferous Limestone. — Associated with the all-important coal districts of this country is a vast geological formation known by the above name, which significantly points out its characteristic locality, and at the same time serves materially to mark the distinction between the magnesian lime stone beds associated with the red ground or new red sand-stone. This rock exhibits generally a close and compact body, capable of a good polish, and imperfectly crystalline, prevailing colour gray. The purest beds contain about 96 per cent, of calcareous matter. By admixtures, not common to the pure species, it passes into magnesian, ferruginous, bituminous, and foetid limestone. For the manufacture of lime, possessing all the essential qualities of a cement, capable of the highest degree of induration, **the carboniferous limestone of England is**

upon the whole the most important in the class of calcareous minerals. From some unaccountable reason, the valuable properties of this mineral have not been sufficiently appreciated by the profession; its use has, consequently, been very limited in our metropolitan works. **In engineering operations good lime is a material that ought to be obtained, regardless of expense.** Indeed, when it is considered, that artificial hydraulic limes, such as are generally used in the metropolis, are obtained from a variety of ingredients collected in various districts (p112) distant from each other, and subjected to careful manipulation, it becomes a question whether the conveyance of the best varieties of this mineral to the London market would not prove of sufficient practical value to counterbalance the excess of outlay required in its general employment in our public works….

P114 The valuable property of the mortar prepared from this limestone (carboniferous from Flintshire) is owing to the presence and (p115) proportion of alumine, and to its property of rapidly absorbing water.

(Chapter on Limeburning. Describes kiln design in Scotland, Yorkshire and Dorking in particular. Then discussion of the behaviour of quicklimes from some of the most commonly burned stones)

P154 A recent examination of the principal buildings erected by Sir C. Wren has satisfied the author that, although **rich lime was extensively employed in their construction**, there yet remains sufficient evidence to show that the architect did occasionally introduce materials, in conjunction with the mortar, of somewhat remarkable character. During the recent repairs of the parish church of St. Vedast, Foster-lane, an opportunity was afforded to institute a minute examination and admeasurement of the tower and spire, completed by Sir C. Wren, in the year 1697. In the course of the examination, particular attention was directed to the state and quality of the mortar originally employed in that building. The vertical joints of the masonry composing the spire were considerably (p155) opened (probably caused by the expansion of the metal cramps), and the mortar was found to be in a weak and crumbling state, but the base of the obelisk terminating the spire, was discovered to be laid on a thick mortar joint in which was imbedded two courses of fiat oyster shells: these, together with the mortar, had remained uninjured for nearly one century and a half. (Discussion of the qualities of oyster shell, which incorporate clays).

P156 The remarks made by Mr. Smeaton on the quality of rich lime, have been confirmed by the more recent experiments of M. Vicat; and it is **now decided that rich lime is incapable of furnishing a good mortar, and that the admixture of quartzose, silicious sands, or other inert substances so beneficial to hydraulic limes, is positively injurious to rich lime** (here he buys into Vicat's vested interest).

P157 CHAPTER VI. ON THE PROPORTION AND ADMIXTURE OF THE INGREDIENTS EMPLOYED IN THE COMPOSITION OF ORDINARY MORTAR, QUALITY OF SANDS, SANDSTONES,

Among the recent investigations which have materially assisted in promoting a more perfect theory of the consolidation of mortars, those of Professor Fuchs are entitled to hold a prominent place. The various compounds of lime and sand, constituting the materials of common mortar, and the admixture of unslacked lime, with broken stones, ballast, or gravel, forming the basis of the strongest concrete, severally possess certain properties, and exhibit distinct phenomena, referrable to a most important chemical and mechanical combination. In the course of his investigations, **Professor Fuchs noted certain facts, from which he concluded that the induration of various kinds of mortar depended upon the formation of silicates of lime, and sometimes also alumina of silicates**. He discovered that these silicates retain the water and acquire the hardness of masses of stone, while the hydrate of lime in excess is gradually united with (158) carbonic acid, **so that the indurated mortar may be considered as a compound of carbonate of lime and zeolite**.

Opal, pumice-stone, obsidian, and pitch-stone, simply pulverized, form a good cement with hydrate of lime, while quartz and sand only produce an hydrated silicate upon the surface of each grain. Although the mass is thus connected, it does not readily become solid. If the quartz has been reduced to a fine powder, the more solid will the mass become. Now, if one-fourth part of lime be mixed with the quartz, and the whole be well calcined, so that the mass becomes a frith, and the whole be afterwards pulverized and mixed with one-fifth part of lime, an hydraulic mortar or cement is obtained, which attains a sufficient hardness to admit of being polished. Felspar with lime hardens slowly, and only at the end of five months; but if calcined with a small quantity of lime it becomes much better. Water abstracts from this mortar six per cent of potash. Common potter's clay, which is worth absolutely little or nothing when uncalcined, produces, when calcined with lime, a cement which hardens perfectly well, provided it contains only a small portion of iron….(he) (p159) tried the employment of calcined dolomite (magnesian limestone) for the cement instead of common lime, **and found that it greatly surpassed the latter, both for the preparation of common mortar and for that of hydraulic mortar.** He also obtained good mortar of the latter kind with calcined marl.

The greater number of specifications prepared by surveyors for the erection of buildings, direct that the mortar shall be composed of stone-lime and sharp river-sand, to be mixed in the proportions of one part of lime to three parts of sand. These proportions will make excellent mortar if properly compounded ; but, **as the quality of the lime varies considerably, so will it take more or less sand.**

Builders employ two methods of compounding their mortar: — First, when it is required to convey it in a dry state to the work, it is done by forming a bed of

lime, surrounding it with sand, and then throwing on the lime a sufficient quantity of water to slack it, and covering it up immediately with sand; after it has remained some time in this state, it is turned over, and, if necessary, screened. The mixture is now in the state of a dry powder, and can be carted to the work, where more water is added and it is chafed up for use.

The other method is employed when there is convenience for making it up at the work. In this case it is what is termed " larryed. " Thus: — the lime is put into the middle of a bed of sand, and a large quantity of water thrown on, and with lime-hoes mixed up immediately until completely incorporated. It is then allowed to remain for a few hours, when it becomes set, and of proper consistency for use. The lime when turned up in this way will admit of a larger quantity of sand, as all the particles of lime are dissolved, whereas by the first method there are always small particles of the lime which cannot be properly mixed, however much it may be chafed up.

Chalk-lime mortar requires two parts of lime to three of sand, and is now chiefly used for plasterers' work.

The theoretical investigations connected with the composition of mortars have for a considerable period occupied the attention of the most celebrated French chemists. In researches of this nature they are considerably in advance of us; but **the reputation of the English builders for practical experience in the manipulation of mortars is, on the other hand, well known and appreciated by all those whose attention has been directed to these important investigations**. The professional practice of English architects, relating to the composition of mortars employed in public or other works, is best exemplified by extracts from their original specifications.

Ordnance Works.

Not less than thirty-nine bushels of lime to every rod of brick-work. The lime to be slacked under cover, and the mortar made on a stone or brick floor, and properly worked until all the parts are thoroughly incorporated.

Farmhouse and Farmery. Erected at Greenford, 1832. Good fresh gray lime and river sand properly screened, and in the proportion of one of lime to three of sand, well tempered together.

Stockport Church, Cheshire. Buxton lime mixed with two-thirds of sand. •

(p162)

Bankrupts' Courts, Basinghall Street, London. The mortar to consist of one-fourth of good Dorking lime, and the remaining three-fourths of clean sharp river sand.

Turkey Street Bridge, Enfield, 1827. The brick-work to be laid in Dorking stone, or blue lias lime mortar, and clean sharp Thames sand, in the proportions of three parts of sand to two of lime; **to be made in a pug-mill and used hot**. The grout to be in the same proportions.

Exeter Higher Market, Devon, 1836. Mortar for the brickwork is to be made with well-burnt stone lime (Plymouth) and good clean sharp grit sand, in proportions of **one and a quarter to three**. The lime is to be **thoroughly slacked with an abundant quantity of water as soon as it is brought on the premises, and immediately after, well protected from the action of the atmosphere by a thick covering of the ingredient with which it is to be mixed; in this state it is to lie until quite cool, and then mixed together in the above proportions. This mixture is afterwards to be sifted through a wire sieve, and made up with such a quantity of water only as will render the compound of the (163) consistency of damp sand. It is to be well tempered in a pug-mill, and to be laid in heaps from two to three weeks, being protected during this period, so as effectually to prevent it becoming dry or setting. Ultimately it is to be worked up for use**. **The mortar for the free-stone is to be made up of fine lime putty, and bright coloured fine sharp sand, washed clean, and well tempered together.**

Silk Mill and Engine House for Messrs. Grout, Baylis, 8f Co., at Great Yarmouth, 1825. The mortar for the mill, engine, and boiler house to be composed of the **best Dorking lime** and sharp sand, in the proportion of three parts of sand to one part of lime. The mortar for the chimney (one hundred feet in height) to be the same as before described, but for the other parts, to consist of **one- third part of the best chalk lime (Yarmouth), used fresh from the kiln, and two-thirds of clean sharp ' sand, well worked together**.

House in Orton's Buildings, Southwark Bridge Road, in the Liberty of the Clink, London. Mortar to be composed of Merstham stone lime and sharp drifts **and from above London Bridge**, in the proportion of **one heaped bushel of lime to two striked bushels of sand, well tempered.**

P164 **Works at the Berkeley and Gloucester Canal.** The mortar must be made of clean sharp sand and **Aberthaw lime** (Wales), in the following proportions; that is to say, **for works under water, and exposed to the river Severn in front, two measures of sand to one of lime; for backing all work under water, and exposed to water, three measures of good sand to one of lime; and for all other backing, four measures of sand to one of lime.** The mortar required for the locks and the outer gates of the basin to be intimately mixed in a pug- mill. **The limestone is to be brought to the ground and burned upon the site of the works,** the contractor having the use of any kilns now thereon; but he is to erect others if necessary.

Greenwich Railway. The mortar to be composed of the best Halling lime and sharp river sand from above London Bridge, in the proportions of one of lime to two and a half of sand.

London and Birmingham Railway. Mortar for all the works near the London station to be composed of the best burnt Dorking or (165) other lime of equal quality and clean sharp river sand, in the proportion of three of sand to one of lime; the compost is to be mixed in a dry state, and passed through a pug-mill with a proper quantity of water.

Watford Tunnel. The mortar to be used in the tunnel shall be made with the best fresh burnt Merstham or Dorking lime, or other lime which the Engineer may deem equally good. **It shall be ground under edge stones in its dry or unslacked state.** The sand must be sharp and clean, and mixed with the lime in the proportion of three measures of sand to one of lime.

Blisworth Division. The mortar to be used in the beds and faces of buttresses, walls, sides, or drains, and invert arch, to consist of one part of lime to three parts of clean river or other unexceptionable sand. **The sand to be passed through a quarter-inch screen; the lime to be fresh and well intermixed by a thorough beating. The mortar for running into the upright joints of the courses, and for filling in the work sound, to consist of one part lime to four parts of small un screened gravel, to be well mixed and beaten to a tough consistency, and liquefied in tubs or other (166) vessels, to be properly adapted to run into and fill up all vacuities. The mortar to be used as hot as is consistent with the safety of the work,** and the sand and gravel to be perfectly free from any loamy or other particles of a muddy nature: The limestone rock found in the excavation, may be used for the mortar specified to be used in the retaining walls of this contract.

The foregoing extracts from the original specifications, respecting the composition of mortar, exhibit a tolerable agreement with each other; and, with the exception that the preliminary directions of some are more copious and explanatory than others, may be considered as affording a concise and satisfactory view of the modern practice adopted by some of the most eminent builders and architects, grounded upon careful observation, and great practical experience. The quality of the sand required for the composition of mortar should undergo careful examination, as it operates with considerable influence on the quality of the mortar.

In districts where sand of the requisite energy and sharpness is unattainable, road-drift has been employed, and, in some instances, recommended in the specification of works. Where the repair of roads has been effected with a mixture of good flint and quartz gravel, and the drift thoroughly screened to separate the muddy and other extraneous particles, such sand (167) may afford a tolerable substitute….

P168 The sand mostly used in London and its vicinity for the manufacture of good mortar, is procured from the bed of the river Thames, above the bridges. This sand has acquired a standard reputation among the principal architects and builders of London, and we shall presently show that its good qualities have not been over estimated by the profession. The river Thames passes through a country where the contiguous stratum is calcarea-silicious and argillaceous.

The immense number of weirs, culverts, road-drains, &c., which are discharged into the river, deposit an immense mass of heterogeneous matter, consisting of calcareous, fossil, quartzose, and flint-sands, particles of coal alluvium, and much iron. Sea-sand, flints, and marine debris are also washed backwards and for- (169)wards with the flux and reflux of the tide, distributing a sand of coarser quality than that deposited by the inland tributaries. The Thames sand, therefore, requires to be well screened and washed, previous to its admixture with the lime, in which state it will be found to consist of two kinds of materials — the first a fine shingle, mixed with calcareous particles, and the second a fine angular **silicious** and quartzose sand. **The accidental circumstances which occasion the deposit of a fine and coarse sand in the bed of the river Thames are the chief causes of its superiority as an ingredient in the composition of mortar, for the interstices between the larger and more quartzose particles become partly occupied by the angular and sharp fragments of the finer sand, which firmly unite with the cement, wedging and dovetailing them together….**

P170 Silver sand, for fine stuff, is procured from the Isle of Wight. This sand is angular, transparent, and colourless; acid has no effect upon it, and it is perfectly free from impurities. The fossil and land-sands of Bagshot Heath, Highgate, and Hampstead (when washed and cleansed from the impurities which they contain), are employed for internal work, such as plastering, &c.

(there follows much discussion about the qualities of different sands encountered in parts of London during major construction projects (such as Highgate Cemetery) and as derived from (mainly) Yorkshire and Forest of Dean sandstones, from which clays would be washed before use as aggregate).

Bartholomew A (1840) Specifications for Practical Architecture. London. John Williams

….we have now, no masons, no bricklayers, whose scientific knowledge is cultivated; no artificer, except the carpenter, now knows anything of drawing geometrical lines, — and he, from the decay of art, rarely knows anything which can carry him in a scientific manner through any structural difficulty, much less enough to ennoble his art.

Carpenters and masons are in general very tractable men, who may be taught any degree of skilfulness, though our modern bricklayers are mostly the rudest and least careful workmen who are to be found at present practising in any handicraft business; and while most other workmen take a pride in trying and rendering their work exact, the modern bricklayer seems to think his dignity offended by altering the position of his materials from the place where they may have been first hastily cast, and would rather abuse you than alter a joint or fill it with mortar; nay, if even the bricks of which he is forming the most important bearing-piers, break under the blow of his trowel, he leaves them where they break, alike unconcerned whether they support their burthen or sink beneath it.

On the Inferiority which is Often to be Found in Modern English Brickwork.

353. It is a remarkable fact, that in proportion as the manufacture and burning of Bricks have improved, **and while the use of Stone-lime has become more general**, the Workmanship of much of our modern English Brickwork, has debased in quality more than the materials of the work have improved. The author is obliged to confess, that although he has taken very great pains, to procure complete soundness in the execution of Brickwork, he has almost wholly failed: his idea of soundness, is nothing more than that the work should be composed of good materials correctly bonded in every part, should be thoroughly cemented together, and that as few broken bricks as possible should be used in the work.

Specification for works to be done at the premises in ALTERING, STUCCOING, and DECORATING the PRINCIPAL FRONT of the said premises, and in other repairs to the said premises.

To repair thoroughly all the tiling of the several roofs of the premises (more particularly of) providing the requisite new tiles and heart of fir double laths, and putting pegs wherever they can be admitted; **to re-set all the ridge-tiles and hip-tiles in lime and hair**, and to secure the whole thereof with T nails, dipped in melted pitch.

To cut out the brickwork at all the settlements therein to the dwelling-house, workshops; and to bond into the brickwork new stock-bricks with **Parker's cement and Thames sand mixed together in equal measures**, so as to repair the same in a secure manner.

To take down and re-build with sound new stock- bricks the defective parts of the parapets; to re-set in Parker's cement and Thames sand mixed together in equal measures, the brick-on-edge and other copings; to repair the string-courses where defective, and to point the tops of all the string-courses with Parker's cement and Thames sand mixed as last described.

To rake out the joints at least ¾ in. deep; to cut out the defective bricks, to repair with new stock-bricks, and to point in a neat and workmanlike manner with **Dorking stone-lime coloured mortar all the external brickwork of where in any way decayed,** the whole of the fence-walls of the adjoining yard, also the East side of the building on the West side of the yard for 8 ft. down from the top of the parapet thereof and wherever else may be requisite.

To repair and point in like manner the whole of the brickwork of the North and East sides of the front yard, the fence-wall on the West side thereof, and where requisite to the brickwork of the workshops on the South side of the yard.

To lime-whiten twice the whole of the ceilings internal walls and the other parts before whited of the buildings on the East and South sides of the front yard.

To prepare the whole of the remainder of the front in order to receive the intended stucco-work, by raking out the mortar from the joints thereof, by cutting away some portions and by adding to the other parts thereof tiles nailed securely to the old brick-work, so as thereby to render the various parts of the front as level straight and uniform as possible: for the cornices over the one-pair windows a course of bricks is to be inserted in the old wall so as to afford the proper projection for the stucco- work.

The whole of the new brick-work and all the extra projections are to be set in Parker's cement and clean Thames sand mixed together in equal measures.

Plasterer:

To put to the two front compartments of the shop, new ceilings lathed plastered floated set and whited.

To execute in the very best manner the whole of the external front of the house next in Parker's cement stucco according to the drawings, with all the mouldings fascias projections and decorations therein represented; the whole to be floated out as accurately as possible, to be roughly coloured in small portions as soon as done, and while yet soft to be jointed very strongly, and finally when directed by the surveyor, to be teinted in imitation of stone, with weather-proof outside-colouring mixed with beer-grounds, Russia tallow, tar, and the other proper ingredients; to perform all requisite dubbing out, and to lath where requisite the window-frames for the formation of the architraves.

Specification for the erection of a Park or Garden Wall.

… The whole of the brick-work (except where herein otherwise directed) is to be laid in and is to be entirely flushed up at every course of the work with mortar composed of one third by admeasurement of the best Dorking (or other, at the case may be,) stone-lime and two thirds by admeasurement of the best sharp river (Thames) sand.

2359. **Common chalk lime should seldom be used in any work, and never in a park-wall. If good river sand cannot be obtained, good clean road drift may be used instead of it.**

Specifications for an Artificial Foundation of Concrete-work.

… The concrete-work is to be formed in the proportion of six parts by admeasurement of clean Thames stone ballast, unscreened, and with rough and fine intermixed, and one part by admeasurement of the very best fresh burnt Dorking stone-lime (or other stone-lime as the case may be) beaten to fine powder on the premises without being slaked.

The ballast and lime are to be thoroughly mixed with each other in small quantities at a time, the lime being slaked with a small quantity of water at the moment of admixture; sufficient scaffolding is to be provided and erected by the contractor, and all the materials of the concrete-work are to be from thence thrown down a depth of not less than 10 ft. into the bed of the work, so as to be the better consolidated in the intended layer of the foundation.

General Treussart (1842) ESSAYS ON HYDRAULIC AND COMMON MORTARS AND ON LIME-BURNING. TRANSLATED FROM THE FRENCH OF GEN.TREUSSART BY M. PETOT, AND M.COURTOIS.

WITH BRIEF OBSERVATIONS OF COMMON MORTARS, HYDRAULIC MORTARS, AND CONCRETES,
AND AN ACCOUNT OF SOME EXPERIMENTS MADE THEREWITH AT FORT ADAMS, NEWPORT HARBOR, R. L, FROM 1825 TO 1838. BY J. G. TOTTEN, LT.COL. OF ENGINEERS, AND BREVET COL. U.S.ARMY.

NEW- YORK: WILEY AND PUTNAM, 161 BROADWAY.

ON HYDRAULIC AND COMMON MORTARS.

Sect. 1.— ON MORTARS PLACED UNDER WATER.

CHAPTER I.

On Lime.— Actual state of our knowledge of this substance.

Lime has been employed from time immemorial. Mixed with sand, or certain other substances, it forms what is called mortar. Although the solidity and durability ot masonry depends on the goodness of mortar; still, few experiments have been made with lime; and the manner of making mortar has almost always been given up to workmen. It is only within about fifty years that a few scientific men have attended to this important subject.

Comparing the mortars of the ancients, and especially of the Ro mans, with those of modern times, it was perceived that the old mortars were much better than ours; and the means have, consequently, been sought of imitating them. Several constructors have thought they had discovered the secret of making Roman mortars: others, on the contrary, have thought that **the Romans had no**

particular process, but that, of all their constructions, those only which were made of good lime had survived to our day. We shall see that my experiments tend to confirm this latter opinion. Lime used in building, is obtained by the calcination of calcareous stones, which occur abundantly on the surface of the globe. Marbles, certain building stones, chalk, calcareous alabaster, and shells, are employed in making lime. The effect of calcination is to drive off the water and the carbonic acid which are combined with the lime. The water and the first portions of carbonic acid pass off easily; but it requires an intense, and long continued heat to dispel the remainder of the acid. Lime, as used in constructions, contains, almost always, a considerable quantity of carbonic acid.

When the stone submitted to calcination is white marble, pure lime is obtained, provided the calcination be carried far enough. According to an analysis which I made of white marble, this substance contained, in 100 parts, as follows: lime 64; carbonic acid 33; water 3.

Lime obtained by calcination possesses the following properties. It has a great avidity for water, imbibes it from the air, and has its bulk enlarged thereby. If a cer tain quantity of water be thrown on lime recently calcined, it heats highly, breaks in pieces with noise, and a part of the water is evaporated by the heat produced….

It is rare that lime derived from white marble is used in the arts; that which is commonly employed, and which is derived from ordinary lime stone, almost always contains oxide of iron, and sometimes a certain quantity of sand, aluminae, magnesia, oxide of manganese, &c. Some of these substances combine with the lime by calcination: and the lime thus acquires properties which it had not before, and of which I shall speak in the sequel.

If we take lime derived from white marble, or from common lime stone, and reduce it as it comes from the kiln, to a paste with water, and if we place this paste in water, or in humid earth, it will remain soft forever. The same result will be obtained, if lime be mixed with common sand and the resulting mortar be placed in similar situations.

It is a common practice to deluge lime, fresh from the kiln, with a large quantity of water, and run it into large basins, where it is allowed to remain in the condition of soft paste. Alberti says (book II., chap. XI.) he has "seen lime, in an old ditch, that had been abandoned about 500 years, as "was conjectured from several manifest indications; which was still so moist, "well tempered, and ripe, that not honey or the marrow of animals could be "more so." There is another kind of lime which possesses a singular property: if it be slaked as it comes from the kiln, as above, and be then placed in the state of paste, in water, or in moist earth, it will harden more or less promptly, according to the substances it contains. The same result is obtained if the lime, being mixed with sand, is made into mortar and placed in similar situations. If this lime be slaked and run into vats, as is done with common lime, it will become hard after a little time, and it will then be impossible to make use of it.

On slaking lime, fresh from the kiln, with enough water to reduce it to paste, it is found to augment considerably in bulk; this augmentation is such that one volume of quick lime will sometimes yield more than three volumes, measured in the condition of thick paste. When lime which has the property of hardening in water is slaked in the same manner, it affords a much smaller volume than common lime. Sometimes one volume of this lime, measured before slaking, will give, when slaked to thick paste, scarcely an equal bulk. For a long time, those limes which had the property of hardening in water were called meagre limes, and those which had not this property were called fat limes. These denominations were affixed because the first kind increased but little in bulk when made into paste, while the other give a considerable augmentation of volume; and because fat limes formed, with the same quantity of sand, a mortar much fatter or more unctuous than meagre lime. But the designation "meagre lime" is alto gether improper to indicate limes which enjoy the property of hardening in water; because there are limes which augment their volume very little, on being made into paste, and at the same time possess no hydraulic property. Belidor gave the name of beton to lime which had the quality of hardening in water; but many engineers continued to call it meagre lime. The de nomination of beton is not suitable; and, in this sense, is not now in use. The following are the terms now employed. In England, the name of aquatic lime has been given to lime which in durates in water; in Germany it is called lime for the water; Mr. Vicat, Engineer of roads and bridges, has proposed the name of hydraulic lime, and this denomination, which is a very good one, has been generally adopted. I shall therefore call that lime which swells considerably in slaking, fat lime, that which swells but little and does not harden in water, meagre lime, and that which possesses the property of hardening in water, hydraulic lime. Fat lime is often called common lime, also. The term quick lime is applied to all unslaked limes whether fat lime, meagre lime, or hydraulic lime. Although meagre lime and hydraulic lime may have been calcined exactly to the proper degree, still they are slower to slake, and give out less heat than jut lime. When fat lime has been too much burned, it, also, becomes slow to slake; while, if properly burned, it begins to slake the instant water is thrown on. Experiments, to be given in the sequel, will show that iron, in the state of red oxide, causes fat lime to slake sluggishly.

(Discussion about what impurity caused hydraulic set – for a long time, manganese thought to be the cause.)

… On the other hand we find in the Bibliotheque Britannique of 1776, vol. Ill, page 202, that Smeaton, the English Engineer, who built the Edystone Light-house, in 1757", attributed this property to clay…

… Mr. Saussure, in his Voyage des Alpes, says that the property possessed by certain limes of hardening in water is due solely to silex and alumine (that is to say, to clay) combined in certain proportions.

(Discussion of Vicat's experiments in making artificial hydraulic lime using air lime and clay fired together (the lime for the second time))…

Such is the process indicated by Mr. Vicat. But this engineer did not content himself with experiments on a small scale: **a manufactory was established near Paris by his means, where artificial hydraulic lime is made in large quantities; he moreover exerted himself to extend the use of hydraulic mortar every where, and he succeeded.**

P6… In terminating this reference to works on hydraulic mortars, which have appeared up to this time, I must introduce a fact, entirely new, announced by Mr. Girard de Caudemberg, engineer of roads and bridges, in a notice published by him in 1827. He states that the proprietors of mills on the river Isle, in the department of Gironde, discovered by accident, a kind of fossil sand to which they gave the name of arene, which has the singular property, without any preparation, of forming, with fat lime, a mortar that hardens under water, and has great durability. I shall have occasion to return to this important fact, and to report what Mr. Girard says, as well as to state the principal experiments which have been made with this sub stance, in other places where it has been found.

CHAPTER II. On slaking Lime; manner of making Mortar; observations on Hydrate of Lime.

There are three modes of slaking lime. The first consists in throwing on the lime, as it comes from the kiln, enough water to reduce it to thin paste. This process is the one generally employed with fat lime. Too much water is added, almost always — that is to say, as much as is required to make it a thin cream. In this state it is run into vats; after some time it thickens, and it is then covered with a layer of sand or earth to preserve it from contact of the air, which would soon convert the upper portion into a carbonate.

It is a common opinion that the longer the lime has been kept in this state, the better it is. My experiments will show that **this is not true**, at least not always true: since some fat lime that I had experimented with, which had been lying in this condition, gave, in the air, when the mortar was composed of lime and sand only, very bad results. The thickening of the lime in the vats is due to the escape of water by filtration, by evaporation, and also to a third cause: for this thickening which is quite prompt, occurs equally when the vats are constructed in moist ground, and when the season is rainy. This third cause appears to me to be this: that the lime, having a strong affinity for water, solidifies the first portions very promptly, but requires a considerable time to saturate itself completely. These portions of the lime which have been too much or too little burned are, besides, slow to slake, I made the following experiment to satisfy myself on this point.

I tooke a portion of lime that had been lying wet in a vat for four years, it was quite thick, I added a little water to bring it to the consistence of sirup, and placed it in a stoneware vessel. I took an equal portion of fat lime, slaked fresh from the kiln, reducing this also to the consistence of sirup, and placing it in a similar vessel. After a short time, this last had become very thick, while the former retained its consistence of sirup; 1 then added water to restore the consistence first given. The thickening again occurred, but more slowly than at first.

The second method of slaking consists in plunging quick-lime into water for a few seconds. It is withdrawn before the commencement of ebullition; slakes with the water it has absorbed, **and falls to powder**. It is preserved in a **dry place.** The operation is performed with baskets into which the lime, broken to the size of an egg, is put.

Mr. de Lafaye, in 1777, proposed this mode of slaking lime, as a secret recovered from the Romans; it made much noise at the time, but experience has not realized the great results anticipated.

The third process consists in leaving the quick-lime exposed to the air. Its strong affinity for water causes it to attract the greater part of that which is in the surrounding air. Lime, thus exposed, slakes slowly without giving out much heat, and falls at last to powder. This mode of slaking is called air-slaking, or spontaneous slaking. It is employed, more or less, in several countries. It is spoken of in several works on constructions, and is generally condemned. Mr. Vicat, however, appears to give it the preference, for, at page 20 of his memoir, he says: "Such are the three modes of slaking lime: the first is generally used; the second has hardly been tried, except as an experiment at certain works; the third is proscribed, and represented, in all the treatises on construction, as depriving the lime of all energy, to such a degree that those portions which have fallen to powder in the air, are considered as lost. We shall not now speak of the processes of Rondelet, Fleuret, and others, because they do not differ much from those described. We shall see, further on, that, as regards spontaneous slaking, these proscriptions of authors who, believing every thing, repeat without examination the errors of those who preceded them, are founded on false observations and are deserving only of mistrust." Mr. Vicat has announced that a mortar made of sand, and fat lime which was air- slaked, resisted perfectly at the end of ten years, the test indicated by Mr. Berard for frost-proof stones; he says on this subject "a hint, this, to those who have written and spoken so much against air-slaking, and in opposition to the opinion which I have had to maintain singly, unable to invoke to my aid any experiments but my own."

The results I have obtained are far from water it absorbs, in a certain number of seconds, a quantity sufficient to reduce it well to powder. We shall have then a like result by throwing the same quantity of water on the lime, and avoid the inconveniences attending the plunging into water.

Since 1817, this process *[aspersion]* has been employed at Strasburg, where considerable masses of lime were operated on. A small building was erected near the works, into which the hydraulic lime, not allowed to arrive too fast from the kiln, was put, to be protected from the weather; the building was boarded on the sides and top, and, in case of rain, covered with a tarpaulin. By the side of this lime-house, a larger shed was constructed, the top only being boarded; a plank floor, on which the mortar was mixed, was laid under this shed. There was a measure, without a bottom, which contained about 10 cubic feet, each dimension of the box being about 2.20 feet, this was placed on the floor and filled with lime; which being done, the same measure was used **for the sand, which was placed around the lime, without covering it:** with large tin watering pots of known capacity, water, **equal in bulk to about one-quarter the bulk of the lime, was thrown on:** the workmen knew they were to empty the watering pots but a given number of times; and the lime being all in sight they saw that they should throw the greater quantities on those parts of the heap where lay the largest lumps of lime. **As soon as the slaking became energetic, the lime was left to itself until the vapours had ceased; it was then turned a little with a shovel, or a rod was thrust in, and if any lumps were found still entire, either for the want of water, or because they were too much burned, a little water was poured on these lumps. A regular form was then given to the heap, and the surface being slightly pressed with the back of the shovel, the lime was covered with the sand that had been placed around it. This process was completed towards evening — as many heaps being prepared as it was presumed would be required during the whole of the ensuing day. By thus leaving the lime, over night, in heaps, the slaking is complete; portions which have too much water impart it to those which have too little, and the water becomes thus uniformly diffused through the heap.**

In the morning the sand and lime of each heap were mixed together, and passed twice under the rab (rabot) before adding any water: in this way, if there were any stones, or pieces of lime imperfectly slaked, they were easily found and rejected. Water was then added in sufficient quantity to bring the whole to the state of very soft paste; because in this dilute state the mortar is, with less labour, mixed more perfectly.

Experiments which follow will show that it is an error to insist that mortar should be mixed with 'the sweat of the labourers:'' it is enough if the sand be well mixed with the lime; and this mixture is better effected, and in a much more economical manner, when the mortar is in a state rather thin, than when it is thick; another reason for making it rather thin is, that it often becomes stiffer than it ought to be, before it is used, in consequence of the lime preserving, as before stated, for a considerable time, the **property of solidifying water.**

When the lime has been properly burned, the operation just described gives a homogeneous mortar not at all granular, and not exhibiting **a multitude of little white specks, which are particles of lime that have been badly slaked.**

At Strasburg the precaution was always taken of **making up only one or two heaps of mortar at a time; so that it should not have too much time to dry before being used, and that the masons might find it in the state of paste, in the heaps in which it was deposited after being well worked**. In making the mortar only as it is needed, there is, besides, the advantage of avoiding the labour of remixing, in the frequent case of being prepared as it was presumed would be required during the whole of the ensuing day. By thus leaving the lime, over night, in heaps,in which it was deposited after being well worked.

A circular trench, having the two sides sloping, is built of masonry; the section of the trench is a trapezoid 2 feet wide at bottom, 3 feet 4 inches wide at top, and 1 foot 4 inches deep ; the inner circle of the trench is 9 feet 4 inches in diameter; at the centre there is a mass of masonry, in which is fixed a vertical axis, of wood, 6 feet 8 inches long, and 8 inches square, and which is bedded in the masonry about 5 feet; the top of this axis is formed into a cylinder 5 ^ inches in diameter, and 6 inches high; around which is fitted a collar of cast-iron, carrying laterally two horizontal trunions 3 j2„ inches in diameter, and 4 T80 inches long; a piece of wood, 26 feet 8 inches long, is notched at its middle upon the collar of the vertical axis. (Instead of one piece of wood, two might be taken, each 13 feet 4 inches long, by strongly securing, with iron, their junction with the vertical axis.) This piece is placed horizontally, and is about 13 inches square in the mid dle, lessening towards the ends, so as to serve as an axletree to two vertical wheels with broad felloes — 6 feet diameter of wheel, and 6 inches breadth of felloe. These two wheels rest in the circular trench in such a way that the one touches the exterior and the other the interior slope of the trench. A horse is attached to each extremity of the horizontal bar, and their united efforts cause the wheels to revolve in the trench ; behind each wheel, attached to the horizontal bar, by means of a hinge, is a scraper of wood armed with iron, these follow the movement of the wheels, scraping the two sides of the trench so as to throw the mortar under the wheels. These scrapers of which the lower end is within two inches of the bottom of the trench, are attached by hinges in order that they may rise over any obstacle. Mortar is made in this machine in the following manner. A cubic metre (35.34 cubic feet) of lime in the state of paste is thrown into the trench, and the horses are started; a little water is added if necessary, and when the paste has become quite liquid and homogenous, the proper quantity of sand is thrown in by the shovel, without arresting the movement; in about 20 or 25 minutes the mortar is made. With this machine 12 batches of 3 cubic metres each (12 x 3 x 35.34 equals 1272:24 cubic feet) may be made in 10 hours labour; the requisite agents being 4 labourers, 2 horses and their driver, and 1 superintending mason. The expense of making a cubic metre or mortar, amounts in Paris to about 80.10; this is a considerable saving over the common mode of making mortar.* It is desirable therefore that frequent use be made of this machine, in places where there are important constructions. The description just given is extracted from the devis-modele of the corps of Engineers, and was prepared by Lt. Col. Bergere of the Engineers. It is stated above that at Strasburg, lime which was to be made into mortar, was slaked to dry powder, and left in that state for twelve hours at least before giving it the quantity of water necessary to convert it into paste. I made the following experiments with limes in the environs of Strasburg, to ascertain the volume obtained in powder and in paste, when the proper quantities of water are used to produce those slates.

All the limes in the above table (not shown), were used fresh from the kiln. I reduced them to powder in a mortar, sifted them, and used, for quantity, about one quart. Thus, for example, I took a measure of quick lime of white marble, and throwing upon it half a measure of water, I obtained 2£ measures of lime slaked to powder, which I measured after it was cold.

The quality of the mortar is superior to that made by the common process; and it is well to remark, that the time during which the mortar is made is precisely that in which the labourers repose: it is therefore their interest lo let the machine go as long as possible, and consequently to render the mortar more perfect, so that the supervision will be directed chiefly to the proportions of the mixture. This note is extracted from the devis-modele du corps du Genie, p. 71. — Tr.

Quantity of lime obtained in powder is given in the third column. I was obliged to throw upon this lime in powder, one measure and one-tenth of water in addition to reduce it to paste. Adding this last quantity of water to the half measure used in the first instance, the total is 1 A measures of water, absorbed by the lime, in being reduced to paste: this is shown in the fourth column. The fifth column shows that I obtained 1|- measure of lime in paste. I followed the same process for all the limes of the above table, producing a uniform consistence of paste, by adding the water little by little. Experience had taught me that these limes were reduced to dry powder by throwing on one-fifth of their bulk of water; and that as much as one-half their bulk might be thrown on without the powders ceasing to be dry: be yond this term, a moist powder would be obtained. The only lime on which I threw less than half its bulk, was that at the bottom of the table, of the Boulogne pebbles; on this I poured but its bulk of water; as this lime forms a moist powder with^ its bulk of water, I was obliged to restrict myself to one-third. This table shows that these different limes afforded very different volumes of powder with the same quantity of water: that the quantities of water absorbed to produce the state of paste were very differ ent, and, also, that the volumes of paste differed much. Experiments which follow will show that, of the limes in the table, those are the most hydraulic which absorbed the least water in passing to the state of paste, and which gave the smallest bulk both of powder and of paste. Those limes, of the table, which are not hydraulic, are those which gave the greatest volumes in powder and in paste. There are in the table two kinds of Obernai lime, one yellow and the other blue; they are of the same limestone, but one more highly calcined than the other. When this lime has been burned just enough, it is of a yellow-fawn colour; when a little more burned, it is of an ashy-gray, and when too much calcined, of a decided blue. It was upon the two extremes of calcination that I made the above experiments, they show that the degree of calcination has a sensible influence on the swelling of this hydraulic lime. As the swelling of lime, shown in the above table, was obtained with quite small quantities, and with pulverized quicklime, I caused experiments to be made at the mortar beds on a large scale, with fat lime and with Obernai lime; these being the two kinds of lime ordinarily used upon the works. The following results were obtained. Fat lime was taken immediately from the kiln, and measured in the boxes in use at the mortar beds; care being taken to break up a portion of the lumps of quick lime into smaller pieces, in order to occupy the interstices between the larger pieces, and to have the measure well filled: water, in quantity sufficient to bring the lime at once to paste of the consistence of mortar, was thrown on without delay, and the quantity of paste thus obtained was measured. Proceeding thus — one measure of quicklime, just from the kiln, required two measures of water to produce the state of paste, and yielded 1.83 of paste, which differs but little from Table No. 1, wherein the produce is 1.75. The same operation was repeated with Obernai lime, after having rejected vitrified pieces, and those which had not been sufficiently calcined: one measure of this lime absorbed 1.30 of water in being reduced to paste, and in this state gave 1.30 of lime. This differs somewhat from the result in the Table. The difference may be owing to this, that in the experiments of the Table, the lime was pulverized, and was twice slaked; that is to say had two successive applications of water, while in the larger experiment the lime was not broken up, and had water poured on but once. The degree ot calcination might, also, have had some influence. Many metallic oxides are susceptible of absorbing and solidifying a certain quantity of water forming compounds which possess peculiar properties. It is to these compounds that the term hydrate has been assigned. It has been seen, above, that lime is a metallic oxide, and that this substance ab sorbs and solidifies a large quantity of water; but the quantity of water absorbed by lime in forming its hydrate is not exactly known. Berzelius asserts that the hydrates are formed of water and oxides in such proportions that the quantity of oxygen contained in the oxide is equal to the quantity of oxygen contained in the water; but Mr. Thenard does not admit this law: he says that the experiments on which it is founded are not numerous enough, nor sufficiently precise, to allow its definitive admission. It is certain nevertheless, says this celebrated chemist, that amongst the hydrates which have as yet been examined, those which contain the most water, are those, also, of which the oxides contain the most oxygen. According to Berzelius, the hydrate of lime is obtained by throwing upon quick lime the water necessary to reduce it to thin paste (bouille,) and exposing this paste in a silver or platina crucible to the heat of a spirit-of-wine lamp. After having dried the hydrate of lime in this manner, it is weighed, and the quantity of water it has absorbed is known by the augmentation of weight. Berzelius made two experiments, one with 10 grammes of lime and the other with 30 grammes. He found in the first experiment, that the lime had increased in weight 32. 1 per cent., and in the second, 32.5: iff this second experiment there was, therefore, an augmentation of four-tenths more than in the first. He attributes this difference to an absorption of carbonic acid, and he admits, as good, only the first experiment, in which 100 parts of pure lime containing 28.16 parts of oxygen, are combined with 32.1 parts of water containing 28.3 parts of oxygen; whence Berzelius concludes that the water absorbed by pure lime contains a quantity of oxygen equal to that contained in the lime. I ha ve repeated the experiment of Berzelius by operating on 20 grammes of pure lime, using, as he did, a spirit-of-wine lamp, and a platina crucible. I was surprised at obtaining an augmentation of only 22.5 per cent. I repeated the experiment several times, successively diminishing the thickness of the wick, and as I did this, the lime retained more and more water. I inferred, therefore, that the hydrate of lime decomposes with a feeble heat; and that, if Berzelius obtained a greater result in the second experiment than in the first, it was not all due to the absorption of carbonic acid, seeing that the operation lasts only a short time; but to this, that heating with an equal flame, two volumes of hydrate of lime, of which one was triple the other, the smaller volume should lose most water by the heat. But there is a fact which proves with how great facility the hydrate of lime abandons a part of its water. All those who have made mortar of lime newly slaked, have perceived that it becomes very dry in a short time. If, when in this state, it be worked for some time without adding water, it will be brought back nearly to the same moist state it had at first ; and drops of water may be seen on the mortar. The same result is obtained with lime alone. It follows from this, that simple friction (working) decomposes the hydrate of lime, and that a feeble heat produces the same effect. To know, therefore, the quantity of water which enters into the hydrate of lime, it appears to me that other means of drying should be resorted to than fire. The various kinds of lime are used in constructions, only after having been brought to the condition of hydrate: nothing, therefore, that relates to the properties of this compound, is a matter of indifference. As yet, few experiments have been made to determine the quantity of water that should be given to lime in making mortar. I proposed undertaking several experiments on this point, but time failed me. The matter should be attended to, because, opinions are much divided thereon, for want of exact experiments. The following are the principal properties of hydrate of lime: it is white, pulverulent, and much less caustic than quick lime; it easily abandons to heat the first portion of water, but it requires a high temperature to drive off all the water entering into its composition. This hydrate absorbs carbonic acid; experiments which follow show that it has, also, the property of absorbing oxygen, and that lime sustains important modifications in con sequence of this absorption of oxygen. According to the chemists, lime is incapable of absorbing a fresh quantity of oxygen: but according to my observations, there is no doubt that the hydrate of lime absorbs a considerable quantity. I shall give, in the following chapter, experiments which I made on this subject.

Chapter Three

I was employed from 1816 to 1825 at Strasburg, at which place they had made no use of hydraulic lime. I ascertained, however, that such lime was to be found in the neighbourhood. Almost all the hydraulic works connected with the fortifications of the place, having been badly constructed, and dating as far back as Vauban's time, were to be rebuilt. Twenty-five years' experience had taught me the great superiority of hydraulic mortars in the air as well as in the water — where, indeed, they are indispensable. I tried, therefore, the hydraulic limes, afforded by the environs of Strasburg, and found them excellent: they were, consquently, used in all the works both in air and water. All the revetments built from port de Pierre to port Royal, having a development of about 1650 yards, were rebuilt or repaired with hydraulic mortar. It was the same with the hydraulic works; they were rebuilt or repaired with the hydraulic lime of the neighbourhood.

An engineer who should use fat lime, even for constructions in the air, when there are hydraulic limes at hand, would be very censurable, because the expense is about the same, and, as regards the strength and durability of masonry, there is a vast difference in favour of the hydraulic mortar. But in countries where no hydraulic lime is to be had, or only that of mediocre quality, what should be done? Shall the engineer adopt the process of Mr. Vicat, which consists in making an artificial hydraulic lime? I answer, emphatically, that I think not; in this case, occurring very often, it is, in my opinion, preferable to make hydraulic mortar by a more direct process which I shall point out.

There are two modes of obtaining hydraulic mortar; the first consists in mixing natural, or artificial, hydraulic lime with sand; the second consists in mixing ordinary fat lime with certain substances such as puzzalona, trass, certain coal-ashes, and brick dust, or tile dust.

…p14 …At other stations, I had several times made hydraulic mortars of fat lime and brick, or tile, dust. At the great works of Vesel, where I was employed, three years, considerable use was made of trass, which was brought from Andernach by the Rhine; and on the experience I had acquired of hydraulic limes, I introduced the use of the Obernai lime in all the constructions of the works of Strasburg, both in and out of water….

P 16 …Before giving my first experiments, I will explain the processes I follow ed, both in making mortars, and in breaking them in order to determine their tenacity. In my first experiments, I fixed the proportions of my mor tars, by slaking the lime to dry powder with one-fifth of its volume of wa ter, and measuring this lime in powder. Afterwards I measured the lime in paste, in order to approach the mode ordinarily pursued in practice with fat lime. I shall take care to state in every instance, which of these modes of measurement I followed. When I had united the lime to its proper pro portion of sand, or other substance, I mixed them well together, adding water, till the consistence was like honey; and I passed the mortar seven or eight times under the trowel. The mortar being made, I put it in wooden boxes which were six inches long by three inches wide, and three inches deep, leaving them in the air for twelve hours, so that the mortars might be some what stiffened. They were then placed in a cellar, within a large tub filled with water. I examined the mortars from time to time, and noted the number of days required to harden. I called the mortars hard, when, on pressing them strongly with the thumb, no impression was made on the surface. All the mortars were left in the water one year; at the end of which time they were withdrawn, and I scraped off the four sides or faces with the chisel of a stone cutter until nearly half an inch was removed, when they were rubbed upon a stone until they were reduced to parallelopepids of 6 inches long by 2 inches square. By means .of a wooden form which they were made to fit, all were reduced, very exactly, to the same dimensions, and had the four faces well squared. It will be observed that I took off from each side about half an inch, with the view of submitting to rupture only the portion which had not been in contact with water. I ought to notice that in doing this it was often found that the mortars were harder at the surface than in the interior: sometimes the contrary happened. By taking off a portion (£ inch) from each face, I rejected all that, from any cause, had received a different degree of hardness from the interior.

Chapter 4 Artificial hydraulic limes

I stated in the first chapter, that, for a long time, the property possessed by certain limes of hardening in water, was attributed to the presence of oxides of manganese and of iron; several very hydraulic limestones were, however, at last found that contained no oxide of manganese and very little iron. It was observed, at a later period, that almost all hydraulic limestone contained from one to three-tenths of clay. This led to the opinion that when a certain proportion of clay is disseminated in limestone, it combines, by calcination, with the lime, and imparts to it the property of hardening in water. I stated that Mr. Vicat, Engineer of roads and bridges, published, in -ash, an interesting memoir on hydraulic mortars, and that he announced that **by reburning fat lime with a certain quality of clay, he obtained very good hydraulic lime**. I was bound to state, also, that Dr. John, of Berlin, presented to the Society of Sciences of Holland, a memoir on the subject which was crowned in 1818, and published the following year. He gave the analysis of many common, and hydraulic limes, as well as of many ancient mortars, and he showed that the hydraulic property of lime is due to a portion of clay which combines with it by calcination, and he calls this clay the cement of the lime.
The Minister of War sent the memoir of Mr. Vicat to those places where public works were in progress, and directed the experiments announced by this Engineer, to be repeated.

… In the erection of the sluices at Strasburg, we composed the mortar of the Obernai hydraulic lime, sand and trass; but this last substance being dear, I had begun making some essays towards replacing it with cement, when the memoir of Mr. Vicat was sent to me. I caused the experiments given in that work to be repeated, in the first place by an officer of Engineers, who used a clay of which bricks are made in the environs of Strasburg: he obtained no satisfactory result. A second officer was directed to recommence the experiments, and he was not more successful than the first. I repeated them, then, myself, and I took great pains in making the mixture of clay and lime; they were then calcined and I obtained a result, but it was a very feeble one. I then began anew, using other argillaceous earths, richer in clay, (plus grasses) and I got much better results.

(table shows experiments with numerous clays. One hardened under water after 5 days; some after ten; most between 10 and 35 days).

A part of my preceding experiments having been printed in 1824 in a small pamphlet which was sent to the public works, and was inserted in the seventh number of the Memorial del'Officier du Genie, Mr. Vicat published, in the Bulletin des Sciences, in 1825, and in the Annates des Mines, Vol. X, 3d livraison, page 501, some observations on the results that I had presented. I propose answering the observations of Mr. Vicat, as the more suitable occasions present themselves. This Engineer commences his remarks in the following manner: "In proscribing hydraulic limes, Mr. Treussart rests upon experiments which do- not appear to be conclusive: in the mixtures he made, sometimes he did not employ the clay in suitable proportions, sometimes he used a clay too aluminous, or charged with too great a quantity of oxide of iron, and sometimes he used quartz pounded very fine, as if the degree of fineness obtained by simple trituration could be compared to that of the silex contained in clay." *[Vicat seeking to defend his commercial advantage as a producer of his artificial hydraulic lime?]*

I do not know what induced Mr. Vicat to say that I proscribed hydraulic lime; the following are the expressions which conclude the pamphlet in question. "We see, by what precedes, that the principal idea of the author (Mr. Treussart) is, that there would be much more advantage in making, directly, mortar with fat lime, and trass, or factitious puzzalona, than in seeking first to make hydraulic lime, and afterward to compose mortars of this lime and common sand."

… It is now more than twenty-five years since I learned to appreciate the good effects of hydraulic limes, whether for constructions in the air or in: water: I have employed them wherever I could procure them: during the nine years that 1 was at Strasburg, there were built, with hydraulic lime, in the works in water and in air, more than a million of masonry: I have, then, used this lime for a long time, and I think few Engineers have used more; it would be strange, therefore, in me to proscribe it. I was bound to show the precautions that should be taken in using it, so as not to risk making very bad mortar out of very good lime; I was bound to say what my experience had led me to think, namely, that, in places where good natural hydraulic lime could not be found, it is preferable, as regards the quality of the mortar, and as regards economy, to make hydraulic mortar, directly, by using fat lime and factitious trass, in lieu of attempting to make artificial hydraulic lime with which to compose mortars by the addition of common sand: the sequel of my experiments will leave no doubt in this respect.

…. The above experiments of Mr. Vicat were made with hydrate of lime, that it to say, with limes reduced to paste with water. We see that ordin ary slaking gave better results than spontaneous slaking; with both fat lime and hydraulic lime. In his table No. XVIII., which contains eight mor tars made with diverse hydraulic limes, and sand; the first five gave greater resistances when the lime was slaked in the ordinary way than when slaked spontaneously. The mortars made of fat lime and sand, as exhibited in tables Nos. XIX., XX.. and XXL, gave, it is true, better results when these limes were slaked spontaneously: but with hydraulic limes he, himself, obtained results very different, since the mortar No. 5 of table No. XVIII. gave a resistance represented by 4102 when the lime had been slaked by the ordinary process, while it was only 3082, when the lime had slaked spontaneously. The experiments of Mr. Vicat are, therefore, far from causing us to reject the **old saying of masons as to the bad results obtained from air-slaked lime**; and we do not perceive how he could regard this saying as a condemnatory assertion growing out of false observations. This old saying appears to me to be well founded as to the greater number of hydraulic limes.

All that precedes proves that hydraulic limes, whether natural or artificial, lose much of their hydraulic property if not used soon after they are calcined.

CHAPTER V.

On Hydraulic Mortars made of fat lime and trass, or fat lime and puzzalona.

Trass is a substance obtained from the village of Brohl, near Andernach, on the Rhine; this village is situated at the foot of an extinct volcano. Trass is of a grayish colour, much resembling gray clay which has been calcined. I have seen several pieces of trass which were covered with lava. This last substance differs much from trass: the separation is distinct: the lava which covers the trass is of a blackish colour, and its surface is full of asperities and cavities, showing that it has sustained a very high heat, and very rapid cooling: trass seems to have been exposed to a much lower heat.

Puzzalona is likewise a burned clay — deriving its name from the village of Puzzoles, at the foot of Vesuvius; it is found at or near the surface. According to Mr. Sganzin, there are a great many varieties of puzzalona: it is found white, black, yellow, gray, brown, red, and violet.
The Dutch have a great trade in Trass. They get out this substance in masses, and reduce it to a very fine powder, by means of windmills. Much has been sent to France, to the North, and to England; but it seems that the commerce has diminished a little. Some authors call this substance the Terras of Holland.

On the shores of the Mediterranean, much puzzalona, furnished from the environs of Rome and Naples, is used.

… Before becoming acquainted with the excellent qualities of the Obernai hydraulic lime, I caused some of it to be brought to Strasburg, and the first hydraulic works that I constructed at Strasburg were made of mortar composed of fat lime, sand, and trass.

(All fat lime/sand/trass mortars tested by Treussart set under water in between 3 and 5 days).

In comparing the results of table XIII., with those of the preceding tables in which mortars were made of natural or artificial hydraulic lime and sand only, we see that these last hardened much more slowly, and gave much less resistance, than mortars made of fat lime, sand, and trass or puzzolana.

(Takes issue with Vicat having taken issue with him, once more. Challenges the comparability of testing methods of his and Vicat's, particularly resistance tests).

… This manner of slaking fat lime is that which Mr. Vicat prefers: he, in Annales de chimie, Vol. XIX. page 22, publishing as follows: "The assertion of Mr. John relative to lime exposed to the air is in contradiction to recent facts, so presented, and so multiplied, that I am constrained to combat it. It was I who first announced that **fat lime slaked spontaneously *[air-slaked]*, and abandoned for one year to the action of the air, under cover and protected from winds, gives better results, than when employed immediately, according to the common method.** This conclusion is founded on a hundred and fifty experiments, varied in several ways: it results, for example, that the force of ordinary mortar being, in the most favourable case of a series of experiments represented by 1506, that of mortar made of air- slaked lime gave, under the same circumstances 2293."

Mr. Vicat acknowledges that the ideas, commonly received, on this point of the doctrine of mortars, are all in favour of Mr. John, and he says, because of this sentiment, almost general, he presumes Mr. John did not examine the matter. I will remark, touching this point, that Lieut. Col. Bergere of the Engineers, notices, in the last *devis instructive*, and in the account he has given of the work of Mr. Raucour, that several Engineers have thought, in times long gone by, that air-slaking gave better results than the other two processes, and that this mode has been in use, from time immemorial, in Spain, and in a part ot Italy. Mr. Bergere says that he used it at Flushing; and that this method is recommended in a letter written in 1764 by Mr. Sienne, an Engineer officer, resident at Graveline. I do not however counsel the process of air-slaking in making hydraulic mortar with fat lime and trass, or other analogous substance; because the mortars made in this way contain a great many white specks which appear to be lime passed to the state of carbonate. We may conceive, in fact, that when lime is left to slake spontaneously, every successive small portion of lime remains for some time exposed to the contact of the air, as the lime falls off in successive layers: there ought, therefore, to be a considerable absorption of carbonic acid: whereas lime slaked to powder with water and formed into heaps, has the surface only exposed to the air.

Besides the experiments of the above table, I have made others of the same kind, by **slaking fat lime into thick paste, and into thin paste** — comparing these results with each other, and with those I got from the same lime slaked to powder.

To make the experiments of the above table, I took fat lime as it came from the kiln, and divided it into three portions: one of these portions we slaked to a thick paste and left in a vessel; another portion was slaked to a thin paste, and, as it thickened, I added a little water so as to keep it in the consistence of sirup; the third portion wa9 slaked to a dry powder with one-fourth of its bulk of water, and put, like the others, in an open vessel. I, immediately, made the mortar in the first column, which may serve as a term of comparison. The others were made, at the periods expressed in the table, of lime slaked in the several modes mentioned. In proportioning the parts, I added, when I made the mortar, a little water to the lime which had been slaked to a thick paste and also to that which had been slaked to powder, so as to bring all to the condition of that slaked to thin paste.

In the first series of the table, **the mortar made immediately gave a result rather weaker than those made afterwards**: the hardening was more prompt in summer than in winter. I left the lime of the second series for six months in a state of clear paste before using it. We see that the results were not so good as those obtained from the thick paste. There are, certainly, several anomalies in the re sults, but, as before remarked, we must look at the whole. The third series was likewise commenced at the end of six months…. If we compare the results obtained in the preceding tables, we shall see that there is a great difference in the effects of mortars made of natural or artificial hydraulic lime and sand, and of these made of fat lime, sand and trass. When the first are made of lime which has for some time slaked to powder, or which has been air- slaked, they generally lose much of their force. There is not the same dis advantage with fat lime: whether the mortars are made as soon as the lime comes from the kiln, or after it has beeq slaked with a little water and left exposed for some time in the air, or after the lime has been air-slaked, good results are always obtained: but we have seen that the best are got by slaking the lime with a little water as soon as it is burned and leaving it exposed for some time to the air in a covered place. Experiments, to be given by and by, will show that I obtained good results, also, by making hydraulic mortars of sand, trass, and fat lime which had been lying wet in basins for four or five years.

We have also seen by comparison of the preceding table, **that mortars made of hydraulic lime, natural or artificial, without trass or puzzalona, did not harden, with sand, until from eight to fifteen days, although giving resistances;**

while those made of fat lime, sand and trass, hardened at the same season of the year, in the space of from four to six days, and, on the average, gave much greater resistances.

Chapter VI

Of Artificial Trass and Puzzalona.

….I made several essays, substituting brick and tile dust for trass. To this end I composed a number of mortars of fat lime and the dust of bricks or tiles taken from all the kilns of the neighbourhood. A part of the mortars were made of brick dust, and a part of tile dust. I obtained many results: — sometimes very good, sometimes indifferent, and sometimes very bad. What struck me much, at first, was, that mortars made of different dusts coming from the same burning gave very different results: notwithstanding that the dusts were of the same burning, were all made of the same clay, were used with the same lime, and that all other circumstances were the same. I saw from this, that great risk was run of making bad mortar, by taking brick or tile dusts without discrimination. I know that the great majority of constructors preferred highly burned dusts, and that, although made of the same clay, they much preferred dust of tiles to that of bricks. To settle my opinion on these two points, and to explain up contradictory results that I had obtained, I made the experiments reported in the follow ing table.

(all at 1:2)

	To harden Underwater	resistance
Fat Lime slaked to powder and measured in powder		
dust of bricks little burned	11 days	330lbs
dust of bricks well-burned	+40 days	180lbs
dust of tiles but little burned	5 days	275lbs
dust of tiles well-burned	+30 days	125lbs

(got somewhat different results with bricks and tiles from another yard)

These opposite results led me to examine the composi tion of the clays of these two brickyards; and I ascertained that the clay which gave the dust of table No. XVII contained very little carbonate of lime, while that which produced the dust of table No. XVI, contained almost a fifth of its weight of that substance. I repeated the experiment with the clays of several other tile kilns, arid I always obtained this remarkable result, namely, when the clays contained little or no carbonate of lime, gentle burning imparted only mediocre qualities, while strong burning gave them excellent qualities. **When, on the contrary, the clays contained from one to two tenths of carbonate of lime I procured good results**

only by heating lightly, and, if I augmented the degree of calcination the quality was impaired; and if the heat had been very great, all hydraulic property was lost.

… It is certain…that the presence of lime in clays has a great influence on the quality of the puzzalona.

… Several Engineers have proclaimed the good results obtained with ashes derived from the combustion of coal in furnaces, or lime kilns; others on the contrary, have denied the effect of this substance.

… The good results of the Tournay ashes* have been known for a long time, and are contested by no one. Having been employed at Lille, in 1815 and 1816, I had an opportunity of knowing the good effects. But when I wished to use, in the same way, the coal ashes at Strasburg, I could not obtain a good result. I made mortars composed of one part of fat lime measured in paste, and two parts of coal ashes: after an immersion of a year, these mortars were as soft as if made of sand….

and on examining different coals and their analyses, I saw that several of them contained quite a quantity of clay, while others contained little or none. But coals are generally burned on a grate: the clay they contain is thus calcined in a current of air; and it is the mixture of this clay with a little iron, constituting the residue, that is used, when we take these ashes: we see, therefore, that it is a real puzzalona that they have been making, for a long time, without knowing it. Should the coal contain no clay, or should the clay be mixed with too much lime; in the first case no result will be got; and in the second, if the calcination has been too high, the ashes will possess but an indifferent quality.

… It is possible that in countries where chalk is abundant it will not cost more to make hydraulic mortar with artificial hydraulic lime and sand, than with fat lime, sand and factitious trass: but in many countries chalk is not to be procured; and then it will be necessary to mix fat lime with clay, and to give a second burning for the mixtures; which will cause embarrassment, and an augmentation of expense. I am convinced that, in such cases, there will generally be economy in making hydraulic mortar at once of fat lime, sand and artificial trass: and besides the relation of the resistance" of these two kinds of mortar, is no important consideration. If we compare the results obtained in all the preceding tables, we shall see that the mortars made of sand and hydraulic lime, whether natural or artificial, afford an aver age resistance hardly amounting to 220 lbs., while it is 352 lbs. for the mortars made of fat lime, sand and natural or artificial trass. To compare the expense justly, therefore, it would be necessary to lessen the preparation of trass, substituting sand, until we arrived at an equal resistance.

I must, besides, observe that we are much more certain to obtain uniform results with hydraulic mortars, composed of fat lime, sand and factitious trass *[brick or* *tile dust; certain ashes]*, than with those that can be made of artificial, or natural hydraulic lime, and sand only.

…. The question, however, is, to know what should be done in a country where there is no hydraulic lime, or where it is of an inferior quality. It is on this point that I differ entirely from Mr. Vicat. This engineer contends that it is best to make factitious hydraulic cement by the process he points out; **while I think there will, in general, be more economy, and better and more uniform results, by making hydraulic mortars at once from fat lime, sand, and artificial trass. It appears to me that the general bearing of the very numerous experiments I have presented, leaves no room to doubt as to this matter. I will add, that, from time immemorial, in countries affording natural hydraulic limes, they have been used with great advantage. Wherever they were not to be had, hydraulic mortars were made, directly, of fat lime and cement.** I have, several times, had occasion to demolish works in water, of which the mortars had been made in this manner. It appears then, that, in fact, I only propose to continue a method long in use, with this difference, that in lieu of using every kind of cement indiscriminately, I give the means of distinguishing the good from the bad, and of making such as will give results equal to those furnished by natural puzzalona or trass.

…. A fragment of each of these bricks (each of a different level of firing) should be separately reduced to a very fine powder, and passed through a very fine wire seive. The finer the dust, the better; in taking it between the fingers no grains should be felt, and it should be soft to the touch. Fat lime which has been reduced to paste for some time, should then be made into mortar with one of these cements — using one part of lime in paste, to two parts of cement. (and placed underwater to observe speed of set, setting having occurred when the sample will resist the hard pressure of the thumb).

… mortars of the hydraulic limes which harden very quickly, did not give great resistances; but those made of cements which have caused fat lime to harden promptly, have always given good mortars. We ought, therefore, to prefer those cements which cause fat lime to harden promptly.

… With brick dust, we may easily obtain mortars which, according to my mode of determining tenacity, will support from 220 lbs. to 330 lbs. before breaking, if composed of equal parts of lime, sand and brick dust. This force is sufficient for gross masonry: but, for important works, such as the floors of locks, foundations of dikes and dams, caps of arches, and for fac titious stones, of which I shall speak in the sequel, it is necessary to have cements that will give mortars capable of supporting from 330 lbs. to 440 lbs.

CHAPTER VII.
Various Experiments on Mortars placed under water.

Much importance has been attached .to the manner of slaking lime. Mr. Lafaye published in 1777, a memoir in which he gives, as a secret recovered from the Romans, the mode of slaking lime by plunging it into water for a few seconds, and then withdrawing it to slake and fall to powder in the air. This powdered lime is preserved in a covered place.

Other Engineers have asserted that there is great advantage in stifling lime as it slakes; that is to say, covering it with sand before it begins to slake, in order to retain the vapours liberated during the process.

Mr. Fleuret attributes great efficacy to this vapour, for he says "**This vapour awakens and excites the appetite of the workmen**, whence I conclude that it contains principles proper to the regeneration of lime and consequently to the hardening of mortars."

To make the three experiments above, I took a piece of Obernai lime which I divided into three portions.

The first portion was slaked by throwing on one fifth of its volume of water, leaving the lime at rest in the air for **twelve hours** before making it into the mortar No. 1. The hardening was slow because the experiment was made in November. No. 2 was slaked in the same manner with this difference, that I covered the lime with the sand as soon as I had thrown on the water. This, also, was left to itself for twelve hours before making it into mortar. These two experiments gave, we see, **the same results.**

The third experiment differs from the first in this, that to slake the lime, I plunged it into water for fifty seconds — afterwards treating it in the same manner as No. 1. The result was less by 22 lbs. It is singular that I got the same results, as will be seen further on, by making similar mortars and leaving them in the air, instead of placing them under water. The result, it seems to me, is owing to the lime, immersed for fifty seconds, absorbing too much water, which is hurtful, as the experiments in the following table will show. I purposed repeating the trial, by varying the time during which the lime should be immersed, but I had not an opportunity *[shame].*

… It often happens that a good deal of mortar is prepared and that bad weather for a day or two prevents the workmen from using it. If it be hydraulic mortar, it becomes hard in the interval of a day, and often of a night, and it would be impossible to use it in that state. By reworking it for a long time, it might be brought to the proper consistence without any addition of water, but this is expensive: it is better to bring it to proper consistence by reworking it for a short time with a little water. **Many Engineers think that mortar is improved by being worked several times a day: they consequently often make mortars several days before hand** — work it well at first, and permitting it to stiffen, bring it

again to proper condition by reworking, because, say they, good mortars must be tempered with the sweat of the Labourer: but the sweat of the Labourer costs money, which it is important to save…..
All the mortars made at Strasburg, whether for works in water or air, were made of the consistence of common mortars, and very often, when, from any cause, they had somewhat stiffened, they were worked up anew with a little water, and we always had very good results.

…. Other philosophers, and several engineers, have thought that the solidification of mortars was owing to the lime passing again to the state of carbonate, by absorbing carbonic acid from the air. This opinion cannot, how ever, be sustained; for we know that carbonic acid penetrates only very slowly into the portion of hydrate of lime which is exposed to the air. Very large masses of mortar, plunged into water, will sometimes acquire complete hardness in three or four days, while other mortars containing the

The following, moreover, is a proof that the absorption of carbonic acid has no influence on the induration of mortars, at least in the be ginning. I took hydraulic lime and reduced it to the state of hydrate with distilled water, making a rather thick paste, which I placed at the bottom of a phial; I then filled the phial with distilled water and corked it tightly; and when the lime was so much stiffened as not to run, I inverted the bottle, (still corked,) placing the mouth in a vessel full of water. I repeated the experiment with mortar made of hydraulic lime and sand, and with another mortar of fat lime and trass. These three substances hardened as quickly as if they had been put in water which was in contact with the air. Being deprived of all communication with the air, we cannot ascribe the hardening to carbonic acid. The surface of several old mortars exposed to the air has been observed to have passed to the state of carbonate; but only for a small depth, and it requires several centuries to produce even this change. The induration of mortars cannot, therefore, be attributed to the regeneration of carbonate of lime. *[wrong-headed, of course, but explaining the difference between air and hydraulic lime mortars without seeming to know it, quite].*

….. To account for the solidification of mortars in water, it seems to be necessary to divide them into two distinct classes; those composed of hydraulic lime and sand, and those composed of fat lime and puzzalona, or some analagous substance. As to mortars made of hydraulic lime and sand, it is not at all necessary to suppose that there is a chemical combination between those two substances, for we have seen by the first tables that the hydraulic limes, alone, when they are reduced to paste, harden promptly in water without it being necessary to mix any substance with them.

… To explain the hardening of mortars made of hydraulic lime, it is not necessary to suppose that it combines with the sand, since this lime hardens when alone in the water. It remains then to explain why hydraulic lime, itself, should harden in water. I will observe, on this point, that this particular lime is a combination of lime and a certain quantity of argil, by means of calcination; **it is a substance, therefore, altogether different from lime, and it has acquired new properties that the lime had not:** lime dissolves in water, while good hydraulic lime does not.

We know that when we mix, in certain proportions, soda, or potash, which are opaque, and soluble in water, with silex, which is also opaque, and heat the mixture, we obtain a new substance, which is transparent and in soluble in water, and which is called glass. It is not, therefore, astonish ing that lime mixed with a little clay and heated, should produce a new substance that will harden in water, while lime alone will remain soft. **Although we give to this compound the name of hydraulic lime, it ought, in fact, to be regarded as a substance altogether different from lime; it is a new body with new properties.**

As to hydraulic mortars made of fat lime and puzzalona, or other analagous substance, I do not see that the hardening in water can be explained without supposing a combination between the fat lime and the puzzalona; for this lime, put alone in water, or mixed with sand, remains always soft. To prove the truth of this explanation, I made the following experiment: I took a mortar composed of one part of lime made from white marble, and two parts of puzzalona, which mortar had been one year in water. From the centre of this mortar I took a piece which I reduced to very fine powder, putting the powder in a vessel which I then filled with distilled water. But we know that if fat lime be put in water, the water will dissolve of its weight in a few minutes. Nevertheless, after twenty-four hours, the distilled water had no portion of the lime. I satisfied myself, on the other hand, that the lime of the mortar had not passed to the state of carbonate: because, on throwing muriatic acid on the powdered mortar, there was very little effervescence. The lime had not therefore passed to the state of carbonate, and still it would not dissolve in water, which could only proceed from its state of combination with the puzzalona.

The hardening of hydraulic mortars in water may be explained, then, in the following manner: if the mortar be made of hydraulic lime and sand, this last substance appears to be in a passive state; the induration of mortar takes place because hydraulic lime hardens of itself in water — this being a property resulting from the state of combination of a small quantity of clay with the lime. If the proportion of lime be too much forced, a good hydraulic lime will no longer be obtained. A similar effect occurs in making glass: if the quantity of soda or potash be too much forced, the re sult is nearly a deliquescent compound. When hydraulic lime is made of fat lime and puzzalona, the hardening takes place because there is brought about a combination of fat lime and puzzalona in the moist way. In this case — that the combination may work well, it is requisite that the puzzalona be in greater proportion than the lime.

CHAPTER VIII. *Of Sand, and Hydraulic Sand (Arenes.)*

"There exists" says Mr. Girard," in the valley of the river Isle, fossil sands of which the colour varies from reddish brown to yellowish red and even ochre yellow. They are called arenes,* which denomination we shall preserve in this notice, to distinguish them from common sands. **These sands are often used alone, as mortar, in walls of enclosures and of houses; and as they have the property of making a paste with water, and as they shrink less than clay, they are very proper for this kind of construction: they represent in this case a pise, which acquires hardness and resists in clemencies. But the proprietors of the mills on the river Isle, in the department Gironde, discovered by accident a quality in the arenes much more important and worthy of serious attention; they use it with common lime more or less) fat, to form mortars which set under water and acquire, great hardness."**

Mr. Girard says that for want of hydraulic lime, he made several Locks with mortar composed of common lime and arenes. He states that he obtained very good results; and that the following year it was necessary to use the pick to break up the concrete that had been made with these arenes. The examination of the arenes showed Mr. Girard that they were all composed of sand and clay in various proportions. By means of washing and decantation he separated the clay from the sand, and in eight kinds of arenes he found the proportions of clay varied from **ten to seventy per cent.** He ascertained **that those arenes which were meagre, were hydraulic only in a very feeble degree.** The sand of the arenes is sometimes coarse and some times fine: it is occasionally calcareous, but more frequently siliceous or mixed. Some of the arenes are red, others brown, yellow and sometimes white.

Mr. Avril anil Mr. Payen discovered, about the same time, in Bretagne,the properties of puzzalona, in gray wacke, and in **decomposed granite**, though to a degree quite **feeble**. They remarked, besides, that natural puzzalonas acquire a new degree of energy by a slight calcination.

Captain Leblanc of the Engineers, employed at Peronne (noted during demolitions of old military fortifications that the old mortars were very hard)… On examining the mortars which were hard, it was perceived that the sand therein was very fine, and that these mortars, from their aspect, seemed to have been made of the sand of the country, **rejected in the official instructions, because too earthy. (This sand is used in all the constructions of the town.)** Another consideration led to the belief that the sand of the country had been used: for all this masonry appeared to be very carelessly put together; the mortar, badly made, showed every where, lumps as large as a hazle nut, of lime not mixed with sand and still soft; although all the surrounding mortar was very hard. It was to be presumed that when applying so little care to all parts of the workman ship, the constructors had taken, no greater, as to the choice of sand: and that they used that which was nearest at hand — namely the sand of the country.

The author states that on recommencing labours in 1827, he made six cubes of mortar, of which three were composed of sand recommended in official instructions, and the other three of the clayey sand whereof the good masonry appeared to have been made. One cube of each kind of mortar was left in the air, one put in a humid place, and one in water. It was in this interval, as Capt. LeBlanc states, that the notice of Mr. Girard appeared. What was said in that notice showed that the clayey sand of the neighbourhood of Peronne was a true arene.

The mortar made of common lime and this arene had completely hardened in the water at the expiration of a month; so as to receive no impression when borne upon strongly by the thumb. A mortar made at the same time of the same lime and of the sand recommended officially, and usually employed, remained entirely soft at the end of several months.

By heating the arenes, Capt. LeBlanc ascertained that the hardening took place much more promptly, for the mortars made of the crude arenes required a month to harden, whereas those made of arenes that had been heated, hardened in eight or ten days.

… At Paris they build the walls of houses with plaster, and cellar walls with mortar. I have had occasion to observe latterly, that several of these mortars were made of clayey sand which appeared to me to be a species of arene: it contained a little lime, and some of it is yellow, and some green ish, like that from Ham. I learned that this sand was brought from the neighborhood of the ancient garden of Tivoli, and that it appears to have been employed at Paris for a long time to improve mortars. I made two mortars of these two clayey sands, adopting the same proportions as with the sands from Saint Cyr, and placed them in water. The results were similar to those given by the clayey sands from Saint Cyr. From what has been said, we see that these clayey sands are arenes of little energy: they do not ap pear to me to be proper for mortars that are to be placed in water; but the hydraulic property they possess, feeble as it is, will give, for works in the air, much better mortar than ordinary sand

…If we mix clay with fat lime, the resulting mortar will take no consistence when put under water. **It is necessary that clays be more or less calcined to become hydraulic**. Mr. Girard seems to think that the arenes have been submitted to the action of fire, and that perhaps they have a volcanic origin; but this second assertion does not seem to be a necessary consequence of the first; all that we may affirm is, that the arenes are clays which have sustained the action of fire. On the other hand, the small rounded stones and pebbles found in some of these deposits, prove that they are, also, alluvial. It is not easy to meet important facts without seeking to account for them, although at the risk of deceiving ourselves.

…The experiments that I shall give in the second section, on mortars made of fat lime and sand, and exposed to the air, will show how important it is to search after good arenes in the environs of our public works; because it is a means of procuring good mortars at a very cheap rate, and because it is the only means of procuring them cheaply, in countries where there are no hydraulic limes.

CHAPTER X. Summary of the First Section. From the facts presented in the foregoing articles, may be deduced the following conclusions.

There are two modes of making hydraulic mortar; first, by making it of lime that is naturally or artificially hydraulic, and of sand; and secondly, by making a mixture of common lime and puzzolana, or of some analagous substance.

In countries where there are good natural hydraulic limes, it is very advantageous to employ them; and in such cases no use should be made of fat lime. In gross masonry, they may be used with sand alone; but when it is required to construct the foundations of sluices, roofs of arches, and other similar works, it is advantageous to add to the mortar, a little hydraulic cement.

In a country where there is no hydraulic lime, in lieu of making it by calcining lime with a little clay, it is more advantageous, and more economical, to make hydraulic mortar by mixing, directly, fat lime with hydraulic cement and sand. The advantage is the greater in countries where there is no chalk, and where it would be necessary to submit the limestone designed to be made hydraulic, to two successive burnings— burning it the second time with a small quantity of clay*

Fat lime becomes hydraulic by being burned to the proper degree with a little crude clay; this result is not obtained if the clay has been previously calcined. Fat lime also gives a good hydraulic mortar, when it is united in the moist way with a mixture of equal parts of puzzolana and sand, and when the proportion of these substances is at least double that of the lime.

Silex, when it is very finely divided and disseminated in lime stone, produces good hydraulic lime, as is proved by the Senonches lime: when fat lime and finely divided silex are burned together, a hydraulic result, though feeble, is obtained. Iron and the oxide of manganese communicate to lime no hydraulic property: iron in the state of brown or red oxide, prevents the lime from heating much in process of slaking. It does not appear that alumina or magnesia, cause lime to become hydraulic; but when these substances are mixed with silex, good results are obtained.

The best process for converting fat lime into hydraulic lime, is to burn it with a small quantity of crude clay; the proportion of 1/5th of clay, seems the most suitable; and it appears that the best clay is that which contains as much silex as alumine. The quality of hydraulic lime is improved by mixing with the clay that is to be burned with the lime, a small quantity of water containing soda; a better result is obtained with potash; but this means would be too embarrassing, and would occasion an excess of expense which might not be in proportion to the advantage, were the operations on a large scale.

Hydraulic lime bears less sand than is commonly thought; there are few of these limes which can be mixed mith more than 2 ½ parts of sand, without sensibly diminishing the resistance of the mortars. Fat lime may take a greater quantity of mixed sand and puzzolana to form hydraulic mortar. Puzzolanas, or hydraulic cements, which are energetic, apply equally to hydraulic lime and fat lime. **In mixing hydraulic lime, or fat lime, with sand and puzzolana, or other analagous substance, in equal parts, a better result is often obtained than by mixing these limes with puzzolana alone.** When very hydraulic lime is used, the addition of sand permits a sensible diminution of the quantity of puzzolana, natural or artificial, required to obtain a prompt induration and great resistance. With fat lime there always results a very good mortar, on mixing it, in equal parts, with sand and natural or artificial puzzolana; and if it sometimes happens that a mortar a little superior is obtained with lime and this last substance, without the sand, the advantage is not so great as to compensate for the greater economy of using sand also.

Hydraulic limes are difficult to burn to the proper degree. When they are not sufficiently burned, they slake badly; and the resulting mortar has not all the tenacity it ought to have.

A degree of heat a little greater than it should be, causes, with these limes, a beginning of vitrification; they then slake slowly; the mortar they form loses its force, it swells after having been used, and may occasion considerable injury to the works. Hydraulic limes should be used soon after leaving the kiln; they should not be slaked with much water, like fat limes, nor be left in a state of cream, like them, because, in a very short time they would become very hard, and it would be impossible to make use of them. **Whether slaked with a small quantity of water to reduce them to dry powder, or left to slake in the air, they, in general, very soon lose a part of their hydraulic properties, and finally pass to the state of common limes.** It is likely that this effect is due to the absorption of oxygen by the hydrate. Notwithstanding the precautions that hydraulic limes demand, it is important to employ them whenever natural limes of this sort, of good quality, can be obtained, because they supply a very good mortar at a cheap rate.

We should carefully study the exact point of burning, and should satisfy ourselves, as to whether or not they soon lose their hydraulic property, on exposure to the air, when slaked to dry powder, or when air slaked; without these precautions, we may expose important works to failure, by making very bad mortar out of very good lime. **Common lime has not, like hydraulic lime, the inconvenience of losing a part of its qualities by a degree of heat a little greater than that which is most suitable.** A very violent fire is required to produce this result. **Whether slaked with much water so as to be made into a fluid paste and run into vats, or with a little, only, so as to be reduced to dry**

powder; or if spontaneously slaked in the air; or if used immediately as it comes from the kiln, a good hydraulic mortar is always obtained by mixing fat lime, in equal parts, with sand and natural or artificial puzzolana. By air slaking the result is the least good.

It appears that by slaking in the air, the lime absorbs a considerable quantity of carbonic acid; and the mortar which results is filled with white points, which are particles of carbonate of lime, that cannot be made to disappear, whatever pains may be taken in the mixing process.

…The best mode of slaking hydraulic lime is to sprinkle it, as it comes from the kiln, with about one fourth of its bulk of water.

The best mode of slaking hydraulic lime is to sprinkle it, as it comes from the kiln, with about **one fourth of its bulk** of water. A measure containing about one third of a cubic metre (a cube of about three feet three inches on each side) permits the mixture of the materials that are to compose the mortar, to be easily made. **Before sprinkling the lime, it is to be surrounded with the mortars that are to be mixed with it, and when it is slaked and gives out no more vapours, it is to be covered with these mortars. The lime is left in this state for twelve hours at least, and for eight or ten days at most. The quantity of water necessary to bring the mortar to the ordinary consistence is afterward added.** Care must be taken to make the mortar no faster than it is needed. The heap of lime surrounded by the sand and other materials should be covered from the rain.

With common lime the process will be a little difficult; being slaked as it comes from the kiln, with **one-third of its volume of water**, the lime, in a state of powder, should be put under cover, and left in this state for one or two months. At the end of this period it should be measured in paste and mixed with the sand and cement in due proportion, adding the quantity of water necessary to bring it to the consistence of ordinary mortar. This process is the one which gives the best results; **but if this be inconvenient the lime may be used as it comes from the kiln, or after it has been lying, wet in vats for any length of time.**

Mortar made of ordinary consistence, and even rather thin, is easier to mix thoroughly, and gives better results than when it has been mixed in a stiff state. If it becomes a little dry before being used, there is no objection to working it anew, with the addition of a little water. It might be left from night till morning, to be then passed twice under the rab: the mortar acquires more consistence by moistening it a little. It might be remixed in this way during a couple of days with out losing its force.

… Cement suitable for making a good mortar for heavy masonry, may be made out of ordinary bricks. The dust of tiles, has no advantage over that of bricks, as a cement. The important point is to know the true degree of calcination which the clay requires. Bricks should not be taken indiscriminately from the kiln, but those should be selected which have been found on trial to afford the best hydraulic cement.

…. Amongst mortars composed of hydraulic lime and sand, those which harden most promptly in water do not always give the greatest resistance: but those do, generally, which are composed of fat lime and puzzolana either natural or artificial.

Sect. 3— ON MORTARS IN THE AIR.

CHAPTER XI.

Of Mortars made of Lime, Sand and Puzzolana.

…We cannot admit, then, that carbonic acid penetrates far into the interior of masonry; and it is proved, by multiplied observations, that moisture remains during a very long time in the interior of certain walls.

Dr. John reports, on this subject, that about ten years ago, they demolished the piers of the Tower of St. Peter's, at Berlin; this tower had been built eighty years, and the pillars were twenty seven feet thick; the mortar on the out side was dry and hard, but that in the middle was as fresh as if it had been lately placed there. I can state that in 1822, that the lower part of a bastion at Strasburg, being under repair, the mortar was found to be as fresh as if just laid, and nevertheless, this bastion was erected in 1666; the revetment was only about seven feet thick, but the moisture of the earth resting against it, prevented the lower part from drying. Similar facts are observed in constructions still more ancient.

It results from what has been advanced, that the good quality of the mortars of several ancient structures is not due to the manner of slaking the lime, as Mr. Lafaye supposed (air slaking), nor to the process of making mortar supposed by Mr. Loriot, nor to the time that has elapsed since they were built.

…. It is the opinion of a great many constructors that when common, or fat lime is to be used, it is necessary to have it lie wet in vats or pits for a long time: **it is asserted, that the older it is the better it is.**

… To make these experiments, I took fat lime which had been slaked and lying wet in a pit for five years — a portion of the same having been used in the construction of the theatre of Strasburg. The mortars were all made in the same manner, and broken in the same way as the hydraulic mortars; they were left in the air in a cellar for one year before cutting them down to their ultimate dimensions and submitting them to the test: the proportions of sand varied from two up to three parts of sand for one of lime measured in paste. The resulting mortars had no consistency, and crumbled between the fingers with the greatest ease.

(same tests with lime and trass and lime/sand/trass. The latter had the best resistance).

… These experiments were made at the same time as those of table No. XV, of the first section, and with the same fat lime. I slaked a part as it came from the kiln, giving it only the quantity of water necessary to reduce it to thick paste, and I made therewith the experiments comprised under Nos. 1 and 2. I slaked a part into thin paste, and made with it the experiments under Nos. 3 and 4, and I also slaked a part into dry powder, by giving it a quarter of its volume of water, and with this I made the two series, Nos. 5 and 6. All these experiments comprise the interval of a year, and the several epochs at which they were respectively made are given in the table. The figures of the table give the number of pounds that the mortars sup ported before breaking.

The series of mortar No. 1, is composed of one part fat lime slaked to thick paste, and two parts and a half of sand. We see that **the mortar made immediately, acquired a hardness which is not, in fact, very great, but which is passable**. The mortars made after fifteen days had nearly one half **less consistency**; at the end of two months it had **two thirds less**, and the mortars made after six months had not strength enough to support the weight of the scale pan, &c, which was twenty-two pounds.

…**we cannot but think that slaking fat lime into vats and letting it lie there in a wet state, is a mistaken practice**. The practice may have been induced from the considerable increase of bulk it gives to fat lime; but the trials I have made show it to be a very bad process, at least with the limes I used.

… The series No. 3 differs from the first only in the lime having been slaked to a thin, instead of a thick paste. The lime was left six months before making any mortar with it. We see that the results were the same, that is to say, were equally bad with those of the first series.

… Series No. 5 was made of the same lime, slaked to dry powder. This series was not commenced till six months after the slaking of the lime. The mortars I obtained had no consistency, and crumbled easily between the fingers. The mortars of the first and third series, made at the same period, bad as they were, gave resistance enough to be submitted to fracture.

… The experiments of table No. XXXIV, were made with **lime just from the kiln**. **The mortars were made immediately**, and with a View to ascertain the quantity of sand which this lime would bear.

The results shew that the greatest resistance corresponded to one part of lime measured in paste, and two parts of sand, and that the resistances diminished in pro portion as the sand was increased. No. 4 had so little strength that it was unable to support the weight of the scale pan; and No. 5 crumbled readily between the fingers. The proportion in general use is one part of fat lime measured in paste, to two parts of sand. Some constructors think that more sand is requisite, but the trials in table No. XXXIV, do not at all confirm this opinion. I regret not having begun by putting a smaller pro portion of sand; these experiments should be repeated.

(One conclusion) **lime, whether common or hydraulic, does not bear as much sand as is commonly thought;** but it appears to be able to bear more trass, whether alone or mixed with sand; which may be attributed to the combination that takes place, in the moist way, between the trass or puzzolana, and the lime.

… I made but few experiments with artificial hydraulic limes in the air, but those which I did make, show that they differ in nothing from natural hydraulic limes. They show, also, **that in the air, as well as in water, better mortars are generally obtained with fat lime, sand, and substances analogous to puzzolana, than with hydraulic lime and sand.**

On comparing the above mortars, left in the air, with the same mortars put in water, we are led to the following conclusions: when mortars are made of hydraulic lime and sand, to be used in masonry exposed to the air, **it is of great importance to use the lime soon after it is burned**: otherwise it loses a great portion of its force, as it does under water. **When we are obliged to wait some days before using it, it should be slaked to dry powder, by throwing on a quarter of its** volume **of water, and be immediately covered with the quantity of sand that is proper to mix with it to make mortar.** These kinds of lime should not be left to slake spontaneously, because they require a considerable time to become reduced to powder, and in general, lose a great part of their energy.

… Comparing mortars made of the same constituents, and in the same manner — some having been left in the air, and others put underwater, we see that the latter, in general, have given the greater resistances. Humidity is, therefore, favourable to hydraulic mortars. *[early hydration is essential when used in the air…]*

In the case of masonry made of fat lime, it has always been recommended, if earth was to be laid against it, that it should be left to dry for some time, before backing it with earth; and with the same object it has been directed to wait a year before pointing the work. We see that with hydraulic mortars used in the air, it will be better to act differently. As the masonry rises, it will be best to throw the earth against it. The pointing should be finished at the same time as the masonry, this being the better and more economical mode. During warm weather, the top of the wall should be copiously watered, at the close of the day, and whenever the masons break off during the day. This was always done at Strasburg, and was found to be a good practice.

CHAPTER XIV.

Observations on Mortars exposed to the Air.

It results from the experiments given in chapters XI, XII, and XIII, that in exposing to the air mortars made of sand, and lime which had been laying a long time slaked and wet, I obtained no satisfactory result; while I obtained tolerable results with sand, and the same lime recently slaked.

…I ought not, however, from this to take up a general conclusion, and counsel against slaking and running lime into vats to preserve it…

I do not know for how long a time the method of running lime into vats has been followed. It may have been introduced in consequence of the considerable increase of bulk which it gives. I do not know that it was followed by the ancients. Vitruvius has left a work on architecture, in which he has given many de tails as to the manner the Romans carried on their works.

It appears probable to me… that the Romans used fat lime as they did hydraulic lime, that is to say, immediately after the burning. This is the more likely, as Vitruvius directs, in the process of stucco making, that only lime that had been long slaked should be used. The following are his remarks on this subject. Book VII, chapter II. " Having examined all that appertains to pavements, the manner of making stucco must be explained. The principal matter in this is, that the lime should be slaked for a long time, so that if there should be some particles less burned than the rest, they may, having time thus given them, be as thoroughly slaked, and as easily tempered, as that which was thoroughly calcined: for, in lime which is used as it comes from the kiln, and before it is sufficiently slaked, there is a quantity of minute stones imperfectly burned, which act on the plaster like blisters, because these particles slaking more slowly than the rest of the lime, break the plaster and mar all the polish." It appears to me that **the precaution of slaking the lime a long time before hand, is here recommended as an exception, and that in the mortars intended for masonry, the Romans used all limes soon after they left the kiln.** It is remarkable that the same author directs, in the first passage cited, mixing with the mortar a portion of sifted tile dust, observing that it will much improve the mortar…..

…. if we examine the two tables in page 111, which contain the analyses of several lime stones, we shall see that many limes which are ranked with fat limes contain, nevertheless, small quantities of clay. Although they may not contain enough clay to harden under water, they ought to afford much better mortars in the air than those limes which contain none. Again, hydraulic limestones are often found disseminated amongst the strata of fat limestones. And, lastly, the important observation of Mr. Girard, the hydraulic proportions of arenes explains easily how very good mortars may have been made of fat lime. I will observe, in addition, that the Romans, in all the countries they occupied, executed a great many works, of which , only those made of good mortars survive to the present day. Saint Augustine complains of the manner in which mortars were made in his day: and the same complaints are found in Pliny; who says, chapter XXII, • that which causes the ruin of the greater part of the edifices of this city (Rome) is, that the workmen employ, from fraud, in the construction of the walls, lime which has lost its quality." We see, therefore, that all the Roman mortars were not good.

….. **We are in the habit of composing our mortars of fat lime and sand; the preceding experiments show that we are wrong: our mortars have, consequently, little durability. We shall not obtain durable masonry in the air, until we make use, therein, of hydraulic mortars. In countries where good natural hydraulic lime is to be had, no other kind should be used tor any purpose whatever. For ordinary masonry, the mortar should, in that case, be made of lime and sand only. In countries where there are no natural hydraulic limes, but where there are arenes, the mortar should be made of fat lime and these arenes: in both these cases the mortars would be cheap. In countries where neither arenes nor hydraulic limes are to be procured, it will be necessary to incur a little additional expense, and make use of fat lime, sand, and hydraulic cement. To combine economy and solidity at the same time as much as possible, the proportions, in cases where there are to be one part of fat lime and two of sand and cement, the mixture may be made as follows, viz: one part of fat lime measured in paste, one and a half of sand, and a half of hydraulic cement;** (according to similar proportions made with trass, as shown in table No. XXVII,) we should have, by this means a very good mortar. The proportions of hydraulic cement, stated above, should be used in all common masonry: in works demanding more care, the mortar should be composed of lime, sand, and cement, in equal parts. I have said, that the proportions indicated for common masonry, should augment the expense but little: but were the augmentation more considerable, it is certainly much more economical to incur at once, all the expense necessary to produce a permanent work, than to build at a cost rather less in the first instance, and to be obliged to reconstruct the work entirely, after no great lapse of time. A government should construct for posterity: and **I do not doubt that this end would be attained by making all masonry with hydraulic mortar, in the manner I have pointed out.**

If, in general, no better results are obtained with fat lime, than those obtained by me, the practice of making mortars of fat lime and sand only, should be abandoned. A small quantity of hydraulic cement, or of some substance of similar nature, should always be mixed in the mortar; that is to say, all air-mortars should be hydraulic mortars. The expense will be a little greater it is true, but there will be full compensation in the duration **of the masonry.** There is no economy in putting up cheap masonry which will require to be rebuilt at the end of a few years; and will need costly repairs, annually: it is much better, and really more economical, to encounter, at once, the expense which will secure to the work an indefinite duration, and exemption from all but trivial repairs.

BRIEF OBSERVATIONS OF COMMON MORTARS, HYDRAULIC MORTARS, AND CONCRETES, AND AN ACCOUNT OF SOME EXPERIMENTS MADE THEREWITH AT FORT ADAMS, NEWPORT HARBOR, R. L, FROM 1825 TO 1838. BY J. G. TOTTEN, LT.COL. OF ENGINEERS, AND BREVET COL. United States ARMY.

Contained within

ESSAYS ON HYDRAULIC AND COMMON MORTARS AND ON LIME-BURNING. TRANSLATED FROM THE FRENCH OF GEN.TREUSSART BY M. PETOT, AND M.COURTOIS.

NEW- YORK: WILEY AND PUTNAM, 161 BROADWAY. 1842.

Lime. — Three kinds of lime were used, namely:

1st. Smithfield Lime."— From Smithfield,R. I. about fifteen miles from Providence. This is a very fat lime — slaking with great violence, when properly burned, and affording a large bulk of slaked lime.

2d. Thomastown Lime.-" — From Thomastown (Maine). This is also a fat lime, at least so far as it has been tried at Fort Adams: but it is probable that some of the many varieties — including those of the neighbouring towns of Lincolnville, and Camden, may prove to be hydraulic. The richer varieties slake promptly, giving a large bulk of slaked lime.
3d. Fort Adams Lime. This is made from a ledge of whitish transition limestone found within the domain of the Fort. The stone is very fine grained and compact, exceedingly difficult to break, and crossed in all directions by three veins of whitish quartz. The ledge is a bed, or large nodule, in graywacke-slate.

After calcination it yields, by sluggish slaking, a lime decidedly hydraulic. A little of this lime, after being slaked, was made into a cake of stiff hydrate; the excess of water being absorbed by bibulous paper: the cake was placed in the bottom of a tumbler and covered immediately with water. In about 7 ½ days, a wire s\of an inch in diameter, loaded to weigh 1 lb., made no impression on this hydrate.

Three modes of slaking the lime were tried in these experiments, namely:
1st. Slaking by Sprinkling. — In this mode, water, in quantity sufficient to slake the lime to dry powder, but not enough to afford moist powder, was sprinkled upon the lime. The lime was not made into mortar until it had become cold.
2nd. **Slaking by Drowning In this mode, water enough was given, in the first place, to reduce the lime to a cream of such consistency as to afford mortar of proper "temper" for common use without any further addition of water, provided the mortar was made up immediately. If the making the mortar was delayed, a further supply of water became necessary.**

3d. Air-slaking. — In this mode, lime, reduced to pieces about the size of a walnut, was left in the air to slake spontaneously.

These were the processes by which the lime used in the experiments was slaked: but by neither of these, nor by any modification recommended by others, or that we, ourselves, could devise, were we able to free the hydrate from **an infinity of small particles of lime, that being imperfectly, or not at all, slaked in the first instance, it was almost impossible, by any amount of labour afterward, to break down and mix with the rest.** The mortar mill, hereafter described, reduced these refractory particles better than any of the ordinary modes of acting upon lime; but not sufficiently, without an unwarrantable amount of labour. All other means having failed, resort was had, at last, for the mortar for the masonry of the Fort, **to grinding the dry lime to a very fine powder between millstones. Lime thus ground gives a perfectly homogeneous mortar:** and some partial experiments lead to the opinion that the gain in the quantity of lime available for mixtures with sand, will, nearly if not quite, compensate for the expense of grinding. So far as the mortar thus made has been tried, the results were favourable: but the experiments on the quantity and quality of lime thus treated, though they justify confidence, are not, yet, so conclusive as to warrant any positive assertions.

… Hydraulic Cement.— Three kinds of hydraulic cement were employed — namely, a kind that will be here designated as hydraulic cement A, which was supplied from the State of New York — another kind, called hydraulic cement B, supplied from a different manufactory in the same State — and Roman (or Parker's) cement," imported from England….

Mortar Making.

With a view to a thorough incorporation of the constituents, at a small expense, and in order, at the same time, to break down the refractory particles of lime before mentioned, a mortar mill was constructed at the commencement of the works at Fort Adams in 1825, which has been in operation ever since. The mill consists of a very heavy wheel about eight feet in diameter (having a tire one foot broad) moving in a circular trough fifteen inches wide at the bottom — the diameter of the circle being about twenty -one feet. **The lime is slaked under the wheel, and ground until, with suitable additions of water, it has become a homogeneous paste sufficiently dilute to make mortar of the ordinary consistency. The requisite quantity of sand is then gradually sprinkled in, as the wheel is in motion.** The draught is easy to the horse until near the last; when, for a few minutes, as he is giving the last turns, after all the sand has been thrown in, it is rather heavy. It was found convenient to use three barrels of lime to each batch of mortar.

The three mortar mills of Fort Adams were competent to supply in one day 3077 cubic feet of mortar… The proportions in the above mortar are about 1 of lime in paste to 2 ½ of sand — should the proportion of lime be greater, the mortar will, of course, cost more.

The above statement refers to mortar made without addition of any hydraulic substance. But such mortars are now never used at Fort Adams. Hydraulic cement, or burnt clay, or brick dust, or some other similar matter is added to every kind of mortar made at the work, in proportions varying with the purpose to which the mortar is to be applied. **The poorest mortar we make contains 1 barrel of hydraulic cement to 3 barrels of unslaked lime and about 15 barrels of sand; the cement being added before the sand, and while the lime is being reduced under the wheel.**

Observations on the Experiments of Table No. LXV. 1st. Generally, within the limits of the experiments, a mortar made of lime and sand, or of hydraulic cement and sand, or of hydraulic cement, lime and sand — whether it was cement A, or cement B, or Roman cement, was the stronger, as the quantity of sand was the less, la 24 comparisons, 3 exceptions.

2nd. It appears that with cement A, or cement B, any addition of sand weakens the mortar. In all the cement experiments, except one, composed of Roman cement 1 — sand |- (No. 26,) **the cement alone, was stronger than when mixed with sand in any proportion whatever.** Cement A (No. 6,) would seem to be another exception, but it is not; the strength of cement A, alone, as given in No. 2, is the average of five results with different specimens of cement, some of which were of inferior quality; while the result given in No. 6 is of one trial only, and that of a cement proving to be the. best used; the particular result of No. 2 which corresponds with No. 6 — that is to say, which was afforded by the same specimen of cement, gave for tenacity 74.7 lbs. and for hardness 1063 lbs., while No. 6 shows a tenacity of 61.9 lbs. and a hardness of 1055 lbs. 3rd. It appears that when cement mortars are not required to be the strongest that can be made — a little lime may be added, without great loss of tenacity, and, of course, with a saving of expense.

4th. Mortar made in the mortar-mill was superior to mortar made by being mixed, in the common mode, with the hoe. *[Our own preliminary tests of the '3 methods' of slaking lime would support this, as well as Totten's experience of a multitude of small lime lumps – which forced action mixing, particularly in a roller mill, would more efficiently incorporate].*

5th. **When the bricks were dry and the mortar more fluid than usual, the mortar was better, both as to tenacity and hardness — in five cases out of seven, than when the bricks, being wet, were put together with mortar of common consistence.** *[this is the opposite of received opinion and advice, which typically accused bricklayers of laziness or expediency for this practice. Hot mixed lime mortars seem to allow for less wetting of the substrates, being less willing to let their water content go].*

In the next table there is a comparison of the three kinds of lime— -of the three modes of slaking, of various proportions of sand — of the effect of wet and of dry bricks on the mortar, &c. In most cases six pairs of bricks were put together at the same time, and of the same materials; of which three pairs were separated after about 6 months, and the remainder after the lapse of 4 years and 5 months.

Observations on the experiments of Table No. LXVI.

1st. Within the limits of the experiments, whatever was the mode of slaking, or the kind of lime, **the mortar was the stronger as the quantity of sand was less.** The lime being measured in paste, the proportions were 1 of lime to 1 of sand; 1 of lime to 2 of sand; 1 to 3, and 1 to 4 of sand.

In all the corresponding trials of the table,

1 lime in paste, to 1 sand, gave the strongest mortar in 35 cases of tenacity, and in 13 cases of hardness.
1 lime in paste, to 2 sand, gave the strongest mortar in 3 cases of tenacity, and in 1 case of hardness.
1 lime in paste, to 3 sand, gave the strongest mortar in 2 cases of tenacity, and in 2 cases of hardness.
1 lime in paste, to 4 sand, gave the strongest mortar in 0 cases of tenacity, and in 1 case of hardness.

2d. Slaking by drowning, or using a large quantity of water in the process of slaking, affords weaker mortar than slaking by sprinkling.
In 24 corresponding cases of the table — The quantity and quality of the materials being alike: and there being no other difference than in the modes of slaking the lime.* , **Lime slaked by sprinkling, gave the best mortar in 22 cases of tenacity, and in 24 cases of hardness**. *[indicating that quicklime allowed to slake close to its maximum potential temperature delivers the better mortar].*
Lime slaked by drowning, gave the best mortar in 2 cases of tenacity, and in **0 case of hardness.**

The average strength in all the 24 cases in which the lime was slaked by drowning was, as to tenacity, 23.79 lbs., and as to hardness, 187.00 lbs. While the average strength in all the 24 cases in which the lime was slaked by sprinkling was, as to tenacity, 38.63 lbs., and as to hardness 417.33 lbs.* ***[This represents a significant difference, of course]*. The relative tenacity then is as 1 to 1.62; and the relative hardness as 1 to 2.23.**
3d. The experiments with **air slaked lime**, were too few to be decisive — but the results were **unfavourable to that mode of slaking**. Average strength of the mortar made of air-slaked lime as to tenacity 20.80 lbs., and as to hardness 202.18 lbs. Average strength of the corresponding mortars made of lime slaked by drowning, as to tenacity 27.10 lbs., and as to hardness 207.50 lbs. Average strength of the corresponding mortars made of lime slaked by sprinkling, as to tenacity 46.70 lbs., and as to hardness 533.83 lbs.

i In 21 corresponding instances, wet bricks and mortar of common consistency gave the best results, as to tenacity, in 5 instances; and, as to hardness, in 12 instances. Dry brick and mortar more fluid, gave the best results as to tenacity in 16 instances; and as to hardness, in 9 instances. *[Weather conditions, particularly humidity, and consequent 'natural' moisture content of the bricks will have affected these results].*

Table No. LXVII. *[not shown here].*

Trials in December, 1836, of mortars made in December, 1835. The results show the weights in pounds required to break prisms of mortar 2 inches square, 6 inches long and 4 inches in the clear between the supports.

(Conclusions):

1st. That in mortars of cement and sand (no lime) the strength is generally greater as the quantity of sand is less.
In 53 comparisons, 12 exceptions.

2nd. That in mortars of sand, cement and lime — the lime remaining the same in quantity, the mortars were stronger as the quantity of sand was less in proportion to the cement. In 57 comparisons, 10 exeptions.

3rd. That in mortars of cement, sand and lime — the quantities of cement and sand being the same — the mortars were stronger as the quantities of lime were less. In 52 comparisons, 15 exceptions.

4th**. That mortars made of cement and sand were materially stronger when the least possible quantity of water was used, than when the mortars were made thin**. In 14 cases, 1 exception.

5th. That mortars made of cement and sand with the least possible quantity of water, were stronger when kept in a damp place, than when kept in a dry one. In 7 comparisons, 1 exception. *[Totten is demonstrating the importance of early hydration to hydraulic mortars].* The experiments did not prove this to be true with reference to mortars made thin. These results were afforded by the experiments but are not included in the above table.

6th. That **in mixtures of lime and sand in various proportions, the mortar was generally stronger as the lime was slaked with less water** *[the less water, the greater heat allowed within the slake, though no 19th C commentators consider heat to be a factor in subsequent performance].*
The average strength of several trials with 0.30 of water being represented by 80 — with .40 of water, it was 98 — with .60 of water, it was 72 — with .80 of water, it was 60, and with 1.00 of water, it was 57. These results were afforded by the experiments, though not included in the table.

7th. **That mortars of lime and sand are materially improved by the addition of calcined clay, but not so much as by the addition of cement** *[the latter inhibiting, and perhaps preventing, carbonation in ways the former does not?]*

8th. **That sand freed from dust by washing and then pounded fine, gives much better mortars, than a sand composed of particles of every size from dust (no dirt J up to grains of ½ (?) an inch diameter**. In 21 comparisons, 2 exceptions.

9th. Many experiments were made to ascertain whether of two cements of the same manufactory, the difference being, probably, only difference of age, **that cement which sets the quickest under water will give the strongest mortars in the air after a considerable lapse of time. The results leave the matter in doubt. The quick cement sometimes giving stronger mortars, and sometimes weaker.**

10th. Of lime kept for three months after being slaked, before being made into mortar — the lime slaked into powder by sprinkling one-third of its bulk of water, gave the strongest mortar — represented by 250 lbs.; the lime slaked into cream gave the next strongest mortar — represented by 210 lbs., and the lime slaked spontaneously during three months, the weakest mortar, represented by 202 lbs.

All these mortars being much inferior to that made of the same lime which had been carefully preserved from slaking by being sealed hermetically in a jar — this last mortar being represented by 364 lbs. It must be remarked here that this result is very extraordinary for fat lime and sand; and it is probable this particular barrel of lime was somewhat hydraulic.

11th. Mortars of cement and sand in which bitter-water alone was mixed (Bitter-water being the mother water after the separation of muriate of soda from sea water,) were weaker than those in which water, or a mixture of equal parts of water and bitter-water, was used. But a mixture of equal parts of water and bitter-water gave much better mortar than water alone — the strongest composition we had, being cement 1 ½ , sand 1, and equal parts of water and bitter-water. In 8 comparisons, 2 exceptions.

12th. Mortars of cement and sand are injured by any addition of lime what ever, within the range of the experiments;

13th. Stone-lime, in the proportions tried, gives better mortar than shell-lime, as 153 to 133: but some previous trials had afforded results slightly the best with shell-lime.

Table No. LXVIII.

Trials made in June, 1836, of mortars made in September, 1835. The results show the weights, in pounds, required to separate each inch square of surface of bricks joined by mortars. The object is to compare grout with mortar.

Observations on Table No. LXVIII.

In order to compare the strength of grout with that of mortar, bricks were joined (as before described) with the mortar given in the table — there being four pairs to each kind of mortar. To obtain similar joints of grout, bricks were supported on their ends and edges, in a box large enough to contain all, in such a way as to admit the proper quantity of grout to flow in be tween each pair. The box was not disturbed until the grout had become quite stiff, when it was first laid on one side, and then taken to pieces. The excess of grout was carefully cleared away from the bricks, which were removed without injury to any of the pairs, and put away by the side of the bricks joined with mortar. It will be seen that, **in every case but one, the grout was much inferior to the mortar. The average strength of all the mortars in the table is 31.78, and the average strength of all the grouts is 20.06. .....**

CHAPTER XXV.

Some recent experiments with Mortars made of Lime and Sand.

There will be presented, in conclusion, some experiments, made very recently at Fort Adams, with lime mortars without cement; they were instituted in reference to the best proportions of lime and sand, and also to a comparison of coarse and fine sand, and salt and fresh water.

In making these, a cask of fresh Smithfield lime, of the best quality, was taken, and the lumps broken into pieces of about the size of a pigeon's egg. These being carefully screened, in order to get rid of all dust and fine lime, and carefully intermixed, in order to obtain uniformity of quality throughout, were slaked by the affusion of water to the amount of **one third** the bulk of lime. **When cold, the slaked lime was returned to the barrel, which was carefully headed** and put in a dry place; and on all occasions of withdrawing a portion of this lime for use, the cask was carefully re-headed.

In making the mortars, just enough water was added to the slaked lime taken from the cask, to make a **stiff paste**. This paste being passed through a hand paint mill, which ground it very fine, was mixed, by careful manipulation, with the due proportions of sand.

… Table No. LXX. Trials made on the 1st of July, 1838 of the strength of the mortars made between the 7th and 15th of May, 1838 (50 days.) The results show the weights, in pounds, required to break prisms of mortar 6 inches long, by 2 inches by 2 inches: the distance between the supports being 4 inches, and the power acting midway between the supports.

1st. Within the limits of the experiments, the mortar was the stronger as the quantity of sand was the less — in 96 comparisons, 12 exceptions.

2nd. Although the above inference is derived from the whole range of the table, still, when the quantity of sand was less than the quantity of lime, the weakening effect of the sand on the mortar was not very sensible. And it would seem from table No. LXV.that from one-fourth to one-half of sand may be slightly beneficial.

3rd. It appears that coarse sand, or, rather, sand composed of coarse and fine particles, (sands No. 1 and 2,) **is a little inferior to sand that is all fine** (sands No. S and 4;) in 36 comparisons, 16 exceptions; and also that **sand reduced by pounding to a fine powder (No. 4,) afforded some of the best results of the table.** It is to be regretted that no experiments were instituted in order to compare sand all coarse, with sand all fine.

4th. It appears that the mortars made with salt water — that is to say, the water of the ocean, **was decidedly weaker than those made with fresh water;** 1 exception in 12 comparisons. The aggregate strength of all the prisms made of coarse sand and salt water was 2674 lbs. ; while the aggregate strength of the corresponding prisms of coarse sand and fresh water was 3174 lbs. And the aggregate strength of all the prisms of fine sand and salt water was 2800lbs. while the aggregate strength of the corresponding prism of fine sand and fresh water was 3346 lbs.

Joseph Gwilt (1839) Rudiments of architecture, practical and theoretical London. Priestley and Weale

Of THE MATERIALS EMPLOYED IN BUILDING.

LIME, SAND, WATER AND CEMENT. Lime is found always united to an acid, as to the carbonic acid in chalk. By exposing chalk to a red heat the acid is driven off, leaving the lime in a state of purity, which is then called caustic or quick lime. It dissolves in six hundred and eighty times its weight of water….(p44)

Before burning any of these for lime, there is no external character by which the simple lime-stones can be distinguished from the argillo-ferruginous ones; but the former, whatever be their colour in a crude state, become white when burnt, the latter possess more or less a slight ochrey tinge. Brown lime is much the best for all kinds of cements, but the white varieties being more abundant are more general in use. To those uninformed on chemical operations, it may be useful to know, that every stone which will ferment with an acid, as aquafortis, is capable of being burnt into lime, but the harder the stone the better the lime. Chalk is not so good as stone, for reasons which will be hereafter given, that of shells the worst: neither should be used for work under water. (p45)

… Lime-stone loses four-ninths of its weight by burning, though it shrinks but little; when fully burnt it falls freely into powder on slaking, and gives about double the bulk it occupied before that process. (p46)

… Lime is also burnt in sod-kilns, which are made by excavating the earth in the form of a cone, and then building up the sides as the earth may require. In this case the lime-stone is laid in with alternate layers of fuel to the top of the kiln, and the top being covered with sods to prevent the escape of the heat, the fire is lighted, and the lime-stone burnt, and not removed till thoroughly cool. This is a tedious process, and expensive from the quantity of fuel consumed. (p46)

Lime which slakes the quickest and heats most in slaking is best, this also falls into the finest powder; if it contain many coarse lumps of core that do not pass through the screen, it is a sign either that the stone has not been sufficiently burnt, or that it contains extraneous matter, which will not only render it inefficient, but also more costly in use. The experiments of Dr. Higgins and Mr. Smeaton have proved, **that if chalk and stone-limes be used equally fresh, their cementitious properties will be equal; but as quick-lime absorbs carbonic acid with greater or less rapidity, in proportion to its spongy or solid texture, so it gradually parts with its cementing nature, and at length becomes totally unfit for the purpose of mortar.** Hence, though stone and chalk-limes be equally good when perfectly burnt and fresh from the kiln, yet there is an important practical difference between them, because the latter takes in the carbonic acid with much greater facility than stone-lime.

In the metropolis, there is now no excuse for the use of chalk-lime, except for the commonest purposes. It is received from Kent and Essex, and **often lies at the different wharfs under open sheds long enough to lose every good property it originally possessed**: whereas the stone-lime may be had at a short distance from the metropolis, not only in abundance, but of the best quality.

The lime, when slaked, must be **passed through a sieve so as to leave only a fine powder**; this is usually performed by means of a screen made of wire, set at an inclination to the horizon, against which the lumps of slaked lime are thrown. That which ought passes through it, the remainder or core falls on the side of the screen against which the lime is thrown. For mortar the core must be entirely rejected; it is, nevertheless, excellent as dry rubbish for filling in the sides of foundations, under wood floors, where they would otherwise lie next the earth, and the like.

The sifted or screened lime is now added to the sand, *[the lime still hot?]* whose proportion to the lime must vary as the strength of the latter.

It is however most important that **the lime and sand be well tempered and beat together after the water is added to them**, and the better this is effected the smaller will be the necessary consumption of lime. For this purpose, what is called a pug-mill, is the best calculated, being of the same nature as the clay-mill used for making bricks. When, however, this is not at hand**, it should be well tempered with wooden beaters, and turned over repeatedly, so as to be thoroughly well mixed.** *[beating allowed less lime to be used and was a cost saving, primarily?].* This is an affair of no small consequence, because as the sand being by far the cheapest article of the two, it will be profitable to use as large a proportion of it as can with propriety be admitted. It is also to be noted that when the sand (p48) predominates, less water is required, and the mortar therefore sets sooner; the work, moreover, settles less, for as the lime will shrink in drying, while the sand continues to occupy the same bulk, it follows that the thickness of the mortar-beds will be less variable. In general no more lime is required than is necessary to surround the particles of sand. *[Gillmore would disagree].*

In London, with the common chalk lime, it is usual to mix one hundred and a half, that is, one hundred and fifty pecks or thirty-seven and a half striked bushels with two loads of sand (30 bushels); but with stone- lime one hundred to two and a half loads of sand is enough. Each of these proportions will give mortar sufficient for a rod of brickwork, which is a superficial measure of two hundred and seventy-two and a quarter square feet of one and a half brick or fourteen inches in thickness. When the tempering, however, is not well attended to, the first-named in the proportion of one hundred, or even less, of lime to two and a half of sand will suffice, and in respect of the latter, it has lately become, and properly, the practice to mix one hundred of lime with three and even four loads of sand. Dr. Higgins, in his experiments, goes so far as to recommend seven parts of sand to one of lime**. The experiments of the laboratory, however, are not always proper foundation for practice**.

… WATER, the medium through which the other ingredients of mortar are incorporated, should be soft and pure. Dr. Higgins recommends lime-water for this purpose. **The screened lime and sand are shovelled and mixed together, then the water is added, the less in quantity the better; afterwards it is tempered by beating and chafing or by passing through a pug-mill, as above mentioned. <u>When mortar is made, it should be used immediately, that is, supposing the lime to have been well burned.</u>**

In respect of that used by plasterers, who employ an inferior lime, it is the practise to **make a large quantity of mortar at a time, and either bury or cover the fresh lime with a yard or so in thickness of sand, and then pour on as much water as will slake it, but not reduce it to dust.** If the sand open, and the smoke rise through the openings, these should be closed up…(p50)

CEMENT. So far with respect to common mortar: but in **works under water** it is necessary to use a cement that will harden quickly in those situations, **which**

common mortar will not do, though it may stand the water well enough when entirely dry, and set.

No cement answers the condition so well as that known by the name of Parker's cement, which is burnt from a limestone found on the Isle of Sheppey. This becomes, in a few minutes, exceedingly hard, either in or out of the water; and wherever the work is exposed to agitated water, the outer beds should be laid in this cement. In many parts of England a limestone is found which, when burnt and used in mortar, gives it the property whereof we are speaking. The best species of these (p51) limestones is the Aberthaw from the Welch side of the Bristol Channel. Mr. Smeaton found the stone of Watchet, in Somersetshire, also excellent in this respect, and traced it through the counties of Monmouth, Worcester, Leicester, by the Vale of Belvoir into Nottinghamshire, in Lincolnshire at a place called Long Bennington, also in the counties of Dorset, Hants, Sussex and Surrey; in Lancashire it goes by the name of Sutton Lime. When burnt all the water limestones fall into a buff-coloured tinge, and contain a considerable portion of clay. If neither of these can be procured, burnt and pounded iron stone, scales from an iron forge, hard burnt tiles, ground and mixed with quick lime, all become hard under water and in damp situations. In the composition of cements advantage has been derived from using water which contained a solution of iron of a dark red colour approaching to black. Clean sharp sand whose particles are angular must likewise be used; gravel small and well washed will do in rubble work.

Pozzolana and Dutch Tarras are now little used in this country, Parker's cement having superseded them. The Mastic, an oil cement, invented near a century since by P. Loriot, for which, extraordinary as it may appear, a patent has been recently granted, is only fit for coating buildings, but it is far inferior to Parker's cement, as also to one for which a patent has lately been granted to Mr. Chambers,

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Hitchcock E (1841) Geology of Massachusetts. Northampton. J S Butler.

Use of Limestone for Mortars. The most important use to which limestone is applied is undoubtedly in the preparation of various kinds of mortar. For while marble must be employed only by the most wealthy, there is scarcely an individual in the community that does not sometimes use lime mortar: and none could be comfortable without it. I hope, therefore, that any suggestions which I may make, whose object shall be to reduce the price or improve the quality of the quick lime generally burnt in Massachusetts, will be received with candor. The burning of lime and its conversion into mortar, have within a few years received much attention: especially in France, by Vicat, John, and Berthier; who have arrived at some important practical results. And as these are not generally accessible in this country, I shall briefly state them, so far as the present state of knowledge in Massachusetts on the subject seems to demand.

Calcination or Burning of Lime. The burning of lime, so as to expel the carbonic acid, is the essential prerequisite in the formation of mortar: and it is accomplished in three modes: 1. Without a kiln: 2. By an intermittent kiln: and 3. By a kiln in constant operation; or as it is sometimes called, a perpetual kiln. The fuel employed is peat, coal, anthracite, or wood.

1. Without a Kiln. In Wales and Belgium the limestone is sometimes piled up in large conical heaps, the fragments being left much larger than when burnt in a kiln, and mixed with wood sufficient to burn it. The pile is then covered with turf exactly like a coal pit, and the process of burning is conducted exactly like that of a coal pit. In Belgium, a pile 16 feet diameter at the base, and 12 feet at the summit, occupies in burning six or seven days; and strange as it may seem, the lime thus produced is constantly preferred, at the same price, to that burnt in a kiln- I am not aware that limestone is ever burnt in this manner in this country: and yet I do not see but it might in some cases be a very desirable mode, especially where fuel is plenty and time and means are not at hand for building a kiln.

2. Intermittent Kiln. This is the most usual mode of burning limestone in this country. The kiln consists usually of a square or circular chimney, sometimes large and high enough to hold 900 bushels, but usually smaller, constructed at least on the inside, of stones that will bear a strong heat. In this chimney the limestone is piled up so as to leave an arched cavity underneath, as a place for the fire; which is usually continued several days before the calcination is completed. The fire is then allowed to go down, and the whole contents of the kiln are withdrawn to make room for a new charge.

It is obvious that by this mode of burning limestone, there is an immense loss of heat, as well as of time, in consequence of allowing the kiln to cool between each charge. Some saving of fuel may be made by constructing the kiln in the form of a cask, or egg, with the extremities cut off. A far more effectual remedy is to substitute the perpetual kiln, which will now be de scribed. Where it is wished, however, to burn only a few hundred bushels of lime in a year, the common kiln may be cheapest.

3. Perpetual Kiln. This kiln is so constructed that the portion of lime which has become thoroughly burnt, can be removed without discontinuing the fire. And thus by removing the burnt lime from the bottom, and filling in at the top with fresh limestone, the process may be continued until the furnace needs repairs ; which, in Belgium, is attended to once a year. (See Dumas' Chimie applique aux Art. Tome Deuxieme, p. 489).

Besides the perpetual kiln that has been described in Richmond, another on the same plan exists in Lenox; and these, so far as I could learn, are the only kilns of this kind that exist in the whole of Berkshire county. Nearly all the lime prepared there, is burnt in the old fashioned intermittent kilns. Indeed, I found among some of the lime burners there, a prejudice against the perpetual kilns; as if they did not accomplish the work thoroughly. These facts have surprised me, when I consider what a great and increasing demand there must be upon

Berkshire for lime from other parts of New England; and being confident that it will be quite an easy matter to reduce the present cost of burning lime there, at least one half: and probably a great deal more. Mr. Haddsel of New Marlborough, who has burnt a vast quantity of lime stone for the last 30 or 40 years, (at present he burns about 12000 bushels annually), and whose lime is considered very good in the Hartford market, told me that the cost of burning and preparing it for market would not fall much short of 25 cents per bushel. His kiln holds 700 bushels; and he consumes 40 cords of wood at a charge. Estimating the wood at $1.50 per cord, and this is probably too low, the cost per bushel is 8 ½ cents. Dr. Jackson, in his second Report on the Geology of Maine, states the cost of fuel per bushel at Thomaston, where the old kilns are used is 8 cents. Now Professor Mather, in his second Report on the Geology of the First District of New York, states that lime is burnt in the perpetual kilns at Barnegat on the Hudson, where 720,000 bushels are annually prepared, for less than 2 cents per bushel: — the fuel costing less than one cent; and the labor of tending the kiln about the same; while the expence of raising the stone is trifling. In Connecticut, according to Professor Shepard, in his Geological Report, an intermittent kiln in Reading, that holds 1200 bushels, requires for a charge 40 cords of wood; another in Brookfield, that holds 700 bushels, requires 35 cords; and another in Derby, that holds 270 bushels, requires from 8 to 10 cords. If the wood be put at $2.00 per cord, the average price per bushel for these three kilns would be about 8 cents. But according to the same report, the perpetual kilns of Pennsylvania burn 700 bushels of lime with 8 cords of wood; and one and a half tons of anthracite: which, (putting the wood at $2.00 per cord, and the anthracite at $6.00 per ton,) amounts to 3 ½ cents per bushel. In New York, Mr. Shepard says, they burn 2000 bushels of lime with 12 cords of wood: which, at the same price, is only a little over 2 cents per bushel. The proprietors of the perpetual kiln in Whately, that has been already described, estimate that their fuel, which is entirely wood, costs them from 3 to 4 cents per bushel; as stated in Mr. Nash's letter inserted on a former page.

It ought to be mentioned that the fuel used at Barnegat is anthracite; which there costs $6.00 per ton: and this is undoubtedly more economical than wood. But the greater part of the difference in the cost of the fuel at that place and in Berkshire, results from the character of the kilns employed as the other facts above mentioned already prove. And if desirable to employ anthracite in Berkshire, it can probably be transported by railroad at so low a rate, as to render it practicable. It is said, also, that coal dust, which costs in New York $1.75 per ton, will answer well for burning lime. Does not this fact deserve the attention of the proprietors of those lime quarries in the eastern part of Massachusetts, that have been abandoned on account of the high price of fuel. Dr. C T. Jackson, in his second Report on the Geology of Maine, states that it has been estimated, that even at Thomaston in Maine, the use of coal would reduce the price of lime from 8 cents per bushel, to 5, and perhaps 3 cents. And if so, why may not the preparation of lime be extensively resumed in the eastern part of Massachusetts?

From these facts I cannot but infer that Massachusetts, proud as she justly is of her skill in manufactures, is in this art very much behind the times.

….At present the burning of lime is a business, so far as I could learn, not very profitable to those engaged in it in Berkshire county. But when its price shall be reduced one half, and ten times more is burnt, I predict that it will become profitable. I have been surprised to find how little limestone is burnt in that part of the state. It is a singular fact, that in most of those towns that have been most distinguished for the burning of lime, such as Washington, Hinsdale, and Peru, no ledges of limestone occur: but dependence has been placed entirely on the loose blocks that diluvial action has driven thither from the neighboring towns. And I have been assured that the inhabitants of some towns, which are based upon good limestone, transport most of the lime that they use from quarries in towns where very little exists in ledges, under an idea that they have no lime tone where they live that is worth burning!

Varieties of Limestone. On the continent of Europe three kinds of quicklime are distinguished by the different sorts of mortar which they produce. 1. Fat lime: (chaux grasse) 2. Meagre lime: 3. Hydraulic lime. The fat lime contains at least 90 per cent. of pure lime: But when the magnesia, silica, alumina, iron, and manganese, which it contains, amount to 20 per cent. it becomes meagre: that is, these foreign matters affect very much the mortar that is made from the mixture. When these foreign substances, however, are in considerably large proportion, the lime sometimes becomes hydraulic; that is, it will harden under water.

Fat Lime. This being derived from an almost pure carbonate of lime, slacks with great energy and the evolution of heat; forms a fine paste with water; **admits the addition of a great deal of sand; is more easily laid on by the mason; and therefore, is the most economical for common purposes. On all these accounts it is regarded as the best kind of lime; and sought after the most**. For it is not generally known in this country, that it does not form so hard and durable a mortar as the next variety.

Meagre Lime. Although this kind of lime often slacks slowly and less perfectly than fat lime, and when water is added, forms a less perfect paste, and therefore, **does not work so well with the trowel; and as it takes up less water and bears less sand, is therefore more expensive, yet after all, it hardens with greater certainty, and to a greater degree, and forms a more enduring and stronger cement. It is especially valuable for the property which much of it possesses, of hardening in damp as well as in dry places; and where mortar is exposed to the weather, it is by far the best.** Nevertheless many of the circumstances mentioned above, **produce a prejudice against this sort of lime, especially among bricklayers.**

It will be seen from the table of analyses of the Massachusetts limestones, that this variety of lime is very abundant among us, especially if we include under it, as is done by European writers, that which contains a large proportion of magnesia. I have had no opportunity of trying but one variety of the meagre lime, and that is the kind that has lately begun to be burned in Whately. Having occasion to plaster a building upon the outside it seemed to me that this lime would be well adapted for the purpose. **I tried it by mixing one part of unslaked lime with one part of sifted ashes, and one part of sand, and found it to produce a cement that spread well and became very hard,** and at a few rods distance can hardly be distinguished from granite or sandstone. The outer coat, however, not having been put on in proper season after the first, does not adhere well. And although the Whately lime answers for outside work better than any I have seen, yet I doubt whether in our climate, it be the best economy to cover the outside of buildings with any kind of calcareous cement. But if it be done, meagre lime is the best; and I doubt not that several other varieties in the State will answer as well as that from Whately. I presume however, that when there is not more than 50 per cent. of carbonate of lime in a rock, it will not produce cement of much value. It will probably surprise the inhabitants of Berkshire county, as it did me, to find that by far the largest part of the limestone burnt there, contains not less than 40 per cent. of the carbonate of magnesia. The fine looking stone burnt in the south part of New Marlborough and Tyringham, near the center of Lee, and in the east part of Lanesborough, from which places great quantities of lime are carried out of the county, and it is in high repute, is all genuine magnesian lime stone. The same is true of the quarries in the eastern part of the state, at Bolton, "Chelmsford, Littleton, &c. Now it is certain that magnesia does not form a paste with water; and yet, so far as I can ascertain, this kind of lime is preferred to that which is pure ; because it becomes harder and is usually whiter. But I consider that there is yet too much doubt resting upon the use of magnesian lime in agriculture to render it expedient to employ it upon land when other lime can be procured. And from the analyses of our limestones that have been given, our citizens can now judge where the different sorts may be obtained. In respect to magnesian limestone, however, there is another important use to which it has not been applied in this state which I shall suggest in treating of the next variety.

Hydraulic Lime. It has long been an important enquiry what ingredients are necessary in limestone to render it hydraulic; that is, to cause it to harden under water. Until recently but little success attended this enquiry: because the manner in which mortar is consolidated, was misunderstood. It was supposed to result from the absorption of carbonic acid from the atmosphere, whereby the lime was reconverted into a carbonate: so that the more completely this process was effected, the harder would the cement become. And this was thought to explain the reason why the ancient Roman cements, that are found in old ruins, are so hard. But upon analysis **it was found that these mortars rarely contained much carbonic acid; and that in general they were harder, the less of this substance entered into their composition. (Traite de Mineralogie, par Beudant, Tome Premier, p. 690.)** That mortars do, however, absorb carbonic acid on their surface, and that this is one of the causes of their induration, can hardly be doubted. **But it is not the principal cause.** Silica operates as an acid in mortars, and forms silicates of lime, magnesia, alumina, &c. and this probably is the principal cause of their consolidation. In this state silica exists in rocks, and to this fact chiefly they owe their hardness : and could the materials of mortar be mixed in such proportions as they exist in rocks, and under as favorable circumstances for induration, they would become as hard as the rocks ; as in fact they do sometimes. This theory shows us the use and even necessity of sand mixed with lime, to form good mortars. It shows us also, why it is **better to have this siliceous matter exist naturally in the rock than to introduce it artificially,** because nature mixes it more perfectly than art can do.

But why should some mortars become silicates only in the air, and others with more facility under water? It is the opinion of distinguished chemists that the latter class are converted, when under water, into hydrated silicates ; while the former, not undergoing this process, are more or less dissolved when immersed, and become mere an hydrous silicates in the air. But the analyses that have been made of these different varieties of limestone do not afford a satisfactory reason why some of them are hydraulic and some are not. Yet it is hence ascertained that certain ingredients besides the lime, are necessary to make them harden under water. It was formerly thought that this property depended upon the oxide of iron, or manganese, which they contained. But the numerous accurate experiments that have been made on the subject, prove that silica is the most important ingredient on which the hydraulic character depends. The results of all these experiments however, I give in the words of Dumas. " It follows," says he, " from all these facts, that silica alone is able to form with lime a combination eminently hydraulic: while magnesia alone, or a mixture of the oxides of iron and manganese, cannot produce a similar combination, but renders the lime meagre, without communicating to it the property of hardening under water. Synthetic experiments confirm the results of analysis; and prove farther. **1. That alumina alone has no more efficacy than magnesia in rendering lime hydraulic: 2. That silica is an ingredient essential to these varieties of lime: 3. That the oxides of iron and manganese, far from playing a part so important as some attribute to them, are on the contrary very often altogether passive: 4. That the best hydraulic lime results from a mixture of silica, lime, and magnesia, or alumina."** — " We must, therefore, consider hydraulic lime as a silicate of lime, or a silicate of alumina and lime, or finally as a silicate of magnesia and lime, with an excess of base. These compounds placed in water produce hydrates; or other combinations of the hydrated silicate with the hydrate of the base in excess." (Chimie aplique mix Arts, Tome Deuxieme, p. 512.) More recently another distinguished chemist, Professor Mitscherlich of Berlin, says in respect to magnesian limestone for hydraulic cement, that " according to experiments in the small way, magnesian limestone merits the preference over the carbonate of lime." (Elemens de Chemie par E. Mitscherlich, Tome Troisieme, p. 120. Brujp- elles, 1836.) Vicat also, recently inclines to the same opinion ; and in our country, Professor William B. Rogers, the able state geologist of Virginia, has made numerous analyses of the hydraulic limestones of this country, from which he not only infers that magnesia operates favorably upon the hydraulic character, but even suggests that this property may depend upon the magnesia, rather than upon the silica. He finds that in all the hydraulic limestones which he has analysed, the carbonate of magnesia bears to the carbonate of lime the proportion of three to five: and he supposes that by this circumstance we may probably determine whether any limestone is hydraulic. Without doubting at all the accuracy of Professor Rogers' analyses and experiments, I confess that I do not know how to reconcile the principle, that the hydraulic character always depends upon magnesia, with the numerous analyses and experiments that have been made in Europe on the subject. In the table below I shall give some of the analyses by Berthier of the best hydraulic limestones in France ; most of which contain but a very small proportion of magnesia: and those which are artificial, and which are in high repute, contain none. Even the septaria of England, from which the famous Roman or Parker's cement, **the best hydraulic cement in the world**, is obtained, contains only one 200th, part of carbonate of magnesia; and a similar rock in France and Russia contains none. On the other hand, in some of the specimens analyzed by Prof. Rogers, the silica is less than two per cent.; and yet they form good hydraulic cement. We have then good mortar of this description, sometimes almost without silica, but containing magnesia; and some times without magnesia, but containing silica. Must we not hence infer, that the hydraulic character does not depend entirely upon either of these substances : but rather upon the mode or other circumstances of their combination with the lime: in other words, that they may replace each other.

Nicholson P (1841) Practical Masonry, Bricklaying and Plastering - Peter Nicholson, 'Practical Builder and Mathematician'

58. Making Mortar.The instructions given by Dr. Higgins for making stucco-mortar, **apply only when a very superior kind is wanted**; but the same general principles ought to be followed even with the commonest kinds of mortar. We will, therefore, insert them in this place. *[This is unfortunate – Nicholson chooses not to elucidate the common craft method, but instead details Bryan Higgins recommended 'scientific' method, which was based on thorough, thoughtful but essentially flawed premises in many of its details. Much below is an almost direct transcription from Higgins's work. Nicholson defers to an 'expert' rather than trust to his practical experience, perhaps, reflecting his own 'upward mobility']*.

Of Sand, the following kinds are to be preferred; first, drift-sand, or pit-sand, which consists chiefly of hard quartose flat-faced grains, with sharp angles; secondly, that which is the freest, or may be most easily freed by washing, from clay, salts, and calcareous, gypseous, or other grains less hard and durable than quartz; thirdly, that which contains the smallest quantity of pyrites, or heavy metallic-matter, inseparable by washing; and fourthly, that which suffers the smallest diminution of its bulk in washing. Where a coarse and fine sand of this kind, and corresponding in the size of their grains with the coarse and fine sands hereafter described, cannot be easily procured, let such sand of the foregoing quality be chosen as may be sorted and cleansed in the following manner :

Let the sand be sifted in streaming clear water, through a sieve which shall give passage to all such grains as do not exceed one-sixteenth of an inch in diameter; and let the stream of water, and the sifting, be regulated so that all the sand which is much finer than the Lynn-sand, commonly used in the London glass-houses, together with clay, and every other matter specifically lighter than sand, may be washed away with the stream; whilst the purer and coarser sand, which passes through the sieve, subsides in a convenient receptacle, and the coarse rubbish and rubble remain on the sieve to be rejected.

Let the sand, which thus subsides in the receptacle, be washed in clean streaming water through a finer sieve, so as to be further cleansed, and sorted into two parcels; a coarser, which will remain in the sieve, which is to give passage to such grains of sand only as are less than one-thirtieth of an inch in diameter, and which is to be saved apart under the name of coarse sand; and a finer, which will pass through the sieve and subside in the water, and which is to be saved apart under the name of fine sand. Let the coarse and the fine sand be **dried** separately, either in the sun, or on a clean iron plate, set on a convenient surface, in the manner of a sand-heap.

Let stone-lime be chosen, which heats the most in slaking, and slakes the quickest when duly watered; that which is the freshest made and closest kept; that which dissolves in distilled vinegar with the least effervescence, **and leaves the smallest residue insoluble, and in the residue the smallest quantity of clay, gypsum, or martial matter** *[that is to say, very feebly hydraulic at best].*

Let the lime, chosen according to these rules, be put in a brass-wired sieve, to the quantity of fourteen pounds. Let the sieve be finer than either of the foregoing; the finer the better it will be: **let the lime be slaked, by plunging it into a butt filled with soft-water, and raising it out quickly, and suffering it to heat and fume**; and, by repeating this plunging and raising alternately, and agitating the lime until it be made to pass through the sieve into the water; and let the part of the lime which does not easily pass through the sieve be rejected: and let fresh portions of the lime be thus used, until as many ounces of lime have passed through the sieve as there are quarts of water in the butt.

Let the water, thus impregnated, stand in the butt closely covered **until it becomes clear, and through wooden cocks, placed at different heights in the butt, let the clear liquor be drawn off, as fast and as low as the lime subsides, for use.** *[This is a preparation of lime-water with which to then slake the main body of the quicklime. This is as proposed by Dr Higgins].* This clear liquor is called lime-water….

Let fifty-six pounds of the aforesaid chosen lime be slaked, by gradually sprinkling the lime-water on it, and especially on the unslaked pieces, in a close clean place. **Let the slaked part be immediately sifted through the last mentioned fine brass-wired sieve: let the lime which passes be <u>used instantly</u>, or kept in air-tight vessels; and let the part of the lime which does not pass through the sieve be rejected.** This finer and richer part of the lime, which passes through the sieve, may be called **purified lime.**

Let bone-ash be prepared in the usual manner, by grinding the whitest burnt bones; but let it be sifted, so as to be much finer than the bone-ash commonly sold for making cupels.

The best materials for making the cement being thus prepared, take fifty-six pounds of the coarse sand, and forty-two pounds of the fine sand; mix them on a large plank of hard wood placed horizontally; then spread the sand so that it may stand to the height of six inches, with a flat surface on the plank, wet it with the lime-water, and let any superfluous quantity of the liquor, which the sand in the condition described cannot retain, flow away off the plank. **To the wetted sand add fourteen pounds of the purified lime, in several successive portions: mixing- and beating them up together, in the mean time,** with the instruments generally used in making fine mortar: then add fourteen pounds of the bone-ash, in successive portions, mixing and beating all together.
The quicker and the more perfectly these materials are mixed and beaten together, and the sooner the cement thus formed is used, the better it will be. *[98 parts sand: 14 parts bone-ash: 14 parts slaked lime – this is very lime-lean, 1:8, as per Higgins's experiments and conclusions – the best mortar being that which shrinks the least, in his estimation].*

This may be called coarse-grained cement, **which is to be applied in building, pointing, plastering, stuccoing, or other work, as mortar and stucco generally are**; with this difference chiefly, that, as this cement is shorter than mortar, or common stucco, and dries sooner, it ought to be worked expeditiously in all cases; and, in stuccoing, it ought to be laid on by sliding the trowel upwards on it. The materials used along with this cement in building, or the ground on which it is to be laid in stuccoing, ought to be **well wetted with the lime-water** in the instant of laying on the cement. The lime-water is also to be used when it is necessary to moisten the cement, or when a liquid is required to facilitate the floating of the cement.

When such cement is required to be of a still finer texture, take ninety-eight pounds of the fine sand, wet it with the lime-water, and mix it with the purified lime and the bone-ash, in the quantities and in the manner above described; with this difference only, that fifteen pounds of lime, or thereabouts, are to be used instead of fourteen pounds, if the greater part of the sand be as fine as Lynn sand. This may be called fine-grained cement. It is used in living the last coating, or the finish, to any work intended to imitate the finer-grained stones or stucco. But it may be applied to all the uses of the coarse-grained cement, and in the same manner.

When, for any of the foregoing purposes of pointing, building, &c., a cement is required much cheaper and coarse-grained than either of the foregoing, then much coarser clean sand than the foregoing coarse sand, or well-washed fine rubble, is to be provided. Of this coarse sand, or rubble, take fifty-six pounds, of the foregoing coarse sand twenty-eight pounds, and of the fine sand fourteen pounds; and, after mixing these, and wetting them with the cementing-liquor, in the foregoing manner, add fourteen pounds *98:14; 7:1]*, or somewhat less, of the purified lime, and then fourteen pounds, or somewhat less, of the bone-ash, mixing them together in the manner already described.

When the cement is required to be white, white sand, white lime, and the whitest bone-ash, are to be chosen. Gray sand, and gray bone-ash formed of half-burnt bones, are to be chosen to make cement gray; and any other colour of the cement is obtained, either by choosing coloured sand, or by the admixture of the necessary quantity of coloured talc in powder, or of coloured, vitreous, or metallic, powders or other durable colouring ingredients, commonly used in paint.

This cement, whether the coarse or fine-grained, is applicable in forming artificial stone, by making alternate layers of the cement and of flint, hard stone, or bricks, in moulds of the figure of the intended stone, and by exposing the masses so formed to the open air, to harden.

When such cement is required for water-fences, two-thirds of the prescribed quantity of bone-ashes are to be omitted; and, in the place thereof, an equal measure of powdered terras is to be used; and, if the sand employed be not of the coarsest sort, more terras must be added, so that the terras shall be one-sixth part of the weight of the sand.

When such a cement is required of the finest grain, or in a fluid form, so that it may be applied with a brush, flint-powder, or the powder of any quartzose or hard earthy substance, may be used in the place of sand; but in a quantity smaller, in proportion as the flint or other powder is finer ; so that the flint-powder, or other such powder, shall not be more than six times the weight of the lime, nor less than four times its weight. The greater the quantity of lime within these limits, the more will the cement be liable to crack by quick drying, and, vice versa.

Where the above described sand cannot be conveniently procured, or where the sand cannot be conveniently washed and sorted, that sand which most resembles the mixture of coarse and fine sand above prescribed, may be used as directed, provided due attention be paid to the quantity of the lime, which is to be greater as the quality is finer, and, vice versa.

Where sand cannot be easily procured, any durable stony body, or baked earth, grossly powdered, and sorted nearly to the sizes above prescribed for sand, may be used in the place of sand, **measure for measure, but not weight for weight**, unless such gross powder be specifically as heavy as sand.

Sand may be cleansed from every softer, lighter, and less durable, matter, and from that part of the sand which is too fine, by various methods preferable in certain circumstances, to that which has been already described.

Water may be found naturally free from fixable gas, selenite, or clay; such water may, without any great inconvenience, be used in the place of the lime-water; and water approaching this state will not require so much lime as above prescribed to make the lime-water; and a lime-water sufficiently useful may be made by various methods of mixing lime and water in the described proportions, or nearly so.

When stone-lime cannot be procured, chalk-lime, or shell-lime, which best resembles stone- lime, in the foregoing characters of lime, may be used in the manner described, excepting that fourteen pounds and a half of chalk-lime will be required in the place of fourteen pounds of stone-lime. The proportion of lime, as prescribed above, may be increased without inconvenience, when the cement or stucco is to be applied where it is not liable to dry quickly; and, in the contrary case, this proportion may be diminished. The defect of lime, in quantity or quality, may be very advantageously supplied, by causing a considerable **quantity of lime-water to soak into the work, in successive portions, and at distant intervals of time; so that the calcareous matter of the lime-water, and the matter attracted from the open air, may fill and strengthen the work.**

The powder of almost every well-dried or burnt animal substance may be used instead of bone-ash; and several earthy powders, especially the micaceous and the metallic elixated ashes of divers vegetables, whose earth will not burn to lime, as well as the ashes of mineral fuel, which are of the calcareous kind, but will not burn to lime, will answer the ends of bone-ash in some degree.

The quantity of bone-ash described may be lessened without injuring the cement; in those circumstances especially which admit the quantity of lime to be lessened, and in those wherein the cement is not liable to dry quickly. The art of remedying the defects of lime may be advantageously practised to supply the deficiency of bone-ash, especially in building, and in making artificial stone with this cement.

As the preceding method of making mortar differs, in many particulars, from the common process, it may be useful to inquire into the causes on which this difference is founded.

When the sand contains much clay, the workmen find that the best mortar they can make must contain about one-half lime; **and hence they lay it down**

as certain, that the best mortar is made by the composition of half sand and half lime.

But with sand requiring so great a proportion of lime as this, it will be impossible to make good cement; for it is universally allowed that the hardness of mortar depends on the crystallization of the lime round the other materials which are mixed with it; and thus uniting the whole mass into one solid substance.

But, if a portion of the materials used be clay, or any other friable substance, it must be evident that, as these friable substances are not changed in one single particular, by the process of being mixed up with lime and water, the mortar, of which they form a proportion, will consequently be, more or less, of a friable nature, in proportion to the quantity of friable substances used in the composition of the mortar. On the other hand, if mortar be composed of lime and good sand only, as the sand is a stony substance, and not in the least friable, and as the lime, by perfect crystallization, becomes likewise of a stony nature, it must follow, that a mass of mortar, composed of these two stony substances, will itself be a hard, solid, unfriable, substance.

This may account for one of the essential variations in the preceding method from that in common use, and point out the necessity of never using, in the place of sand, which is a durable stony body, the scrapings of roads, old mortar, and other rubbish, from antient buildings, which are frequently made use of, as all of them consist, more or less, of muddy, soft, and minutely divided particles.

Another essential point is the nature and quality of the lime. Now, experience proves that, **when lime has been long kept in heaps, or untight casks, it is reduced to the state of chalk, and becomes every day less capable of being made into good mortar**; because, as the goodness or durability of the mortar depends on the crystallization of the lime, and, as experiments have proved, that lime, when reduced to this chalk-like state, is always incapable of perfect crystallization, it must follow that, as lime in this state never becomes crystallized, the mortar of which it forms the most indispensable part, will necessarily be very imperfect; that is to say, it will never become a solid stony substance; a circumstance absolutely required in the formation of good durable mortar. These are the two principal ingredients in the formation of mortar; but, as water is also necessary, it may be useful to point out that which is the fittest for this purpose; **the best is rain-water, river-water the second, land-water next, and spring-water last.**

The ruins of the antient Roman buildings are found to cohere so strongly, as to have caused an opinion that their constructors were acquainted with some kind of mortar, which, in comparison with ours, might justly be called cement: and that, to our want of knowledge of the materials they used, is owing the great inferiority of modern buildings in their durability. **But a proper attention to the above particulars would soon show that the durability of the antient edifices**

depended on the manner of preparing their mortar more than on the nature of the materials used. The following observations will, we think, prove this beyond a possibility of doubt

Lime, which has been slaked and mixed with sand, becomes hard and consistent when dry, by a process similar to that which produces natural stalactites in caverns. These are always formed by water dropping from the roof. But, when the small drop of water comes to be exposed to the air, the calcareous matter contained in it begins to attract carbonic acid from the atmosphere. In proportion as it does so, it also begins to separate from the water, and to re-assume its native form of lime-stone or marble. When the calcareous matter is perfectly crystallized in this manner, it is to all intents and purposes lime-stone or marble of the same consistence as before. If lime, in a caustic state, be mixed with water, part of the lime will be dissolved, and will also begin to crystallize. The water which parted with the crystallized lime will then begin to act upon the remainder, which it could not dissolve before and thus the process will continue, either till the lime be all reduced to an effete, or crystalline state, or something hinders the action of the water upon it. It is this crystallization which is observed by the workmen when a heap of lime is mixed with water, and left for some time to macerate. A hard crust is formed upon the surface, which is ignorantly called frosting, though it takes place in summer as well as in winter. If, therefore, the hardness of the lime, or its becoming a cement, depends entirely on the formation of its crystals, it is evident that the perfection of the cement must depend on the perfection of the crystals, and the hardness of the matters which are entangled among them.

The additional substances used in making of mortar, such as sand, brick-dust, or the like, serve only for a purpose similar to what is answered by sticks put into a vessel full of any saline solution; namely, **to afford the crystals an opportunity of fastening themselves upon it.** If, therefore, the matter interposed between the crystals of the lime is of a friable brittle nature, such as brick-dust or chalk, the mortar will be of a weak and imperfect kind but, when the particles are hard, angular, and very difficult to be broken, such as those of river or pit-sand, the mortar turns out exceedingly good and strong. **That the crystallization may be the more perfect, a large quantity of water shoud be used, the ingredients be perfectly mixed together, and the drying be as slow as possible.** An attention to these particulars, and to the quality of bricks and stones, would make the buildings of the moderns equally durable with those of the antients. In the old Roman works, the great thickness of the walls necessarily required a vast length of time to dry. **The middle of them was composed of pebbles thrown in at random, and which, evidently, had thin mortar poured in among them.** *[still slaking hot mix].* Thus a great quantity of the lime would be dissolved,and the crystallization performed in the most perfect manner. The indefatigable pains and perseverance, for which the Romans were so remarkable in all their undertakings, leave no room to doubt that they would take care to have the ingredients mixed together as well as possible. The consequence of all this is, that the buildings formed in this manner are all as firm as if cut out of a solid rock ; the mortar being equally hard, if not more so, than the stones themselves.

59. Water-Mortars or Cements. The cementing materials are either found ready combined in certain kinds of stone, as in the case of Roman cement; or the effect is produced by mixture, as when we mix the lime of poor lime-stones with Dutch terras. The natural combination is, however, **by far the best**; and it is only in cases where the other can be obtained at a much less expense, that we advise it to be resorted to; but, for such cases, we propose to describe the best compositions now known.

60. Roman Cement is made from the kind of stones called clay-balls.* The best stone contains about 60 per cent, of carbonate of lime, and 8 or 10 per cent, of pro-oxide of iron, the rest being silex and alumine nearly in equal parts. The inferior stones contain peroxide of iron, and often soluble earthy and alkaline salts. **Stone of the best kind is procured on the coast of the Isle of Sheppy, and from the alum-shale on the coast of Yorkshire, near Whitby. S**tone of an inferior quality is procured near Harwich, and other places on the coast of England, and at Boulogne, in France. The stone is, after being broken to a proper size, slowly calcined in kilns or ovens, and then it is ground to a fine powder, of a light snuff- colour, when the stone is good and of a deeper, approaching to a burnt-umber brown, when the quality is inferior. The powder should be kept perfectly dry till it is to be used; and, in order to use it, mix it with not less than an equal portion, by measure, of dry, clean, and sharp, river-sand ; then add as much clear water as will form it into a stiff paste, but not more ; and the whole that is so mixed must be used before it begins to set, which, with good cement, happens in about fifteen minutes from the time of adding the water; but, in cements very fit for building, the setting may not be commenced in less than half or three-quarters of an hour. When the setting begins, all the moisture on the surface disappears, and the cement feels dry and warm to the touch, and hardens; the hardening continues for some months, and **is increased by frequent wetting the work,** in cases where it has not to be exposed to water immediately on its being set. A coat of this cement is impervious to water, and it is therefore **most extensively used for lining cisterns, tanks, reservoirs, &c.**

61. Roman Cement may be used alone, but it does not become so hard and durable, as when it has a proper quantity of good sand mixed with it. **A mixture of Roman cement and common mortar should never be made, for their setting properties depend on different combinations, and which interfere with each other when acting in the same mass**; and the best mortar and best cement may be both rendered worthless by mixture. In using cement, the more expeditious the workman is in his operations the better; and when once setting has commenced, the work should be no further disturbed.

If the setting take place too rapidly for the nature of the work, let the cement, in powder, be spread out so as to expose a large surface to the air in a dry place;

in this manner the time of setting may be extended according to the time the powder is exposed, and though the quality of the cement is injured by the process, it is not so much destroyed as by working the cement after its being partially set.

62. Puzzolana Mortar. An excellent mortar for water-works is formed by combining the lime of poor lime-stones with the earth, called puzzolana, which is procured in Italy. The limestones adapted for this purpose are the *blue* lias of Somersetshire, the clunch of Sussex, and the hard gray chalk of Surrey.

Smeaton used the lime of the lias procured at Aberthaw *[Watchet, Somerset, in fact]*, in Wales, for the Eddystone lighthouse.

An article, called British puzzolana, has lately been manufactured, but it does not possess the same properties as the foreign kind ; and, indeed is rather a substitute for sand than for the true puzzolana.

63. Terras Mortar, is also very good for water-works; it is composed of an earthy material called terras, found near Andernach, in the department of the Rhine and Moselle, which is mixed with any lime of a nature similar to the blue lias. Terras is much used by the Dutch for their sea and canal works, and it has the singular property of forming stalactitical excrescences at the joints of the work. Smeaton employed it in the following proportions, according to the nature of the work.

The customary allowance of beating for terras-mortar is a day's work of a man for every bushel of terras.

64. When neither Roman cement, puzzolana, nor terras, can be procured, except at great expense, then we may have recourse to calcined iron-ore, scales from smith's forges, calcined basalt, clay, and other substances, containing a considerable proportion of protoxide of iron. Lime may also be improved by peculiar treatment in burning, for it appears that even common chalk-lime acquires a setting property resembling that of the lias-lime, **bv being long exposed to a certain degree of heat.**

G5. **All limes fit for water-cements require to be ground to powder**, and the finer the better. If these limes be slacked, the setting property is partially destroyed; and it is important that no more mortar should be made up at once than can be used within a few hours.

PLASTERING

That the Romans, at a very early period, practised the art of plain plastering, is sufficiently evident by the portions which remain attached to the walls of some of their most ancient buildings, the antiquity of which must be considered as proved, when we look at the manner in which the carbonic acid contained in the atmosphere has acted upon the lime and sand, it having reduced the various particles into a solid and compact substance resembling stone, and which, indeed, is a carbonate of lime, defying the most dexterous applications of the hammer and chisel to separate it from the walls without bringing off pieces of the stone attached to it.

Connected with this art, and indeed belonging to it, is one of the most elegant branches of decoration, formerly called stucco-working, but now known by the more comprehensive title of Ornamental Plastering, including modelling, casting, and working in stucco.

The invention of stucco-working has been attributed to Margaritoni, an Italian, who died in 1317.

The materials used by him were **sifted lime and white marble pounded, which were kneaded together to the consistency of potter's clay, pure water alone being used in their amalgamation.**

330, Lime, which forms a most essential ingredient in all the operations of plastering, is prepared from two substances, viz. lime-stone and chalk, which are broken into small pieces, and piled in convenient layers, with coal, furze, or other fuel, in proper kilns, where they are kept for a considerable time in a white heat.

Bishop Watson found, by experiment, that, upon an average, every ton of lime-stone produced 11 cwt. 1 qr. 4 lbs. of quick-lime, weighed before it was cold; and that when exposed to the air, it increased in weight daily, at the rate of a hundred weight per ton, for the first five or six days after it was drawn from the kiln, owing to its gradual absorption of carbonic acid.

Great precaution ought always to be exercised in the choice of lime, particularly avoiding the stone of a hard nature, for if great care be not taken in the slacking, owing to the quantity of magnesia it contains, which being almost insoluble in water, it will eventually spoil the work, however great the pains which may have been taken in the finishing, by breaking out in ugly protuberances, called by the plasterer, blisters. The lime of Breedon, in Leicestershire, is found to contain half its weight of magnesia.

The principal portion of lime used in London and its vicinity is prepared from chalk, and the greater part of it is brought from Purfleet, in Essex; but for stuccoing and external finishing, in which strength and durability are required, the lime manufactured at Dorking is preferred. This useful article is sold at the wharfs about London, in bags, containing each one hundred pecks.

331. Sand, which is so material for the making of good mortar, ought always to be chosen of the sharpest description, of a consistency approaching to fine

gravel, free from all particles of earth or clay, for on the purity and quality of the sand, the strength and durability of the mortar entirely depends.

Lime and Hair, or coarse stuff, is prepared in different ways, which must be determined by the quality of the materials.

When prepared from chalk or lime-stone of a weak nature, **it is screened and prepared in the usual way, similar to common mortar, with the addition of hair from the tan-yards, and may be used a few days after its preparation** ; but when the lime-stone is of a hot or hard quality, it is not advisable to adopt this method, for if the stuff be used soon after its preparation, it will inevitably cause blisters in the work.

The safest mode of preparing lime and hair, when the stone is of a strong nature, is by forming a pan or binn of a convenient size, perfectly water-tight, and about 18 inches in depth. A large tub must then be procured into which the lime, **after having been well slacked must be put and mixed with a proper proportion of water**, and run through a sieve with apertures not exceeding a quarter of an inch, until the pan is filled, **when the hair and sand must be added,** the whole being well incorporated with a drag or three-pronged rake. There must then be a small hole made at a suitable height in the side of the pan, to allow the water to escape. **After thus remaining until it be sufficiently set, it may be taken out of the pan and made fit for use by the labourers.**

This composition is used for the first or pricking-up coat, and for the floating of ceilings and walls. It is also used for mouldings and cornices which require much stuff, in which case it is mixed with plaster of Paris.

3o3. Fine Stuff is commonly used for giving the last coat to the plain surfaces of floated work. **It consists of pure lime slacked with a sufficient quantity of water, and well saturated.** It is afterwards run through a fine sieve, and put into tubs in a **semi-fluid state,** where it is allowed to settle and the water to evaporate, when a small portion of white hair may be added, which will very much improve its quality.

334. Stucco, for inside walls, called trowelled or bastard stucco, is composed of fine stuff, above described, (omitting the hair,) and very fine washed sand well incorporated with it, in the proportion of one of the latter to three of the former. All walls intended to be painted or papered should be finished with this stucco ; but for what is termed rough stucco, commonly applied to staircases, passages, and entrance-halls, a larger portion of sand ought to be used, and that of a much coarser quality.

335. Plasterers' Putty is prepared from unslacked lime, the process being performed by immersing the lime in water where it remains until it be completely dissolved; the liquid being then strained through a very fine sieve must be left in this state until set, when it is considered fit for use.

Putty is used in all the **finer** branches of plastering, **as for the setting or last coats of soffits, and for the running of mouldings and cornices**. When it is used for mouldings, it is mixed with plaster of Paris, which induces it to set quickly and become more dense.

336. Stucco, which was used by the old ornament-workers, is prepared in a very peculiar manner. It has, since the invention of casting ornaments in moulds, almost entirely fallen into disuse; however, it is but proper here to notice it for the benefit of the curious.

A sufficient quantity of fine putty being procured to complete the portion of work contemplated, some marble-dust, made very fine, or pounded alabaster, (and in some cases very fine silver-sand,) must be added. This mixture must be well chafed and spread over a brick-wall, in order to assist the co-operation of the water. After it becomes stifl", it must be taken from the wall, and well chafed with a wooden beater until it becomes tough ; it must then be spread over the wall a second time, and the same process repeated, viz. chafing it well with the beater until it becomes plastic, when it is fit for use, and may be applied to the ornamental work after it has been first boasted with lime and hair.

This kind of stucco is sometimes mixed with a small portion of burnt plaster of Paris, prepared in the manner of lime, instead of being, according to the usual mode, baked in an oven, which prevents it from setting within twenty-four hours.
Many specimens of ornament worked with this composition by Durham, who was a pupil of Catezi's, may be seen in many parts of the north of England.

Stucco, used at the present day for the working of Gothic ornaments, such as bosses, spandrels, and corbels, is merely a simple mixture of putty, with silver or very fine house-sand.

337. Plaster of Paris, as it is commonly called, is the composition on which the plasterer materially depends for giving the precise form and finish to the decorative part of his work; by its aid he executes all the ornaments applied to ceilings and cornices, besides sometimes mixing it with his lime used in the finishing coat of the walls and ceilings of rooms, in cases of emergency, when time is of material consequence.
This composition is known amongst chemists, by the several names of sulphate of lime, selenite, and gypsum.

The property which plaster possesses, of setting into a compact mass when mixed with water, was, according to Herodotus, the Greek historian, well known to the ancients. According to his account, the inhabitants of Ethiopia had a peculiar method by which they preserved the remembrance of their deceased relatives. After having dried the body in the sun, they enveloped it in a paste of gypsum, and afterwards painted the likeness of the real figure on the encrustation with which it was covered.

The sulphate of lime is found in immense quantities in the hill named Mont Martre, in the vicinity of Paris, and hence its name, plaster of Paris. The stone from this place is, in its appearance, similar to common freestone, excepting its being replete with small specular crystals. The French mode of manufacture is by breaking the stone into small fragments, about the size of an egg, then burning it in kilns with billets of wood, until the crystals lose their brilliancy; it is afterwards ground with stones to different degrees of fineness, according to the different purposes for which it is intended. This kind of specular gypsum is found in great abundance in Russia, where it is said to be used in the windows of their cottages, as a substitute for glass.

The specific gravity of gypsum, or plaster of Paris, varies from 1.872 to 2.311and, according to Bergman, contains 32 parts of lime, and 68 of acid and water, requiring 500 parts of cold, and 450 of heat, to dissolve it. In the process of burning, or calcination, it decrepitates, becomes very friable and white, and heats a little with water.

The plaster commonly used in the metropolis is prepared from a sulphate of lime, produced in Derbyshire, and called alabaster. It is brought to London in a crude state, calcined, and afterwards ground in a mill, when it is ready for use, being usually sold in brown paper bags, each containing about half a peck.

At Chelaston, near Derby, 800 tons are annually raised. It is also found in most of the cliffs in the Severn, especially at the Old Passage, near Bristol. There are also excellent quarries near Rippon and Hull, in Yorkshire, great quantities being annually shipped from the latter place.

This mineral is much used in Derbyshire, for laying the floors of cheese-rooms, granaries, &c. After preparing it in the usual way, they mix it with water, and spread it on the floors about 2 ½ inches thick, which, when dry, forms a smooth surface and durable flooring, the whole expence not exceeding 1s. 6d. per square yard.

Of External Compositions.
341. Within the last fifty years, considerable improvements have been made in the art of Plastering, by the invention of various compositions for the covering of the exteriors of buildings, such as **Roman Cement, Terra Cotta, Mastic, and Bailey's Composition.**
These compositions are susceptible of being applied both to the finishing a plain face, to be jointed to imitate stone, and also in the formation of ornaments of every description.

Before the period alluded to, the application of cements to the exteriors of buildings was unknown; but the facility of their adaptation, on account of their cheapness, has tended greatly to foster the art of design, and produce a diversity of architectural display which heretofore was never dreamt of, as an inspection of Regent Street, and the terraces in the Regent's Park, will fully substantiate.

The careful study of the antique examples of architecture, both in Greece and ancient Rome, has also acted as a powerful stimulus to the promotion of the art of design, as well as ornamental plastering, more particularly in the getting up of Greek and Roman capitals, the former of which were, until within the last few years, scarcely known in this country, and the latter have been most amazingly improved by means of a reference to the casts procured from the originals now extant.

The invention of compositions has, no doubt, been facilitated by the great scarcity of good stone in the southern parts of Great Britain, a misfortune which appears very evident in comparing the streets and public buildings of the metropolis with those of the Scottish capital.

342. Roman Cement, which is by plasterers, for the sake of brevity, called Compo, was first introduced to public notice by the late James Wyatt Esq. It was originally known as Parker's Patent Cement, and sold by Messrs. Charles Wyatt and Co., Bankside, London ; but there is now a **much superior article** prepared from **a stone discovered by William Atkinson, Esq., on the estate of the Earl of Mulgrave, at Sandsend, near Whitby, in Yorkshire, and which is now universally known by the appellation of Atkinson's Cement**. The latter is certainly, in the first instance, a little higher in price, but it will bear a great deal more sand than the former; is of a more delicate stone colour, and for situations constantly exposed to the action of water, not to be surpassed by any cement now in existence.

Roman cement is prepared from the kind of stone, called clay-balls, or septaria, by being, after the manner of manufacturing plaster, first broken into pieces of a convenient size, slowly calcined in kilns or ovens, and afterwards ground to a fine powder, and put into proper casks, great care being taken to preserve it from damp.

Two parts of this composition, with three parts of clean grit-sand, will form a very durable substitute for stone. In selecting the sand, great care must be taken to procure it possessing qualities of a sharp and binding nature, and free from clay or mud; if it cannot be procured free from these, it must be washed until perfectly clean.
After the walls intended to be covered have been well soaked with water, the cement must be prepared by the hawke-boy on a stuff-board made for the purpose, adding as much water as brings it to the consistency of paste, but no more must be mixed than can be used in ten minutes. It must be laid on with the greatest possible expedition, in one coat of three- quarters of an inch in thickness, and, after being well-adjusted with the floating-rule, the hand- float

must be incessantly used to bring it to a firm and solid surface before it sets, which takes place within fifteen minutes, if the cement be good.

When the work is all finished in the stuccoing, viz. after it has been drawn and jointed to imitate well-bonded masonry, it may be coloured with **washes composed of five ounces of copperas to every gallon of water, mixed with a sufficient quantity of fresh lime and cement, adding the colours necessary to produce an exact imitation of any particular stone which may be required.** When this mode of colouring is executed with judgment, and finished with taste, so as to produce a picturesque effect, by touching the divisions with rich tints of ochre, umber, &c., it is with difficulty distinguished from real stone.

It has been attempted, and in some cases very successfully, to produce ancient Gothic ruins in cement, and although to consummate the deception, great skill and judgment are required, yet we have no doubt that, by paying proper attention to the style of architecture, as well as the manner of colouring, imitations of this kind might be carried to great perfection.

FARMER'S GUIDE, COMPILED FOR THE USE OF SMALL FARMERS AND COTTER TENANTRY IRELAND. 1841.

The cottage walls should be built of stone, either dry or with mortar, the crevices in the former case being well filled with moss, or dry peat mould, and both outside and inside carefully pointed with mortar. The inside should never be without whitewashing, at least once a-year. This is of consequence on the score of health, and also makes your rooms lighter, giving a cheerful appearance even in the gloomiest weather; and there is a decency and propriety in a nicely whitewashed apartment, however homely the furniture, that is always pleasing. The floors may be of earth or, clay, well mixed with sand and lime, and beaten hard and smooth, and raised from eight inches to a foot above the level of the ground outside; the roofing ought to consist of beams and rafters laid properly on the walls, and the thatch may be of heath, bent, fern, or straw, and should be well laid on, at least one foot in thickness. Fern and heath make a durable thatch, either singly or mingled with straw; but the best of all roofing is slate, whether for the palace or the cottage.

The Penny Magazine of the Society for the Diffusion of Useful Knowledge Volume 11(1842). London. Charle Knight & Co.

Different carbonates of lime have different degrees of excellence as materials for cement. Marble and chalk are, for opposite reasons, unfitted for the purpose. Bituminous and magnesian limestones are capable of being 'calcined' and "slaked' into a valuable material for mortar. Those varieties of limestone which contain a considerable proportion of iron, or iron mixed with clay, are capable of forming a cement which will bear exposure to the water, and which thus acquires a peculiar value in engineering operations. Of these latter kinds an example is furnished by the chalk marl or grey chalk, which is the lowest stratum of the chalk formation, and exhibits a considerable admixture of ferruginous clay, amounting sometimes to twenty-five per cent. The blue limestone, or lias-limestone, which extends in a continuous stratum, averaging two hundred and fifty feet in thickness, from Yorkshire to Dorsetshire, is a valuable carbonate of lime, in which the ferruginous clay varies from nine to twenty two per cent. The ferruginous clay, just alluded to as an ingredient which converts lime into a water-cement, appears to exist in puzzolana, trap [trass], and Rowley rag. The first of these (found by the ancients in the Bay of Baiae) is a concreted mass of volcanic ashes. The second is a bluish-black lava, found near the Rhine, and used by the Dutch as a material, when mixed with lime, **for water-cement**. The third is a basaltic material, capable of being used for the same purpose as trap. The substance which is most commonly used with slaked lime as a material for cement is sand, or small flinty particles, which seem to act as a means of clinging the particles of lime together and combining them into a whole.

In the manufacture of lime from limestone, it is necessary to slake it, or convert it into a hydrate of lime, very soon after the stone has been burnt; otherwise carbonic acid will be re-absorbed. A piece of white Bristol lime has been known to increase in weight 33 per cent in seven days, simply by exposure to the air. The chemical changes which distinguish every part of the preparation of lime for mortar are curious; for the limestone loses a considerable portion of weight by being converted into quicklime, and the latter again increases in weight by conversion into slaked lime. If slaked lime be mixed with water, it will form a paste or cement, but of so weak a nature, that a shower of rain will wash it away. Sand, or some other hard pounded substance, is therefore added to give firmness.

Common London mortar consists of one part white chalk, lime to two and a half of clean sharp river-sand; but if the lime has been imperfectly burned, or if the sand be dirty (both of which too often occur), the mortar adheres imperfectly to the bricks. The Romans had an intimate acquaintance with the nature of mortar cements; for Pliny relates that there was a law among them to the effect that **after the ingredients of mortar had been rubbed together with a little water, they should remain in a covered pit for three years before being used.** He states that the buildings in which this mortar was used were more durable than others in which the mortar had been made from lime not so treated; and also that certain buildings had failed because the mortar employed in their construction contained **too large a proportion of sand.** The number of water-cements and kinds of artificial stone proposed at various times is considerable, both in relation to the number of ingredients and the proportions between them. The substance employed by the Romans as a cement for moles and other structures exposed to the action of the sea, consisted of three parts of puzzolana mixed with one of lime. British engineers have used a great variety of such cements, composed frequently of mixed lime and sand, but some times of other substances. Smeaton employed in the construction of the Eddystone Lighthouse a cement formed of equal bulks of powdered Aberthaw lime and powdered puzzolana; the mortar made from these ingredients was well beaten before being used, a process which seems to increase the tenacity of the cement.

In the neighbourhood of Dorking is found a kind of grey chalk which forms an excellent water cement when mixed with three or four times its weight of sharp river-sand. A kind of water-cement used for setting the bricks that form the facing of the London Docks was formed of lias-lime, river-sand, puzzolana, and calcined ironstone. A cement called cendrée, or Tournay ash mortar, is made in a very curious manner; large pieces of lias-lime are burned in a kiln, and with the ashes of the fuel are afterwards found small fragments of the lime, in the average proportion of three parts of ashes to one of lime. Of this mixture about a bushel at a time is taken, and is sprinkled with water only sufficient to slake the lime; the whole quantity, thus treated, is then put into a pit and covered with earth, where it remains for some weeks. It is then taken out, and well beaten with an iron pestle for half an hour, which brings it to the consistence of soft mortar; it is then laid in the shade for a day or two to dry, and again beaten till it becomes soft. This is repeated three or four times, till at length it is only just sufficiently soft for use; being then applied to brick or stone, it forms in a few minutes a very compact mass, and after twenty four hours has acquired a stony hardness.

Within the last few years many schemes have been set on foot, and many patents procured, for the manufacturing of cements and artificial stone from various ingredients. In some cases the object is to form a mortar, with which stones or bricks may be bound together; in others, a water-cement for liming walls and other structures exposed to the action of water; in others, to form a pavement, terrace, or floor. One patent is for "making cement from the accumulated sand in the mouth of Harwich harbour;" another, "from calcined limestone and clay;" a third, under the name of "Vitruvian," composed of "marble, flint, chalk, lime, and water;" another, from "slaked lime and white clay;" a fifth, from "Painswick ragstone and Bisley stone." A manufacturing chemist at Manchester proposes to use as materials for cement the hitherto useless residue from the manufacture of chromates of potash and soda, and other salts; the residue contains lime, oxide of iron, silicate of alumina, and other substances which are supposed to form fitting ingredients for a durable cement.

Doyle M (1844) CYCLOPEDIA OF PRACTICAL HUSBANDRY, RURAL AFFAIRS IN GENERAL. BY MARTIN DOYLE, London 1844

Stones and bricks are often too scarce and expensive for the poorer classes of farmers and labourers; but happily for them, **clay walls, if properly constructed, and well plastered and dashed on the outside with lime-mortar, are cheap, durable, and warm**. The mode of preparing mud wails is as follows:

A sufficient quantity of cohesive clay, free from any stones, being collected, the labourer digs it thoroughly, and renders it as fine as possible; when well saturated with water, he works it with his shovel until it acquires the consistence and toughness of dough.

After lying eight or ten days, it should be again wetted sufficiently for use, and a small quantity of sound chopped straw (for if this be long and stringy, the surface of the wall will not be easily dressed and polished afterwards) is to be intermixed through the mass. The foundations of the walls are best laid with stone, or brick, two feet or more in depth, and two feet in thickness. On these, the mortar, being sufficiently turned and worked, should be placed in courses of two or two and a half feet in height. At this level it has been recommended by a recent writer, who himself attached great importance to the invention, to bed into the mortar at the angles, single or double ties or braces, of any timber, provided its scantling be not less than two inches and a half, and to pin them into the walls with pegs about nine inches long.

…Before the winter rains set in, the roof should be put on with double collars, and thatched with a considerably projecting eave, for the protection of the walls: walls left unthatched, soon become materially injured. Common farm-labourers are in many places very expert in building these walls, and smoothing them at both sides perfectly with spades. If the plastering and dashing, or either, be carefully preserved on the outside, such walls will last for a long series of years. The floor should be laid on a stone foundation, as well as the partition walls, and covered with tiles, bricks, or clay and lime mortar, well tempered and evenly laid.

Thatching is often very defectively executed. The thatcher, in order to save the labour of his hands, allows the straw to be almost rotten before he uses it, instead of wetting and pressing it well as he requires it. Wheat or rye straw, not beaten by the flail, but left in a reedy state, is better than any other kind of straw; but the true Irish thatcher will not admit this. He asserts, from ignorance of his trade, that reedy straw soon decays from exposure to the weather — that its unfitness for compression causes it to fail — that it cannot be made to lie as close as barley straw, which is generally preferred by those who do not understand the English method of preparing strong straw, by combing off the short straws, and lapping the layers of thatch, (tied down at narrow intervals by twine to the rafters,) so that every drop of water quickly runs off as from a bundle of quills.

Wheat or rye straw is much more durable for thatch than spring corn straw, and resists the wet much better on account of the silex contained in it, which gives that varnished quality that enables it to throw off moisture. Barley and oat straw imbibe moisture like a sponge. Wheat and rye being sown in the autumn have longer time to absorb the silicious matter from the soil into which they push their roots often to a prodigious extent.

Thatch properly put on by an experienced hand, will last four or five times longer than the coat of straw, beaten, pressed, and half-rotted, in the usual Irish fashion. The English mode of fastening down the thatch on the ridge with bent twigs, fancifully arranged, is very neat. Where this is inconvenient, a coat of mortar on the ridge, with pointed elevations of the same substance at the extremities, in the form of gigantic comfits, as they are pasted over many of the cottages of Forth and Bargy, in the county of Wexford, and white-washed annually, has a very clean and decorative appearance.

In many parts of England walls of mud and straw are used about the farmer's house and yard, with a thatched eve; they last some time, if not exposed to severe frost, which soon crumbles them away; at best they are not very durable, and are much less permanent than wooden walls or paling, where timber is abundant and cheap.

The Builder's Pocket Manual Containing the Elements of Building, Surveying & Architecture ... by A. C. Smeaton

A. C. Smeaton January 1, 1840
London M.TAYLOR,1,WELLINGTON ST. STRAND.

CEMENTS. Having explained the manner in which bricks are made, and the means of distinguishing their qualities, it willbe necessary to state the composition of the several kinds of cement that are used in order to bind or connect the several parts together; and it may here be necessary to mention that we shall not confine our remarks to those cements which may be used by the bricklayer, but shall also refer to those which may be commonly employed by the mason; for as we must speak of the origin of the cementitious principle, it seems desirable to explain all the several kinds of substances, in the composition of which this principle is called into action. But before we speak of the cements themselves, it will be necessary to refer to the nature of that substance, lime, which is their principal ingredient.

LIME
distinguished from other substances by its properties. It is an earth having a colour, and produces a caustic sensation upon the tongue; is incapable of fusion by ordinary temperatures, being one of the most infusible substances in nature, and is but little soluble in water, though it is more soluble in cold than in hot water. Lime is seldom, if ever, found pure in nature, but is generally in combination with an acid; most frequently with carbonic acid, as in the formation of chalk, limestone, and marble. Lime is a very abundant ingredient in the composition of the earth's crust, and generally makes its appearance as a carbonate, but both sulphates and carbonates of lime are found to occur as constituent parts of mineral substances. To obtain pure lime, that is, lime separated from an acid, with which it is uniformly combined in nature, the mineral must be submitted to a red heat, which drives off the acid and leaves

the lime in a state of purity; it is then called caustic or quicklime. Chalk, limestone, marble, oyster-shells, and other substances, are carbonates of lime; and either of these will, when burnt, furnish the material required in building; but the two former are chiefly used for this purpose.

Builders are well aware of the fact that all limestones, or mineral substances containing lime as an ingredient, do not possess the same cementitious properties. One stone may yield, when burnt, a lime very superior to another, and this difference depends upon the quantity and character of the adventitious substances which are combined with the lime. Many of these may be detected by the appearance of the mineral, or by very simple experiments. When the limestone has a deep brown or red colour, it generally contains iron, and when burnt has a yellowish hue; when it does not freely effervesce with the application of an acid, and is sufficiently hard to scratch glass, it contains silex; when it effervesces slowly, and gives a milky appearance to the acid, it contains magnesia. The effects of these and other substances upon cements, have not been accurately determined. The cementing quality of lime seems to arise from its chemical combination with the substances with which it is mixed. First of all it unites with a certain proportion of water, forming a hydrate of lime , which appears to have a chemical attraction for silica, that is to say, the sand with which it is mixed. After exposure to the atmosphere for a short time, it abstracts and applies a portion of carbonic acid, which greatly increases its hardness, and on this account all old mortars are remarkable for their cohesion and strength, frequently becoming stronger than the stones they unite. Sir Humphrey Davy, speaking of cements, says. " The cements which act by combining with carbonic acid, or the common mortars, are made by mixing together slaked lime and sand. These mortars at first solidify as hydrates, and are slowly converted into carbonate of lime, by the action of the carbonic acid of the air. Mr. Tennant found that a mortar of this kind in three years and a quarter, had regained 63 per cent of the quantity of carbonic acid which constitutes the definite proportion in carbonate of lime." But there are two kinds of cement used in building: that in which lime forms a prominent combination with water. and this is called a water cement; and that which combines with carbonic acid, which is called a mortar: this distinction is a very important one; one kind has the property of setting under water, the other has not.

Sand.

Sand is a. very important ingredient in cements, and too much pains cannot be taken to obtain it pure. River sand should be always preferred to pit sand, for it is less likely to be mixed with clayey or other substances, which greatly injure the indurating property of the cement. But wherever the sand may be obtained, it should be well washed, and this is especially necessary if taken from the sea; for the salt with which it is combined, having strong hygrometric properties, would prevent the cement from drying. This effect we remember to have frequently observed in a little seaport town, where beach-sand had been used by the builders without suflicient washing.

Mortar. Mortar is made of lime and sand, thoroughly mixed together, and brought into the consistency of a paste, by the addition of water. Different proportions of these substances are used by builders; and this must necessarily be the case, for a larger or smaller quantity of sand must be added in proportion to the quality of the lime. A good lime will take more sand than a bad one, and the value of the cement may, in a great measure, be judged of by the quantity of sand it contains. Builders are accustomed, for instance, to use more sand with stone~lime than with chalk-lime; not that there is in general much difference between the two, when first burnt, but because the quality of the chalk-lime is speedily injured by a very rapid absorption of carbonic acid. With one hundred and fifty peeks, that is, thirty-seven and a half striked bushels of chalk-lime, the workman mixes two loads of sand, each load consisting of thirty striked bushels; but twenty bushels of stone-lime will frequently bear two loads and a half of sand. It is estimated that the mortar produced by either of these proportions, will do a rod of brickwork, that is, two hundred and seventy-two and a. quarter square feet, superficial measure, a brick and a half thick, that is, about fourteen inches. According to the experiments of Dr. Higgins, a proportion of one peck of lime to seven of sand makes the best mortar. When mortar is to be used in a situation where it will dry quickly, it should be made with as little water as possible, but it is better that the mortar should dry gradually and slowly, as it then becomes more indurated. It is stated by some writers that mortar is injured by keeping, and under one condition, exposure to the air, it is; but, if excluded from the air, it is rather benefited than injured. Pliny states, that the Roman builders were prohibited by law from using a mortar that was less than three years old; and attributes the stability of all their large buildings to this circumstance. But when old mortar is used, it should be well beaten up before it is employed. The reader must not, however, suppose that these remarks justify the exposure of mortar to the air for a considerable time before it is used, a practice very common but highly improper. This practice probably arose from the difficulty which workmen sometimes find in slaking the lime, in consequence of its being insufficiently burnt, or containing a large portion of argilaceous matter. But of all other things, it is important to use good lime, and to soak the bricks which are to be bedded, before they are laid; for, if the bricks are dry, they imbibe the moisture of the cement, and destroy its quality. There are two things which cause mortar and cements generally to crack, too small a quantity of sand and a too rapid exhalation of the water. There must always be a contraction, but it is least in these mortars which contain the greatest proportion of sand; for it is the moistened lime which contracts during the process of drying. All mortars may, for a time, be affected by atmospheric changes, and especially by alternate wetting and freezing; but this is most remarkable in those which are liable to crack. A mortar which sets without cracking will always stand afterwards. Dr. Higgins, to whom we are much indebted for his experiments upon cements, invented one which he speaks of as admirably adapted for both internal and external work; and becomes as hard as Portland stone when dry. "Take," he says, " fifty-six pounds of coarse sand and forty-two pounds of fine sand; mix them on a large plank of hard wood, placed horizontally; then spread the sand so that it may stand at the height of six inches, With a flat surface, on the plank; wet it with the cement ing liquor; to the wetted sand add fourteen pounds of the purified lime, in several successive portions, mixing and beating them together; then add fourteen pounds of the bone-ash in successive portions, mixing and beating all together." Whatever may be the quality of this cement, it is not likely ever to come into general use, as it would be more expensive, and give more trouble in preparation, than many others which are now found to answer the builder's purpose. This, however, was pro posed as a water-cement. Mortar is evidently unfit to be used in any situation where the force of water is to be resisted; for although it is said that mortar-composed of lime and sand, in the proportion of one and seven, will not suffer from water, yet, as this composition is seldom, if ever, obtained, it would be folly to risk the security of a building by its use.

The insufficiency of mortar for all those works, the whole or part of which are under the water, induced the scientific builder and chemists to seek a substitute. Many compositions have been recommended, and several of them have been found to answer the purpose. There is one substance, however, Roman cement, which, above all others, is extremely useful for a number of purposes, and will require our attention; and if our remarks should occupy a space which may appear to have no proportion to the length of the other parts of the volume, the importance of the subject will be a sufficient excuse.

The Plasterer

Coarse Stuff. Coarse stuff; or lime and hair, as it is sometimes called, is prepared in the same way as common mortar, with the addition of hair procured from the tanner, which must be well mixed with the mortar by means of a three-pronged rake, until the hair is equally distributed throughout the composition. The mortar should be first formed, and when the lime and sand has been thoroughly mixed, the hair should be added by degrees, and the whole so thoroughly united that the hair shall appear to be equally distributed throughout.

for inside of Walls. This stucco consists of the fine stuff already described and a portion of fine washed sand, in the proportion of one of sand to three of fine stufl'. Those parts of interior walls are finished with this stucco which are intended to be painted. In using this material, great care must be taken that the surface be perfectly level, and to secure this it must be well worked with a floating tool or wooden trowel. This is done by sprinkling a little water occasionally on the stucco, and rubbing it in a circular direction with the float, till the surface has attained a high gloss. The durability of the work very much depends upon the care with which this process is done, for if it be not thoroughly worked, it is apt to crack.

Gauge Stuff. This is chiefly used for mouldings and cornices which are run or formed with a wooden mould. It consists of about one fifth of plaster of Paris, mixed gradually with four fifths of fine stuff. When the work is required to set very expeditiously, the proportion of plaster of Paris is increased. It is often necessary that the plaster to be used should have the property of setting immediately it is laid on, and in all such cases Gauge Stuff is used, and consequently it is extensively employed for cementing ornaments to walls or ceilings, as well as for casting the ornaments themselves.

Bailey's Compo. The plaster or stucco known under this name is composed of three parts of Dorking lime, and one part of fine washed river sand. These ingredients are well mixed together in a dry state and put into casks, to prevent the access of the air. When required for use it is first mixed with water to the consistence of thick whitewash, and applied with a. stiff brush, as a ground, preparatory to spreading the wall with a mortar of sufficient thickness. The mortar is floated, that is well rubbed with the wooden float, or the trowel, sprinkling it occasionally with water, till the surface is quite smooth and level.

Higgins' Patent Stucco. The stucco invented by Dr. Higgins is **seldom, if ever, employed, as much from the trouble as the expense of making it.** To fifteen pounds of the best stone lime add fourteen pounds of bone ashes, finely powdered, and about ninety-five pounds of clean, washed sand, quite dry, either coarse or fine, according to the nature of the work 'in hand. These ingredients must be intimately mixed, and kept from the air till wanted. When required for use, it must be mixed up into a proper consistence for working with lime-water, and used as speedily as possible. Parker's Cement. This cement, which is perhaps the best of all others for stucco, as it is not subject to crack or flake off, is now very commonly used, and is formed by burning argillaceous clay in the same manner that lime is made; it is then reduced to powder, by the process described in a previous part of this work. The cement, as used by the plasterer, is sometimes employed alone, and some times it is mixed with sharp sand; and it has then the appearance and almost the strength of stone. As it is impervious to water, it is very proper for lining tanks and cisterns. –

As this is the most common wash for walls, and is at the same time the cheapest, it is generally used for common work. But a very superior wash may be made with it, if proper care be taken in its preparation, for it is less apt to peel than those which are made with whitening and size. The following process will be found to answer the purpose: Take a sufficient quantity of small pieces of the best lime, and pour clean water upon them, stirring the liquid for some time. Then let the solution remain for a few minutes, and pour it into another vessel, leaving the heavy particles behind. Add more water, stirring it as before, and leave it again to settle. Then pour off the water from the top, and strain the whole through a very fine sieve, and keep it covered until wanted for use, when a sufficient quantity of water to reduce it to the proper consistence may be added. In using lime-wash, it is better to put two thin coats on a wall than one thick one, for the first coat has often a smeary and uneven appearance. With these precautions a very superior lime-wash may be made, fit to be used for any kind of work, and not liable to the faults of the common wash. It is, however, necessary that care should be taken as to the cleanness of the wall or ceiling to which it is applied, and especially that it be not applied over a coat of size, for then it is almost sure to turn yellow.

Thomas Webster T (1844) AN ENCYCLOPEDIA OF DOMESTIC ECONOMY: London. Longman, Brown, Green and Longmans

P29 Subject. 3.—Mortar and Cement.

88. Where walls have been constructed with very large and heavy blocks of stone, as was the case with some in ancient Greece and Italy, the remains of which, called Cyclopinn, are seen to this day, no cement was necessary, the weight of the masses being sufficient to keep them from being displaced; but with bricks or stones of the ordinary size, some cement is required to make a firm wall. In countries where bitumen is plentiful, this substance has been employed, as was the case in the buildings of ancient Babylon, existing remains of which have been described by recent travellers.

But cements derived from calcareous substances are by far the most general, and are the only ones used in this country for the ordinary purposes of architecture. **Our common mortar is composed of lime made into a paste with water and sand,** which, when completely dried, becomes of a stony hardness; and, the strength of walls depending much upon the excellence of this material, it is proper that the principles upon which its good quality depends should be understood.

89. Lime, or calcareous earth, familiar by sight to every one, is never found pure in nature, but is always combined with some other substance. Before it can be employed for mortar, it is necessary to detach it from its combinations; and all of what is so employed is obtained by exposing certain limestones to a strong heat, or burning them, as it is termed, in a kiln. Limestones consist of lime combined with carbonic acid, the properties of which as a gas will be particularly detailed in our section on Fermentation. In the limestone it is, however, in a solid state, combined with lime; and the stone is what chemists term carbonate of lime. When a red heat is applied to lime stones, the carbonic acid separates from the calcareous earth in a gaseous state, and flies off, leaving the lime pure, which is then called quicklime. This quicklime differs essentially from powdered limestone, and from chalk, which is also a carbonate of lime, in being caustic and soluble in water, which the carbonate is not. **The newly-burnt caustic lime is next to be slaked by pouring water upon it;** the lumps immediately crack, fall to pieces, and soon become a fine white powder, at the same time giving out much heat, which occasions abundance of steam. **But the greater part of the water is absorbed, enters into combination with the quicklime, and passes into a solid state; for instead of a moist paste being the result, as might be expected, the lime remains quite dry in the state of white powder. The union of the water with the lime forms a hydrate of lime, and is termed by builders slaked lime**.

90. Limestones are easily distinguished from other rocks, by pouring upon them a little diluted acid of any kind, such as the nitric or muriutic: if an effervescence ensues, or the rapid formation of minute bubbles, the substance is limestone, the bubbles consisting of the carbonic acid gas which has been liberated from its combination, on account of the lime having a stronger attraction for the new acid than for the carbonic acid. A few other minerals besides limestone will afford the same appearance of effervescence; but as these are not in sufficient quantity to form large rocks, this test may be considered as practically sufficient to ascertain limestones. Although all limestones consist essentially of lime and carbonic acid, and though may be obtained from them all by chemical means, yet, practically, all are not equally fit for burning into lime: for instance, white or statuary marble is a very pure carbonate of lime; but, when heated in a kiln, it is sometimes liable to fall into a coarse powder before the carbonic acid gas can be driven off, which prevents quicklime being obtained from it. Nor is it necessary that the limestones should always be of the purest kind for this purpose; for **many limestones that contain a small quantity of other substances make better lime for mortar than the purest carbonate of lime**. Limestones, indeed, may be divided into two kinds, as far as relates to their affording lime for mortar. Those which consist of pure, or very nearly pure, carbonate of lime; and those which, besides lime and carbonic acid, contain likewise a portion of clay, iron, magnesia, and sometimes a minute quantity of other matters. **The lime procured from the first is capable of making a mortar that dries hard in the air, and which, when well made and become thoroughly hard, will not afterwards soften in water; but if water he kept in contact with it before it has dried, it will never set or become hard: hence it is totally unfit for hydraulic purposes, or building under water.** On the contrary, all those limestones that contain a considerable proportion of clay, and particularly if that be ferruginous, afford, when burned, what is called **hydraulic or water lime, because, when made into mortar by the addition of sand and water, such mortar sets hard even under water; on which account it is extremely valuable for building piers, docks, and similar works.** An opinion is very generally entertained among builders, that the harder the limestone, the better must be the lime obtained from it by burning. But this is not strictly true.

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Chalk, when burned in the best manner, as it was by the late Lord Stanhope, makes lime as fit for mortar as the hardest pure limestone, provided it be used for this purpose immediately: but it is a fact of practical importance, that lime made from soft porous stones like chalk absorb from the atmosphere the carbonic acid which they have lost in burning, **sooner than lime made from more compact stone**; and as chalk lime is seldom secured from the access of air before it is worked into mortar, it has sometimes returned so far to the state of chalk as nearly to have lost its binding quality. Every description of lime should be used as fresh as possible. **The lime used for common mortar in and about London is made from white chalk, often imperfectly burned; but a superior**

kind is procured from employing the grey chalk of Dorking, which contains some clay, yet not enough to form the best hydraulic lime.
91. The sand for mortar should consist of clean, angular, silicious grains, not too fine, and as free as possible from any admixture of earthy substances. River sand is usually the best, or pit sand if it be of the proper size, and not dirty, which it is apt to be; clay or earth of any kind weakening the mortar. Sea sand is improper, except it is well washed to deprive it of the salt that adheres to it, as that would prevent the walls from ever being dry, causing them to attract the humidity of the atmosphere. The sand is passed through a skreen or sieve, to reduce it to the proper degree of coarseness; and what consists of very small rounded grains is not so proper as what is rather coarse and sharp. Old and bruised mortar skreened, and rubbish scraped from the roads, which some brick layers are apt to use, are improper.
92. **To form mortar, fresh slaked lime is mixed up with a sufficient quantity of proper sand, water enough being added to make it into a tough paste.** In mixing the lime and sand together, considerable labour should be used; as it is found that the beating the mortar well, so as to incorporate the materials thoroughly, is essential to make it of good quality, and fit for the mason or bricklayer. The inferiority of modern to ancient mortar has been a subject of frequent remark and regret; and the chief cause is, no doubt, owing to the less care now taken in the selection of the materials, and the less labour bestowed upon them. The lime employed for London houses is sometimes imperfectly burned; and having been conveyed from a distance of from ten to twenty miles, without any precaution to keep it from the air, it has often lost much of its cementing properties before it is used. This is too frequently mixed with dirty sand, except a surveyor superintends the work; **and the whole is merely incorporated with a spade, in a slovenly manner, with too great a quantity of water, to save trouble in beating it.**
93. Hydraulic mortars, or water cements, are, as we have stated, made by using lime from limestones containing clay, generally ferruginous, or from other materials not calcareous, which we shall describe. ‘

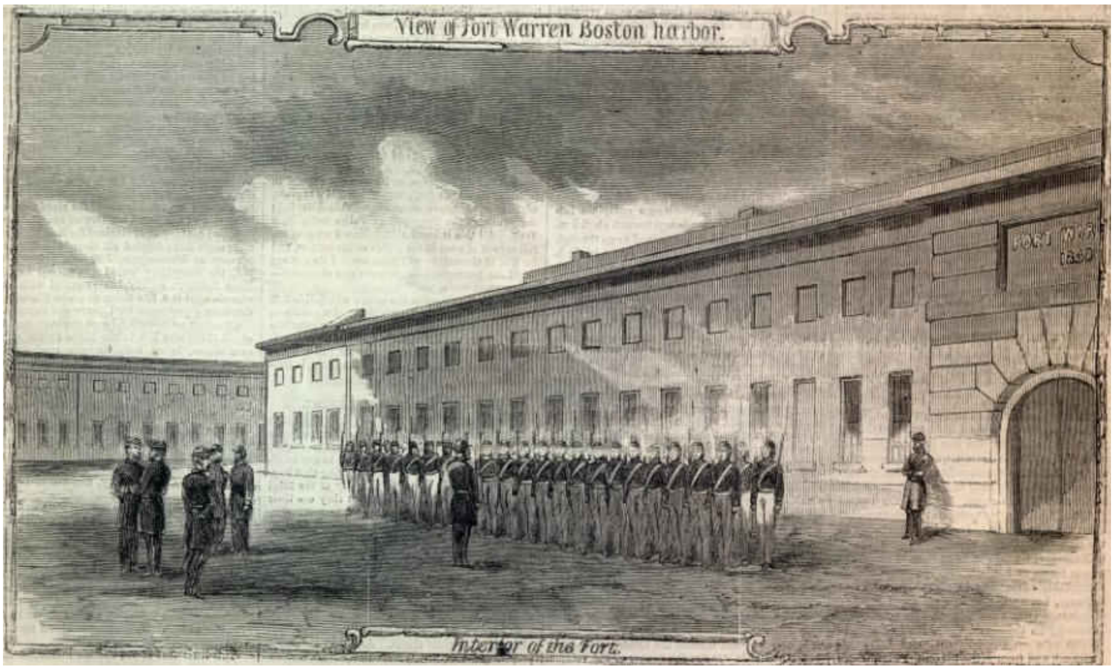
Limestones of this kind are found in various countries, though less commonly than pure limestones. In England, the most abundant material of this kind is the Lias limestone, which is found in a belt stretching across England, from Whitby to Lyme Regis, in Dorsetshire; and it is likewise plentiful round Bath, and in several parts of Gloucestershire. It has long been extensively worked at Watchet, Aberthaw, and Barrow in Leicestershire. The Lias stone, which is found in thin beds alternating with slaty clay, is of a dull grey colour and earthy fracture, containing about 11 per cent. of clay and iron. The lime made from it was employed successfully by Smeaton in constructing the Eddystone lighthouse, mixed with Puzzolano. **In Bath and other places this, with sand, forms the common mortar, which is excellent. In London it is little used, from its price being 25 per cent. more than that of Dorking lime**; but it is employed in a cheap and good stucco. There are a few other substances, not calcareous, that are still superior to those we have mentioned, for their property of causing mortar to harden under water. Pozzolana is brought rom Pozzuoli near Naples, and consists of volcanic ashes that have concreted into a cellular mass of a baked appearance and rusty colour. It was this material that enabled the Romans to construct those remarkable moles and summer retreats in the bay of Baim, the ruins of which may yet be traced in the sea. When mixed in proper proportion with mortar made with common lime and sand, it causes it speedily to set under water, and become as hard as stone, affording the strongest water-cement known. Dutch tarras or trass is another substance nearly similar, which used formerly to be imported from Holland, where it is extensively employed in hydraulic works. This is made from a porous lava found near Andernach and other places on the banks of the Rhine: it is ground to powder, for the purpose of using instead of Pozzolana. **Its use here is now superseded by Parker's cement,** which will be described among stuccoes. Grout, or liquid mortar, is common mortar made so fluid with water, that when poured on a course of brickwork when just laid, it will run into the joints, and cement the whole together very firmly: this practice is employed occasionally where great strength of walls is required.

94. Asphalte is a material lately introduced into building, and which has some valuable properties. It is a bituminous substance, found in various places; but perhaps the (p31) best known to us is that brought from the south of France, where it is found near the town of Seyssel, on the east of the Jura. It is there dug as a calcareous stone impregnated with bitumen: this is pounded and exposed to a strong heat, by which the whole is fused or rendered soft; when cooled it is made to form a hard cement. The asphalte is used in various ways, mixed with sand, gravel, pebbles, &c. according to the various uses to which it is applied. It has been largely employed, instead of stone, in the trottoirs or side pavements in Paris and other places; and examples of this kind may be seen in various places in London, which appear to answer very well. This would no doubt be imitated oftener, but that our abundance of good stone renders it less necessary to use this resource. It is very useful as floors in offices of buildings of various kinds, being perfectly tight, warm, and impervious to vermin. It is said likewise to form excellent walks in gardens, and succeeds in terraces where damp prevails. It is said to be little inflammable; but it is not used here on roofs, though occasionally employed in this manner on the continent. There are some other varieties of the asphalte, but it is difficult yet to speak of their comparative merits.

Wright W (1845) A BRIEF PRACTICAL TREATISE ON MORTARS: AN ACCOUNT OF THE PROCESSES EMPLOYED AT THE PUBLIC WORKS IN BOSTON HARBOR. BY LIEUT. WILLIAM H. WRIGHT, UNITED STATES CORPS OF ENGINEERS. BOSTON: WILLIAM D. TICKNOR & COMPANY.

Many able works have been written on the subject of mortars. But no one of those, with which I am acquainted, contains enough of detail to afford much assistance to inexperienced constructors; and they are, in general, so voluminous, and withal so badly arranged, that the information which they contain can only be acquired after laborious research. The necessary consequence follows, that few read them, and the composition of mortars, upon which the stability of structures so much depends**, is in most cases left entirely to the judgment of uninformed workmen. Such a system must obviously lead to the worst practical results,** and indicates an absolute necessity for some new effort upon a subject so important.

At the request of the Chief Engineer, and **with the hope of inducing constructors to bestow some personal attention upon the mortars which they employ,** these pages have been drawn up. They embrace every thing of practical interest that I could obtain from the existing treatises at my command, as well as the results of my own experience at Fort Warren, Boston Harbor, while acting as the assistant to Col. Thayer, of the Corps of Engineers, United States Army.



CHAPTER I.

CALCAREOUS MINERALS, AND THE LIMES WHICH THEY FURNISH.

…2. The calcination of each variety of limestone furnishes a different product, with properties peculiar to itself. Yet, in truth, there is but one species of lime (the protoxide of calcium), that which is obtained by calcining pure white marble. All the other products, called heretofore meager lime, hydraulic lime, &c, are only natural mixtures of lime and sand or crude earth, existing originally with water and carbonic acid in the impure limestone.

3. Lime is obtained principally from calcareous minerals, but there are some localities, where it is procured from marine deposits, oyster shells, madrepores, animal products; these, however, are rare cases.

… 6. If pure lime, immediately after being calcined, is mingled with a proper quantity of water, a large amount of hot vapor is evolved, and the lime is reduced to a thick, clayey paste, equal in bulk to more than three and a half times its original volume. The lime is thus brought to a thorough state of division by the addition of water (with which it enters into chemical combination), and is now said to be *slaked*.

7…. if it (quicklime) be pure, and is supplied with water as soon as it comes from the kiln, it will absorb three and a half times its weight (in water) — a property peculiar to lime, and serving to distinguish it from other earths.
Pure quick lime, when converted into paste by the addition of water, will retain its soft consistence, as long as it is kept damp. It is, however, dissolved very sparingly by water, though it possesses the singular property of being more soluble in cold than in hot water. It has a great affinity for carbonic acid, attracting it readily from the atmosphere, and can only be preserved pure by being kept in close vessels.

8. In the preceding remarks, I have spoken of pure lime. **The lime, however, which is used for building purposes, is rarely in this state**, but, besides water and carbonic acid imbibed from the atmosphere, contains usually some of the foreign substances mentioned in Article 4.

These substances modify the properties of pure lime, and, when combined with it in certain proportions, entirely change its nature. It will therefore be convenient to arrange the limes employed in constructions into four different classes: **1st. The fat or common limes; 2nd. The poor or meager limes; 3rd. The hydraulic limes; and, 4th. The hydraulic cements.**
9. The fat or common limes are more than doubled in volume during the process of slaking… Builders call them fat limes, because the paste, which they form with water, is soft and unctuous to the touch.

10. The poor or meager limes include all those which, in slaking, do not undergo an increase of volume equal to twice their original bulk, but exhibit, when immersed, the same qualities as the rich limes, with this difference, that they dissolve more partially in water, leaving usually a large residue of insoluble matter.

11. The hydraulic limes possess the property of setting under water, in periods of time varying from **one to forty days** after immersion, and continue to harden more or less rapidly, according to the hydraulic energy which they respectively possess. They all slake, but with difficulty; the stronger kinds exhibiting few or none of the appearances usually seen in fat lime during the slaking process, little or no vapor being formed, and scarcely any heat disengaged; and they undergo an increase of volume, in the inverse ratio of their hydraulic energy.

12. The hydraulic cements differ from the limes, in not slaking at all after calcination, unless they are previously pulverized; and they then form a paste with water, without any perceptible disengagement of heat, or augmentation of volume. They contain a large amount of the hydraulic base or principle, and set under water in a much shorter time than the limes require to set in air.

....

CHAPTER II.
THE VARIOUS MATERIALS EMPLOYED IN THE PREPARATION OF MORTARS.

These materials may be comprised under three heads:
1st. The limes.
2d. The different kinds of sand, properly so called.
3d. The pouzzolanas, both natural and artificial.

THE LIMES.

The limes were divided (article 8), into four classes viz the Poor Limes, the Fat Limes, the Hydraulic Limes, and the Hydraulic Cements.

The first should never be used, except in case of absolute necessity. Besides being entirely devoid, like the fat limes, of hydraulic energy, they are usually mingled with a large amount of inert matter, and acquire little or no increase of bulk in slaking. My remarks will therefore be directed to fat lime, hydraulic lime, and hydraulic cement; and in the first place to the two former of these. **Fat or common lime, in consequence of its great consumption for building purposes, is now an article of commerce in all the cities of the country, and its manufacture has become an important and distinct branch of the useful arts.** It is prepared on the largest scale in the State of Maine, and the kilns of Thomaston and the neighboring villages furnish it in great abundance, at very cheap rates and of most excellent quality. **At the public works in Boston Harbor, the Thomaston lime has been generally preferred, as it combines lowness of price with a considerable degree of richness.** It slakes promptly, and yields, in stiff paste, a volume of eight cubic feet for each cask of 240 pounds.

Hydraulic limestones (as distinguished from cement stones) exist in great abundance in this country, though, I believe, they are nowhere calcined with a view to sale in the large way. The limes which they yield form the intermediate class between the common limes and the hydraulic cements, and fill up all the gradations between the inert character of the one and the exceeding energy of the other.

Both fat and hydraulic limes should be kept in tight casks and in a dry room, so as to be sheltered as well as possible from the action of the atmosphere. It is economical to use them as soon as possible after calcination, for **if exposed for any length of time in the casks, which soon become loose on account of the**

drying action of the lime, they slake with difficulty, and the resulting volume of paste is greatly diminished**, while the energy of the hydraulic varieties is at the same time much impaired.**

As lime comes from the kiln in the condition of quick lime, it is necessary to slake it, before it can be employed in the preparation of mortars.

There are three modes of doing this. **The first consists in throwing upon it sufficient water to reduce it to a thick pulp. This is the ordinary method, but it is generally abused by pouring so much water upon the lime as to drown it, or in other words to form a thin cream, and thus impair its binding qualities**. One volume of fat lime, slaked in the above manner, yields from two to three and a half volumes of stiff paste, while the meager limes and the more energetic hydraulic limes rarely give more than one and a half volumes.

34. There is one precaution to be observed in employing the method of slaking, above described. **Sufficient water to produce the desired result should be used at first; or at all events, any additional quantity that may be requisite, should be supplied very gradually.** If any portion of lime is permitted to slake to dryness, and water is afterwards thrown suddenly upon it, it appears to become benumbed, and falls to powder very imperfectly.

35. The second method of slaking lime consists of plunging it into water, and then with drawing it after a few seconds, before the commencement of ebullition. The lime hisses, bursts with noise, and falls into fine powder, evolving hot vapor at the same time. It is then said to be slaked by immersion. The powder thus obtained, does not again become heated upon being made into paste with water, and may be preserved for a long time, if care be taken to protect it from the atmosphere.

36. In order to ensure the best result in slaking by immersion, the fragments of quick lime served, should be reduced in the first place to the size of a walnut, and **heaped together, immediately after they are withdrawn from the water, in casks or large bins. The heat is thus concentrated, and a large amount of vapor, which would otherwise escape, is absorbed by the lime**, which is brought in consequence to a more thorough state of division.

This third method of extinction was formerly proscribed, and the powder resulting from it regarded as worthless. (some recent experiments seem to show its development of hydraulic properties, but no general conclusions).

… The ordinary method most perfectly divides the fat limes and the hydraulic limes of all degrees, and consequently raises their expansion to the highest limit.

… We see from the table, **that both fat and hydraulic lime yield the largest volume of paste, when slaked by the ordinary process. The largest quantity of**

mortar may therefore be obtained by employing this method, as the proportion of sand in practice is always regulated by the amount of paste. It must therefore be regarded as the most economical, even if each of the three modes of extinction involved the same cost of manipulation. ***[Totten's experiments also seem to show that it produces the better mortar].***

39. Fat lime, slaked by the ordinary method, may be preserved for an indefinite period of time, by placing it in trenches or other reservoirs, and securing it from the action of the atmosphere by a covering of sand or fresh earth. When slaked by immersion, or spontaneously, it may be kept without change for a tolerably long time, either in casks or under sheds in large bins, covered with cloths or straw.

40. Hydraulic limestone is calcined with difficulty to the proper degree, and when not sufficiently burned, the resulting lime slakes badly. The mortar, made with it in such a state, is less tenacious, and is moreover apt to swell after being used, to the great injury of the masonry. **To ensure thorough slaking, it should generally be allowed, after extinction, to remain twelve hours or more before it is employed**, but it is best in every case to ascertain approximately the time required for this purpose, by experimenting in a small way. **Hydraulic lime becomes hard, however, in a short time after being converted into paste, and should never be slaked in greater quantity than will suffice for two days' consumption at most.** After leaving the kiln, it soon loses a portion of its energy, if exposed to the action of the air, and finally passes to the state of common lime. Notwithstanding the precautions required in its use, it may be employed very advantageously when of good quality; as it frequently offers the only means of making excellent mortars, at a cheap rate.

41. **Hydraulic lime, if previously slaked by immersion, and then secured in the powdered state in casks, or sacks of cloth, may be kept for a long time without sensible alteration**. The following method has, however, been employed with success, in preserving a considerable quantity in the caustic state for five or six months. A layer of the lime, reduced to powder by immersion, about seven inches thick, is first spread upon the floor of the shed or room in which the mass is to be kept. On this layer, the quicklime, packed as closely as possible, is then piled up. If there be no planking, the sides of the heap are finished in slopes, which are finally covered by a layer of lime, placed there the moment after immersion. This, falling to powder, lodges in the interstices of the lumps of lime, and thus furnishes a secure protection against the air and moisture.

42. **When a limestone contains twenty per cent or more of its weight of clay, it may furnish the substance termed hydraulic cement….** The English cement, now known as Parker's Roman cement, is obtained by the slight calcination of a limestone containing above thirty per cent of clay, with some hundredths of manganese and carbonate of magnesia. It is of the same nature with that manufactured in large quantities in the State of New York, and probably owes

its superiority over our own cement (which is believed to be very little), to the greater fineness of the powder to which it is reduced.

POZZOLANS

These substances (pozzalans and fired clays) offer very important advantages in the improvement of mortars, and deserve particular attention, **because hydraulic cement is not always to be had, and hydraulic limes often give mediocre results, unless they are mingled with a certain proportion of pouzzolana; and the latter has, moreover, this advantage over the hydraulic limes — <u>its qualities are scarcely at all impaired by exposure to the air and moisture.</u>**

(the following on this subject, a – referenced – blend of Treussart and Vicat).

CHAPTER III. ON THE GENERAL COMPOSITION OF MORTARS.

The object which we propose to attain, in mingling sands with a cementing material, is to form, as cheaply as possible, compositions, which, exposed to all vicissitudes of weather, and even placed under water, may nevertheless become hard and solid, attach themselves strongly to building materials, and attain, in the end, a resistance superior to all disturbing forces. Such combinations are called mortars.

… We may observe, then, that the resistance of mortars in general, is composed of three parts, essentially distinct, viz.:
1st. The constant resistance of the enveloped parts, generally designated by the name of sands.
2d. The resistance, varying with time, of the enveloping parts, or cementing ingredient.
3d. The force of adhesion of the constituent parts, which may be of two kinds; one resulting from the affinities existing between them, the other arising from the penetration of the cementing material into the interstices of the sands.*

Four modes of measuring lime have been employed, and all of them are attended with some uncertainty.

The most ordinary mode is to measure it in lumps, as it comes from the kiln; **a second method is to measure it in slaked lime powder; a third, in quick lime powder; and a fourth, in slaked lime putty or paste.**

The first method is usually employed by builders, when their works are not on a large scale, and is always supposed to be adopted, if nothing be said to the contrary. It is obviously very imperfect, as almost every lime yields a different volume of paste. *[but the builders would know their lime and also its optimum proportions in use, depending upon the sand].*

The method of measuring in slaked lime powder, though recommended by Smeaton, has not been employed to any great extent, by reason, probably, of its inconvenience. The third method, in which the quick lime is supposed to be reduced to powder, involves the necessity of grinding and sifting, and is attended, therefore, with so much expense, as to forbid its use almost entirely, even were there no other objections to its employment. The fourth method has been adopted at the public works in Boston Harbor, and may be regarded as the most convenient and economical, in all large operations.

… Referring now to Article 78, we see that the cheapest admissible mortars are those in which we add, to twelve measures of coarse sand, five of the cementing ingredient; to five measures of the middling sands, two of the cement; to three measures of fine sand, one measure of the cement.

If all the various kinds of sand can readily be obtained, we may mingle them together in proper proportions, and diminish still more the amount of cementing material otherwise necessary.

83. Mortars formed upon the principle above proportion mentioned (as previously remarked), are the verv cheapest that are admissible. **Such mortars, however, would not give good results in practice, and a larger proportion of the cement than that indicated in Article 81 ought to be mingled with the sand, on several accounts.** The first reason has reference to the shrinkage, which fat limes undergo in drying; on this account, the proportions of cementing matter above prescribed must always be augmented, when such limes are employed. This necessity, however, becomes less urgent, as the lime is more hydraulic in its character, and scarcely at all obtains in the case of hydraulic cement.

The second reason is derived from the imperfection of the manipulation….

In the third place, as before observed, a mortar composed on the principle in question (just enough to fill the voids), **would not possess the requisite tenacity for binding materials together.**

For these various reasons, it would generally be advisable to increase the proportions of cementing matter, mentioned in Article 81, about one-half.

… When sand is present (in the limestone burned), it should be regarded as so much sand already added, and a deduction of the amount, whatever it may be, must always be made from the proportion which might other wise be mingled with the cement. (Likewise added pozzalanic clays)

86. Though any addition of sand impairs the making strength of hydraulic cement, a moderate quantity is usually mixed with it, for the sake of economy; and experience shows that very good mortar may be made, by mingling the two

together, in the proportions of **one volume of hydraulic cement paste to one and a half volumes of sand, the grains of the latter being of medium size. When this substance is mingled with fat lime, with the view of making hydraulic mortar, a convenient rule, which works well in practice, is to add two volumes of sand for each volume of lime paste, and one and a half volumes of sand for each volume of hydraulic cement paste.**

... The constructor, having determined his proportions, however, in accordance (as far as possible) with the considerations contained in the preceding articles, should proceed, in the next place, to bestow some personal attention on the manipulation of the ingredients. This is, too often, left entirely to the management of indiscreet workmen, through whose negligence the best materials, combined in the best proportions, may be completely spoiled.

88. Mortars ought always, if possible, to be prepared under cover, not only to avoid the rapid desiccation which takes place in summer, but the equally serious inconvenience of having them drowned in the rainy season. In either case, their qualities would be impaired; but a hydraulic mortar, if permitted to dry too rapidly, may lose the whole of its energy.

Moreover, as the pouzzolanas, as well as hydraulic cement, should always be used in the state of impalpable powders, some loss of material might be incurred, in large operations, during the prevalence of high winds, unless the mortar-mill was sheltered from their action.

89. **The ingredients of all mortars should be thoroughly mixed together, so as to form a perfectly homogeneous mass. With this view, sufficient water may be added to bring the whole to the condition of a soft paste, care being taken, at the same time, not to drown the compound. In this state, the ingredients are incorporated with each other more perfectly and more economically; and the mortar, too, may be somewhat thin with advantage, as, otherwise, it is apt to become so dry, before it is used, as to lose some of its good qualities, and to require tempering with a further addition of water, which is always to be avoided, if possible. The common idea, that every good mortar must needs " be worked with the sweat of the laborer," has induced much unnecessary expense, and is believed to be entirely erroneous.**

In making mortars with mixed sands, it is well to commence by adding only the finest sand to the cementing ingredient. When these two are thoroughly incorporated, we may mingle with the compound a coarser sand; and this latter being well mixed with it, the sand next in order of coarseness may be added, the operation being thus continued, until the coarsest material has been employed. In the first case, the cement envelopes the fine sand, the combination of the two then envelopes the coarser sand, and so on. This mode of mixing the ingredients produces the most homogeneous result, and the best mortar. For a similar reason, mortar made with a machine is superior to that made by hand; and it should be prepared by such means, in all operations on a large scale.

CHAPTER VI.

ON THE PREPARATION AND APPLICATION OF VARIOUS KINDS OF MORTARS.

The mortars to be considered will be arranged, for the sake of convenience, into four classes: 1st. Pointing mortar; 2d. Stucco mortar; 3d. Mortar for masonry; and 4th. Mortar for concrete —

128. The ingredients of the mortars used at Fort Warren, were common lime from the vicinity of Thomaston, Maine; Rosendale hydraulic cement, manufactured at Kingston, in the State of New York; and quartzose sea sand, obtained usually from Provincetown, Cape Cod, and sometimes from Newburyport, Massachusetts. These materials were all of excellent quality; the lime had no hydraulic properties, but was quite rich, yielding a large volume of paste; the cement energetic, setting in eight minutes after immersion, when tested in the mode before prescribed; and the sands extremely heavy, with angular grains, consisting almost entirely of quartz.

… The Newburyport sand, as it appears, is finer than the other, and was on that account preferred for brick masonry; though the Provincetown, being somewhat purer and heavier, was regarded as the better sand for most purposes, and, during the past year, has been used exclusively at Fort Warren. I will suppose, therefore, that this latter sand was always employed.

…. POINTING MORTAR.

131. Mortars employed in masonry usually contain a portion of fat lime, and are not capable of resisting the vicissitudes of the weather for any great length of time. And, indeed, any mortar used in the construction of a wall must needs be wanting in compactness at the exterior edge of the joints, and is, therefore, in good condition to be attacked by rain, heat, and severe frosts. Accordingly, after exposure for a short time, it cracks and peels off, leaving a fresh surface to be acted upon in a similar way. The masonry is thus disfigured, and its stability endangered in the lapse of time.

It becomes, therefore, necessary to point the wall, or, in other words, to protect its joints, by filling them with some substance which will withstand all the injurious influences before-mentioned.

132. **Mortar, to be well adapted to this object, should be capable of attaining great hardness, and be as little liable to crack as possible. Such a composition may be made by mingling hydraulic cement with the maximum quantity of**

sand, and the minimum quantity of water, due regard being had, at the same time, to the coherence requisite for proper manipulation.
(Ingredients were mixed by weight:) one pound of cement powder to three pounds of dry sand,

136. Before commencing the operation of the joints, pointing, the joints of the wall were carefully cleaned out, the old mortar being removed with a suitable instrument to a depth of one inch at least. It is most convenient to do this during the construction of the masonry, while the mortar used for laying the stone is still soft. The mason himself, or the laborer who attends upon him, immediately after each course is laid, may then easily rake out the joints…

For some days before the pointing was executed, the wall was made thoroughly wet, in order that it might imbibe as much water as possible. The joints too were well brushed out and moistened, a short while before the application of the composition, care being taken to remove any superfluous water. The mortar then became hard, in the state in which it was used, without giving up any of its moisture to the wall, or, on the other hand, receiving from it any additional quantity.

Stucco.

Interior:

Coarse stuff contains ox or horse hair, in addition to the ordinary ingredients composing the mortar of the brick-layer. The hair should be free from grease or filth of any kind, and as long as it can be procured, and when matted together, should be well switched before it is employed. It is intended to act as a sort of bond to net or tie the whole mass together. If the mortar is to be made with common lime and sand, they may be used in the proportions of **one of lime paste to two of sand, and one measure of hair may be added for every six measures of the lime paste. But a mortar of common lime does not harden for a long time, except upon the outward crust, and even for plastering on the interior walls of any important work, it is advantageous to add to the mortar, a small proportion of hydraulic cement, not less than one of cement paste to six of lime paste. When this is done, we may further add one and a half volumes of sand for each volume of cement paste.**

Fine stuff is the putty of white lime, thoroughly slaked or rather macerated in water, and then dried to the proper consistence for working; it is sometimes mixed with a small quantity of hair.

Gauge stuff consists of three parts of the putty to one of plaster of Paris, and, as it sets rapidly, is prepared only in small quantities at a time.

(Plastering, METHOD:)

142. When the plastering is to be applied to laths, the work is either " laid," or "pricked up," according as it is to be finished with one, two, or three coats." Laying " is a pretty thick coat of coarse stuff, brought to a tolerably even surface with the trowel only. For this purpose, the mortar must be well tempered, and of moderate consistence, thin or moist enough to pass readily between the laths, when pressed with force, and bending over them so as to form keys; but at the same time, stiff enough to allow no risk of its falling apart by its own weight. If the work is to be in two coats, " laid and set," the laying is allowed to dry a little, and is then rudely swept with a birch broom, to roughen the surface, when the set, a thin coat of fine stuff, is at once applied. This is done with the common trowel alone, or only with the addition of a hog's bristle brush, which the workman uses in his left hand to rub over the surface, and afterwards presses and smooths it with the trowel in his right. Should the laid work, or first coat, have become very dry, it must be slightly moistened, by sprinkling or throwing water upon it from a brush, before the set, or second coat is put on, otherwise the latter may shrink in drying, crack, and fall away.

In floated work, or work with three coats, the first is laid roughly on the laths, the object being merely to make the keying complete, and form a surface to which the next coat may attach itself well. It should be of pretty equal thickness throughout, standing about a quarter or three- eighths of an inch upon the surface of the laths. When it is finished, and the mortar yet quite moist, the plasterer scores it all over with the end of a lath, in parallel lines from three to four inches apart. The scorings should be as deep as possible, without laying bare the laths, and the rougher the edges, the better. When the pricked up coat is so dry as not to yield to pressure in any degree, preparations are made for the floating. Ledges of wood, or margins of lime and hair, about six inches wide, called screeds, must be made at the angles or borders of the surface, and at intervals of four feet apart, throughout the whole area to be floated. These screeds are made straight with each other, and proved, in every way, by the application of straight edges. When they are ready, and the mortar of which they are composed somewhat hard, the inter spaces are filled up flush. A straight edge is then made to traverse the screeds, and thus bring the whole to an even surface. When the floated, or second coat, is sufficiently set and nearly dry, it is brushed with a birch broom as before described, and the set, or hard finish, then applied. When the surface is to be colored or whitened, the third coat should consist of white lime putty alone. If it is to be papered, a small quantity of hair may be added with advantage. When the surface is to be painted, the mortar should be composed of lime putty and fine clean sand, in the proportion of two measures of the former to one of the latter. The third coat should be worked of exactly the same thickness throughout, in order to pre serve the advantage gained by the second operation. The trowel and brush are considered sufficient to produce good work, except when the walls are to be painted, in which case the third coat must be gone over with the hand-float. In performing this operation, the surface is first made as smooth as possible with the trowel, for an extent of two or three yards. The workman then takes the hand-float in his right hand, and rubs smartly over the surface, pressing gently to condense the mortar.

143. The operation of plastering upon brick or stone differs only in name from that described in the case of laths. When the masonry is of recent construction, its surface should be well cleaned from dust, and slightly moistened before the stucco is applied. When old masonry is to be plastered, the mortar should be raked from the joints to the depth of half an inch, and the surface made perfectly clean; if blackened by smoke, or at all greasy, it should be scraped or roughened, and it must always be well moistened with water, before the plastering is commenced.

144. Ordinary mortars, or mixtures of fat lime "stucco"* and sand, should never be employed for stuccoing the exterior of walls…

145. The ingredients of the stucco used at Fort Warren, were hydraulic cement and the sand before described. The proportions adopted were one volume of stiff cement paste and one and two-thirds volumes of damp sand perfectly compacted, or what amounts to the same thing, one measure of cement powder and two measures of sand measured loosely.

150. Intelligent constructors universally agree that the use of "ordinary mortars," of fat lime and sand, should be proscribed on all important works. They are incapable of acquiring great hardness, and of resisting the inclemencies of the weather, and should in every case, where durability is desired, be improved by the addition of some hydraulic substance.

Nevertheless, ordinary mortars are in general use among the masons of the country, and their great cheapness **will always cause them to be employed in the erection of small dwelling-houses and the like.** When in free contact with the atmosphere, but shielded at the same time -from the action of frost and rain, they may in time become hard, and can therefore be employed without great disadvantage in dry situations and thin walls.

151. In ordinary practice, the cohesion of the mortar is greatly impaired by too large a proportion of sand, **which should not in general exceed two volumes, for every volume of lime paste**. The equivalents of such a composition, in the form most convenient for small operations, would be, — one cask of lime = 240 lbs. net. = 8 cubic feet of stiff paste, and sixteen bushels of **sand, damp, and measured loose, after the common custom of laborers.**

152. It was supposed, for many years, that the longer the lime was slaked before it was used, the better mortar it would make. Recent experiments prove, however, that **this is not the case with mixtures of fat lime and sand only.** Better results are obtained with such mortars, **if the paste be mixed with the sand as soon as the slaked lime has become cold, and care should be taken to**

use no more water, in the process of extinction, than may be required to produce a thick pulp.* (Treussart)

153. **In preparing ordinary mortars, it will be convenient to place the unslaked lime upon a plank floor, under shelter from the sun and rain, and then (without covering) to surround it with the proper quantity of sand. The water, requisite to produce a thick paste, previously ascertained by experiment, should be poured on the lime with the aid of watering pots of known capacity. The lime must then be well stirred, so as to expose every part of it to the action of the water, and afterwards left to itself, until the vapors have ceased entirely. The ingredients may now be thoroughly incorporated by means of the hoe and shovel. If the mixture is made with difficulty, a little water may be added, but only enough to produce a homogeneous mass.**

(Mortars at Fort Warren mixed by mortar mill and lime slaked by being thrown into a surplus of water…)

159. The lime, thus deluged with water, **loses probably some portion of its binding qualities, but the mortar at Fort Warren almost always contains hydraulic cement;** and as this substance sets rapidly, it is highly essential that the lime should be thoroughly slaked before the admixture of the ingredients. With the view, therefore, of ensuring this, as well as from regard to convenience and economy, the lime is reduced to the milky consistence before-mentioned, and allowed to remain in the vat as long as possible. **It should be remembered, that the above method applies only when cement is added to the lime. When no cement is used, the lime must be slaked in the ordinary way, as the drenching of the lime would greatly impair its binding properties….**

168**.** In constructing masonry, either of stone or bricks, care should always be taken, before the application of the mortar, that the materials to be cemented should be well brushed and thoroughly moistened. Every stone should be laid in a good bed of mortar, and be well settled in its place by heavy blows from a maul or mallet of wood. The bricks should not be merely laid, as is the common custom of workmen, but rubbed and pressed down, so as to force the mortar into their pores and crevices. The constructor of every work should direct his personal attention to the vertical joints of the walls, **as the mason frequently neglects to fill them with mortar.** To obviate the ill effects of his carelessness in this regard, some builders cause the several courses of masonry to be grouted; that is to say, a mortar made liquid, and called grout, is poured on them with the view of filling all the joints that have been left vacant. But, at best, this is only doing with liquid mortar, what may be done with mortar of better consistence; and grouting, being objectionable in other respects, has never been employed at the public works in Boston Harbor.

Archive accounts quoted in Slade H G Harling and Vernacular or We **Are All Gentlemen Now Vernacular Building, 22 (1998), 32-8**.

Glamis Castle Archive Box 141 Bundle 11

Contract between the Earl of Strathmore and John Sherres Sklaitor 1701

…the said John Sherres binds & oblidges him to cast and harle the said noble Earles Castle of Glammis old and new work thereof with lyme on the front sides and round the same as also to point and make water-tight the roof of the said Castle old and new work thereof so soon as lyme, other materials & necessary engines shall be furnished for the work, which he is to perfect and finish betwixt the date hereof (30th March 1701) and the first day of September next to come…as much lyme to be mixed with sand sufficient and sowered as shall cast and harle the said castle and lyme sufficient for pointing etc the roof of the same. *(This would indicate dry slaking with sand/sand slaking, and then banking the mortar to sour before it is knocked up to a mortar for use. This might indicate a hydraulic lime; it might be to allow for some late slaking, or both. The mortar may be wetter, however, before souring and banking. Souring is the process of allowing time for late slaking to occur before use. The necessary period of souring might vary with the lime)*. Together with a sufficient strong cradle for holding two men for working and harleing strong rops and pullyes sutable & necessary for the upper partr of the work. Togither also with two strong ladders for working and harling below so far as can be worked upon the same as also to provide thie or four workmen according as need shall require for constant attendance with every thing also that may be found necessary to the perfecting of the said harleing which the said noble Earl is to provide and have in readiness in due time…

Mount Stuart Archive. 1761

Directions for roughcasting stone walls in the new way

Let the walls to be roughcast be made perfitly clean of all the old lyme and louse stons on the wall be wasted thos must be broached over with a tool to take away the sandey parts.
Let the walls be swept clean and watered with a brush so as everey louse partickle may be removed befor the plaister be laid on.
Let all the holou parts of the wall be closely and carfuly made up with building lyme and smoke stons in such a manner as the wall may be brought to as near a straight as possible, so as when the plaister is laid on it may be of an equall thickness, and care must be taken that thos holous so made up must be perfitly firm, I mean that the little stons put in with lyme in the hols in the wall…
Let a sufficient quantity of lyme of the best kind to be sifted as for plaister to which add a like quantity of the cleanest and best sand free of earth, sifted through the same sieve to which add a small quantity of plaister hair, about 1 ½ stone to each boul of lyme; let all be mixed and soured up with water for about three weeks then beat it all over with a wooden beater. Then begin at the top of

the wall and lay on the plaister, still beting it in parcels as it is laid on, beat it on a wooden board or door, lest it take up earth from the ground, lay on the plaister about ¼ inch thick or so, not exceeding 3/5 lest it be too heavy and separate from the wall, and ought to be laid on straight for ornament's sake and while the plaister is wett. Throw it over with pibls afterwards to be described, throwing as many as the plaister will receive and press them a little with the back of a trowel into the plaister but not so much as to sink them entirely. And as a yard or thereby of plaister will be sufficient to be laid on at a time till it be thrown with pibls care must be taken that it be not too dry when thrown…and likewise care must be taken that the plaister thus laid on at separate times be made to joyn closely that ther be no crack at the joynings, which may be prevented by using water.

(pebbles to be whitened with flour of lime before casting)

…whitewashing repeted when needful will defend the worst of walls from the insults of the wether and will last a very long time.

Brodie Castle – letter from James Wylson concerning repairs to the exterior of the same, 1846. *(Wylson was an architect brought in to complete major works begun in 1824 under architect William Burn)*

…I am doing everything in a plain, substantial manner, leaving the ancient character in view and doing no more than what seems necessary.

I have been thinking a good deal about the Rough-casting, and have come to the conclusion that it ought not to be repeated – there are many arguments against it: when it gets old, it looks very shabby; when it is renewed, it is expensive; when merely repaired, the rain gets between the coats and flakes it off, especially in case of frost; then where the window and door jambs, mullions and parapetsand other similar parts are in hewn masonry, the colouring matter only applies to these, and they are the first to get bare and black; lastly, it has not even temporary beauty to recommend it, at any rate where preserving the venerable appearance of ancient walls is an object *(this a fair representation of Victorian fetishism for bare stone, and for the 'scraping' of plasters and renders against which William Morris railed)*. In the present case, if it is adopted, it must be done from the very root, and five distinct operations are necessary, namely:

Scraping it all off and raking out the joints;
Washing to remove dust and ensure adhesion;
Pointing the beds and joints;
Coating;
Dashing – with colouring.

…As something ought to be done, I have to propose a mode of treatment which I think would be better in point of durability – and antiquity, and which would also harmonise better with the newer buildings…after scraping, raking out and washing, to **point the joints and cracks out solid and flush with the following composition: 2 parts lime, 1 part sand, and 2 parts scoria from a blast furnace, or the forge scales and filings from a smithy, or a combination of these; the foundry and smithy waste to be pounded and sifted, the sand also sifted; the lime used hot from the kiln, and the mixture made as the lime is slacked, the joint to be struck with the trowel as in ordinary rubblework.** *(This would be very hard and not especially breathable).* The great property of induration which is possessedby a mixture such as this, and which it derives chiefly from the presence of iron, is well known, and its dark colour, as it approaches the tone of the old masonry, is in its favour rather than otherwise. This method I consider would be in itself superior to the rough-casting; and if you thought proper then to coat the whole of the old building with boiled linseed oil, it would be an excellent protective for the stone, entering as it would, into the surface and there hardening and rendering it impervious to water. *(Such treatment and such misconception was not at all uncommon in the past and was certainly applied to York Minster during the 19thC).* It ought to be done in the dry season, if hot, perhaps the better, but more expensive.

(Works being put out to tender in Forres).

Accounts and Papers, Post Office; Public Works and Buildings; Shipping Vol 22. 1847-1848. London. House of Commons.

Returns and Contracts Relative to the New Houses of Parliament

That they the said Henry Lee and John Lee (builders) shall and will forthwith proceed to do, perform and execute all the excavators', pile-drivers', builders', bricklayers', masons', smiths', carpenters', and all other work requisite and necessary to be done and performed in and about the forming, erecting and completing the Cofferdam, River Wall and other Works forming part of the foundations of the intended New Houses of Parliament… and also, that they the said Henry Lee and John Lee, their executors and administrators, shall and will, at their own proper costs and charges, find, furnish and provide all the stone, iron, timber, bricks, **pozzolano, lime**, gravel, sand, clay and all other materials of every kind and description whatsoever requisite or necessary for the doing and performing the said Works… and that the same stone, iron, timber, bricks, pozzolano, lime, gravel, sand, clay and other materials shall be the best of their respective sorts and qualities…

And further, that if anything shall be found to have been omitted in the said plans, elevations, sections, drawings and designs, and the descriptions upon them respectively, and the specification here under written, or any or either of them, which is necessary to the due and effectual completion in the best manner of the said Works and every part thereof, and which can be fairly considered as omissions, the said Henry Lee and John Lee, their executors or administrators, shall not obtain or claim to be entitled to any charge or recompense by reason of any such omission, but shall be obliged to complete and perform the Works hereby agreed upon as if such omissions had never been made, on the contrary, as if the work so omitted to be mentioned and described had been described with the utmost accuracy and to the greatest advantage, and that in the most sound, substantial, complete and workmanlike manner…

Schedule of works for Cofferdam, River Wall and other Works forming Part of the Foundation of the proposed NEW HOUSES of PARLIAMENT.

… The concrete of the foundations of all the walls is to consist of 6 measures of gravel and sand to 1 of ground lime, **mixed dry, and then well worked together with water,** and in this state teemed and thrown into the work from a height of at least 10 feet, and is to be brought to a level surface at the proper depth to receive the first footing-course, which is to bed solid upon it….

The stonework is to be laid out on a thin bed of mortar prepared as hereafter directed, the front joints being pointed with cement and then grouted full, and all the stones are to be worked on the ground and set with lewises and proper tackling….

The space between the river wall and the front wall of the building is to be brought up to the level of the top of the walls with concrete composed of 10 measures of gravel and sand to 1 of unslacked lime washed in with water, and levelled in regular and thin courses as the work proceeds.

MORTAR AND CONCRETE. The mortar throughout is to be composed of 1 measure of the best fresh-burned Merstham, Dorking or other equal and approved lime, 1 measure of finely-ground genuine Italian pozzuolana, and 2 measures of sharp above-bridge river sand, all clean and free from rubbish, dirt and other impurities; the proportions are to be correctly ascertained, after which the lime (which is to be brought from the kiln in small quantities, as required, and kept dry under cover) is to be slacked and mixed with the pozzuolana and sand; **they are then to be passed together in the dry state through screen, the water added, the mortar well tempered and worked to a tough and proper consistency in horse or pug mills for the work generally, but for the stonewoik, ground with edge stones worked either by horses or by means of gear attached to the steam-engine for pumping the water out of the dam.** Fresh-burned lime of the above description, and clean coarse river gravel, having mixed with it a proper quantity of sharp sand, are also to be used in proportions stated in making the concrete that has been specified for the foundation of the walls and the backing.

(Further foundation works -)

BRICKLAYER. The bricks to be sound, hard, well burned square stocks, equal to a sample to be approved by the Architect and deposited with the Clerk of the Works ; the whole of the brickwork to be laid English bond, and no four courses to exceed 11 ½ inches., and every course flushed up solid in mortar. **The**

mortar to be composed of stone lime and sharp river sand, in the proportion of three measures of sand to one of lime, the whole well mixed in a pug-mill. The lime to be kept in an inclosed shed, and no more mixed at one time than is sufficient for the day's consumption.

Signed Charles Barry (Architect), Henry and John Lee 08.11.1837

For completing Carcase of the River Front, and the North and South Flanks of the Building.

Thomas Grissell and Samuel Morton Peto, both of Lambeth, in the county of Surrey, Builders and Co-partners (submitted lowest tender and were accepted)…Charles Barry.

BRICKLAYER. The backing up of the stone facing of the external walls and the whole of the inner walls of the building, shown by a tint of red, are to be of brickwork, and built of the several heights and thicknesses as shown on the accompanying drawings, of the best hard, well- burnt, sound stock bricks, laid in mortar composed of the best Dorking or Merstham or other equal and approved stone lime, and clean sharp river sand, free from all filth and impurities, well mixed together in the proportion of two equal measures of sand to one equal measure of lime, ground and tempered in a pug or horse-mill until it becomes of an equal and proper consistency. The lime is to be thoroughly and freshly burnt, and must be kept in an enclosed shed ; and no more mortar is to be made at one time than is sufficient for each day's consumption….

The backs of the stone parapets to be rendered with Keen's Patent Cement, properly jointed with the flashings.

All the Roman Cement to be composed of one measure of the best fresh-ground Roman Cement that can be procured, mixed with one equal measure of clean sharp sand, to be well chafed up for use in small quantities and used immediately.

MASON

The plinth of the external walls… is to be of the best granite from the Fogging Tor Quarries, Devonshire, from Penryn, or from the Island of Guernsey, of a fine grain, similar to that of the best Aberdeen, or from Aberdeen, and of an even colour throughout, being entirely free from large crystals of quartz or felspar, as well as from redness or stains….

The granite work throughout is to be laid on a thin bed of mortar prepared as hereafter described, the face of the joints being pointed with cement, and the rest grouted full with mortar….

The mortar for the granite work is to be composed of one measure of fine ground genuine Italian pozzolana, two equal measures of clear river sand, and one equal measure of good fresh burnt Dorking lime mixed with water and well worked to a proper consistency, and in that state ground with edge stones….

(Cramps to be grouted in with Roman Cement; window stones etc to be bedded in the same).

Signed 26.09.1839

SPECIFICATION of WORKS to be performed and Materials used in forming the Foundations of a Portion of the South Flank of the Building, the Royal Staircase and adjoining Rooms, the House of Lords and its Appuitenances, the Public Corridors and Central Hall, and the House of Commons and its Appurtenances.

The mortar is to consist of the best **fresh burnt Merstham or Dorking lime**, **and clean sharp river sand, in the proportion of three measures of sand to one equal measure of lime, well compounded together in a proper pug-mill.** The lime is to be kept in an inclosed shed, and the supply to be duly regulated by the quantity of work in hand, so that the same may be **used in a fresh state**; and no more mortar is to be made up than is required for the day's consumption….

Contract No.7

For the internal Finishings of the Building generally.

BRICKLAYER. Brickwork, including Scaffolding — the Bricks to be all bedded, drawn up and flushed with Mortar.

Reduced brickwork done with hard well-burned sound grey stocks, **chalk lime** and river sand… Rubbed and gauged arches, straight on the plan, either circular or camber soffites, with red stocks or malms **set in putty** with 4-inch soffites… Flat joint pointing with coal ash mortar, including raking, dubbing and scaffolding ---------- Ditto, ditto in cement --------- Tuck pointing with a neat joint to new work, including scaffolding - Tuck pointing to old work, including scaffolding, raking out the joints, cleaning down and staining the brickwork…

TILING. Pantiling, laid dry, including hips and ridges, laid in mortar, heading and filletting .... Pantiling, bedded and pointed inside with lime and hair… Pantiling, bedded and pointed outside with lime hair… - Pantiling, bedded and pointed inside and outside with lime and hair… Pantiling, laid dry, including hips and ridges laid in mortar, all but tiles .... Pantiling, bedded and pointed inside with lime and hair…

LIME, MORTAR, SAND, &c. Delivered at the Works.

Dorking or Mertsham lime
Chalk lime
Lime and hair
Pargetting
Fine stuff
Blue pointing mortar
Darkened or coloured pointing mortar
Stopping mortar for tuck pointing
White mortar for ditto
Cement
Windsor loam
Stourbridge ground clay
Clean river sand
Plaster

INTERNAL WORKS, WITH CHALK LIME AND FIR LATHS.

(from table of measured rates; rates removed here)

Pugging
Lathing only with cast nails
Lath and plaster, one coat
Ditto, circular or elliptical
Lath and plaster, one coat and set
Ditto, circular or elliptical
Lath and plaster, two coats and set
Ditto, circular or elliptical
Floted lath plaster, not set
Add**, if set with putty and plaster**
Trowell'd stucco on laths
Labour to gauging, one coat
Ditto two coats
Ditto three coats
Gauging two coats, labour and plaster "
WHITING, COLOURING, &c. including cutting out Cracks, stopping, etc. with Putty and Plaster, and cleaning off Splashes from Walls, Wood Work, and, Floors,
Clearcole and white to new work
Ditto plain mouldings
Ditto enriched ditto
Clearcole and colour to new work
Ditto straw
Ditto French grey
Wash and stop

Wash, stop, clearcole and white
Ditto, ornament ceiling
Ditto plain mouldings
Ditto enriched mouldings
Lime whiting, twice done (first cleaned and stopped)
Clearcole and common colour (first washed and stopped)

DAY WORK.

Coarse stuff
Outside lime and hair stone lime
Fine stuff
Putty
Stucco
Roman cement
Mastic Linseed oil .
Boiled oil
Washed and dried sharp sand
Plaster
Whiting Double size
Ditto Lime white
Whiting and size
Colour….

PAVING. Laid on Screened Gravel, including the forming of the Ground.

Grouting, and forming foundation for paving, with six parts of screened ballast, and one of stone lime, or Dorking lime, properly mixed

Grouting to granite paving with lime and sand.

Brees (1852) THE ILLUSTRATED GLOSSARY OF PRACTICAL ARCHITECTURE AND CIVIL ENGINEERING. London. Savill and Edwards.

By S. C. BREES, ARCHITECT, CIVIL ENGINEER, AND SURVEYOR, AUTHOR OF " RAILWAY PRACTICE," ETC.

(Plymouth Breakwater) The masonry above low water mark was set in mortar, composed of one part of pozzolono, one of Aberthaw, or Plymouth lime, and two parts of fine, sharp, clean, fresh water sand, well mixed together, with as little water as possible, which soon set, and became very hard.

Concrete composed of 5 parts of sand was also thrown on the blocks above, and even below low water mark, being used in large masses, and protected from the action of the waves during the process of setting. The exterior beds and joints were further pointed with good roman cement.

BRICKWORK…

The mortar should be used **fresh**, and as stiff as possible (see Mortar), and the bricks dipped in water as they are laid, more especially if the weather be dry, and well bonded together — (see Bond). **Brickwork is usually built with mortar composed of lime, sand, and hair,** but it is some times executed in cement and sand, mixed together in equal quantities, which prevents the shrinkage or settling of the walls, and is therefore advantageously employed in making additions to buildings, repairs, &c.

It is of the utmost importance to keep the tops of the walls of a building well covered over with straw or weather boarding during the course of execution, and such times that the works may be left, and they should on no account proceed during the prevalence of frost, since one of the great causes of decay in buildings, particularly those executed in brickwork, arises from the effects of the weather, and the action of frost and rain.

The strength and durability of a wall depends considerably upon the bond, wherefore a wall executed with one description of bricks is stronger than one faced with a better sort, since the former can be built with a more uniform bond; whereas, in the latter, there is not that connexion of the exterior with the interior, and the bricklayers will frequently cut the heading bricks of the facing bricks in half to make the better material go further, which totally destroys all bond. It is to be lamented that any other bond than old English bond should be employed; but Flemish bond is generally adopted for facings, on account of its requiring a less number of bricks, and its appearance being considered neater.

Brickwork is measured in London by the rod, and was taken from the original standard of 16 feet cube, which gives 272-25 square feet, or 2724- square feet of brickwork, 1 ½ - bricks (13 ½ inches) thick, as the superficial contents of 1 rod of reduced brickwork (the quarter foot being disregarded in practice). The standard thickness of a brick wall being 13 ½ inches, there are consequently 306 cubic feet in 1 rod of brickwork…

1 rod of brickwork will require 1 ½ yards of chalk lime, or 1 yard of stone lime, and 2 ½ yards of sand with stone lime, or 2 yards with chalk lime for the mortar. One bricklayer will lay 1000 bricks per day in common walling, with the assistance of a labourer, so that he will complete one rod in four and a-half days; but an allowance is required to be made for the apertures and other adjustments.

…COARSE STUFF, the mortar employed as the first coat in plastering the walls of houses on the inside face. It is prepared with lime and sand, similar to common mortar, with the addition of cow hair from the tan-yard, which is afterwards worked into it.

CONCRETE, an artificial cement composed of lime and gravel, or sand, and in high repute at the present time for the foundations of structures.

It was first used in the year 1815, by Mr. Ralph Walker, C.E., at the West India Docks, and subsequently at the Custom House of London, after piles had failed.

Concrete is prepared in various proportions; about one-seventh or one-eighth of ground lime is the most general, but it depends entirely on circumstances. Two-thirds of the ballast should consist of small stones, with none larger than a hen's egg, and one-third of sand. This, in fact, constitutes Thames ballast, which makes excellent concrete when combined with Dorking lime. **It should be mixed together, and slaked like mortar, and always used hot,** and thrown from barrows wheeled along planks from a height of 10 or 12 feet to the site of the intended foundation.

This will have the effect of driving the particles closer together, and giving greater stability to the whole mass; after which it ought not to be disturbed until properly concreted and set, when it may be levelled, the footings laid upon it, and the walls carried up. It is thus distributed, in layers from 7 to 10 inches thick, and each should be allowed to set before another is commenced. It is further advisable to perfect one layer before commencing a second, but if this is not convenient, the second layer should be cast short of the first, and the whole stepped down in succession.

The foundation for the Greenwich Railway viaduct was executed by Mr. Macintosh, after a different plan.

Having first dug to a good bottom, a certain quantity of water, say equal to one foot in depth, was pumped into the trenches, the ballast and lime were then mixed together in a dry state, and thrown in, after the usual manner, until the water was absorbed. The concrete was then turned, and levelled by shovels, and more water pumped in, and filled up again as before. This plan offers great facilities for putting in the foundations of bridges in some situations, but great care and some management are necessary to be employed, since it is usually desirable to effect the induration of the concrete as soon as possible, and more water than is absolutely necessary to bring about a perfect admixture of the materials is not merely unnecessary, but prejudicial.

Recourse should also be had in these cases to those limes which possess the property of setting under water, as the blue lias, and others. Whenever the water can be kept from the foundation for a short time only, as in working between the level of high and low water, and it is desirable that the concrete should set immediately, hot water should always be substituted for cold; the proper induration of the mass, however, can only be acquired by time. A good concrete may be formed in the vicinity of the sea, by a due admixture of stones and sand from the beach with lime, as practised at Dover. Smeaton and others have proved, that mortar prepared with these **becomes harder than with**

ordinary materials; both salt water and sea sand were used in the Eddystone Lighthouse.

FINE STUFF, the mortar employed as the finishing coat in plastering the ceilings and inside walls of common houses. It consists of lime slacked with a small quantity of water, and a little fine sand is accordingly added, and sifted through a fine sieve. It is kept in a tub, or oblong box, in a semifluid state, until the water has nearly evaporated ; a small portion of hair is sometimes mixed with it. A thin coat of the fine stuff is laid over the first coat of plastering, and which operation is called setting. FINISHING COAT, the third and last coat in plastering; when the last coat is formed for paint, it is executed very carefully, and called stucco ; if for paper it is composed of fine stuff, and called ' setting.

GROUT, or GROUTING, a description of mortar used in brick and stone work, consisting of **quick lime and a portion of fine sand, employed in a thin semi-liquid state**; it is poured into the upper beds and internal joints of the work. Brickwork should be well grouted every four courses.

HYDRAULIC, or WATER LIME, a lime which possesses the property of hardening when used in water operations. A small mixture of ground burnt clay, smiths' forge scales, or calcined basalt (pozzolano), **added to the lime at the time of burning**, will give it this quality; or brick and tile dust; but natural pozzolano, or Dutch terras, form the best substances, and are very valuable in hydraulic works.

Blue lias lime is an excellent water lime. It appears that even common chalk lime may acquire a setting property like the former description, by being long exposed to a certain degree of heat; **it also requires to be ground to powder, and the finer the better**. The setting property is partially destroyed by slaking ; it is therefore important that no more mortar should be made at once than can be used in a few hours.

LAYING, the operation of laying the first coat of plaster in two-coat work, when spread on laths, as applied on ceilings and partitions; the first coat of two-coat work on brickwork being called rendering. Both laying and rendering are composed of the same materials, viz., coarse stuff mixed with sand or drift; **the surface is swept over with a broom**, and not scratched over with a scratcher, as in pricking up and roughing in.

LIME, a valuable substance much used in building, and for other purposes, being the most essential ingredient in all cements; it forms one of the primitive earths, although never found native or in a state of purity, but is always combined with acids which exist in prodigious quantities in it; marble, limestone and chalk, are all carbonates of lime, and gypsum is sulphate of lime. Lime may be prepared from any carbonate of lime, as limestone or chalk, calcined or well burnt in kilns for some time to a white heat, by which the carbonic acid and acid contained in those substances are expelled, and the earth left in a fragile mass with very little coherence, having lost nearly 44 per cent. of its weight; **it may now be easily reduced to powder, when it is called quick lime,** in which state it shows a great disposition for water, upon applying which it instantly swells and cracks, producing a considerable degree of heat (it will absorb one-fourth of its weight of water, **and yet appear dry**), it then falls into a fine white powder, when it is called slaked lime, having about double its former bulk.

Stone lime *[feebly hydraulic]* is generally used in extensive buildings, and the quality of the lime is supposed by many to be in proportion to the hardness of the stone from which it is produced. Brown stone lime *poor limestone; hydraulic]* is said to be the best for all kind of cements, although blue lias lime is considered by some to be superior, as it withstands the action of water exceedingly well; it was used by Mr. Smeaton in building the Eddystone lighthouse, where it succeeded after all other descriptions of lime had failed.

Good chalk lime, although said to be inferior to stone, is yet much esteemed. Lime should always be kept under an enclosed shed, particularly chalk lime, as it suffers considerably from exposure to the air: the efficacy of lime also depends upon being well burnt, **after which process it should be used as soon as possible.**

LIME AND HAIR, a mixture of lime and hair, and employed with the plaster in first coats and floating; a greater quantity of hair is used in the latter than in the former. It is also sometimes called coarse stuff.

LIME CORE, the coarse lumps of extraneous matter and inefficiently burnt stone lime, which do not pass through the screen in the operation of screening. Lime core is unfit for making cement and mortar, but it is very serviceable as dry filling at the backs of walls and under floors and paving.

LIME KILN, a kiln employed in burning limestone, shells, and other calcareous matter. The most simple kind of lime kiln consists of a hole dug in the ground in the shape of an inverted cone, and situated on the top of a high bank, in order to admit of the materials being put in at the top, and taken out at the bottom. The sides may be built up in bricks or sods, or left naked, according to the nature of the ground. The limestone properly broken is spread in alternate layers with coal or furze, the top being covered with sods, and 1 bushel of coals produces about 3 of lime. The fire is lighted at the bottom, where a door is left to remove the lime and admit a draught to the interior. The better sort of lime kilns are formed in the shape of a hogshead or an egg broken off square at each end, and com pressed a little at the base to an oval shape, with an eye, or draft-hole, at each end of it. There is an inside and outside wall, a layer of clay, 2 feet in thickness, being interposed between them. A metal plate below receives the materials, admits the draught, and facilitates the discharging. These are constantly burning, and are distinguished by the name of draw-kilns.

LIMESTONE, the stone from which lime is produced; the most crystalline marble, all calcareous stone, as well as chalk, being composed of lime. Every stone, in fact, which will ferment with an acid (as aqua fortis) is capable of being burnt into lime, and the harder the stone the better will be the lime.

Limestone is of various colours, as brown, blue, grey, red, yellow, and green. When any of these are combined, it is called marble. The lime stones found in this country are mostly either of a yellowish red or bluish cast. The limestones used for building are classified into three, — **1st, the pure limestones, which contain from 79 to 93 of carbonate of lime ; 2ndly, the oolite, containing about the same quantity ; and 3rdly, the magnesian limestone**.

The Balsover, of which the new Houses of Parliament are built, is at the head of this class, and contains 51-1 of carbonate of lime, 40-2 of carbonate of magnesia, and 3-6 of silica. The cohesive powers of the Balsover are upwards of five times as great as the Bath oolite. It requires 296-01 cwt. to crush a cube 2 inches square of the former. An admixture of silica is very advantageous ; thus the Chilmark lime stone possesses 10 per cent of silica, and consequently rises almost equal to the Balsover in point of cohesion, and is superior to it in non-absorbent properties.

MORTAR, a cement used for building purposes, composed of lime, sharp coarse sand, and the hair of cattle, which should be thoroughly mixed together in a pug mill, or well tempered with wooden beaters, with a small portion of water, in the proportion of 1 of lime to 2 of sand, well chafed. The lime should be used as fresh and stiff as possible, and it ought to be kept under an enclosed shed.

The bricks or stones should, if possible, be well saturated with water, particularly in hot weather.

Twenty-seven cubic feet make 1 load of mortar, which contains half a hundred of lime, and a proportionate quantity of sand; and a hod is 9 inches by 9 inches, and 14 inches long; 2 hods of mortar make nearly 7 bushels. **No more than about a bushel of lime should be slacked at one time, and no more water should be employed than is required to reduce it to powder, when it ought to be immediately covered with sand to prevent the gas escaping, which constitutes its indurating quality**. **The mortar should be beaten three or four times over, so as to incorporate the lime and sand together, and to break any pieces of lime that may have passed through the sieve, the operation being performed with scarcely any water.** This improves the strength of the mortar considerably. If the mortar is laid by for any time, it ought to be beaten up again before being used, to save the time of the bricklayer, and it should be used soft in summer, **and rather stiff in wintry weather.**

The perfection of the cement must, therefore, depend entirely upon the perfection of the crystals. That the crystalization may be more perfect, it has been recommended to mix the ingredients well together with a large quantity of water, and allow the drying to be as slow as possible.

The middle of the old Roman walls was composed of pebbles thrown in at random, and some think that the mortar must have been liquid, so as to have been poured in among them. This would have the effect of dissolving a large quantity of the lime, and thus render the crystalization very perfect, so that the mortar would become as hard as the stones themselves. —

PLASTER, the name applied generally to the composition employed for covering the walls of buildings on the inside. The plastering used at the present time is vastly inferior to that found in ancient structures**. It is the practice of plasterers to mix a large quantity of plaster at once, by either burying or covering the fresh lime with a great thickness of sand, say a substance of two, three, or more feet, and then pouring on sufficient water to slake it, and wherever the sand opens and allows the heat and smoke to escape it is carefully closed**; this method has the effect of thoroughly slaking the lime, which is a great object, since the blisters so often observed on the face of plastering are caused from bits of unslaked lime cracking and bursting out.

POINTING, a term applied to the finishing of the external face of the several courses of a wall. There are two kinds of pointing. In the first, the mortar is scraped out and then filled up with blue mortar, the courses being simply marked with the edge of the trowel; this is called flat joint pointing. In the second, the joints are further finished by fine plaster, which is neatly inserted, and pared to a parallel edge, which slightly projects, and is called tuck pointing, or tuck joint pointing. This is sometimes performed with Roman cement.

Sloan S (1852) The Model Architect, a Series of Original Designs for Cottages, Villas, Suburban Residences etc. Philadelphia. E S Jones & Co.

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In the article upon excavations mention was made of concrete as a valuable aid in procuring good foundations.

Little attention has been given to concrete in this country, at least for such small structures as dwelling houses. It is composed of stone chips or coarse gravel **mixed with lime while hot from slacking. Sometimes the lime is mixed in the caustic state with the stone or gravel and water then poured upon it. This practice is strongly reprobated by the most experienced, who insist that it is far better for the lime to be brought to a thick paste before using**. It may also be made into a mortar by mixing with it a small quantity of sand. In any case marble chips combined with hydraulic lime, are the best materials that can be used.

When hydraulic lime is used in combination, **instead of the ordinary lime**, the mass is usually termed beton.

When concrete is placed in its position it should be rammed until the mortar begins to flush out at the top. This then, allowed to dry, is incompressible and firm, and gradually becomes converted into an artificial stone. It is evident that this concrete or beton can only be used when it has a support at the sides. It has often been used to fill between inner and outer courses of stone where the walls are of great thickness. It frequently may be advantageously placed at the bottom of the foundation trenches, thus producing a firm and uniform bearing surface. Concrete may be regarded as a sort of imperfect rubble work, and its value consists in becoming quickly 'set,' and its ready self-adaptation to an uneven surface

THE MORTAR.

It will doubtless be a matter of surprise to some that this subject should receive an extended notice, although really **it is of the highest importance**. Unfortunately, however, it is one of the points in which little or no care is exercised, and the master mason usually builds with mortar prepared either by a careless apprentice or an ignorant laborer. He never thinks of the permanence of his work, unless it be surrounded by extraordinary destructive agents, but if the finished structure stands, he and his employer are satisfied.

But in the present day, when our walls are built so thin and lofty and are often veneered upon the outside with slabs of marble or granite, a mortar should be used that will bind the mass together, and make the whole as one stone, otherwise premature decay will continue to crumble our dwellings, and our cities and villages, as indeed is now the case, will require rebuilding every few years. It is time that all interested should be aroused to attend to this matter, **more neglected perhaps than any of the many neglected processes connected with erection of ordinary buildings**. There have been a few treatises on mortars published by those whose position has interested and enabled them to experiment extensively, but **the little light admitted by these researches seems to show that we are almost void of any knowledge of the subject.**

What we shall say is <u>mainly derived</u> from such sources, and combined with a little practical knowledge acquired by observation, may serve to awaken inquiry in the minds of some who have as yet treated longer and more complete essays with indifference.

Mortar may be described in a general way as a compound of various substances capable of entering into a chemical combination that indurates the mass, attaching it at the same time to the building materials, and thus binding them firmly and lastingly together. One of these ingredients is sand, of which little need be said, but that little is important.

It consists essentially of silica or quartz, the purer the better except in the case of arenes, the foreign matter in which is of a nature to increase its value *[arenes used in parts of France, a clayey stone-dust aggregate which seems to have conferred accelerated, pseudo-hydraulic set by reaction]*.

Sea- sand, when none other is accessible, must be thoroughly washed in order to free it from the salt with which it is impregnated, and indeed **in all cases the sand should be washed and sifted.** River-sand when well selected will answer every purpose, but pit-sand, when economically obtained, is preferable. The former is generally cleanest, but the grains composing it are apt to be rounded in their passage down the stream, and it consequently contains fine powder, the result of the abrasion, which must be avoided. The grains of pit-sand never having been subjected to such action are sharp and angular, and therefore, as will hereafter appear, are much better fitted in this respect for the purposes of the builder.

The other essential and most important ingredient of mortar is lime. The limestone yielding it is found native, and contains in addition a certain amount of carbonic acid chemically combined, thus forming a carbonate of lime. Before the lime is fit for use this acid must be expelled by calcination in kilns, which is always accompanied by a loss of weight to the amount of about forty-five per cent, which includes also the water. A high degree of heat is requisite to disengage the carbonic acid, and the whole process is one requiring experience and care. The smaller the pieces of limestone are, the less is the time required, the disengagement of the acid being greatly aided also by having them moist when placed in the kiln, but still a good red heat must be maintained for several hours, varying in number according to circumstances. This heat too must gradually be augmented, since the last remaining portions of the acid are most difficult of expulsion.
It requires no small amount of skill to know how much heat to apply, and when to stop the process. Some of the best limestones if over heated are rendered useless or " killed," and often the calcination must be stopped before all the acid is expelled. With the rich limestones an almost inexplicable case obtains. If a certain portion of the acid be retained the lime is excellent; if the burning cease at the point when all the acid is expelled the lime is almost useless, and if it be continued for a certain time beyond this point the lime is again excellent, except that it is apt to swell in setting.

Unfortunately, **so little is certainly known** that we cannot yet give definite directions on the calcination of limestones, although it is as important as any other point connected with our general subject; but as **Mr. Burnell, who is perhaps the most recent and best authority**, says: —" At present our best guide is experience, and a kilnsman who has watched the action of his own kiln for years **knows more upon the subject than the first theoretician in the world**."

The lime thus obtained is by no means chemically pure, but always contains a variable quantity of clay, which consists of alumina and silex together with certain other substances in such small quantities, however, that they may be disregarded. But the result is materially affected by the proportion of alumina and silex which may exist in the lime. The varieties thus produced will be spoken of as lime, hydraulic lime and cement. Villeneuve thus classifies them and says:—

"The calcination of the carbonate of lime containing from **one to six per cent, of clay produces ordinary lime**; if the quantity of the clay be greater (equal to **from six to twenty-three per cent.) the lime is suitable to be made into hydraulic mortar.** Beyond **twenty-three to twenty-seven per cent, of clay** the result of the calcination of the calcareous compound is termed **cement."**

"Practical experience has shown that between lime suitable for hydraulic purposes and cements, a line of demarcation exists in the form of the lime containing about twenty-three to twenty-eight per cent of clay.
This combination neither slacks into powder when wetted with water, nor does it cohere permanently when mixed with water and beaten together."

But this can only be regarded as a general statement, which may fail in practice, and hence the selection of a limestone should rest mainly on experiment. Vicat, whose extensive and valuable researches gave the first impulse to enquiry on the subject, says:

"The physical characters which serve to distinguish calcareous compounds fail to give any certain indication of the qualities of the lime they contain. Even chemical analysis is but an approximate mode of investigating them. **Experience by actual trial ought to be the builder's only guide."**

We may remark in passing that the limestones of the United States are very generally characterized by containing a large amount of **magnesia,** which seems to **unfit most of them for building purposes.**

Before the mortar is compounded the lime must be slacked. It is a well known property of caustic lime to combine powerfully with water, forming what is technically termed the hydrate of lime, or in common parlance, slacked lime.

This action is accompanied by the evolution of considerable heat, and the lumps decrepitate into powder to a greater or less extent, after which the whole will be found to have increased in weight according to the quantity of water combined.

The rich limes should always be slacked by gradually adding water and allowing them to remain wet, for these limes will retain their plastic state beneath the water, until the effect is thoroughly accomplished. We are told the Romans had a law that the lime should not be used until it had laid in a moist state for three years. This it was supposed would give ample time for the most minute particles to become hydrated. *[and was generally prescribed for stucco* *work, not for building, and was actually 3 months, due to a long-standing mis-translation].*

The case however is different with the hydraulic limes, and **the better their quality the more imperfect will be the comminution of the lumps.** It is therefore **essential, we may say, that they should be brought to a state of fine division before slacking, either by pounding them, or much better, when the magnitude of the work justifies the expense, by grinding them in a mill.** Another reason why this should be done is that very soon after slacking the hydraulic lime begins to set, and **hence everything which facilitates the rapidity of mixture and use adds to its value.**

After being ground it should be slacked by sprinkling with water and working the paste until the slacking be thorough and complete, which is important, since limes swell in slacking and will therefore disintegrate the mortar if not fully hydrated.

We have remarked that the limes containing from six to twenty-three per cent, of clay are suitable for hydraulic mortars. The great superiority of these has led to their artificial production by mixing various foreign substances with the rich limes.

It was ascertained that the Roman artizans in preparing their mortar, which at this day is more firm than the building stones, mixed with their lime a volcanic substance called puozzolano. Subsequently the same material was discovered in Germany, where it is called trass, in France and in Scotland, and has been used with wonderful success. It consists chiefly of alumina and silex, mixed with a small proportion of lime and highly magnetic oxide of iron. When introduced into the mortar it communicates the property of setting with great rapidity even under water, and of retaining a firmness and cohesive power for ages, after the manner of natural hydraulic mortar.

Some clays after a moderate calcination are found to possess the same properties to a very considerable extent when not subjected to the action of sea water. Their composition is nearly the same as that of the puozzolanos, but the components are hydrated and this water must be driven off by the calcination. **Mr. Burnell thinks that the lime and clay should be calcined together** so that a more intimate mixture may be secured, thereby favoring chemical action. Experiment at present is the only way to test the goodness of the clay and the degree of calcination. The Romans often used pounded bricks or tiles, and the slag and scoriae from iron furnaces are also excellent ingredients. They must previously be reduced to a powder, and only those are fit for the purpose which will dissolve or become gelatinous under the action of muriatic acid. **Ashes of various kinds have also been successfully tried, but before mixture they must be freed from the alkalies by washing.**

Experience has shown that the best plan in preparing mortar is first to bring the lime to the consistence of a smooth and uniform paste before adding the components. The sand must be gradually intermixed and the whole thoroughly worked together. **<u>This is a point usually but little attended to,</u>** but nevertheless is of great importance.

The more the mortar is worked the more sand will it take, and the greater will be its durability. The old Romans, Vitruvius says, had a proverb that mortar should be moistened with the sweat of the brow. It may be proper to observe that in the case of hydraulic mortar this working must be done with many hands since it is requisite that it should be placed in position as soon as possible. As to the proportionate quantity of the sand to the lime, again we cannot be definite, so much does it depend on the various qualities of the latter; we may state, however, that the rich limes require a larger quantity than the hydraulic. Vicat thinks it better to err in a deficiency than an excess of lime in mortar made from the rich limes, and vice versa with that from hydraulic limes. According to Vitruvius, the Romans prescribed three parts of coarse sand to one of lime; and according to Pliny, four of the former to one of the latter. In compounding the artificially hydraulic limes, such proportions must be used as experiment shows to be best.

Except where both are calcined together **the clay, burnt and powdered, must be mixed with the lime after slacking and before the sand is introduced.**

The setting frequently alluded to is an imperfect crystallization by which the whole becomes converted into an indurated crystalline mass. The result is greatly aided by the sharp angles of the sand grains which afford nuclei for this crystallization, and are points of attachment by which the whole is firmly bound together.

On this principle, also, the mortar adheres to the stone or brick of which the wall is constructed. In the ordinary mortars, those composed of rich lime and sand, the crystalline portion is carbonate of lime, and hence if all the carbonic acid be expelled in the calcination it must be reabsorbed from the air **before the setting can take place. This is a slow process. The mortar may become somewhat dry in the course of a few days and possess a slight cohesive power, but it may require years in order to become thoroughly indurated.**

Such is the case with hydraulic mortars both artificial and natural. They set in a few hours after being prepared hence we must believe, and indeed subsequent analysis shows that the crystalline substance is **not carbonate of lime, but some other chemical compound of the several ingredients**, this, however, chemists are not as yet fully prepared to pronounce.

The hydraulic mortars have engaged most of our attention, because of them little is practically known, and they certainly are of the first importance. The name hydraulic is given them because of their property of setting under water, and heretofore they have been used **<u>almost exclusively for marine and other hydraulic works.</u>** **It is highly important, however, that we should possess and put into practice the means of giving greater durability and security to our ordinary buildings, and there is no reason why the hydraulic mortars should not be used to this end.** They act equally well, if not better, in air, and with skill can doubtless be made so economically that the difference in expense is no ground of preference for ordinary mortars. **It is only necessary that the experiment be made a few times. Success is certain, and will be the greatest, the most valuable advance in modern construction.** *[these statements clearly illustrate the previous general use of air limes or very ffebly hydraulic limes for building. Sloan is here making the case for hydraulic limes to be used above ground and <u>instead</u> of air limes. This determination only accelerated after this, to be followed by the use of Roman and then Portland cements in similar circumstances].*

Of cements little has been said, since they are rather disconnected with the peculiar views which we wished to inculcate. It is nevertheless gratifying to know that their composition and properties are being thoroughly examined, and the recent experiments at the World's Exhibition show that little is left to be desired in the accomplishment of **the purposes to which they are particularly adapted.**

Dobson E (1854) Rudiments of the Art of Building. London. John Weale.

(p69) 141. Limestone may be divided into three classes. 1st. Pure limes — as chalk. 2nd. Water limes — some of which are only slightly hydraulic, as the stone limes of the lower chalk, whilst others are eminently so, as the lias limes. 3rd. Water cements— as those of Sheppy and Harwich.

142. In making mortar the following processes are gone through. 1st. The limestone is calcined by exposure to strong (p70) heat in a kiln, which drives off the carbonic acid gas contained in it, and reduces it to the state of quick-lime. 2nd. The quick-lime is slaked by pouring water upon it, when it swells, more or less, with considerable heat, and falls into a fine powder, forming a hydrate of lime. 3rd. The hydrate thus formed is mixed up into a stiffish paste, with the addition of more water, and a proper proportion of sand, and is then ready for use.

143. Pure Limes. — Chalk is a pure carbonate of lime, consisting of about 5 parts of lime combined with 4 of carbonic acid gas. It expands greatly in slaking, and will bear from 3 to 3 ½ parts of sand to one of lime, when made up into mortar. Chalk lime mortar is, however, of little value, as it sets or hardens very slowly, and in moist situations never sets at all, but remains in a

pulpy state, which renders it quite unfit for any work subjected to the action of water, or even for the external walls of a building….

145. Water limes have obtained their name from the property they possess in a greater or less degree of setting under water. They are composed of carbonate of lime, mixed with silica, alumina, oxide of iron, and sometimes other substances.

146. Dorking lime, obtained from the beds of the lower chalk, at Dorking, in Surrey; and Halling lime, from a similar situation near Rochester, in Kent, are the principal limes used in London for making mortar, and are slightly hydraulic; they expand considerably in slaking, but not so much as the pure limes, and will make excellent mortar when mixed with 3 parts of sand to 1 of lime. Mortar (p71) made with these limes sets hard and moderately quick, and when set, may be exposed to considerable moisture without injury; but they will not set under water, and are therefore unfit for hydraulic works, unless combined with some other substance, as puzzolana, to give them water-setting properties.

147. The blue lias limes are the strongest water limes in this country. They slake very slowly, swelling but little in the process, and set very rapidly even under water; a few days only sufficing to make the mortar extremely hard. The lias limes will take a much smaller proportion of sand than the pure limes, the reason of which will be understood when it is remembered that they contain a considerable proportion of silica and alumina, combined with the lime in their natural state, and consequently the proportion of sand which makes good mortar with chalk lime, would ruin mortar made with Aberthaw, Watchet, Barrow, and other lias limes. In the Vale of Belvoir, where the lias lime is extensively used, the common practice is to use equal parts of lime and sand for inside, and half sand to one of lime for face work….

(p72) Before that time *[1796 and the invention of Parker's natural cement]*, hydraulic mortar, for dock walls, harbour work, &c, was usually made, by mixing common lime with trass, from Andernach in Germany, or with puzzolana from Italy; both are considered to be volcanic products, the latter containing silica and alumina, with a small quantity of lime, potash, and magnesia. Iron is also associated with it in a magnetic state.

CONCRETE AND BETON.

153. Rubble masonry, formed of small stones bedded in (p73) mortar, appears to have been commonly used in England from an early period; and similar work, cemented with hydraulic mortar, was constantly made use of by the Romans in their sea-works, of which many remains exist at the present day in a perfectly sound state.

154. This mode of forming foundations, in situations where solid masonry would be inapplicable, has been revived in modem times; in England under the

name of concrete, and on the Continent under the name of beton. Although very similar in their nature and use, there are yet great differences between beton and concrete, which depend on the nature of the lime used, concrete being made with the weak water limes which will not set under water, whilst beton is invariably made with water-setting limes, or with limes rendered hydraulic by the addition of puzzolana. Describing the two by their differences, it may be observed that concrete is made with unslaked lime, and immediately thrown into the foundation pit; beton is allowed to stand before use, until the lime is thoroughly slaked: concrete is thrown into its place and rammed to consolidate it; beton is gently lowered and not afterwards disturbed: concrete must be thrown into a dry place, and not exposed to the action of water until thoroughly set; beton, on the contrary, is made use of principally under water, to save the trouble and expense of laying dry the bottom.

155. Concrete is usually made with gravel, sand, and ground unslaked lime, mixed together with water, the proportions of sand and lime being those which would make good mortar without the gravel, and, of course, varying according to the quality of the lime; with the common limes, slaking takes place at the time of mixing, and the quality of the concrete is all the better for the freshness of the lime. If lias lime be used, the concrete becomes beton, and must be treated accordingly. The lime in this case must be thoroughly slaked (which often takes many hours) before it can be considered fit for use; and, if this precaution be not attended to, the whole (p74) of the work, after having set very hard on the surface, cracks and becomes a friable mass, from the slaking of the refractory particles after the body of the concrete has set….

(p95) A cubic yard of mortar requires 9 bushels of lime and 1 load of sand. Lime and sand, and likewise cement and sand, lose of their bulk when made into mortar.
The proportion of mortar or cement, when made up, to the lime or cement and sand before made up, is as 2 to 3.

Lime or cement and sand to make mortar require as much water as is equal to their bulk.

Plastering

(p118) 237. Materials. — Coarse stuff, or lime and hair, as it is usually called, is similar to common mortar, with the addition of hair from the tanner's yard, which is thoroughly mixed with the mortar by means of the drag.

Fine stuff is made of pure lime, slaked with a small quantity of water, after which, sufficient water is added to bring it to the consistence of cream. It is then allowed to settle, and the superfluous water being poured off, it is left in a bin or tub to remain in a semifluid state until the evaporation of the water has (p119) brought it to a proper thickness for use. In using fine stuff for setting ceilings, a small portion of white hair is mixed with it. Stucco is made with fine stuff, and clean-washed sand. This is used for finishing work intended to be painted. Gauged stuff is formed of fine stuff mixed with plaster of Paris, the proportion of plaster varying according to the rapidity with which the work is required to set. Gauged stuff is used for running cornices and mouldings….

The variety of compositions and cements made use of by the plasterer is very great. Roman cement, Portland cement, and lias cement, are the principal ones used for coating buildings externally. Martin's and Keene's cements are well adapted for all internal plastering where sharpness, hardness, and delicate finish are required.

L J Vicat - Traité pratique et théorique de la composition des mortiers, ciments, et gangues à pouzzolane 1856 Translated by Emma Michel 2016.

p8 Fat limes are so named because, after receiving a sufficient amount of water, they become a fine, fat paste. This paste stays indefinitely malleable in humid places, sheltered from air, and also consequently dissolves gradually until it completely disappears. This phenomenon varies in its intensity depending on the nature of the lime. It is generally more pronounced with fat limes than hydraulic limes.

P15 Slaking of quicklime :
Every (*type of*) lime, taken straight out of the kiln, or shortly after, and thrown into a tub full of water, bursts with noise, swells and turns into a mash, emitting heat and boiling. This particular slaking is called **ordinary slaking or 'à grande eau'** *(great amount of water)*. *(No other author in this period, or before or until the 20th C, other than Vicat himself, indicates this method, rather indicating the addition of sufficient water to the lump lime).*
In this form of paste or thick gruel, lime becomes what we call 'chaux fondues, coulées ou fusées' - melted, fluid/flowing or fused. We can, in its form, change it to a thick consistency or a liquid one depending on its use. …Fat limes expand a lot more than hydraulic lime. Fat limes give a paste neither too soft nor too hard, from 2 to 2½ times to one of quicklime measured in stones, and the voids between them. Hydraulic lime in the same circumstances only produces from 1 to 1½.

Generally, 100 kg of very pure and reactive fat lime produces 0,24m3 of paste. However, when the lime has been burnt several days before and that lime is not very pure, that number falls to 0,18m3. Between these limits are the variations of expansion of the other limes.

P16 If, instead of slaking the lime underwater, we only dip it for a few seconds and tip it out before the starting of that pasty expansion, it whistles, bursts with noise, spreads steam and reduces to powder. However we achieve the same results if we only spray the quicklime spread on the floor. In both cases, it is better to make a heap to concentrate the heat that will facilitate and accelerate the reduction into powder.

Once the lime has been turned into powder, it does not heat up with water, and retains, with fat lime, from 18 to 20 parts per 100 and with hydraulic limes, 20 to 30 parts per 100. This is what we call '*l'extinction sèche par immersion ou aspersion*' = **dry slaking by immersion or aspersion.**

In some areas, we gradually form the lime as a heap while spraying it, we then cover it with fresh sand in which the lime crumbles to powder and can be conserved and used for a few days.

P17 There is a third method of slaking that we do not use: the '*extinction spontanée ou naturelle*' = spontaneous or natural slaking, and we are only going to say that once exposed to the air, it absorbs the carbonic acid and humidity. These limes crumble to a great fine powder and are different in terms of their quality. It needs not less than 3 months for this spontaneous slaking to be completed when made from a fat lime in which the quicklime lumps are the size of an egg. (…) **After the end of that natural slaking, the fat limes and the sand are a better mortar than when slaked artificially**: but their slowness in reaching the right consistency does not allow it to be practically used.
We should not forget to say that the slaking described above was done in a sheltered area.

P24 <u>Making and employment of fat lime mortars</u>

These mortars are made, as is commonly known, of sand and lime in paste mixed with water and generally **in average proportions of two measures of sand for one measure of lime.** Sharp sand is better for this mortar than fine sand. (…)

For the lime, the spontaneous slaking is preferable to the ordinary slaking because it strengthens the mortar by about two thirds, but the cost also increases due to the need of a greater quantity of lime for the same volume of paste.

Fat lime mortars are better when mixed several times, which justifies the 'Lyonnaise' method, in which they make a big heap in advance and take only the amount needed for the day, softened by the addition of water.

This improvement –which we put in evidence in 1819 - is that fat-air-slaked lime delivers a better mortar than the one slaked with the ordinary method, **whether in the form of powder or with a great quantity of water** but with the strict proviso that when using the spontaneous slaking method, the lime has to be thoroughly slaked - which we have observed to be difficult - otherwise it could ruin the masonry. The 'lyonnaise' method provides a lot of carbonic acid and helps the definitive reduction of the lazy parts of the lime.

P25 The history of fat lime mortars can be concluded in a few words, in what we observe in the demolition of old houses. This demolition starts from the last storey of the house to the bottom **with great ease**. The mortar breaks and sometimes turns into dust with the use of a hard sweeping brush. Between the floor and the base of the foundation, we find a mortar not very consistent or **still soft** if it is only a few years old. **However, this mortar can be very hard after 200 years and more.** When the masonry built in fat limes in any type of constructions, were from the outset, in contact constantly in some areas with running water, then these areas after some time would be stripped of their mortars. The stones in the stonework seem, under the technical expression '*être posées à sec*' <= to be dry wall, the water having broken down and destroyed the mortar.

To conclude, fat lime mortars, without their insoluble crust covered on their surfaces with carbonic acid and without their superficial resistance to the rain would be a worse choice than a good *'pisé'* = rammed earth *(construction)*.

(Indeed, many of the mortars Vicat criticizes were probably lime stabilized earth mortars).

However, as it is those mortars we use generally in buildings of low importance, and that rubble is sufficient for the core, it is possible to obtain the least worst possible mortar by doing the opposite of what masons do. Instead of drowning the lime to slake it and to waste the mortar with a very soft, almost fluid consistency, lime should be employed in a firm state and to add water only if the sand is too dry and if it absolutely needs it in order to obtain a mortar of good consistency. With all these precautions, we will never achieve a mortar in practice in which its final cohesion is more than 3kg per centimetre square *(0.294 Mpa – highly improbable, lest it be a particularly sandy earth mortar)*.

The kinds of mortars that are destroyed by water and severe weather; that are weak and turn into powder in the walls of common houses, (P26) **are not suited for greater construction, particularly not for monumental buildings.** *(These mortars are quite likely earth-lime mortars)*.

P38 In the foundations, on the contrary, when the fat-lime mortar can stay a long time humid without the lime dissolving and when the carbonic acid is trying to penetrate the mass to operate the regeneration of the lime into carbonate, it then produces a confused crystallisation. **This effect provokes a strong adherence between this new body and the sand.** But this intimate process can only be observable after several centuries, explaining the great hardness of some fat lime mortars found in the demolition of huge foundations dated back to the Middle-Ages, in which the employment of gunpowder was required**.**

P74 Antique mortars compared to the Medieval mortars and modern mortars.

The monuments in Egypt are without doubt the most ancient examples that we can cite of the employment of lime in building. The mortar that joints the stones in the pyramids, particularly those in Cheops, **are exactly similar to our mortars in Europe**. The mortar we see between the joints in decayed edifices in Ombos, Edfou, on the Isle of Philae and in other places indicates by its colour and grain, a very fine reddish sand *(pozzalanic aggregate?)*, mixed with lime in common proportions. The use of mortar was then known more than 2000 years before our era.
By only using the mortar for very fine/narrow joints that separate huge blocks, the Egyptians, by assigning this almost insignificant role to the use of mortar, seemed to have sensed the *(bad)* influence a scorched and dry climate could exert on the curing and the lasting of that mortar.

Time has proved their caution because the works of Romans on the edge of the Nile, no longer exist, whereas after 20 centuries, a few Egyptian temples remain intact for our admiration.

It is true that the masonry built with small materials could not suit a people that sculpted on the façades of their monuments the history of their customs, arts, wars and conquests. Unbaked brick, *('la brique crue' = literally, raw brick)* ***adobe*****, cemented with clay was enough for simple dwellings and under a constant cloudless sky, this way of building was as safe as it was quick and economic.**

It was in the country of Fine Arts, in Greece, so fertile in ingenious (p 75) inventions that the industry, stimulated by a very different climate, succeeded in varying the employment of lime and to slake it for a variety of purposes unknown in Egypt.

From this moment, the Greek colonies brought and popularised their methods in Italy, the Roman architects were able to be educated, thanks to the writing of Vitruvius, on the Greek authors and the art of building. These writings did not survive; Vitruvius extracted everything and passed it on to us. It is therefore his book we must resort to when it is needed to explain some parts of the controversy on the methods of building in use in these ancient times. But it is impossible to find anything there to believe a particular method whose secret is lost. Everything related to lime, sand and pozzolan is clearly explained.
According to Vitruve, Roman builders thought the best lime was from the purest and hardest marble, that is, **the fattest lime possible**.
(…)

The Roman mortars are usually all similar to each other; we can recognise them thanks to the presence of sand mixed with gravel, **the lime lumps are sometimes so numerous that it is impossible to think it is a defect of grinding.** The incomplete slaking of fat lime by spraying or immersion is the only way *(to explain it)*. The mortars designed for humid places, cisterns, drains and tile floors (pavimenta) (<=*in the book*) were usually made with fragments of crushed bricks from a nut size to gravel size and put in (P76) one part of fat lime. (…)

The prevalence of a blind admiration for all Roman mortars and, subsequently, the supposition of a particular method of fabrication whose secret was lost, is as much exaggeration as it is mistaken, and easy to refute. Even with the decadence of arts that followed the Roman Empire, we still continued to build or repair houses, and the methods in use, still employed by the workers, were transmitted from father to son until old age. This is so very true that even today, Italian masons, who most certainly have not read Vitruvius and have not improved anything, make coats *(enduits = very wide meaning, plaster, layer, coat, to cover something)* in tanks and concrete floors, the way we find in antique ruins.
It is not true that Roman mortars are, everywhere and always, equally good (…)

If Roman masonry had always and equally been of good *(quality),* time only would have not erased as many constructions, monuments of which we find hardly any trace today. The Berbers had no interest in destroying them completely, knowing that it would be more pain than profit to do so, the use of explosive being then unknown to them. It is common knowledge that frequently, powder (explosive) should be employed to demolish old ramparts, old castles and other constructions dating back from the Middle-Ages.

Should we conclude then (P77) that the secret of the Romans was still known at this time and would have been lost only later on, precisely in the Renaissance,(...) is this supposition admissible? Therefore let us assert, on the contrary, with Vitruvius, that the Romans used lime, sand and materials from their country to build, as we do it today. In addition, the chemical analysis of their mortars has shown **no new element from our own mortars,** however, by the action of the carbonic acid, and in a lot of cases, by the accession of elements able to attack the sand and to induce the silica to combine with the lime; these mortars reached a very strong hardness that we admire, and could turn them into very mediocre ones when those means were not achieved.

Our great superiority since 1820, in this part on the art of building, is from now on unquestionable.
Chemistry has taught us by which routes, the elements contributing to the solidification of calcareous parts form an intimate link in chemical combinations. We can determine, with the proportions, the reasoned choice and the preparation of materials, how to satisfy all requirements in building. Such is the current progress in this report, that after a few months with our eminently hydraulic mortars and after a few days with some cements, **our masonries can equal in solidity the best ancient masonry.** *(and this is a good thing?)*

Burnell G R (1857) Rudimentary Treatise on Limes, Cements, Mortars, Concretes, Mastics, Plastering, etc. first edition 1857.

Burnell represents himself as a 'scientist', keen to bring the insight of science to the building site. His primary thrust is to argue that all limes should be slaked to a 'paste' before being mixed with sand or other aggregates and that this will ensure maximum performance from the material. This does not mean that it should first be made to putty and laid down – rather, that the ordinary method of hot mixing with an excess of necessary slaking water was preferable to dry-slaking. Modern research would indicate that the particle size of the slaked lime run to a paste during slaking is finer, with more surface area and porosity, than when it is first slaked to a dry powder, the particle size of which is more coarse. This translates into greater or lesser stickiness and bond. He frowns upon the practices of 'slovenly London bricklayers', who hot mix their mortars initially to a dry hydrate. The majority of Burnell's sources and references are to French treatises, beginning with Vicat. He is not advocating the making of putty lime to be stored or laid down. It is at the very least implicit that he is advocating the slaking of both air and water limes to a paste (quite a thick one) immediately prior to the addition of sand, so that the slaking quicklime paste would remain hot when the mixing of the mortar occurs. In the first edition, he is generally sceptical about the advantages or benefits of Portland Cement, continuing to prefer either hydraulic or pozzalanic mortars or 'Roman Cement' in damp or wet situations. An appendix to a later edition makes plain his unreserved conversion to Portland Cement, not simply for wet situations, but generally for external applications. If nothing else, this indicates where he was coming from all along and his dismissiveness of air limes generally must be read in this context. He was, however, much aware of the influence of different sands and aggregates and discusses their potential reactivity at some length. At no point does he discuss or consider the influence of the heat of slaking upon the mortars made.

Excerpts:
ON THE MAKING OF MORTAR

The making of mortar comprehends the slacking of the lime and the mixture of the ingredients worked up with it. As we have already seen, both the former process and the nature of the latter differ, according to the lime to be dealt with. **It is, however, a universal rule,** in contradiction to the slovenly practice of London builders, **that all limes, of what nature soever, should be reduced to a paste before being mixed with the other ingredients.**

People who have not studied the action of hydrates in a scientific and consecutive manner, **oppose the introduction of the previous manipulation of the lime on the score of the extra expense, and <u>on the pretence that the lime loses in strength thereby.</u>** As to the objection of the expense, that must, of course, be estimated by the importance of the works. The second objection is to be met by observing that the rich limes require to be for a long time exposed to the air to enable them to take up the carbonic acid gas; and that, therefore, so far from losing, they gain by exposure; and moreover, the hydraulic limes being very difficult to slack, it is necessary that all their particles should be put into contact with the water. If the lime be not previously reduced into a state of a perfect hydrate *[he means a wet, not a dry hydrate],* it is always exposed to blister, and to disintegrate, in a manner depending upon the comminution of its particles before being employed*;* for **it is evident that if the lime be ground, the more inactive particles are in a more favourable condition for the absorption of the water.**

The degree of consistence of this paste should vary with the nature of the extraneous materials. **It should be stiff whenever it is intended to form a gauge for substances whose particles are hard and palpable,** and which are capable of preserving sensible distances from one another. **It should be more liquid when the substances to be mixed with it are pulverulent, of impalpable and fine grains,** presenting an homogeneous appearance, and in which it is impossible to distinguish the separate elements, such as the puzzolanos etc. **To secure a proper state of hydrate, it is of great importance, however, not to use too much water in slacking the lime** [*almost universal practice for the last 40 years].* **So much should be used, and only so much, as is necessary to cause the quicklime to fall to powder** *[so - dry slake and immediately mix to a paste and then mix with sand?Otherwise contradicts the above assertions].* **It is also equally important not to mix up into the state of paste more lime than is immediately required to be used.** *[or may the dry hydrate be stored, being made to a paste only for immediate use?].*
In France, where great care is required in the fabrication of mortars, **the lime is worked up into a paste in a mill, consisting of two vertical stones working in a trough. The lime, after going through this operation, is then mingled with the sand in a pug-mill, or by hand, upon a floor.** ***[In this case, the slaked lime paste would be hot when mixed to a mortar with the sand, clearly].***

The quantities of sand to be used vary…according to the nature of the limes, and also the sand itself…we find that, for the rich limes, the resistance is rather increased if the sand in the proportions varying from 50 to 240 % of the paste **measured in bulk in the state of a firm paste.** Beyond that point the resistance decreases. The resistance of hydraulic limes increases if the sand be mixed in the proportion of 50 to 180 % of the paste. from thence it decreases.The much greater proportion of sand the rich limes are able to support, may perhaps, **account for the partiality of the builders in their favour** *[A-ha!].*

If it be required to mix common lime and puzzolanos, the best proportions, according to General Treussart, are 1 of lime in powder to 2 1/2 of puzzolano; 1 of lime to two of trass; or 1 of lime to 1 of sand, and 1 of puzzolano or trass. ***[It is clear from all 19th C texts that hydraulic limes were rarely, if ever, mixed at 1:3, most often at 1:2 or richer in lime. Similarly, pozzolans of all description were used in significantly higher proportions of the mortar than they have been over the last 40 years. The lime here is quicklime].***

The best hydraulic limes…lose much of their qualities if long exposed to the air; it is therefore advisable to work them only for the time absolutely necessary to ensure, firstly, their perfect reduction to the state of hydrates; and, secondly, he intimate mixture of the lime and sand. The rich limes, however…., inasmuch as they absorb the carbonic gas with difficulty, gain by being exposed for a longer period to the contact of the atmosphere [*not exactly…]*….it is advisable, then, to protract the operation of their manipulation as much as possible; it is even advisable *[or simply just possible]* to work up large quantities of such mortar beforehand, rendering it fit for use by a second manipulation.

Some of Vicat's experiments show that all limes lose 2/5 of their strength if mixed with too much water *[air limes do not necessarily and if the aggregates are limestone dust, their strength is improved, whatever the water content (Lawrence 2005)]*. It is better to wet the materials to be used and to employ a stiff mortar, than to follow **the course usually adopted by masons and bricklayers of using very soft fluid mortar** *[however, a hot mix used hot will be the latter initially, becoming the former quite quickly…the best of both worlds?]*.

There are conditions of the atmospheric state which affect the goodness of the mortars…For instance, **those made in summer are always worse than those made in winter….**Vicat asserts that (mortars) lose 4/5 of their strength if allowed to dry very rapidly. He recommends…that the masonry be watered during the summer months, in all constructions of importance, to guard against this danger. *[especially important for NHLs]*. The freedom of the water from carbonic gas in solution is also a necessary condition of the successful use of the hydraulic limes *[really?]*. Their success depends, to a certain extent, upon the slow, gradual manner in which they take up that gas from the atmosphere, and crystallise about the nuclei offered to their action.

The position in which a mortar of any description is to be used, also modifies the proportions of sand which it is desirable to mix it with. Underground, in the water, and in damp positions, less sand should be employed than in the open air, where it is exposed to the changes in the atmosphere.

CONCRETES

The term 'concrete' is usually applied to a species of rough masonry of small materials, consisting of gravel or broken stone mixed with a lime, either previously worked into a mortar or not, as the nature of the lime may require. It is principally used for the purpose of distributing the weight of a large heavy construction over the greatest surface possible; or for the backing of coursed masonry, in cases where walls are required of great thickness. Properly speaking, it would be better to apply the word 'concrete' to this sort of masonry, **when executed in the manner usually adopted in our country, by slacking the lime upon and in immediate contact with the gravel.** When the lime has been previously worked into a paste, the French word 'beton' might be applied, for the sake of distinguishing the two processes.

…The situations in which it is to be used are mostly those in which there is a great amount of humidity…it is necessary to employ only such materials as are susceptible of a rapid setting and continued progression of the powers of resistance…the limes which unite the above conditions are the hydraulic limes, obtained either from the argillaceous, or the magnesia-argillaceous, carbonates of limes. In their absence, some ingredients of the nature of puzzolanos, burnt clay, slag, or cinders must be used. But it should always be borne in mind, that these mixtures are but very imperfect imitations of the natural productions *[are they?]* ; they should never be used if the hydraulic limes can be obtained, even at an increased price; and….of the hydraulic limes, those obtained from the calcination of the limestone itself are preferable to those made artificially.

In almost every work upon the art of construction, we meet with descriptions of modes of making concrete. It is, however, very discouraging to observe that, in spite of all that may be said, **the majority of architects and engineers treat the subject with such utter indifference that the old imperfect systems are still retained, and <u>the conduct of these works is left almost invariably to some rule-of-thumb workman, who only knows that he has been accustomed to make concrete in a certain manner, without knowing any one of the principles which regulate the action of the materials he works with *[!!!!]*</u>.** We thus find that the greater part of the concretes made in or near London, where the building art ought to be the most advanced, is made simply **by turning over the ground stone lime - a very moderately hydraulic one, by the way, amongst the gravel. It is then put into barrows, and shot down from a stage.** Such a mode of proceeding is rapid and economical; but it is eminently unscientific…**Unfortunately, in England, we do everything in such a desperate hurry, especially since railroads have been constructed, that we cannot afford the time necessary for a perfect execution of the works.** Failures are consequently frequent, the waste of materials enormous; and, of course, between the two, the expense is out of all proportion to what it ought to be *[plus ca change! But hot-mixing not necessarily a function or a cause of this, predating by far Burnell's time]*.

(Burnell then advocates the same procedure as for mortars - slaking the quicklime to a 'thick paste' before engagement with the aggregates or pozzolans. Concrete should be wheeled in and laid before being 'beaten with a rammer' avoiding any separation of the ingredients due to be dropped from height and keeping the distribution of the binder constant *[but would it do this better than a hot mix, which holds onto water better than putty lime mortars, which readily generate separation and laitance?]*

…A very excellent concrete for either sea or river works is made by a mixture of a mortar made of **three parts of fine sand to one of hydraulic lime <u>unslaked</u>, with equal quantities of gravel or broken stone.** No water should be mixed with the mortar and gravel during their manipulation; the mortar itself, if possible, should be prepared in a pug-mill, and mixed with the gravel being frequently turned over on a platform…the concrete thus made should be spread in layers from 10 inches to 1 foot in thickness, and well rammed, until the mortar begins to flush up at the top. …

When the works are left to the care of mere workmen, as they too often are with ourselves, a very absurd mode of making concrete is often adopted where there is much water to be contended with. **The lime is mixed with the gravel, without having been previously slacked and left to absorb the water necessary for its passing to a hydrate as it may.** Such a course is unphilosophical and dangerous in the highest degree, and cannot be too carefully guarded against. (argues that hydration is 'robbed' from other lime in the mix and 'must disintegrate the mass')…

Broken limestone appears to add very much to the qualities of concretes, betons and mortars. Very probably this may be attributed to the affinity between the molecules of the already formed carbonate of lime, and that which is in the process of formation; the new crystals may group themselves more easily about bodies whose form is similar to the one they are themselves to assume. Or possibly there may be **a tendency in the chemical elements to arrive at a state of equilibrium; and the carbonate of lime may, therefore, be supposed to part with a certain portion of its carbonic acid gas.** *[seeding carbonation…].*

ON THE SANDS AND OTHER INGREDIENTS USED IN CONJUNCTION WITH LIME TO MAKE MORTAR.

These ingredients are of several natures, **and they exercise very different and very important effects upon the qualities of the respective combinations into which they enter.** They are 1, the sands…whether fluvial or pit sand; 2, the clays, either in their natural or their burnt state; 3, the puzzolanos, trass, or other volcanic productions; and 4, the produce of artificial calcination, such as cinders, slag of furnaces, or scoriae….

1 Sands….

The generally received opinion that the sand should be perfectly free from all earthy matters, is only true to a certain extent (discussion of the use of 'arenes' for construction in France - between 25% and 75% clay mixed with chalk aggregate, and used with rich limes for waterworks…). Some of the decomposed grauwacke rocks also yield an argillaceous sand, composed of quartz, schist, feldspar and particles of mica agglutinated by a species of clay, which is very valuable, whether used in its natural state, or calcined to make artificial puzzolanos, like the arenes. The granitic rocks of Devonshire, some parts of Brittany and of the extreme NW of Spain, all of which are characterised by a remarkable excess of feldspar, yield a sand of great value for building purposes, especially when the mortars composed of it are not immediately exposed to the effects of running water. In all probability, the potassa present in the decomposed and decomposing feldspar may influence the setting of the limes mixed with the sands thus obtained.

2. The Clays

The clays are rarely used in their natural state in combination with lime, **unless it be to give a certain degree of consistence to mud walls or pise work [*and for earth mortars and plasters throughout the UK and elsewhere!]*.** When burnt, they act somewhat in the manner of puzzolanos; and for all cases in which the mortars thus made are not exposed to the action of sea water, they appear to answer very well.

3 The puzzolanos

The puzzolano is a volcanic substance of a pulverulent character, and a violet red colour, which was fist employed in the fabrication of mortars by the Romans…

Its aspect varies, however, very much; sometimes it is in a state of powder, at others in coarse grains; often in the form of pumice, scoria, or of tuffa or in small rubble-stone. Its colour is often brown, or yellow, or grey, of black, even in the same locality.

The Tripoli, and the sandstones and limestones altered by contact with the rocks of eruption, also frequently take the character of puzzolanos and may be classed, therefore, as pseudo-volcanic products of a similar category….The puzzolanos are principally composed of silica and alumina, with a little lime in combination, mixed with potash, soda, magnesia, and oxide of iron. The iron appears to be in a peculiar state of magnetism; for although in very feeble proportions, it is capable of affecting the needle.

…it is evident that the effect produced by the mixture of the puzzolanos and trass is eminently useful in rendering the rich limes fit for every description of works executed in either sea or fresh water….Less (puzzolano) is required when hydraulic limes are used, than when they are mixed with the rich limes. **The latter will bear at the same time a large quantity of sand or gravel, the former only a very small quantity.**

4. The term ‘slag’ is usually applied to the vitrified earths which are left in furnaces, either for glass or iron, after the purer products are withdrawn. ‘Scoriae’ are the lighter, more porous, and less perfectly vitrified earths, which arise principally from the puddling and refining of iron; the term is also applied to the less compact portions of the slag. Cinders are the earthy residues from the combustion of woods, peat, coal, or other combustibles.

The slags and scoriae….principally consist of silica, with a feeble proportion of alumina, magnesia and very large proportions of the oxides of iron and manganese.

(compared to pozzolano and trass…'a very remarkable difference in the proportions' in slags and scoriae, as also between scoriae and slag, with the latter having little iron, the scoriae a lot).

Coal cinders…when properly mixed appear to render the rich limes moderately hydraulic.

Wood cinders are often objectionable in consequence of (an) excess of alkali: if this be removed by washing, they may occasionally be useful in the absence of other materials capable of communicating hydraulic properties.

Vicat classes the different materials named and described above still further, **according to the energy of their action upon the limes with which they are mixed:**

He calls '**very energetic**' any substance which, after being mingled with lime **slacked in the usual manner, and brought to the consistence of a thick paste,** produces a mortar capable of setting **from the first to the third day; of acquiring after the lapse of 12 months a degree of hardness equal to a good brick;** and of giving a dry powder if sawn with a tooth saw after that time.
'**Simply energetic',** any substance which will determine the setting **from the fourth to the eighth day;** and which is capable of acquiring **after twelve months the consistence of soft stone, and of giving a damp powder under the tooth saw.**

'Slightly energetic', when the setting only takes place between **the tenth and the twentieth day; the consistency of hard soap…after 12 months, and the mortar would then clog the tooth saw.**

'Inert' when the materials, if mixed with rich limes, exert no influence upon their action under water.

In all these cases the mortars are to be immersed immediately.

might this, without immersion, be a reasonable rule-of-thumb method?]

(Vicat maintains that no pozzolano added to rich limes can make them set under water…)

General Treussart, however, does not agree with Vicat, in supposing that the chalk, or rather the rich limes, cannot be rendered capable of setting by the mixture of pozzolanos; and, indeed, **the experience of almost all builders would lead us to believe that Vicat has, in this case, been carried away by the love of theory.**

OF CEMENTS

A peculiar class of the argillaceous limestones yields on calcination a species of lime capable of setting under water with considerable rapidity, of acquiring a great degree of hardness within a very short space of time, and of being employed without the admixture of any foreign substance.

(First discovered by Parker, 'Roman Cement' using septoria from the Isle of Sheppy); Mr Atkinson introduced another made from the nodules of the argillaceous limestone of the secondary formations of Yorkshire [*Sandsend, near Whitby], (*subsequently Frost, using septoria of the coast of Essex)

On the coast of France a similar material was found in 1802, at Boulogne. Lacordaire discovered it also at Pouilly in…Burgundy…It occurs in the Isle of Wight, in the Bay of Weymouth…

…The mineralogical composition of the stones from which the cement is made differs very much; but the **characteristic type may be said to consist of above 30% and below 60% of clay and other extraneous matter in combination with the carbonate of lime.**

The Sheppy stone usually contains 55 parts of lime, 38 of clay and 7 of iron; **the Yorkshire stone contains 34% of clay; 62% of carbonate of lime and 4% of iron;** the Harwich stone contains 47% clay; 49% carbonate of lime, and 3% of oxide of iron.

…The cement stones are burnt in conical kilns with running fires, and, in England at least, with coke or coal….the precise point of calcination does not appear to affect its qualities.

Before being burnt, the stone is of a fine close grain, of a peculiar pasty appearance; the surfaces of fracture are rather greasy to the touch, and somewhat warmer than the surface of the stone…It sticks easily to the tongue; it does not strike fire; its dust, when scraped with the point of a knife, is a greyish white for the most part, especially when derived from the blue lias formation. It effervesces with nitrous acid, and gives off nitrous acid gas, During calcination the cement loses about 1/3 of its weight, and the colour becomes of a brown tinge, differing with the stones from which the cement is obtained. When burnt it becomes soft to the touch, and leaves upon the fingers a very fine dust; and it sticks very decidedly to the tongue….

Calcined cement (is) of no use until it is pulverised, this is always done at the mill of the manufacturer…it is usually put into casks well closed when thus ground and may be preserved for a very long time; but contact with the atmosphere rapidly deteriorates its quality….

Though all cements and limes tend to reassume a state of carbonisation similar to that in which they existed in the stones from which they were extracted, **they only do so to a very imperfect degree…**Cements, on the contrary, harden very rapidly; but we have no instances *[in 1857]* of their acquiring the strength of the original stone).

It is always dangerous to be obliged to rely upon the skill or integrity of workmen, who either do not understand the necessity of taking pains with their work, or who, from being paid by the piece, have an interest in slurring it over.

A small quantity of water only is necessary to work up cements to their greatest point of resistance, which General Treussart found to be the most successfully attained when the water was employed in the proportion of **one third of the cement in volume.** It is necessary to beat up the cement very frequently; indeed, the more it is turned over before the setting commences, the harder it becomes. The time of setting varies with the nature of the water used and the quantity of sand present. With sea water the time is longer than with fresh, and the sand retards the process of setting considerably. When the cement is new…the time of setting, if it be used pure, should never exceed half an hour, a quarter of an hour being the normal period. (but sometimes 5 or 6 minutes).

Pure cement has much greater powers of resistance [*compressive strength]* than when it is mixed with sand in any proportion whatever - in this again differing from the limes.

…Cement adheres very strongly to iron, to granite, and to bricks….

From these considerations, it would appear that **the best mode of using the natural cements is to employ them without sand in all works under water, or where a great crushing weight is to be brought upon them at once. For foundations in damp situations, where rapidity of execution is desired, they may be mixed with 2 parts of sand to 3 of cement; the same proportions are suitable for cornices, or coatings exposed to weather. 3 parts of sand to 2 of cement make a good mixture for perpendicular faces…**

In England, owing to the cheapness of the so-called Roman cement, whether specifically identified as Atkinson's, the Medina, or merely called Roman, **almost all the works executed in water at the present day are executed with it.** But there are reasons to make us doubt whether we do not in this case adopt a system **which is at least open to objection. Cement is so convenient, that engineers and architects neglect to study the qualities of lime;** and some very unfortunate accidents have arisen from that neglect.

…good hydraulic limes in time attain a degree of resistance sufficiently great for all practical purposes, and at much less expense. **To use a hard, quick-setting material upon a yielding base, is a degree of ignorance totally unaccountable on the part of any professional man of average discernment.** In fine, the uses of these cements are many and various; we, in our country, are rather inclined to abuse them.

There are many sorts of artificial cement employed which are obtained either from the over-calcination of the hydraulic limes (all of them possessing the faculty of acquiring a more rapid setting, and a greater degree of hardness when so burnt), such as the Portland cement before mentioned; or from the mixture of burnt clays with the rich limes. In some parts of the continent, where the natural cement stones do not exist, the latter are much used, and they yield a very tolerable substitute for the articles they replace….but they are far from attaining the hardness of either the natural cements or the overburnt artificial ones. **Their use is principally confined to a mixture with the slow-setting limes when they are employed in damp situations, and in these cases they succeed remarkably well.** The cess-pools and water tanks throughout the interior of Normandy are lined with a mortar made in this manner, and they resist perfectly…

It is to be observed, that although the Portland cement is occasionally exposed to the before-mentioned inconvenience of expanding whilst setting, it has other qualities of a very remarkable nature. It becomes, in equal times, after the first setting (which, by the way, is very irregular), **much harder than the Roman cements. It will admit of a much greater quantity of sand for every purpose; and, moreover, as it does not absorb the humidity of the atmosphere with the same facility it consequently resists the action of frost more successfully, and is less exposed to discolouration by the formation of vegetation.** *(this is, of course, early, less refined Portland cement, hence its variability. Even so, Burrell identifies its lack of porosity as marking it out].*

Dempsey (1857) Architectural Practice, Containing Detailed Working Drawings, Specifications, Bills of Quantities, Estimates, Tenders, etc etc. Forming a Supplement to Dempsey's Builders Guide in Materials and Construction. London. Actchley & Co.

In thick walls the use of **grout** (that is, liquid mortar) is the best safeguard against the too frequent carelessness of workmen. **This composition should not be merely the mortar thinned with water, but should be mixed separately in large tubs, in the same proportions as mortar; and should be used moderately hot, so that it may not impoverish the mortar with which it comes in contact, and that it may set more quickly.** Care should be taken that no more mortar be used than is absolutely necessary to produce adhesion: and for this reason it is usual to restrict the rise of the brick-work, allowing about 5/16 of an inch for each bed of mortar, which will produce l ¼ in. for the thickness of four beds; so that if bricks be 2 ½ in. thick, four courses of brick-work should not rise more than 11 ¼ in. If thick beds of mortar be allowed, the mortar will be pressed out and imbibe moisture, which, freezing and thawing, will burst, crumble away, and render pointing necessary.

All arches in brick-work should be set in cement, if the lime used in the mortar be not strong, so as to set quickly:

Walsh J H (1858) A Manual of Domestic Economy; Suited to Families Spending from £100 to £1000 a Year. London. G Routledge and Co.

MORTAR is made of varying proportions of lime and sand, depending greatly upon the species of lime used. The average proportion is as 1 of *(quick)*lime to 3 of sand, but with many kinds 1 to 4 is a still better and stronger proportion. Sometimes cinders are added to increase the hardness or give colour, both of which purposes they effect. Common mortar is made as follows: A bed of sand is first made by heaping it up around the space which is to be occupied by the mortar. In this area the quicklime is then heaped, and water thrown over it sufficient to slack it; after this, enough sand to cover all up is thrown over the surface, and the whole is left till the next day, during which time the lime becomes thoroughly slacked. The next operation consists in mixing in more sand and water, which is done by labourer, usually with his shovel, beating it over again and again, until the whole is thoroughly incorporated. It is now fit for use, and **should never be laid on more than a day or two old, if it is desired to set strong, and to adhere firmly to the bricks.** The contray opinion is very commonly held, but it is merely an excuse for laziness, and to avoid the waste which occurs when mortar long mixed is rejected. I am quite satisfied that the strength of brick walls mainly depends upon attention to this point. Sometimes a mortar pug mill is used when large works are in hand…*(but for smaller works)*…it mixes too large a quantity at once.

CONCRETE consists of lime and gravel, mixed as fast as it is used, and poured into the trenches cut for the foundations from a height of six or eight feet, using a stage for this purpose….

PLASTER for the walls requires all the lime to be slacked in a large iron furnace or wooden tub, where it is mixed with water till it assumes the consistence of cream. It is then strained off into a large area, bordered by sand to a height of about eight inches, where it is left for ten days or a fortnight, and is then mixed with sand in the proportion of three, four or six parts of sand to one of lime. Sometimes Bristol lime is used, in which case no sand is mixed with it, and the mortar is as white as snow, and it is called 'putty'. Hair is sprinkled over the lime before the sand is added, and worked thoroughly in with a rake. Plaster mixed largely with sand, and hair addeded to it, is called 'coarse stuff' and is used for the first rough coat. Lime mixed with water, and left to get thick, with or without the addition of hair, is denominated 'fine stuff'…

ROUGH CAST AND STUCCO are forms of mortar used for external work, the former being mortar mixed with fine gravel, while the latter is composed of sand and lime, mixed when dry carefully together, and then tempered with water, and used as rapidly as possible.

PUGGING is rough plaster mixed with chopped hay, spread over rough boards fixed between the floor and the ceiling, to break the sound between the several floors.

Contract and Specifications for the Parliament Buildings Ottawa Fuller & Jones Architects 1859. (Toronto Public Library)

Foundation

Large, well-bedded and well-bonded stones laid in mortar and **properly grouted with hot liquid mortar**

…The outside face of the walls to batter…

Flying Buttresses of Library

…joints most carefully wrought…to have slate dowels and be set in mortar formed with the best hydraulic lime or the best Portland cement.

Pinnacles (to have similarly tight joints) and be set in cement

Floors

9″ thick concrete with 1 ½ " of Portland cement laid by plasterer.

Concrete to be formed of the best well-burnt hydraulic lime to 7 measures of gravel, sand and broken stones. The lime is to be ground and kept dry under cover in bags until used.

Masonry

All the mortar for rubble masonry to be composed of 2 measures of fresh, well-burnt lime to 5 measures of sand. All the mortar used in the brickwork to be of the best fresh burnt brown lime, 1 part lime and 3 of clean, sharp pit sand.

The whole to be properly mixed together dry and a sufficient quantity of water added, the whole to be ground under edge runners or in pug mills.

The mortar to be used as hot as possible and no more mortar to bemixed in one day than can be used on the same.

The pointing mortar – 1 part best brown lime, 1 part sharp forge ashes, 1 part iron scales.

Mixed and ground under the edge runner to a fine paste as required **for immediate use.**

Interior joints – fine mortar made with lime and sand formed of the stone or marble used.

External brickwork – tuck-pointed with dark mortar. When any is being done in dry weather, the joints are all to be first well-wetted.

Plasterer

Best fresh-burnt Ottawa lime or other approved, the best clean pit sand and best long hair…the lime is to be run some considerable time before being used (from hydrate?). Setting coat of lime and marble dust.

Lime whiten 3 times, all walls.

Floors finished with 1 ½″ Portland cement – the cement to be mixed with an equal quantity of clean, washed sharp river sand…finished all in one coat…the whole of the cement used to be best Portland from Messrs White & Co, Millbank, London, England.

Skirtings also of cement.

From **Contract, Specifications and Schedules of Prices of Departmental Buildings, Ottawa City 1861 publisher Augustin Cote Quebec.**

Pointing to be with an indented joint in blue mortar, prepared with smith's blowings and other materials as will be directed. ¼″ thickness.

Mortar for rubble work

1/3 best hard burnt lime from the Gloucester quarries and 2/3 clean sharp gravel or coarse sand. And grouted with lime and sand in a liquid state every foot in height. The mortar to be mixed, ground in a pug-mill and used fresh from day to day.

All the cut stone dressings to be laid in putty.

Bricklayer

Flemish bond for 13″ and English bond for 9″ walls.

Mortar – 1/3 best burnt lime and 2/3 sharp sand also mixed in a pug mill and used fresh from day to day, every course to be fully flushed up with mortar and every 4th course carefully grouted with hot grout as before described.

Plasterer

The mortar of the first and second coats to be compounded of the best hard burnt lime, of the district, and clean sharp gravel or coarse river sand, mixed in the proportion of 3 parts of sand and 2 of lime and a sufficient quantity of long

cow hair. The lime to be all run through a screen and mixed at least 3 months before it is required to be used.
White finish – the lime used for the finishing coat of plastering is to be brought from Guelph, mixed with fine sharp clean sand. *(Guelph was a source of dolomitised limestone).*

Lath to be cleft, not sawn.

Espinosa Pedro Celestino (1859) MANUAL DE CONSTRUCCIONES DE ALBAÑILERIA. Ingeniero Jefe de primera clase de Caminos. Canales y Puertos. Severiano Bas Madrid.

CALES. Ideas generales. -—Clasificacion y análisis. Utilidad de las cales.—Orden adoptado para el estudio'de las cales. '—-Cómo se consideran.—Variedades de las piedras calizas.—Me dios de reconocer si una piedra es caliza.-—Division ó clasificacion de las cales.-—Cal comun ó grasa.-—Arida.-—Medianamento hi dráulica. —Eminentemente hidráulica.—Cal limite—Cemento li mite inferior.—Medio.—Limi te superior. -—Opiniones sobre la hi draulicidad de las cales.—Fraguado de la cal.—Caractéres lisicos de las piedras calizas.—Ensayos prácticos.—Esperimentos con los cementos.—Análisis de las calizas.-—Varios métodos emplea dos por Regnaud para el análisis.—Complemento del método anterior.—Método de Berthier.—Método de Delanocie.

p53 APAGADO Ó ESTINCION DE LA CAL Y CONSERVACION DE ESTA.

La piedra caliza. despues de haber sufrido la operacion del calcinado. y antes que la humedad y los ácidos repartidos en la atmósfera (para los cuales tiene mucha afinidad) hayan empezado á obrar sobre ella notablemente, presenta diversas circunstancias que vamos á indicar. Decimos notablemente porque rara vez subsiste la cal viva sin esta influencia en razon á la afinidad espresada. La cal mas pura tiene despues de calcinada, un color muy blanco, es cáustica, infusible é inalterable al fuego. soluble en el agua; su peso especifico en dicho estado es unas dos y tercio veces el del agua destilada.

Limestone, after having undergone calcination, and before the humidity and acids contained in the atmosphere (and for which the same has great affinity) have begun to work notably upon it, presents various circumstances which we are going to indicate. We say notably because in is rarely the case that quicklime is without some such influence due to this affinity.

Para convertirla en cal apagada ó hidrato de cal, ó como suele decirse en la práctica, en cal muerta, hay que procurar al sorba el agua. Al verificar la absorcion, la cal pura ó con pocas mezclas accidentales, desprende calor, el agua se evapora, produce una especie de silbido, se hiende la cal y se deshace en polvo, aumentando considerablemente de volúmen, según se ha *indicado en su clasificacion. Cuando las calizas contienen mezclas accidentales. como sucede con las arcillosas. se modifican los fenómenos de la estincion; asi es que á medida que contienen mayor cantidad de arcilla, la absorbtion, el desprendimiento de calor, el hendimiento. etc.. van siendo mas lentos, y en los cementos llegan á ser insensibles ó nulos, y por es la razon es necesario pulverizarlos mecánicamente para poderlos emplear despues de calcinados.*

To convert this to slaked (apagada - switched off; extinguished) lime, or hydrate of lime, or, as they say in practice, slaked (muerta - dead, putty) lime, it needs to have taken sips of water (small volumes). To confirm the absorption, pure lime or with small quantities of accidental mixtures, there will be heat and the water evaporates, the lime will hiss, disintegrate and fall to powder, increasing considerably in volume, according to its classification. When the limestones contain accidental inclusions, as when they are clayey, the extinction will be modified; and when it contains a higher quantity of clay, the absorption, the release of heat, the breaking up, etc will be slower, and in the case of cements approaches imperceptibility or none at all, and for this reason it is necessary to mechanically pulverise them to facilitate their use after calcination.

Hay varios métodos de apagar las cales, que son los siguientes:

There are various methods of slaking lime, which are the following:

Primero Método: llamado ordinario de aspersion ó método ordinario. Consiste en echar agua sobre la piedra calcinada, sea con cubos, con regadera u otro medio. Es necesario que la cantidad de agua que se echa no sea escesiva, pues en este caso se verifica lo que comunmente se llama ahogar la cal. Este método es el que parece convenir (p54) mejor para la estincion de las cales comunes é hidráulicas en particular cuando estas últimas se apagan á poco tiempo de calcinadas. Se considera que está bien apagada la cal cuando ha quedado con una consistencia pastosa; cuando toda la masa está fria y no contiene huesos ó partes sin apagar. Para probar si se han verificado las circunstancias indicadas, se introduce un palo en diversos puntos y se examina la cal que sale adherida al mismo.

First method: called ordinary aspersion or the ordinary method. It consists in throwing water onto lump lime, by sprinkling or other means. It is necessary that the quantity of water that is added is not excessive, lest the lime should be drowned. This method is that which achieves the largest part of the extinction of common and hydraulic limes, especially when the latter will air slake soon after burning. Lime is considered to have been well-slaked when it is left with a dough-like consistency, when the whole mass is cold and contains no lumps or unslaked particles. To test if all the above has been met, one randomly pokes it with a stick and examines the lime that has stuck to it.

Las cales comunes apagadas de modo que tengan una consistencia pastosa algo fuerte, producen en dicho estado dos á dos y medio volúmenes del que tenian antes de apagarse, y esta circunstancia es la que mas aprendían los prácticos que no conocen las propiedades de las cales hidráulicas considerando como la mejor cal para cual quiera obra la que mas hincha; siendo así que la mayor parte de las cales hidráulicas, y las eminentemente hidráulicas,no producen mas que el de una cuarta parte á un medio de aumento.

Common limes slaked to a stiff dough-like consistency produce in the said state 2 1/2 volumes that it had before slaking, and this must be learned by practitioners who do not know the properties of hydraulic limes who consider the best lime for whatever kind of work is that which swells the most, since the majority of hydraulic limes and the eminently hydraulic limes, do not augment in volume by more than between 1 1/4 and 1 1/2 times.

Cuando se echa el agua de golpe sobre la cal comun, se hiende á veces en seco en algunos puntos, y si se vierte de nuevo agua sobre estos, suele deshacerse con dificultad quedando por consiguiente mal apagadas, siendo tanto mas notable esta circunstancia cuanto mas fria está el agua que se emplea, sobre todo en las cales comunes. Las cales que se han aireado mucho despues de salir del horno. se hacen perezosas, es decir, se apagan después lentamente, en particular cuando son hidráulicas.

When you throw water in one go onto common lime, it will fall to a dry powder in places, and if you throw more water onto these, which will slake with difficulty and remain poorly slaked, and this is the more pronounced the colder the water used, especially in common limes. Quicklimes which have been much in the air after leaving the kiln become lazy, it is said, and slake slowly, particularly if they are hydraulic.

La cantidad de agua necesaria para apagar las cales es variable, sea su calidad; para averiguarlo. se pesará un trozo de esta cuando esté sin apagar, y se pone en un vaso; en este se echa agua en mayor cantidad que la necesaria para que se apague la cal y verificada la extinción se decanta el agua que queda en esceso, teniendo cuidado de que nose remueva la calaposada. Pesando la lechada que resulta y restando lo que pesaba la cal viva se tendrá la cantidad de agua que ha sido necesario emplear para la estincion.

Para apagar la cal por el método ordinario se dispone esta sencillamente en las obras sobre un suelo horizontal y seco, formando un recinto artificial alrededor del espacio que ocupa, con el objeto de mezclar con ella despues los materiales que constituyen los morteros. Estos recintos se hacen comunmente con la misma arena que se ha de mezclar. Es mejor formar un noque ó alberca de poca profundidad con tablones ó de mamposteria cuando es obra de mucha (p55) duracion, lo cual es todavia mas conveniente cuando sean cales hidráulicas las que se apaguen.

To slake lime by the ordinary method, put it upon a dry horizontal surface, and form a ring (enclosure) around it, with the intention of afterwards mixing with it the materials which will constitute the mortar. <u>These 'basins' are commonly made with the same sand with which it will be mixed.</u> It is better to form a shallow pit with sides of stonework, when the works will be of long duration, the same is also more convenient when slaking hydraulic limes.

En este caso se estiunde la cal en capas de unos 20 á 25 centimetros de espesor lo mas , y se echa el agua de modo que penetre bien en todos los huecos; pero teniendo cuidado de no echar una capa antes que se haya apagado la inferior. No debe apagarse cuando se emplea esta clase de cales sino la precisa para usarse antes que pueda endurecer; deben tenerse dos albercas para este efecto, pues es necesario tambien que se deje durante doce horas ó mas para que se apague bien. Con el objeto de obtener de la cal apagada ó mezclas la consistencia que se quiera se disponen varias albercas escalonadas eligiendo cuando es posible un terreno con la pendiente necesaria. Se hace comunicar estos por medio de caños colocados á las alturas convenientes, con el objeto de que las lechadas mas claras pasen á las albercas inferiores. Se empezó á emplear en Inglaterra y se ha generalizado bastante, el uso de un aparato para apagar la cal que tambien tiene mucha aplicacion para hacer las mezclas de la cal con la arena, ademas de los aparatos que se describirán para este efecto al tratar de los morteros.

Lay out the lime in layers of between 20 and 25 centimetres at the most, and throw on the water in a way that it will reach all of the hollows; one must be careful not to disturb the layer until all has slaked….(be careful with hydraulic limes not to give them too much water, unless they are to be used immediately, because they will set. Have two tanks - one to slake, another to mix to mortar); it can take up to 12 hours for (hydraulic quicklime) to slake. In order to obtain slaked lime or mortars of the consistency wanted (for different purposes), one should have various tanks, staggered when the ground has the necessary gradient. These are connected by pipes…with the objective that the cleanest grouts (of lime) will flow to the lowest tank. **They are beginning to use these in England, where it is becoming widespread to use an apparatus (mill) not only to slake the lime but also to mix the lime with the sand and make the mortars.**

Está representado por la parte esterior en la figura 58; es un tonel de forma cónica con un árbol giratorio central . el cual tiene brazos con paletas ó cuchillos. En la parte inferior hay una tram pilla corrediza para sacar la cal apagada. El árbol se hace girar por medio de una caballeria ú otro motor. La figura 59 representa el árbol giratorio con brazos atravesados por cabillas de hierro, y la figura 60 otra disposicion del mismo que puede adoptarse para remover mejor. Puede construirse fácilmente con duelas de madera como las *cubos ó toneles comunes, ó bien de hierro.*

(reference to drawings of mortar mills and brief descriptions of these).

Segundo método.—El método de inmersion consiste en colocar la cal en un saco ó cesto e introducirlo durante algunos segundos dentro del agua; á veces es necesario algunos minutos de inmersión, lo que depende de la clase de cal: se saca del agua cuando deja de absorber esta, lo que se conoce por cesar el pequeño ruido que produce la absorción; pero siempre ha de verificarse antes que empiece la fusion pastosa. Debe apilarse la cal inmediatamente para concentrar el calor y facilitar el apagado.Debe apilarse la cal inmediatamente para concentrar el calor y facilitar el apagado. Las cales comunes apagadas por este método, no retienen término medio sino 18 á 20 partes de agua por 100 de cal. Las hidráulicas de 20 á 50 partes de agua por 100. lo contrario de lo que sucede en la extinción ordinaria, que absorben menos las (p56) segundas. Cuando los trozos de cal son grandes. se apagan con dificultad por este método. Si se ha dejado la cal expuesta á la intemperie antes de apagarse, queda después de la inmersión con mucho hueso; para evitar esto se reduce la cal que haya de apagarse por este método al tamaño de una nuez próximamente y se coloca así que se saca del agua, en toneles ó capacidades en las cuales pueda concentrarse el calor que despide el agua al evaporarse, y no teniendo salida obra sobre la cal y esta se apaga mejor.

Second Method.
Immersion consists in placing the lime in a sack or basket and submerging it in water for some seconds; sometimes for some minutes, depending upon the class of lime. It is removed from the water when it stops absorbing it, which can be known by the ceasing of the slight noise produced by the absorption; but this should be verified before beginning the slaking to doughy consistency. One should immediately heap the lime to concentrate the heat and facilitate the slake. …When the lumps of lime are large, they slake with difficulty by this method. If one has left the lime exposed to the weather before slaking, many small lumps will be left after slaking by immersion; to avoid this one should reduce the lump you are going to slake by this method roughly to the size of walnuts; placing it in barrels on removal from the water can concentrate the heat which would otherwise dissipate in evaporation and makes the work easier for being better slaked.

Las cales comunes apagadas por este método producen 1.50 á 1.70 por uno del volúmen que tenia antes de verificarse esta ope ración; las hidráulicas de l.8 á 2.18 . midiendo la cal viva en polvo y después de apagada también en polvo suelto y sin apegotar.

Este procedimiento fue indicado por La Faye en 1777 como un secreto de los romanos. En el día ya se está en el caso de apreciar debidamente cuando *conviene emplearle según la calidad de las cales. Se necesita un jornal de operario próximamente para partir, sumergir y apagar tres metros cúbicos de cal viva, lo que hace salga algo cara la operación; para evitar esto se han ideado varios aparatos de inmersión; el mas sencillo es una percha flexible clavada en tierra, y sostenida en posicion algo inclinada por dos tronantes; en estas hay colgado un cesto de poco fondo por medio de una cuerda y un gancho, de ¡'nodo que corresponda verticalmente encima de un tom.l con agua: otro cesto igual se coloca debajo de una tolva que reciba la piedra. Cuando se haya apagado la cal contenida en el primer cesto, se sustituye por el que se ha llenado de piedra, y asi sucesivamente.*

This procedure was indicated by La Faye in 1777 as if a secret of the Romans….

It takes approximately one man day to break, immerse and slake three cubic metres of quicklime, making it somewhat expensive; to avoid this, various apparatuses have been contrived, the simplest being a flexible rack secured to the ground, and held in an inclined position by two props; in this one should lodge a shallow basket held in the middle by a rope and a hook…with another similar basket beneath a hopper that receives the lump lime. When the lime has been slaked in the first basket, the latter is substituted for the one which had been full of lump lime, and so on.

Raucourt describe el aparato representado en las figuras 61 y 62, que presentan la vista de costado y una sección vertical, y en la 65 que figura detalles del molino. Un operario basta para manejarle y vaciar el tonel T cuando se ha llenado. a a es una tolva colocada á la altura de la trampilla del horno de cal, por ella se va echando piedra ya calcinada , y por medio de la manija g se hace girar el volante Cd, cuyo piñon mueve la rueda ef. Esta hace girar en el interior de la tolva una pieza de fundicion P de forma angular, la cual quebranta los trozos de cal apretándolos en las paredes interiores m n; quebrantados estos. caen al cesto 2 que está suspendido por medio de un eje en la rueda A B, sujeta al travesero E D por medio de riostras H h.
Cuando está lleno el cesto 2 hace girar á la rueda por la accion de su peso; el 5 que estaba en 4 se vacia por medio de dos pequeñas varillas i j que le hacen girar sobre su eje: la cal que estaba en este (p57) cesto cae al tonel T. El aro A B continúa su movimiento. el cesto .ll se aproxima á las varillas i j, y el cesto l viene á colocarse debajo de la tolva; entonces se para y queda sumergido el tiempo necesario para que se llene el l continuando despues el movimiento. El tonel T se reemplaza por otro cuando está lleno , y el depó sito de agua se debe tener siempre al mismo nivel. El movimiento de la máquina se arregla segun el tiempo que ca'— da clase de cal haya de permanecer sumergida , siendo dependiente el movimiento de la cantidad de piedra que suministre el molino; si quiere acelerarse, se consigue ailojando las cuñas k l, y de este modo se separan mas las paredes laterales m n de la pieza P, los trozos de cal resultan en este caso muy gruesos; ó bien se puede aumentar la fuerza poniendo mas operarios á los manubrios. ó

disminuyendo la magnitud de los ceslos l. ′.3, 5, fl. En el caso de que el molino suministrase demasiada cal. de mo do que no diese el tiempo necesario á la inmersion. se emplean me— nos operarios. Colocando una tablilla en a: s no caeria al molino mas que la cantidad de cal qtte se quiera. Tanto el molino como las paredes, ruedas y estremos de los vo′ 1antes son de hierro fundido, las cuñas Ir l. los ejes de los costos y rle las ruedas .4 B de hierro forjado; los cojinetes son de bronce, los cestos pueden ser de alambre. Estos aparatos son algo complicados y caros, por lo que en ge neral se usan los medios mas sencillos. Solo cuando bubiese necesi dad de emplear gran cantidad de cal en obras de mucha duracion. podria letter cuenta el construir este u otro aparato.

(Descriptions of machines).

Tercer método ó estincion espontánea.—Consiste en colocar la piedra calcinada extendida en el suelo , formando una capa de unos 20 á 50 centimetros de espesor, espuesta á la acción de la atmósfera, debajo de un cobertizo para que el agua de las lluvias no perjudique. El desprendimiento de calor no es tan pronunciado en este caso, como con los demas métodos de estincion y los vapores que se desprenden apenas son perceptibles. De tiempo en tiempo se revuelve con la batidora. Las cales comunes apagadas por este método aumentan unos dos quintos de su peso, y su volúmen hasta 5,52 por uno de cal viva medida en polvo. Las cales hidráulicas solo absorben sobre una octava parte de su peso de agua al estinguirse de este modo dando 1.75 hasta 2,55 de volumen por uno de cal viva en polvo. Estos resultados se obtienen cuando la extinción se ha verificado completamente, y cuando el tiempo no es muy húmedo.

Third method or spontaneous extinction - consists in spreading the calcined stone on the floor, forming a layer of some 20 to 50 centimetres deep, exposed to the atmosphere, in (an open-sided) shed to prevent it being rained upon. The release of heat in this method is less pronounced than in the other methods of extinction and the vapours released are rarely noticeable. From time to time, it should be stirred with a stick. Common limes slaked by this method gain two-fifths in weight, and in their volume 5.52 times for one of quicklime in powder. Hydraulic limes only gain an eighth part of their weight…and give 1.75 to 2.53 volumes to one of powdered quicklime. These results will be achieved when the extinction is complete and when the weather is not very humid.

(p58 Blank)

(p59) de cal; las cales comunes exigen mas cantidad de agua que las hidráulicas y que las áridas. Raucourt está de acuerdo con Vicat respecto de los métodos de extinción; pero propone un método complejo, que consiste en apagar la cal al salir del horno por el segundo ó tercer método; pasado algún tiempo amasar el polvo que resulta, y de este modo producir una segunda extinción. Treussart también está de acuerdo con Vicat respecto de los tres procedimientos indicados; pero como el método de inmersión exige obreros hábiles que solo tengan sumergida la cal lo preciso y se desperdicio parte por los claros del cesto no encuentra muy conveniente su aplicación.

Propone apagar la cal echando sobre ella una cantidad de agua igual á la que absorbe sumergida. **Esta operación debe hacerse bajo un cobertizo á la proximidad de la obra; se echa la cantidad de agua precisa sobre la cal, y se la deja apagarse sin removerla durante la fusion, y cuando cesa de producir vapores, se revuelve un poco con la batidera ó se introduce un palo para ver si están algunas partes mal apagadas y se echa algo de agua sobre estos trozos. Concluida esta operacion se hace un gran monton, alisando la superficie y cubriéndola de arena y asi concluye de apagarse en una noche que se tenga de este modo para emplearse al dia siguiente.** Las cales que hemos llamado limites se apagan difícilmente. Apagado cuando llegan al grado de cementos ya no obra el agua sobre ellos. y es **preciso pulverizarlos después de calcinados y emplearlos como el yeso asi que se amasan en razon á que fraguan y endurecen pronto.**

(**Treussart** proposed a variation on the slaking methods advocated by Rancourt and Vicat - immersed quicklime loaded into barrels to cook and mature) Proposed slaking the lime by throwing upon it a quantity of water equal to that which would be absorbed during immersion. **This operation must be performed in a covered area <u>next to the works;</u>** one throws the necessary quantity of water over the lime, and leaves it to slake without disturbance, and when it ceases to produce vapour, agitate it a little or use a stick to see if there are any poorly slaked parts, throwing some water on these bits. At the end of this operation, **make a large heap, smoothing its surface, and cover it with sand, the slake completing overnight for the mortar to be used the following day.**

The limes we are talking about (hydraulic) slake with difficulty. When they reach the grade of cements there is no point putting water to them to slake - they should be ground after calcination and used like plaster of paris/gypsum and kneaded on account of their setting and hardening quickly.

En los experimentos que se hagan con las cales para comparar los procedimientos de extinción, deben verificarse por peso y no por experimenten en volúmenes pues á consistencia igual varian estos últimos en cada clase de extinción. El aumento de volumen que experimentan las cales después de apagadas o la contracción de los cementos al amasarse se puede determinar por el método empleado por la comisión encargada en la exposición de Paris de 1855 de informar sobre los materiales de construccion presentados en la misma. Consiste en formar uncilindro recto de palastro delgado. muy flexible, asegurado solo con aros en las cabezas. En este cilindro se marcan los volúmenes correspondientes las diferentes alturas por experimentos preliminares. Se echa la cal en polvo, moviéndola para que quede horizontal la superficie, pero sin apretar y se ve el volumen que marca la señal lío seguida se amasa con poca agua, y antes que fraguar. se vuelve á (pages blank)

(Experiments and tests should be measured by weight, not volume)

(p62) *Siendo la arena de forma angulosa traba mejor con los morteros, y en este caso está la arena de mina. Cuando tengan que emplearse las de mar ó de rio, se preferirán las depositadas mucho tiempo en las orillas, que no han sido arrastradas tanto como las del lecho y por consiguiente estarán menos redondeadas. La arena puede ser cuarzosa. granítica. caliza, volcánica, etc. Se da este nombre á toda sustancia mineral en forma de granos mas ó menos gruesos é insolubles en el agua. Las arenas pueden hacerse artificiales moliendo ladrillos ó piedras. Hay arenas cuarzosas de grano irregular, mezcladas con arcilla en proporciones variables. Se encuentran generalmente en la parte superior de algunas colinas. en fijones en las calizas; pertenecen á terrenos de aluvión. Estas son las arenas llamadas de mina. Tambien se encuentran conglomerados de arenas de cuarzo, esquistos ó feldespatos, y particularmente de mica, reunidos mecánicamente por otra materia (grawaka de los alemanes); de estos pertenecen á las areniscas las mas esquistosas suaves al tacto, amarillas, rojas ú oscuras de grano fino que forman pasta con el agua; se pueden emplear en la confección de morteros; pertenecen á los terrenos esquisitosos primitivos, y se encuentran en bancos y venas.*

La arena que se emplee en las argamasas debe estar limpia de tierra y pasada por el arenero para que deje las piedras que contenga. Al tratar de los morteros se indicará la influencia del grueso de las arenas según los casos ú que estos se destinen. Cuando haya que emplear arenas de mar, deben dejarse algun tiempo ***espuestas a la acción de las lluvias*** *para que se laven y suelten las sales que contienen. Si la arena que se usa en los morteros no estuviese limpia de tierras y de materias animales, formaría una pasta jabonosa soluble,* ***que retardaría el fraguado.*** *Se reconocer si está limpia echándola en agua y viendo si enturbia esta, en cuyo caso debe elegirse otra clase. También se reconoce si es buena arena apretándola en la mano en cuyo caso sera áspera al tacto, crujirá y no dejará polvo ó barro. Es necesario fijar limites para el tamaño de las arenas. La clasificacion admitida por Vicat es: arena fina cuando, supuestos redondos los granos, tienen de medio á un milímetro de diámetro; gruesas cuando es el diámetro de uno y medio á tres milímetros y de grano medio cuando el diámetro está comprendido entre los dos indicados. Polvo cuando las partículas mayores no llegan á un quinto de milímetro. ′*

Sharp, angular sand binds better in mortars, and especially pit sand (‘sand from the mine’). When one has to use sea or river sand, one prefers deposits that have been long on the shore, and have not been as much rolled around as those from the (river or sea) bed and will be less rounded. The sand can be quartz, granitic, calcareous, volcanic, etc. One gives this name to all mineral substances in the form of grains more or less coarse and insoluble in water. Sands may be made artificially by grinding bricks or stones. There are quartz sands of irregular grain, mixed with clay in variable proportions. One generally finds them on the higher slopes of some hills, in 'fijones' for limestones, in flood plains. These are pit sands. Also, one finds agglomerations of quartz, schist or feldspar, and particularly of mica, mechanically reunited with other material (greywacke to the Germans). To these belong the schist sands, soft to the touch, yellow, red or dark of fine grain which form a paste with water and which may be used in the confection of mortars - they belong in the schist lands and one finds them in banks and veins.

The sand used in plasters and mortars must be free of earth and passed through a sandbox to rid it of stones. When dealing with mortars the grading/size of the sand is significant according to the case and the end use. If you have to use sea sand, leave it sometime in the rain to wash out the salt it contains. If the sand used in mortars is not free of earthy or animal matter, it will form a soapy paste that will retard the setting. To ascertain if it is clean throw it into water, and if it muddies it, choose another source. Another way of assessing its goodness, is to squeeze a handful, whereupon it will be sharp to the touch and will crunch without leaving dust or mud. (Then gives Vicat's sand classification).

p78 Hormigones. Composición— Se da el nombre de hormigón **á la mezcla de cal, arenas y piedra pequeña** machacada ó sin machacar. ó mezcladas ambas clases; sue len emplearse también fragmentos de ladrillo ó escorias hormigones Los romanos hicieron mucho uso del hormigon en las obras subterráneas, en las hidráulicas y también en los edificios civiles; en estos, mas bien que hormigón, era una mampostería hecha con piedra de pequeñas dimensiones.

p79 La proporción del mortero en los hormigones varia segun sea el tamaño de las piedras y debe ser tal, que envuelva completamente estas y rellene los buecos. Las cantidades asignadas por los autores en los tratados de construcción son muy variables aconsejan— dose por algunos que **no debe mezclarse menos de dos volúmenes de piedra por uno de mortero;** pero debe tenerse presente el objeto con que se empla el bormigon. Cuando el mortero no está destinado para resistir á la presion del agua, el volúmen del mortero que se mezcla es igual ó inferior al de los buecos; pero si lo está, se echa un esceso de mortero de una cuarta parte de estos buecos. Las proporciones de los materiales que entran en un metro cúbico de hormigón, empleando piedra sin partir cuyas dimensiones sean inferiores á 0,05 segun el Aida memoire de Claudel, son las siguientes, contando con el esceso de mortero.

Cements.

p90

Fabricación de los morteros y hormigones.

En las obras de poca duración ó importancia se hace la mezcla tomando la cal lo mas pronto posible despues de apagarse y se **va apilando con la arena en la proporcion que se adopte;** se riega la superficie del montón y se forma asi una costra que preserva el interior. **De aquí se va sacando la necesaria, batiendo la mezcla con el agua en un recinto ó poza que se forma con arena.** Es mas cómodo y mas conveniente el batir la mezcla en noques ó albercas, como las indicadas al tratar del apagado de la cal. **Es conveniente que la manipulación del mortero se haga con el esmero necesario, para que resulte una mezcla intima de la cal con la arena;** pero pasado cierto limite seria perjudicial, cuando se emplean cales hidráulicas, el efecto mecánico de una trituracion demasiado prolongada y habria mas facilidad de que perjudicase la accion atmosférica.

Making mortars and cements.

(p91) Cuando se hace el batido de la mezcla debe cuidarse de no emplear el agua con exceso, pues en este caso se obtiene sin consistencia, se ahoga y resulta que no tiene el mortero en lo sucesivo tanta resistencia, en particular cuando las cales son hidráulicas (l).

En las obras de alguna importancia *es necesario tener un encargado especial al cuidado de los operarios con las instrucciones convenientes.* ***El agua debe echarse poco á poco removiendo sucesivamente la mezcla hasta hacerla adquirir la consistencia de una pasta arcillosa. Las echadas solo se emplean en circunstancias especiales, como sucede cuando hay que rellenar juntas de sillería ó para blanqueos****. La manipulacion no debe dejarse hasta que esté perfectamente mezclada la cal con la arena.*

In works of little duration or importance, one makes the mix (la mezcla - vernacular for mortar), by taking the lime as quickly as possible after it has slaked and heaping it with sand in the adopted proportion; sprinkling the surface of the heap - this forms a crust that preserves the interior. From here, one takes what is necessary, beating the mortar with water in a ring ('enclosure') which one forms out of sand. It is easier and more convenient to beat the mortar in pans or (shallow) tanks, like those in which lime is slaked. It is desirable that the manipulation of the mortar is done with the necessary care, so that an intimate mixture of lime and sand is achieved, although beyond certain limits can be prejudicial - when one uses hydraulic limes, the mechanical effect of a an over-long trituration (is not good) and they are more vulnerable to the action of the atmosphere.

When beating the mortar one must be careful not to add an excess of water, because in this way one obtains a mortar without consistency, drowned and results in a mortar without enough resistance (tenacity), especially when the lime is hydraulic.

In works of any importance it is necessary to issue the operatives with appropriate instructions. The water should be added little by little, stirring the mix until it acquires the consistency of a clayey paste. What results will only be used in particular circumstances, such as ashlar joints or for lime washes (whitewashes - blanqueos). The manipulation does not have to wait until the lime and the sand are perfectly mixed.

Cuando se emplean arenas de distintos gruesos, puzolanas ó grava para formar hormigones, se mezcla primeramente la cal con la mas fina de las arenas ó con la puzolana, y cuando está bien mezclada se continúa por las que siguen en tamaño; de este modo se hace **con major facilidad** la mezcla y se forma un todo mas homogéneo.
El batido del mortero debe hacerse **á cubierto para que las lluvias no alguen la operación y no estén espuestos á secarse demasiado por la accion del sol.**

When using sands of different grades, pozzalans or gravels to make concrete, one first mixes the lime with the finest of the sands or with the pozzalan, and when this is well mixed, continue to add in order of their size; in this way one makes a more homogenous mortar with greater facility.

The beating of the mortar must be done under cover so that rain cannot hamper the operation and it is not exposed to drying too quickly in the sun.

En verano absorbe el mortero gran cantidad de agua; pero es preciso añadirla con precaución cuando se amase. para no esponerle á los efectos indicados anteriormente. En las obras de larga duración hay que disponer los talleres para la fabricación de morteros y hormigones del modo mas conveniente para el servicio, tratando de obtener la economía posible, que depende de la buena disposición que aquellos tengan. Es conveniente acopiar los materiales en la parte mas elevada del terreno en que se sitúe el taller, para que haya mayor facilidad para su conducción á los sitios en que han de emplearse. Esto se verifica comúnmente cuando se ejecutan obras en los rios en que favorece la pendierito general del terreno.
En estos casos se coloca la cal, arena, puzolanas, etc. en la parte mas alta, los aparatos para las mezclas del mortero mas abajo y mas que estos los de fabricar el hormigón; de este modo están mejor dispuestos para conducirse cuando se cargan los carretillos, y aun puede aprovecharse á veces la sola accion de la gravedad para dicho objeto. '

Jacques D H (1860) Rural Architecture: OR, HOW TO BUILD COUNTRY HOUSES AND OUT-BUILDINGS; EMBRACING THE ORIGIN AND MEANING OF THE HOUSE, THE ART OF HOUSE-BUILDING, INCLUDING PLANNING, STYLE AND CONSTRUCTION; DESIGNS AND DESCRIPTIONS OF COTTAGES, FARM-HOUSES, VILLAS AND OUT- BUILDINGS, OF VARIOUS COST AND IN TIIEIR DIFFERENT STYLES OF ARCHITECTURE, ETC., ETC. AND AN APPENDIX, CONTAINING RECIPES FOR PAINTS AND WASHES, STUCCO, ROUGH-CAST, ETC. AND INSTRUCTIONS FOR ROOFING, BUILDING WITH ROUGH STONE, UNBURNT BRICK, BALLOON FRAME, AND THE CONCRETE OR GRAVEL WALL . BY D H JACQUES, Author of "The Garden," "The Farm,'* "Domestic Animals,* "How to Do Business," " How to Write," "How to Talk," etc.

RECIPES FOR PAINTS, "WASHES, STUCCO, ETC.

The following cheap and excellent paint for cottages is recommended by Downing. It forms a hard surface, and is far more durable than common paint. It will be found preferable to common paint for picturesque country houses of all kinds. **Take freshly-burned unslaked lime and reduce it to powder**. **To one peck or one bushel of this add the same quantity of fine white sand or fine coal ashes, and twice as much fresh wood ashes, all these being sifted through a fine sieve. They should then be thoroughly mixed together while dry. Afterward mix them with as much common linseed oil as will make the whole thin enough to work freely with a painter's brush.**

This will make a paint of a light gray stone color, nearly white. To make it fawn or drab, add yellow ochre and Indian red; if drab is desired, add burnt umber, Indian red, and a little black; if dark stone color, add lampblack; or if brown stone, then add Spanish brown. All these colors should of course be first mixed in oil and then added. This paint is very much cheaper than common oil paint. It is equally well suited to wood, brick, or stone. It is better to apply it in two coats; the first thin, the second thick.

2. A Cheap Wash. — For the outside of wooden cottages, barns, out-bulldings, fences, etc., where economy must be consulted, the following wash is recommended: Take a clean barrel that will hold water. Put into it half a bushel of quick lime, and slake it by pouring over it boiling water sufficient to cover it four or five inches deep, and stirring it until slaked. When quite slaked dissolve it in water, and add two pounds of sulphate of zinc and one of common salt, which may be had at any of the druggists, and which in a few days will cause the whitewash to harden on the woodwork. Add sufficient water to bring it to the consistency of thick whitewash. To make the above wash of a pleasant

cream color, add three pounds of yellow ochre. For fawn color, add four pounds of umber, one pound of Indian red, and one pound of lampblack; for gray or stone color, add four pounds of raw umber and two pounds of lampblack. The color may be put on with a common whitewash brush, and will be found much more durable than common whitewash. — Horticulturist. For a for barns the Horticulturist also gives this: Hydraulic cement, one peck; freshly slaked lime, one peck; yellow ochre (in powder), four pounds; burnt umber, four pounds ; the whole to be " dissolved" in hot water, and applied with a brush.

4. Stucco and Stuccoing. —Take stone lime fresh from the kiln and of the best quality, such as is known to make a strong and durable mortar (like the Thomaston lime). Slake it by sprinkling or pouring over it just water enough to leave it when slaked in the condition of a fine dry powder, and not a paste. Set up a quarter-inch wire screen at an inclined plane, and throw this powder against it. What passes through is fit for use. That which remains behind contains the core which would spoil the stucco, and must be rejected. Having obtained the sharpest sand to be had, and having washed it, so that not a particle of the mud and dirt (which destroy the tenacity of most stuccoes) remains, and screened it to give some uniformity to the size, mix it with the lime in powder, in the proportion of two parts sand to one part lime. This is the best proportion for lime stucco. More lime would make a stronger stucco, but one by no means so hard — and hardness and tenacity are both needed. The mortar must now be made by adding water, and working it thoroughly. On the tempering of the mortar greatly depends its tenacity. The wall to be stuccoed should be first prepared by clearing off all loose dirt, mortar, etc., with a stiff broom. Then apply the mortar in two coats; the flrst a rough coat, to cover the inequalities of the wall, the second as a finishing coat. The latter, however, should be put on before the former is dry, and as soon, indeed, as the first coat is sufficiently firm to receive it; the whole should then be well floated, troweled, and marked off; and if it is to be colored in water-color, the wash should be applied, so as to set with the stucco.— Downing.

5. Rough-Cast. — The mode of putting on rough-cast is as follows: The surface of the wall being brushed off clean, lay on a coat of good lime and hair mortar. Allow this to dry, and then lay on another coat as evenly and smoothly as possible without floating. As soon as two or three layers of the second coat are finished, have ready a pail of rough-cast, and splash or throw it on the wall. This is usually done by another workman, who holds the trowel with which he throws on the rough-cast in one hand, and a whitewash brush dipped constantly in the pail in the other, which follows the trowel until the whole is smooth and evenly colored. The rough-cast itself is made of sharp sand, washed clean, screened, and mixed in a large tub with pure, newly slaked lime and water, till the whole is in a semi-fluid state. A little yellow ochre mixed in the rough-cast gives the whole a slightly fawn-colored shade, more agreeable to the eye than white.— Downing.

5. Mortaring Concrete, Laying up, etc. — It will be well to have at least four large mortar beds, one on each side of the house - made of strong plank, in the usual way. These should be surrounded by casks of water (oil casks cut in two are excellent , piles of rock, sand, gravel, etc.— the lime, of course, to be kept under cover, and used as wanted. Slack up your lime until it forms a thln, smooth, creamy mass, then add four or five parts of clean, sharp sand, stlrrlng and mixing constantly, and using water enough to bring the whole, when thoroughly mingled, to the consistency of a thick batter. Into this "batter" mix course and fine gravel (that has previously been screened) until the mass is thick enough to be lifted on a common shovel. [The proper and fhorough mixing of the sand with the lime, and the gravel with the mortar Afterward, is very important, and should only be intrusted to your most careful hands.] Having one or two beds full of this mixture, you are ready to begin your wall. "Wheel the rnortur to the foundation in common railroad wheelbar rows, letting the common' hands shovel it into the bottom of the trenches, while the superintendent or "boss" workman spreads it evenly with his trowel. "When the bottom layer of mortar, three inches thick, is laid in, wheel large and small rock (previously sprinkled with water) to the wall, and press it into the soft mortar at every available point, leaving a small space between each piece of rock, and working the soft mortar against the plank boxing, to preserve a smooth surface on the wail. When you can press no more rock into the mortar, pour another layer of the latter over and through the rock, then add a layer of rock, as before, and so on, until your boxing all round is full. You have now ten Inches or a foot of wall, all around, built; and if the lime is good and the weather dry, it will he hard enough in twenty-four hours to raise your boxes another tier. This is readily done by knocking out the wedges between the plank and the scanting, raising up the plank and sustaining it in place by M cleats nailed on the scantling. In raising the boxing, begin at the point where you commenced laying up the day previous, as that portion of the wall will, of course, be the hardest. It is not necessary to raise all the boxing at once, or go entirely round the wall in a day. A foot or a yard of the wall can be completed at a time, if advisable; but if the complete round can be made, so much the better. Planks to cover up with, in case of a sudden shower, or when a storm is apprehended, should be provided, and placed wilhin reach.

PRACTICAL HINTS BY A BUILDER.

1. The Roof. — No roof should project less than one foot — it may project as much as you like up to two feet. Too often, at present, in the commoner kind of country houses, the roof-boards are cut off even with the sides and ends of the house, and the shingles allowed to project only half an inch. What happens ? All the rain that falls upon it runs over the entire surface of the house, discoloring the paint and washing it away. 2. Window — There should be a bold projection over each window, instead of the single inch which the cap, so called, is now generally allowed to extend beyond the casing. The slight projection furnishes no

protection to the sash, which is continually washed by the rain, and prematurely decays. The casings or dressings of the windows are generally too narrow. They should never be less than three and a half inches, and may be wider if yon like. Let the head or top piece be an inch and a half wider than the sides. One and a quarter inches is the proper thickness for all outside casings. For caps, one- and three fourth-inch plank (one-and-a-half- inch will do) should be used. They should be six inches wide. Reduce one edge to the thickness of an inch. Nail the cap upon the edge of the top casing, and against the frame of the house, and it will form a bold and efficient projection. 8. Gutters. — Let the ends of the rafters come out flush with the side of the frame. To these and to the plate are nailed the brackets, cut from one-and-a- quarter-inch stuff, which are to support the gutter. The brackets should project one foot, and be lined with inch boards for trimming. The outside must be covered with dressed stuff of the proper style. There must be a frieze or margin, running the entire length of the house, under the gutter, and also on the gable. It may vary in width, on different houses, from ten to twenty inches. — A. Blaucett.

UNBURNT BRICK FOR BUILDING. The following particulars are compiled from the Report made by Mr. Ellsworth while Commissioner of Patents: Almost every kind of clay will answer; it is tempered **by treading it with cattle**, and cut straw is added, at the rate of two bundles of straw to clay enough for one hundred bricks. It is then ready for molding. It is found that the most economical size for the bricks for building such cottages is the following, viz., one foot long, six inches wide, and four inches thick. The cellar or foundation must be formed of stone or burnt brick. In damp soils, the dampness should be prevented from rising from the soil into the unburnt wall by laying one course of slate, or of brick, laid in cement or hydraulic mortar, at the top of the foundation. The walls of the cottage are laid up one foot in thickness of the unburnt brick. This thickness is exactly the length of the brick, or the width of two bricks, and the strongest wall is made by laying the work with alternate courses of leaders and stretchers (ie one course with the bricks laid across the wall, the next course side by side). A weak mortar of lime and sand is generally used for laying the bricks, but a good brick mortar is preferable. Where lime is scarce, a mortar composed **of three parts clay, one part sand, and two parts wood-ashes,** answers very well as a substitute for lime mortar. The division walls may be six inches thick, just the width of the brick; but when the cottage has rooms wider than twelve feet, it is better to make the first-story partitions two bricks thick. The doors and window-frames being ready to insert, the cottage is very rapidly built. These frames are made of stout plank, of the exact thickness of the walls, so that the casing inside and outside helps to strengthen the wall and covers the Joints. If lintels and sills of stone are not to be had, pieces of timber three inches thick, of the same width as the wall, and a foot longer on each side than the opening, may be used instead.

The roof may be of shingles or thatch, and it is indispensable in a cottage of unburnt clay that it should project two feet all around, so as completely to guard the walls from vertical rains. The outside of the wall is plastered with good lime mortar mixed with hair, and then with a second coat, pebble-dashed, as in rough-cast walls. The inside of the wall is plastered and white washed in the common way. Built in the simple way of the prairies, these cottages are erected for an incredibly small sum, costing no more than log houses, while they are far more durable and agreeable in appearance. But we have also seen highly ornamental cottages built of this material, the bricks made entirely by the hands of the owner or occupant, and the whole erected at a cost of not more than one half of that paid for the same cottage built in an equally comfortable manner of wood or brick. When plastered or rough-cast on the exterior, this mode of construction presents to the eye the same effect as an ordinary stuccoed house, while it is warmer and far less costly in repairs than any other cheap material is.

Robert Scott Burn R (1860) Handbook of the Mechanical Arts, concerned in the construction and arrangement of dwelling houses and other buildings, Edinburgh and London. William Blackwood and Sons

(Originally prepared for the exclusive use of COLONISTS and EMIGRANTS…This second edition of broader scope)

Example specifications:

P36 Level and ram down hard, the beds of all footings, and consolidate the earth about same, and also against all walls, drains, &c. Lay under the external walls round building, a course of good lime-concrete, mixed in the proportion of one part of Blue Lias, Dorking, or other approved stone-lime, and five parts of clear dry gravel (the large stones or flints being broken), or Thames ballast, 1 foot wider than the lowest course of footings, and 18 inches deep. Throw the concrete into the trenches from a stage at least 6 feet above their level.

The brickwork to commence on the concrete, the first course being laid and bedded in mortar. The whole of the brickwork, as shown on plans, to be constructed with the best hard, well-burnt, sound stock-bricks, laid English bond, and to be carried up regularly. **The mortar to be composed of one-third well-burnt Dorking, or other approved stone-lime, and two-thirds of sharp, clean, river or other approved sand or road grit, free from salt, the whole to be well laboured.** No four course of the work to rise more than ¾ inch beyond the collected height of the bricks; every course to be filled in and fully flushed up with mortar; **and grouted with liquid mortar of hot lime and sand every second course below level of ground floor, and every fourth course above.** No variation to be made between the inside and outside work; the joints inside throughout to be left rough, to form key for plastering. Lay all round the walls under ground-floor joists, a double (p37) course of Countess slates, the whole width of brick- work breaking joints and to be bedded in cement…. Carefully gather in the chimney-throats, and carry up fines of not less than 14 X 9 in. in the clear, well pargeted **with well- laboured cow-dung pargeting**. Bring out in cement all projections for string-courses, &c., as shown on elevations, and bed-courses of 2-in. rough York core, where necessary, for cornices, mouldings, &c. Bed in mortar all bond timber, plates, lintels, wood-bricks, templates, and other wood-work required to be set on the brickwork; bed and point round all window and door frames with lime-and-hair mortar, and bed the sash-sills with white-lead….

Pave the scullery and larder with stock-brick in mortar, to be jointed in cement.

P47…Plasterer

Externally——Compo the whole of the external walls, and run the whole of the cornices, strings, mouldings, and dressings generally, with Greaves blue lias lime, mixed with clean sharp river-sand, in the proportion of two parts sand and one part lime— care to be taken that all arrises, mitres, mouldings, Mouldings, quirks, angles, &c., are to be out clean, sharp, and 5" true, and the several enrichments cast clean, and fixed firmly and accurately.

Internally.—The lime to be used for internal work (p48) to be the most approved chalk lime—to be run through a fine sieve, mixed with clean sharp grit sand and strong cow-hair, well mixed and tempered together, prepared a proper time before using, and every precaution to be taken to prevent blistering…. Run all the external angles with Martin's cement, free from with lime-plaster, animal matter, or other material whatsoever.

Painter

Paint the whole of the external and internal wood, stone, and iron work, four times in oil, with a tint to be approved of. Grain oak, and twice varnish, the street door and fanlight properly; prepare, stop, and knot the work.

P110

The following is Mr Roberts' plan of forming hard, cheap, and durable floors:— "A foundation or substratum should be prepared about 6 inches thick, with coarse gravel, or brick bats and lime-core, well beaten to a level surface. In damp situations, tar may be added to the concrete on which the ash-floor is to be laid, thus prepared: Take good washed sand, free from all earth and stones, together with the ashes of lime fresh from the kiln, in the proportion of two-thirds of sand and one-third of lime-ashes (where obtainable, the sub stratum of the third portion of smiths' ashes, or pounded coke for one-half of the sand, increases the durability and hardness of the floor); mix the sand and lime-ashes well together, and let them remain in a body for a fortnight, in order that the lime may be thoroughly slaked; then temper the mortar, and form the floor with it 3 inches thick, well floated, and so worked that it be not trodden till it has lain for three days, or according to the dampness of the weather, when it should be well rammed for several successive days, until it becomes hard—taking care to keep the surface level ; then use a little water, and smooth it with a trowel; after this keep the floor free of dirt, and when perfectly dry it may be rubbed over twice with linseed oil, which gives the appearance of stone instead of sand. Where joists are used, a durable and cheap floor may be made as follows: Reeds are laid across the joists, or, if these cannot be obtained, laths may be used; these are laid close to one another, perhaps two or three deep; across these long laths are nailed to the joists, to keep the laths in their places. The plaster-of-Paris is then mixed and laid over these, spread with a large scraper, and levelled with a mason's level, till of a uniform thickness….

P111
A solid and lasting floor, that will be impervious to wet and impenetrable to rats, is made of mortar in the following way: Break a quantity of stones, so as to pass through a ring 2 inches diameter; lay these in an even layer on the floor to a depth of 5 or 6 inches; make a gravel-and-mortar concrete, with small gravel and newly slaked lime; pour this in a thin state equally over the stones to a depth of 2 or 2 ½ inches. When this layer has set, spread over it another layer about 1 ½ inch thick, composed of one part lime to two parts sand; just before this is dry, go over the smooth surface with a whitewash brush; this outer finish will last nearly as long as the floor itself. Where hydraulic cement can be obtained, it makes a first-rate floor.

P124 Pise, or HARD-RAMMED EARTH.

TAKING into consideration the ease with which the material is obtained, worked into its requisite form, and the durability which undoubtedly characterises it, we are certainly surprised that it should have been so sparingly adopted. No valid objections have yet been raised against it. It is admitted by all to be cheap, and no less efficient than cheap. Numerous examples have been carried into sheet with marked success, and abundant evidence is easily obtained to prove that it is lasting. _ The term " pisé " is derived from the name of the instrument with which the earth is rammed down, pisoir. The kind of earth or soil best adapted for pisé is that known as gravelly. By this term is meant a soil in which the pebbles or stones are round, not flat or angular. It is evident that in ramming the soil the packing will lie equally round the circular pebbles, while the flat or angular ones may resist the stroke of the rammer, and ward off in a measure the force of the stroke from some portion of the soil beneath them. Brick earths are well adapted for pisé; but, owing to the capacity for retaining moisture, they are apt to crack, unless carefully shielded from the wet, during the process of drying the walls. All kinds of earth, however, may be used, with the exception of light poor lands, and strong clays : these, however, will do if judiciously mixed with other better-fitted soil. To show how this mixing may be most successfully carried out, a few sentences may be useful: the principle of mixing is simply to blend a light earth with a strong, a clayey with a sandy or gravelly kind. Where the best kind of soil that is gravelly cannot be obtained, small round pebbles, &c., may be mixed with it. All animal or

vegetable substances that are apt (p125) soon to decay must be carefully kept out of the soil to be used. The following indications, which may be observed in order to judge of the fitness of the soil for pisé in any district, may be useful: In digging, if the spade brings up large lumps at a time, the soil is well adapted for the work 3 this holds also where the soil lies on arable land in large clods, and binds after a heavy shower and a hot sun. Where vermin holes are smooth in the inside and firm, or where the small lumps generally found in plenty in all fields are difiicult to be crumbled between the fingers, the soil is good. Soil of good quality is generally found at the bottom of slopes that are in cultivation, and on the banks of rivers. In preparing the earth for building, the first operation is breaking the clods or lumps, and thereafter placing the soil in a conical heap : this form facilitates the removal of large, flat, and circular stones, which, falling to the bottom, are easily removed from the mass by means of a rake. The teeth of the rake should be placed at intervals of 1 inch or thereabouts, so that only stones exceeding this in size may be withdrawn; or what would be better and quicker, a bricklayer's sieve or "screen " might be used, having the meshes about an inch square. Where two varieties of soil are to be mixed, the operation should be done at this stage. Enough of soil should only be prepared to last a day's working. Care must be taken to prevent rain saturating the earth with water, as in this state it will form mere mud in the mould. It is necessary to note that the soil is in best condition for working when neither too dry nor too wet. It is very evident that less time will be lost in slightly wetting the soil, when too dry, than in waiting for it to dry should it get saturated with rain by a careless exposure.
The next point we have to explain is the construction of the " mould." This should be made of clean thin planks of pine, or other light wood, well seasoned, to lessen the chances of their warping. Their thickness should be about 1 inch, well planed on both sides. The length should be from 12 to 14 feet for ordinary work; but shorter moulds, as 7 feet, will be at times useful. The depth of the mould should be 14 inches—some recommend 2 feet 9 ; but a practical experiment, where the former depth was adopted, showed that it was more convenient than the latter…

P131

UNBURNT BRICKS.

MUCH as many may dispute the fact, it is nevertheless true, that unburnt bricks form a much drier wall than ordinary burnt bricks, inasmuch as they are not so absorbent of wet or damp. To make these, any ordinary clay will answer. If dry when obtained, it must first be moistened, and thoroughly worked by the feet of cattle, or pounded by hand. Cut some straw into pieces about 6 inches in length. After being duly mixed with the straw, the clayis ready to be made into bricks. A mould of any size must be made; a convenient size is 12 inches long, 6 inches wide, and 5 inches deep : this mould should have a bottom, but not air-tight, in order to prevent the brick from sticking in the mould. The clay is put into this mould, and the brick formed much in the same way as ordinary bricks.

. Should the clay be very tenacious, a little sand sprinkled in the mould will enable the brick to leave it freely. The bricks are placed upon level ground to dry, turning them on their edges on the second day; thereafter left in piles, protected from the rain, for ten or twelve days. The foundation must be formed of stone or burnt brick; and, to prevent damp rising, a course of slates should be laid above the footings in hydraulic cement. The walls formed of these bricks will be exactly 12 inches in thickness—that is, the length of the mould; the partitions are formed by laying the bricks length- wise, thus giving a thickness of 6 inches, the breadth of the mould. To obtain the necessary bond in the walls, the work is carried up in alternate courses of headers and stretchers— —one course having the bricks laid across the wall, the next course having them side by side. A good ordinary brick mortar is to be preferred, although a weak mortar of lime and sand will do for laying the bricks. The doors and window (p132) frames should be previously made, to be ready to insert when required. These frames should be of stout plank, the exact width of the thickness of walls—they will thus help to cover the joints and strengthen the walls. Lintels and sills of stone, when easily had, will much improve the appearance of the structure: pieces of timber 3 inches thick, width equal to thickness of walls, may be used in place of stone ; these should have a clear bearing of at least 12 inches on each side of the opening. Of whatever kind the roof is, it is essential, in this form of material for external walls, that it should be an overhanging one, in order to guard the walls from vertical rains. The outside of the walls is plastered with good lime mortar mixed with hair, and then with a second coat pebble dashed as in roughcast. The inside walls are finished in the usual way. A cottage may be built in this way for an in credibly small sum—warm, dry, and of course comfortable. As to its durability, it is only necessary to state, that it is by no means a difficult matter to adduce instances where such structures have existed in thorough efficiency for a great length of time; in some, for upwards of two hundred years. The method of forming the unburnt bricks will be described under the head of BRICKMAKING.

P276

Mortars. -— CONCRETE. — CEMENTS. LIME, as used for building purposes, is obtained from several of the varieties of stone, marble, and chalk, termed limestones. It is prepared by burning or calcining the stone, thus driving off the carbonic acid in which it abounds. After calcination it is reduced to a white powdery material, which greedily takes up water; it is then known as quicklz'me. In making mortar, fresh-burned lime is to be taken from the kiln, and laid in a heap in a convenient space, and, sprinkling a quan tity of water on it, the lime begins immediately to crack and fall down, steam issuing from the heap in considerable quan tities—a high degree of heat being at the same time induced. On the completion of the process of decomposition, the lime is reduced to an impalpable powder, which goes by the name of “ slacked or slaked lime.” The slacked lime thus obtained is next to be well mixed with water, forming a paste, and afterwards have the proper proportion of sand added—two thirds sand to one-third of lime….

Mortar thus prepared sets very soon on being exposed to the atmosphere, but it is by no means calculated to stand under water, or in very moist and damp situations. Where mortar is required for such work, hydraulic mortar, or hydraulic cement, must be used. The first may be made of hydraulic limes, which are found naturally in many situations. The limestones yielding this substance are either argillaceous or magnesian,)p277) or argillo-magnesian. When the proportions of the lime and clay are equal, or vary from forty parts of lime to sixty of clay, or sixty of lime to forty of clay, the lime does not slake under any circumstances, and hardens under water with great rapidity. It is very dillicult to distinguish between an ordin ary limestone and a hydraulic lime; direct experiment is generally to be resorted to. Hydraulic cements are com paratively easily made, and are on the whole as useful as hydraulic mortars—it is, in fact, a disputed point as to which is the best. The Romans used a mortar containing pounded bricks or tiles, which was valuable for water-works. Clay, burned and mixed with lime, will enable the mortar to with stand to a certain extent the action of water. **Where a rich lime is obtainable, a hydraulic lime may be made by mixing twenty parts of dry clay to eighty of the lime.** "Puzzolano" cement is made by mixing this substance with lime ; it is a volcanic substance of a violet-red colour. Coal-cinders ground to a powder, and mixed with lime, make a mortar which will be useful in wet or damp situations.

Concrete is used for forming the foundations of buildings in bad or yielding soils. It is composed of quicklime well pulverised, sand, and gravel, these being first thoroughly mixed in a dry state ; sufiicient water being added to bring it to the consistence of ordinary mortar, and rapidly incor porated with a shovel. It should be put into the foundation to be formed while hot —that is, immediately after the thorough incorporation of the materials is effected. A good proportion for the materials is the lime and sand in sufiicient quantities to form a good mortar—say two parts sand, one part lime—the gravel being twice the bulk of the sand. For situations where the soil is very damp, a composition called beton may be used : this is made with hydraulic mortar (artificial or natural), with fragments of broken brick, stone, or gravel incorporated with it—the fragments'not being larger than the size of a hen's egg. As many fragments should be mixed with the mortar as the latter will admit of. An economical beton may be made by a mixture of broken stones or brick with common mortar, having pounded brick incorporated with it (thus making it an artificial hydraulic lime), and of course a fine gravel incorporated with the mass. In making it, the mortar is first incorporated with the finer gravel, (p278) and spread out into a flat surface some 4 or 6 inches in thick ness; over this surface the large gravel and broken stones ' are uniformly strewed, and pressed down, and the whole thoroughly incorporated. Beton may be used in all cases where concrete would be required, and with superior advan tages, especially in damp situations. In making concrete or beton, an able authority recommends that the mortar should first be made into a paste before being mixed with the other materials; this insures a better incorporation of the mate rials.--(Limes, Cements, Mortars: Rudimentary Treatise, 1.9.: Weale. By GEORGE BURNELL.) Fragments of limestone may be mixed with advantage in concretes and betons: the con crete or beton should be laid in regular layers not exceeding a foot in depth, going over all the surface of the foundation regularly before beginning to the second layer.

Henry Stephens and Robert Scott Burn (1861) The Book of Farm Buildings, their arrangement and construction Edinburgh and London

531. Section Fourth. — Mortar, Concrete, Beton, Hydraulic Cements, and Cements.
532. Mortar is a combination of lime and sand. Lime, in its ordinary state of carbonate, is useless for building purposes; but, when burnt, a new substance is produced, which has a powerful affinity for water: this new substance is termed an oxide of calcium. When water is added to this, a hydrate is formed, which, when combined with sand, forms a new substance again — namely, a silicate. The office which the sand performs is simply to act as nuclei, round which the crystals of carbonate of lime, and the portions of silicate which are formed, may arrange themselves. Sand, therefore, must not be rotten or friable; moreover, it must contain no salt calculated to make the lime soluble; hence the use of sea-sand must be avoided.
533. The Sands used for the preparation of mortar are generally classed as pit, river, and sea sands. Of these, river-sand is generally considered the best, pit-sand being dirty and sometimes friable; while the sea-sand is objectionable for the reason stated in last paragraph, as also from walls built with it being peculiarly liable to atmospheric influences, soon showing damp, arising from the affinity salt has for moisture. A mixture of coarse and fine sand is better than sand of equal fineness. For good mortar, the proportion of lime to sand should be two and a half of sand to one of lime.
534. Concrete is a compound of lime finely pulverised, gravel, or broken stones — the more angular the better — and sand. The whole must be mixed up near the spot where the concrete is to be used, as it sets very quickly. The proportions of this compound vary with the locality, and with the practice of engineers. **The lime must be fresh burned, and pulverised without slacking.** A proportion adopted in London is five parts of gravel and sand to one of lime. The materials are thoroughly mixed up while dry, and a little water is then added to bring the whole to the consistence of mortar; it is then quickly worked up with a shovel, (p142) and applied. In filling in foundations, it is considered by some a good plan to " toss " in the concrete from some height, as it tends to consolidate the mass. A contrary result may, however, be apprehended, as it tends, we think, to separate the constituent parts. When first made, the bulk of concrete is less than the bulk of the materials of which it was composed; but the mass ultimately expands, in the proportion of nearly half an inch in height for every foot of depth.
535. In some instances concrete is applied in blocks as a building material, but both in durability and transverse strength it is very deficient. Away from atmospheric influences, such blocks may be used in the interior of thick walls.

As a material for securing a good foundation, and for the prevention of damp, it is exceedingly valuable, and is deservedly in high repute.
536. The term Beton is applied to any mixture of hydraulic lime with fragments of brick, stone, or gravel. The most economical mixture, and one which is very good, is broken stone or brick, in fragments of the size of pigeon eggs, with coarse and fine gravel. In preparing beton, the lime is first prepared, with which is next incorporated the finer quality of gravel used. This is then spread out where required to a depth of some 4 or 6 inches, over which the coarse gravel and broken fragments of stone or brick are then strewed, and the whole brought to a well-mixed condition with water by the spade or the lime-hoe. Beton is superior to concrete, especially for foundations under water, or in wet soils.

537. Hydraulic Cements. — Pure lime, when reduced to a paste by the addition of water, has no tendency to harden — the lime, after the water has evaporated, returning to its original dry condition. Different effects are produced, however, on different limes by the addition of water: thus, in some, termed " rich or fat limes," the bulk is much increased; in others, the bulk is very slightly altered. These last are termed " poor" or "meagre " limes, and are those only which, in combination with silica, alumina, and magnesia, have the power of hardening under water. This combination of poor limes with silica, &c, is called a hydraulic mortar or cement.
538. There are various methods of forming this species of cement. Smeaton's mortar, as used at the Eddystone lighthouse, was “composed of equal parts of Aberthaw lime in the state of hydrate of lime in fine powder, and puzzolano also in fine powder, well beaten till it had acquired the utmost degree of toughness." Puzzolano is a volcanic concrete thrown up from Vesuvius; it is so named from the town Puzzuoli, where it was first found. An artificial puzzolano is prepared by burning clay. The cement or hydraulic mortar used by the Romans was composed of two parts of puzzolano to one of lime. The facing of the London docks was cemented with an excellent mortar, composed of four parts of lime, six of river-sand, one of calcined limestone, and one of puzzolano. A good hydraulic mortar may be composed of two and a half parts of burnt clay to one part of blue lias lime, to be pulverised between rollers, mixed, and used immediately.
539. Many calcareous clays or argillaceous limestones possess the property of hardening under water when made into lime or hydraulic cement. When the proportion of clay is only about 10 or 12 per cent, the hydraulic cement made from these takes about twenty days to set in moist places. The hardening, however, takes place in two or three days, when the proportion of clay readies to 20 or 25 per cent. A minute division of the clay, and a condition in which part of the silica is given up on the application of caustic potash, is considered to give the best results.
540. Roman or Parker's Cement is made in England from nodules of calcareous matter, found in the London clays of Sheppey and Harwich, and the Oxford and Kimmeridge clays. The Medina Cement, so called, is of the same kind, but of lighter colour, and is made from the Hampshire septaria. Atkinson's Cement is made from the lias.

541. Portland Cement. — The most important of the artificial hydraulic cements is that known as Portland. It is " made from carbonate of lime mixed in definite proportions with the argillaceous deposit of some rivers, running over clay and chalk." The whole are pounded together and afterwards dried and burnt. It is called Portland cement from its colour, resembling that of the well-known Portland stone. It is a cement possessed of extraordinary strength, being four times nearly as great as that of any of the natural hydraulic cements. It forms, when mixed with small or even with broken bricks, a concrete of great strength: the proportion of cement required being so small as a tenth or even a twelfth part….

548. Of the cements known as Martin's, Keene's, and Parian, sulphate of lime or gypsum is the base. In these " the plaster in the state of fine powder is thrown into a vessel containing a saturated solution of alum, sulphate of pot ash or borax. After soaking for some hours it is removed and air-dried, and subsequently rebaked at a brownish-red heat. When taken out of the oven it is once more reduced to a fine powder, and carefully sifted, after which it is fit for use, but when slacked a solution of alum is employed instead of pure water. The cement is called Parian when borax is used; Keene's when sulphate of potash; and in Martin's, pearl-ash as well as alum is employed."
549. Keene's, Parian, and Martin's cements are principally used for decorative purposes, but so far as the Farm Buildings are concerned, a much more practical value is attached to them, from the circumstance of their being peculiarly well adapted for forming skirtings of granaries, barns, &c, uninjured by damp and perfectly vermin proof.
550. Stucco for decoration is a combination of plaster-of-Paris — calcined gypsum — with a solution of gelatine or strong glue.

… 563. Section Fifth. — Exterior Finishings, Rough-Casting, Stuccoing. — We purpose giving a few hints on the finishing of external walls, as rough-casting, stuccoing, &c. The outside walls of prairie houses are finished in two ways — these are, rough-cast and stucco. Rough-cast consists of a small quantity of mortar diluted with water in a tub; to this a trowelful of pure lime is added, so as to make the whole of the thickness of cream. To finish the walls with greater expedition, the joist-holes may be left not filled up; into these, joists may be inserted, on which to place scaffolding to bear the operatives. The walls are prepared for plastering by indenting them all over from top to bottom with numerous hammer or pick marks: the closer these are to each other the better. The rough-cast is laid on as follows: The indentations in the wall being first carefully swept, the wall being sprinkled with water, the workman takes his brush filled with rough-cast mortar and dashes it against the wall. The indentations in the wall give the appearance of the ordinary rough-cast with pebbles in it. The scaffolding being placed at the top of the wall, he lowers his scaffold, takes out the joists, fills up the holes with bricks, mortar, &c, and, fastening his scaffold lower down, proceeds as before.
564. Stucco for outside work is made with one bushel of unslaked lime to six bushels of clean sharp sand. Stucco-finishing is laid on as follows: The walls

being previously indented, swept, and sprinkled with water, the workman places some mortar on a flat piece of board 12 inches square, provided with a handle, and with a plastering-trowel lays this on the wall, pressing it closely between the indentations, and working the surface, finally, fair and level, it being sprinkled at the same time by means of a brush with some of the thin mortar, — the poorer the mortar the better the stucco. Lime-wash is used as a final covering to the stuccoed wall. This is made by dissolving some unslaked lime in clear water, and sprinkling it on the wall before the stucco is dry. When applied in this manner the stucco sets very hard, and the white colour of the wash is so incorporated with it that it will never wash off, although no size or oil is used — indeed, the using of these renders the white dead and less brilliant; whereas, if the lime-wash is alone used, the colour will remain naturally as long white as the plaster lasts. All the plastering should be done at one time: new plastering never sets well with old. **It is absolutely essential that the walls shall be thoroughly dry before the plaster is laid on**. If this is not attended to, the plaster will inevitably scale and blister off, leaving unseemly spots.

565. The method of Rough-Casting Rubble Stone or Brick Walls is as follows: First wash the earth from the gravel or coarse sand, and bring it to a uniform size by sifting it, or passing it through a screen; mix the gravel with newly-slaked lime and water, to the consistence of thick cream. Having cleaned the part of the wall to be operated on with a rough brush, a coat of lime and hair is laid on smooth, and, as fast as some two or three square yards are finished, the rough-cast is thrown upon it. Some recommend the first coat of lime and hair to be allowed to dry, and a second coat put on, upon which the rough-cast is finally thrown. , Instead of throwing the rough-cast on, small pebbles may be stuck in the mortar while yet in a soft state. This, however, is a tedious process.

566. Mr Downing recommends a strong and durable stucco for the finishing of the outside of rough brick and stone walls, as follows : " Take stone lime fresh from the kiln, and of the best quality, such as is known to make a strong and durable mortar. Slake it by sprinkling or pouring over it just water enough to leave it, when slaked, in the condition of a fine dry powder, and not a paste. Set up a wire-screen at an inclined plane, and throw this powder against it. What passes through is fit for use; that which remains behind contains the core, which would spoil the stucco, and must be rejected. Having obtained the sharpest sand to be had, and having washed it so that not a particle of the mud and dirt (which destroy the tenacity of most stuccoes) remains, and screened it, to give some uniformity to the size, mix it with the lime in powder, in the proportion of two parts sand to one part lime. This is the best proportion of lime stucco. **More lime would make a stronger stucco, but one by no means so hard** — and hardness and tenacity are both needed. The mortar must now be made by adding water, and working it thoroughly. On the tempering of the mortar greatly depends its tenacity. The wall to be stuccoed should be first prepared by clearing off all loose dirt, mortar, &c, with a stiff broom. Then apply the mortar in two coats: the first a rough coat, to cover the inequalities of the wall, the second as a finishing coat. The latter, however, should be put on before the

former is dry, and as soon, indeed, as the first coat is sufficiently firm to receive it: the whole should then be well floated, trowelled, and marked off; and if it is to be coloured in water-colour, the wash should be applied so as to set with the stucco.

567. Whitewash for External Walls. — A cheap wash for the outside of wood cottages, outbuildings, &c, is made by slaking fresh quicklime with boiling water, and adding some sulphate of zinc — sufficient water being put in to bring the whole to the consistence of cream. The addition of the sulphate of zinc tends to harden the wash, and make it more durable. The addition of a little sulphate of iron will give the wash a warm tint, which will be much more agreeable to the eye than the pure white resulting from the above.

569. The following is the recipe for making the celebrated stucco white wash used in the President's house at Washington, United States : " Take half a bushel of good unslaked lime, slake it with boiling water, covering it during the process to keep in the steam. Strain the liquor through a fine sieve or strainer, and add to it a peck of clean salt previously dissolved in warm water; three pounds of good rice, ground to a thin paste, and stirred in while boiling hot; half-a-pound of powdered Spanish whiting, and a pound of clean glue, which has been previously dissolved by first soaking it well, and then hanging it over a slow fire in a small kettle, within a large one filled with water. Add 5 gallons of hot water to the mixture, stir it well, and let it stand a few days covered from dirt. It should be put on quite hot : for this purpose it can be kept in a kettle on a portable furnace. It is said that one pint of this mixture will cover a square yard upon the outside of a house, if properly applied It retains its brilliance for years. Any required tinge can be given to the preparation by the addition of colouring matter."

571. Section Sixteen. — Finishing of Interior Walls — Plastering. — In many cottages, &c, the stucco already described as useful for outside may be adopted for inside walls, partitions, &c. Plaster proper is made of gypsum, or sulphate of lime; this is burned or calcined in a simple rectangular kiln or enclosure, formed of brick walls. The largest lumps or stones of lime are placed on the floor of the kiln, in such a way as to form, as it were, a series of arches, into the space of which the firewood or fuel used in calcining is put, the smaller stones being placed above. After being calcined, the time for which operation varies according to the quantity of lime to be burnt, the lime is powdered either by hand or a mill, after which it is protected from the atmosphere until ready to be prepared for plaster. This is done by slaking the powder with water, the quantity of water depending on the degree of stiffness required in the plaster.

572. The first coat is laid on the walls in a thinnish state, and left rough to take on the next coat, which must be laid on stiff, and smoothed up with a hand-trowel, the surface being levelled with a flat rule. For ordinary work, a plaster termed "coarse stuff" may be made of common mortar mixed with coarse hair — cattle or horse, from the tanyard — and thoroughly incorporated. In laying this on brick or stone walls, the first coat, which is termed " rendering," is to be crossed or made rough with the trowel, in order to form a key to the next coat This not done where the work is " two coats " only.

573. In this case the first coat or " rendering" is left smooth; the second coat is then put above this — the material for the second coat being of pure lime slaked with a small quantity of water, more being finally added to bring it to the thickness of cream. After being allowed to settle, the water is poured off, and the lime allowed to remain, till, by the evaporation, it is brought to a proper thickness for working. Where fine stuff is used for ceilings, a little hair is mixed with it, the colour of this being white.
574. Three-coat work is executed by first laying on a coat of coarse stuff, crossing it with the trowel ; then above this another coat, smooth and floated with a rule, and then finished with a " set," or smooth coat of fine stuff.
575. In partitions where laths are placed across the timbers, and in ceilings where only one coat of coarse stuff is laid on between the laths, the operation is termed " lath and plaster." A more finished method, where laths are used, is by first laying on a coat (leaving it crossed) of coarse stuff, thereafter a coat of fine stuff; a still higher kind of finish being — first, a coat of rough stuff, crossed ; next, a second coat, smoothed ; lastly, a coat of fine stuff.

Gillmore Q A (1886, but written 1861) Practical Treatise on Limes, Hydraulic Cements and Mortars.

Chapter VI

Calcareous mortar, being composed of one or more of the varieties of lime or cement, natural or artificial, mixed with sand, will vary in its proportions with the quality of the lime or cement used, the nature and quantity of sand, and the method of manipulation. No fixed rules for its preparation, that shall be equally well adapted to all the varying circumstances of locality, temperature, and the seasons, can be prescribed.

The objects to be attained by the use of mortar are chiefly of two kinds, as follows:

First to bind together the solid materials used in masonry constructions; or, in other words, to produce in each particular case, artificial monoliths, of the required form and dimensions.
Second to form coverings to solid materials…Under this head may be included all exterior covering, and interior plaster work and ornamentation.

Sand exercises no sensible chemical action in the composition and induration of mortars of hydraulic lime; if the sand be silicious, there is believed to ensue a slow formation of silicate of lime, which considerably augments their power of resistance *[compressive strength],* and in positions excluded from contact with the air, such as the interior of thick walls, become an important auxillary in the hardening process *[right, but for the 'wrong' reason – he does not consider the reactive silica burned in the hydraulic limestone, but ascribes their effect to silica within the added sand].*

In practice…mortars are weakened by the addition of sand (or other aggregates, including brick). These…have the important effect, however, of preventing or diminishing shrinkage, of hastening the induration of rich limes, and of rendering all kinds of mortars less liable to crack in drying, which is often of very great advantage. They are, moreover, by far the least costly ingredient of mortar, and a due regard for economy compels their use in the largest possible proportions.

(**However**, whilst)…it might be inferred that the **minimum amount** of the cementing material that can be used in any case is exactly equal to the volume of the voids in the sand, when the latter is well compacted *[typically 1:3]*. This theory supposes that there is no shrinkage in the matrix while hardening, and that the manipulation *[slaking]* is complete. But as these conditions can never be fully attained in practice, it is **unsafe to descend to this inferior limit.** Moreover, mortars composed on this principle would **be deficient in both *adhesive* and *cohesive* power,** from the fact that the particles of sand would present a large area, practically void of matrix, **to the surfaces of the solid materials that are to be bound together,** and would, for the same reason, be in **more or less intimate** contact with each other throughout the mass. In order to avoid these defects, **it is customary** to determine the amount of cementing matter to be used in any particular case, by adding 45 to 50 per cent to the volume of void space in the sand.

[Gillmore perhaps the only historic author on limes to consider that the lime rich nature of traditional lime mortars is for a good reason, rather than simply craft practice and habit].

….METHODS OF SLAKING LIME

Lime is usually sent to market in barrels, either in lumps, as it leaves the kiln, or, in the case of those varieties that are more or less meagre, and consequently difficult to reduce to a fine pulp by any of the known methods of slaking, in the condition of coarse powder to which it has been brought by grinding. In either case, it must be slaked before it can be employed as a matrix for mortar.

Three methods of slaking lime are usually described in works on mortars; on the continent of Europe, the third method, and in the United States, the second and third are seldom resorted to in practice.

The first or *ordinary* method termed *drowning* from the excessive quantity of water **sometimes** injudiciously employed, consists of **pouring upon the lumps of lime,** collected together in a layer of uniform depth not exceeding six to eight inches, either in a water-tight wooden box or a **basin formed of the sand to be subsequently added in making mortar,** and coated over on the inside with lime paste, to render it impervious to water, **a sufficient measure of fresh water –** previously ascertained approximately by trial – **to reduce the whole to the consistency of thick pulp.** It is important that all the water required for this purpose…should be added at the outset, or, at least, before the temperature becomes sensibly elevated. In this condition the lime will remain entirely submerged, and comparatively quiescent, until after an interval of five to ten minutes, the water becomes gradually heated to the boiling point, when a sudden evolution of vapour, a rapid increase in volume, and a reduction of the lime to pulp, ensues.

This process is liable to great abuse at the hands of workmen, who are apt to use either too much water, thus conferring upon the slaked lime a condition of **semi-fluidity**, and thereby injuring its binding properties; or, not having used enough in the first instance, they seek to remedy the error by adding more after the extinction has well progressed, and a portion of the lime is already reduced to powder, thus suddenly depressing the temperature *[??]* and chilling the lime, which renders its granular and lumpy.

As soon as all the water required has been poured upon the lime, it is recommended to cover up the vessel containing it with canvas or boards, **in order to concentrate the heat and the escaping vapour,** and direct their action upon the uppermost portions deprived of immediate contact with the water, by the swelling of the portions at the bottom. **When it is not practicable to apply this covering, a tolerable substitute is found in the sand to be subsequently added to the mortar.** This can be spread over the lime in a layer of uniform thickness, **after the slaking has well progressed.**

Another precaution of equal, and perhaps greater importance is **not to stir the lime whilst slaking;** but to allow it gradually to absorb the water by capillary attraction and its natural avidity for it, taking care that all portions are supplied with it to that degree requisite **to produce a paste of the slaked lime, and not a powder.** When the lime is to be used for whitewashing or grouting, the water should be added at the outset in larger quantities than specified above, and the whole mass should be **run off while hot into tight casks, and covered up to prevent the escape of water.**

In slaking, the essential point is to secure, if possible, the reduction of all the lumps. It will be found difficult to do this with the hydraulic varieties, and the difficulty increases in direct ratio with the hydraulic energy…Even with those hydraulic limes that do slake, it is often necessary to employ a mortar mill to reduce the lumps – a condition which should always be secured, as these lumps constitute not only a dangerous substitute for sand, if left intact, but furnish when pulverised, the most energetic portion of the gang.

[For a more familiar (and probably more common) version of this method, see below. It is easy to see how this method became (and doubtless already was] the 'craft method', which saw the sand and the slaking quicklime being mixed together quite soon after the addition of water, for better or worse. Indeed, Gillmore himself ventures this option as an 'improvement' to the method above later in the text, amongst other proposed 'improvements'].

*Slaking by Immersion***.** The second method of slaking (*by immersion)* consists in **suspending the quicklime**, **previously broken into pieces of about the size of a walnut, and placed in a basket or other suitable contrivance, in water, for one or two minutes, taking care to withdraw it before the reduction commences. The lime should then be quickly heaped together, or emptied into casks or bins, and covered up, in order to concentrate the heat and prevent the escape of vapour. In this condition it soon begins to swell and crack, and finally becomes reduced to a fine powder,** which may be preserved several months without serious deterioration, if packed in casks, and kept from direct contact with the atmosphere. The expense which would ordinarily attend the practical application of this process, and the difficulty, and even impossibility of securing with certainty, at the hands of workmen, the period of immersion, have led to a **modification** of it, which consists in sprinkling the broken fragments formed into heaps of a suitable size, with one-fourth to one-third of their volumes of water. This should be applied from the rose of a finely gauged watering-pot, **after which the lime should be immediately covered with the sand to be used in the mortar.** In this condition it should not be disturbed **for at least a day or two,** and the opinion prevails in the southern portions of Europe that the quality of the lime is improved by allowing the heaps to remain several months, without any other protection from the inclemency of the weather than an ordinary shed, open on the sides. In the vicinity of Lyons this custom very generally obtains, the autumn being usually selected for slaking all the lime required for the following season's operation. In Europe this method of slaking is applied **to the fat and slightly hydraulic limes only,** and not to those that are eminently hydraulic, upon which it seems to act disadvantageously, by depriving them, in a measure, of their hydraulic energy.

Spontaneous Slaking.

Quicklime has a great avidity for water, and when not secured from direct contact with the atmosphere, **gradually absorbs moisture from it and falls into powder,** exhibiting **but very slightly** and sometimes not at all, the other phenomena usually developed in slaking. The lime is then said to be slaked *spontaneously,* or *air-slaked.*

It has been claimed by some engineers that this method, if the precaution be taken to stir the lime frequently, so as to expose every portion of it to direct contact with the air, **confers a slight degree of hydraulicity upon fat lime….**

[common to all methods of slaking is the conviction that the best mortar is produced by using quicklime slaked with a ***minimum of water,*** *begging the question as to whether this is the key 'secret' to the enhanced performance of hot-mixed mortars – and that the intimate engagement of sand may be* ***incidental,*** *borne of the economy and efficiency of doing this.* ***Testing of mortars made to the three methods above – with lime proportion constant between all samples - might answer this question}.***

A great and insurmountable objection to the process, however, is the expense of storage room or sheds which it necessarily involves, to say nothing of the time required for its completion. Spread out in layers of from ten to twelve inches in depth some varieties of fat lime might become thoroughly reduced in twenty or twenty-five days; others would require as many weeks; while with a few, the process would continue for a whole year. Hydraulic limes are greatly injured by spontaneous slaking.

…(takes various issues with Vicat's findings regarding the volumetric expansion of lime on slaking and Vicat) says that the absorption and penetration of (carbonic gas) proceeds more rapidly in the hydraulic limes than in the fat limes – and statement which not only needs confirmation, **but is believed to be the converse of what is true.** My researches lead me to the same results as those enunciated by Geo: Robertson Esq…"the depth to which carbonic acid is absorbed into mortar in a given time, and to a certain extent, the induration from that cause **varies inversely with the hydraulic properties of the lime, which depend upon the silica contained in it".**

The incrustation is due in the case of hydraulic limes to the **combined influence of reactions, considerably more complicated and obscure than those which obtain with the hydrate of fat lime.** The hydrosilcate and aluminate of lime…are formed in addition to the hydrocarbonate. The formation of these compounds is **not confined to the crust on the surface** *[as it may be initially in the 'case-hardening' of an air lime mortar],* **but takes place throughout the mass,** and is really the **principal efficient cause** of the induration of this class of limes, when placed under water or in humid localities excluded from atmospheric influences….

The hardness assumed by the hydrate *in the air* is **intimately connected with the process of slaking** and appears to sustain a direct ratio with increase in volume The three modes of slaking arranged in order of their superiority in this respect stand as follows:
1st For fat limes: ordinary slaking; spontaneous slaking; slaking by immersion
2nd For hydraulic limes: ordinary slaking; slaking by immersion; spontaneous slaking….

…(the second and third methods of slaking (by immersion or air have been tested little by practical experience in the USA, and) **the first mode of slaking inasmuch as it is attended with less original outlay, gives more certain results, and requires fewer precautions at the hands of the workman *[who probably blends the slaking lime and sand sooner than in Gillmore's description, in practice]* may be regarded as the most advantageous in nearly every case,** *provided the precaution is taken to pour on at the outset all the water required to produce a stiff paste,* but no more.

General Totten announced the following as the results of experiments made at Fort Adams, upon the different modes of extinction:

1st Slaking by drowning, or **using a large quantity of water in the process of slaking, affords <u>weaker mortars</u> than slaking by sprinkling.**
2nd Experiments with air-slaked lime were too few to be decisive, but the results were **unfavourable** to that mode of slaking.

Preservation of Lime. The paste of fat lime, whatever may have been the mode of extinction, may be preserved intact for an indefinite length of time, if kept from contact with the air. It is usual to put it in tight casks, or in reservoirs or trenches covered up with sand; or, when shed-room is available, to form it into rounded heaps, similarly protected and under cover.

The **powder** derived from the second and third modes of extinction may be preserved for several months, without sensible deterioration, in covered casks or bins, or if heaped up in dry sheds and covered over with straw, cloth or dry sand *[however, most accounts of heaping in practice make clear that the sand and lime are previously engaged and mounded to 'sour out']*

Until quite recently, opinions **among engineers** were divided as to the effect of time upon the quality of paste of fat lime, preserved with suitable precautions for future consumption. General Treussart entertained the opinion that they **should be made into mortar and used soon after their extinction.** This idea finds few advocates at the present day, **<u>although the practice in this country conforms to it with</u> singular <u>unanimity.</u>** ***[which is to say that, in practice, and <u>craft practice</u> in the US, hot mixing was generally by the first method and taken directly to a mortar and used soon after being made].***

Fabrication of Mortars. The relative quantities in which sand and the cementing substance, whether the latter be derived from common or hydraulic lime, or cement, should exist in in mortar, depend in a great measure on the character of the work in which it is to be used; its locality and position with regard to a state of moisture or dryness; and, if subjected to alterations in this respect, the character of the moisture, depending on its proximity to or remoteness from the sea, the nature and magnitude of the forces which it will be required to resist, the peculiarities of the climate, and the season of the year in which the work is to be performed.

When mortar is to be made in quantities sufficiently large to warrant the expense, a **mortar mill** of some approved pattern should be provided, for incorporating the ingredients, as the mortar thus obtained is **invariably superior** to that produced by the use of the hoe and shovel only….

(detailed description of a mortar mill constructed for the building of Fort Warren, Boston harbour), (where) mortars composed of lime and sand only, the lime was slaked in the ordinary way with a sufficiency of water, simply to produce a thick pulp….the limes most extensively in use for public works on our Atlantic coast, the largest augmentation of volume in slaking is secured by adhering to the following directions, viz: **put the lime into a box, break up the**

larger lumps with a hammer; pour in at once the quantity of water (ascertained previously by trial) necessary to reduce them to a stiff paste, and then cover up the box so as to prevent, as much as possible, the escape of heat and vapour, allowing it to remain in that condition, without stirring, until the reduction is complete. In order to connect this process with the operations of a mortar mill, it might be necessary to provide several boxes, so that the lime might, in all cases, **have at least forty-eight hours to digest before it is made into mortar.**

…Extensive operations requiring large quantities of mortar are frequently carried on by experienced engineers, without the aid of a mortar mill of any kind.

When ordinary lime mortars are thus made by hand, it is customary and convenient to slake the lime by the first method described, and **in no greater quantity than may be required for immediate use.** The operation should be conducted under a shed. **The measure of sand required for the 'batch' is first placed upon the floor, and formed into a basin for the reception of the unslaked lime.** After this, the latter is put in, and the larger lumps broken up with a mallet or hammer; **the quantity of water necessary to form a stiff paste** is let on, from the nozzle of a hose, or with watering pots, or even ordinary buckets. **The lime is then stirred with a hoe, as long as there is any evolution of vapour, after which the ingredients are well mixed together** with the shovel and hoe, a little water being added occasionally if the mass be too stiff. At this stage of the operation, it is **customary to heap the mortar compactly together, and allow it to remain until required for use.** When circumstances admit, it should not be disturbed for several days, and during the period of its consumption **should be broken down and 'tempered' in no larger quantities than may be required for use from day to day.**

It is believed that certain slight modifications of this common method of procedure can be made, with decided advantage in the final results. As follows:

1st All the lime necessary for any required quantity of mortar **should be slaked at least one day** before it is incorporated with the sand.
2nd The sand-basin, to receive the unslaked lime should be coated over on the inside with lime paste, to prevent the escape of water.
3rd All the water required to slake the lime to a stiff paste, should be poured on at once. This will completely submerge the quicklime. **The heap should then be covered with tarpaulin or old canvas, and left until next day.**
4th **The ingredients should be thoroughly mixed, and the mortar heaped up for future use.**

(The mortar used for the construction of Forts Richmond and Tompkins in New York Harbour was made by hand)…

When required for stonemasonry, or concrete, it was composed of **hydraulic cement and sand, without lime.**

Four men constituted a gang for measuring out and mixing the ingredients, who proceeded to the several steps of the process in the following order:

1st The sand is spread in a rectangular layer of two inches in thickness;

2nd The dry cement is spread equally all over the sand;

3rd The men place themselves, shovel in hand, two on each side of the rectangle, at the angles, facing inwards. Furrows of the width of a shovel, are then turned outwards along the ends of the rectangle until the whole bed is turned. The two men on one side thus find themselves together, and opposite the two on the other side…they then move back to their original positions in turning furrows as before…the turning is executed by successively thrusting the shovel under the material, and turning it over about one angle as a pivot….

4th A basin is formed, by drawing all the material to the outer edge of the bed.

5th The water is poured into the basin thus formed.

6th The material is thrown back upon the water, absorbing it, when the bed occupies the same space it did at the beginning.

7th The bed is turned twice, by the process described above.

If required for mason's use, the mortar is then heaped up, to be carried when and where required. If for concrete:

8th The broken stones are spread equally over the bed.

9th A bucket of water, more or less (depending upon the quantity of the stones, their absorbing power, and the temperature of the air), is sprinkled over the bed.

10th The bed is turned once as before, and then heaped up for use. The act of heaping up, which is done with care, has the effect of a second turning.

(takes 20 minutes to make batch; 10 minutes more when for concrete).

When the mortar is required in very small quantities, to avoid deterioration, instead of proceeding to the fourth step of the manipulation, the mixture of cement and sand is heaped up and the water added and paste formed with the hoe, in such quantities as are required.
(Mix for these forts was 1 hydraulic cement powder: 2.44 casks of sand well compacted).

(Mix at Fort Warren was of lime, hydraulic cement and sand:

1 dry cement: ½ Rockland lime: 14 ½ cubic feet of well compacted sand)

Some engineers object to the use (of so much sand as at Forts Richmond and Warren)…others again very seldom add lime to their cement mortars. Touching this last…recent experiments show, with a uniformity quite satisfactory, that **most American cements will sustain, without any great loss of strength, a dose of lime paste equal to that of the cement paste;** while a dose equal to ½ or ¾ the volume of cement paste may safely be added to any energetic Rosendale cement, without producing deterioration in the quality of the mortar…Neither is the hydraulic activity of the mortars so far impaired by this limited addition of lime paste, as to render them unsuitable for concrete, under water or other submarine masonry; while, for constructions not subject to immediate submersion, or the action of the returning tide, **it is to be preferred on many counts.** By the use of lime, we secure the double **advantages of a rather slow mortar –** one that is in no danger of setting before it reaches the mason's hand – and a cheap mortar. We also avoid the principal serious objection to the use of a quick-setting mortar, due to careless and tardy attendance on the masons, and consequently the **constant breaking up of the incipient set on the mortar-board, whereby cements are degraded in energy to a level with ordinary hydraulic limes.**

POINTING MORTAR

In laying up masonry of any character, whether with common or hydraulic mortar, the exposed edges of the joints will naturally be deficient in density and hardness, and, therefore, unable to withstand the destructive action of the elements; particularly variations in temperature, producing extremes of heat and cold. It is therefore **customary** to fill the joints as compactly as possible, to the depth of about half an inch, with mortar prepared specially for the purpose…. The cleaning out of the joints to the requisite depth should take place while the mortar in new and soft; and (in stonemasonry) when the stones come into contact, or nearly so, the joints must be enlarged, to the width of about three-sixteenths of an inch by a stone-cutter *[a new one on me]*.

[Gillmore, like almost all historic authors on the subject, has no concern about, or even appreciation of compatibility of materials, although for the most part the buildings he is familiar with will have been built and pointed with the same mortars].

Pointing mortar is compounded of a paste of finely ground cement, and clean sharp silicious sand, in such proportions, in such proportions that the volume of cement paste shall be very slightly in excess of the volume of the voids in the sand. *[pointing with a mix more binder-rich than the bedding mortar has long precedence, certainly in North Yorkshire, with lime-rich pointing over earth or earth and quicklime bedding mixes. Doubtless, this was common with lime mortars. Gillmore is transferring the principle to natural cement work.]*

…Before pointing, the wall should be thoroughly saturated with water, and kept in such a condition, that it will neither absorb water from the mortar, nor impart any to it, two conditions of special importance, the first being paramount.

Walls should not be allowed to dry too rapidly after pointing, but should be kept moist for several days, or better still, for two or three weeks….

INTERIOR PLASTERING

…The mortars used for inside plastering exclusively, are 'coarse stuff', 'fine stuff', 'gauge stuff' or hard finish and 'stucco'.

Coarse stuff **is nothing more than common lime mortar,** suitable for brick masonry, to which has been added a quantity of well-switched bullock's hair, to act as a kind of bond. The following proportion is a good one:

1 cask lime – 8 cubic feet of paste:
Sand – 16 to 18 cubic feet
Hair – 1 ½ cubic feet.

When ample time for hardening cannot conveniently be allowed, it will be advantageous to **replace 12 to 15 per cent of the lime paste in the coarse stuff, by an equal volume of hydraulic cement or plaster of Paris.** Coarse stuff forms the principal part of all inside plastering. For the second coat, in three-coat work, the quantity of hair given above may be slightly diminished.

Fine stuff is made of **pure lump lime slaked to a paste** with a moderate quantity of water, and **afterwards** diluted to the consistency of cream, and then placed where it can stiffen by evaporation to the proper condition for working *[all this whilst still hot, therefore]*.

Fine stuff is used for the finishing coat, but **never** without the addition of plaster of Paris, except for what is termed 'slipped coat'. Even for slipped work, a little fine sand is sometimes added, to make the paste work more freely.

Guage stuff or *hard finish* is composed of fine stuff (lime putty) and plaster of Paris, in proportions regulated by the degree of rapidity required in hardening. It is used for the finishing coat of walls, and for cornices, mouldings and other kinds of ornamentation. **For finishing, the proportions are three to four volumes of lime putty to one volume of plaster of Paris, and for cornices etc about equal volumes of each.**

Stucco is composed of **lime putty and white sand,** with a preponderance of the latter. The usual proportions are **three to four volumes of sand for one volume of lime putty.** Stucco is only used for the finishing coat.

…In ‘rendering’ (on hard) the joints of the masonry should be raked out to the depth of half an inch, the surface freed of dust, and the walls moistened. Old masonry, if smokey or greasy, should also be scraped out and roughened [*common enough practice, but the opposite of current guidance]. …*

Except for very common work, the laying coat should be hand-floated , to give it density and solidity. This is done by using the float in the right hand, and a hair brush holding water, in the left; both…passed quickly over the wall at the same time, the brush preceding the float, and wetting the surface to the required degree. The firmness and tenacity of plastering is very considerably increased by hand-floating, and at a moderate expense.

Hand floating must take place while the mortar is green, when it is intended as a preparation for the setting coat.

…After the first coat, whether it be a laying coat or a screed coat, has become partially dry, so as to resist the pressure of the trowel, it is ready for the setting, or finishing coat….the surface must receive it **must be roughed up with a birch or hickory broom.**

A *slipped coat* is merely a smoothing off of a brown coat (coarse stuff), with the **smallest quantity of lime putty** that will answer to secure a comparatively even surface. It is seldom sufficient to cover the browning up entirely.

Finishing or setting in stucco is suitable for a screed coat, but is never applied to laying (on lath) or to inferior work, on account of the extra work it requires. The stucco is applied with the trowel, to the thickness of about one-eigth of an inch, keeping in view the fact that the straight surface gained by screeding (plumbed screeds being set out and filled between to achieve straight surface) can only be preserved by applying the set in a coat of uniform thickness. The stucco is well hand-floated, the water brush being used freely while so doing. After the wooden float has been used, the surface is again floated with a cork float, which, being soft, leaves the surface in good condition for polishing. The polishing is performed with a trowel and brush; this operation is omitted when the stucco is intended to present a rough appearance for painting, or for any style of ornamentation in distemper.

Bastard stucco, like stucco, is also used as a setting coat on screed work. It is done in stucco mortar, containing a smaller quantity of sand than is suitable for genuine stucco, and **sometimes a little hair.** There is no hand floating in this kind of work, and the trowelling is done with less labour than that conferred on trowelled stucco, as above described. Bastard stucco is superior to slipped work as a preparation for papering.

…*hard finish*…the advantage of hard finish over stucco in its requiring less labour to apply it. It is extensively practiced in the United States.

Three-coat work. The first and second coat are termed respectively the *scratch* coat and the *brown* coat, and the third is either *hard-finish* or *stucco*.

The scratch coat, or first coat, is applied in the same manner as *laying*…to form a good foundation for the *screeding* which follows, its thickness need not exceed one quarter to three-eighths of an inch. When completed and partially dry, though still quite soft, the mortar is *scratched* over nearly to its entire depth, with a pointed stick, in two systems of parallel scorings at right angles to each other, running diagonally between the extreme limits of the surface covered. These scorings are about two inches apart, and assist the adhesion of the coat which follows.

The second coat is applied in screeds and 'filling out'…

The finishing or setting is also applied as before described.

EXTERIOR PLASTERING OR 'STUCCO'

Mortars composed of the paste of common lime and sand, either with or without the addition of plaster of Paris, are **unsuitable** for covering surfaces exposed to the direct action of the elements.

Lime, however, forms the basis of many excellent outside stuccos, and, by proper treatment, may be rendered very durable.

If the water for mixing the mortar contains **coarse sugar or molasses in solution**, the effect on the solidification of the outer surface of the stucco is very beneficial. This method is practised (in)…India, as reported by Captain Smith in his translation of Vicat. The proportions for the sweetened water are about one pound of sugar to eight gallons of water, except for the outer or hand-floated coat, in which one pound of sugar should be mixed with two gallons of water *[a lot of water to add to a mortar if the lime is already slaked to a putty or paste]*.

Powdered slaked lime and smith's forge scales mixed up with bullock's blood in suitable proportions, makes a durable and moderately hydraulic mortar, which adheres well to masonry previously coated over with boiled oil *[ouch!]*.

The custom in the United States is to use hydraulic cement and clean sand, mixed up with a sufficiency of water to produce the ordinary consistency of mortar for plastering, and in such quantities that it may be used up before the batch begins to set. The proportions are one volume of stiff cement paste to 1.66 volumes of damp, compact sand; or, if measured dry, one volume of cement powder to two volumes of loose, dry sand.…The mortar is laid on in two coats in one operation…

Many of the best cements of the US are of too dark a colour to furnish an agreeable shade for the exterior of dwelling houses. A very simple remedy for this is to use light coloured or white sand, in whole or in part. (Or)…**lime paste may be added, without material injury, until its volume equals that of the cement paste.** Lively tints may be obtained by a judicious use of the several ochres, singly or combined….

As a general fact, within certain limits, solid bodies resist the action of frost in proportion to their density, or inversely as their capacity for imbibing water; but this rule is **not capable of strict application, and it is quite possible for one mortar to be better proof against frost than another less porous in its character.** Moreover, of two mortars of equal density, one may be materially impaired in tenacity and hardness by the action of frost, while the other exhibits few, if any, evidences of its effects.

CONCRETE OR BETON

(Terms have become synonymous, and) apply to any mixture of mortar (generally hydraulic), with coarse materials, such as gravel, pebbles, shells, or fragments of tile, brick, or stone. Two or more of these materials, or even all of them, may be used together. More strictly speaking, as originally accepted, the matrix or gang of beton possesses hydraulic energy, while that of concrete does not *{or, at least, uses pozzalanic addition to assist its set].*

…*the volume of the cementing material should always be somewhat in excess of the volume of voids in the coarse materials to be united.* The excess is added as a precaution against imperfect manipulation.

In England, some years ago, when concrete first came into extensive application, **common or feebly hydraulic lime, such as the Blue Lias limestone yields,** was generally used for the cementing substance. The quicklime, having been first reduced to a powder by mechanical means, **was incorporated with the sand and coarse materials in the dry state.** Water, in sufficient quantity to slake the lime, being then added, the concrete was rapidly mixed up with a pug-mill or with shovels, conveyed away in barrels or carts, and **used while hot.** It was employed extensively for foundations, or as a sub-stratum in light and yielding soils. In order to secure the requisite degree of compression and density, it was customary to throw it into its position from a height, and sometimes to ram it afterwards. In mixing the materials for **fat lime concrete,** as usually composed, there is a contraction of about 1/8 in volume; this is succeeded by expansion, when the setting takes place, of about 3/8 of an inch for every foot in height, which does not entirely cease for a month or two afterwards.

Concrete of fat or feebly hydraulic lime has been extensively employed in Europe for making artificial blocks of any required form and dimensions, which, after attaining in the air a degree of hardness and strength sufficient to render the handling of them safe and practicable, are laid up in walls with mortar joints, like ashlar-work.

Of late years, the practice of laying **fat lime concrete hot** has grown into disrepute among English architects and engineers. They now prefer that the lime should be thoroughly slaked, reduced to a pulp, and made into a mortar with the sand before the coarse materials are added. This process is always followed in making beton. The advantages of it are, immunity from the danger of partial slaking before use, superior homogeneity in the mass, and economy in the amount of lime required.
Neither the **English method** of making concrete to be used while hot, (nor artificial block making)…have ever received any extensive application in the United States.

Natural hydraulic cement to which…paste of fat lime is sometimes added, in quantities seldom greatly exceeding that of the cement, is almost invariably used as the basis of the concrete mortar: and the concrete, when made, is at once deposited in its allotted place, and well rammed in horizontal layers of about 6 inches in thickness, until all the coarser fragments are driven below the general surface. The ramming should take place before the cement begins to set, and care should be taken to avoid the use of too much water in the manipulation (so as to avoid any 'quicksand motion')…(but too much water better than too little, because) a too rapid desiccation of the concrete might involve a loss of cohesive and adhesive strength, if insufficient water be used….

On account of its continuity and impermeability to water, (concrete) is well suited to the purposes of a substratum in soils infected with springs, for sewers and conduits, for basement and sustaining walls, for columns, piers and abutments, for the hearting and backing of walls faced with bricks, rubble, and ashlar-work, for pavements in areas, basements, and cellars; for the walls and floors of cisterns, vaults etc. Groined and vaulted arches, and even entire bridges, dwelling houses and factories, in single monolithic masses, with moulded ornamentation of no mean character, have been constructed of this material alone.

(Long discussion about the hydration and setting of hydraulic limes. Most pertinently says that the clay compounds will combine with their equivalent of lime, the rest of the lime remaining 'free).

…The setting of mortars of fat lime and pozzuolana, natural or artificial, is likewise due to the formation of hydrated compounds of lime with silica and alumina. The lime attacks the silica and alumina, freeing them from previous combinations, when such exist, and **slowly** forms with them calcium silicate and calcium aluminate.

It has been recommended to allow these mortars to **remain mixed for some time before tempering them just previous to use,** a precaution which rests upon a plausible, and doubtless, a sound theory; for while the combinations of lime with silica and alumina **previously exist in the hydraulic limes and cements (**having been formed during the calcination, and are, therefore, in condition to

become hydrates at once, in presence of water), the conditions are quite different with mortars of fat lime and pozzuolana, in which the silica and alumina have first to free themselves from combinations peculiar to, and existing in the pozzuolana **before** they can form in the wet way those compounds those compounds, which **afterwards** become hydrates, and confer hydraulicity.

From this we can comprehend why fat lime should be used in preference to hydraulic lime for pozzuolana mortars, since the compounds formed during the burning of the hydraulic lime will have become hydrates, and will have **initiated the hydraulic set, before those formed in the wet way between the free caustic lime and the pozzuolana will have completed the preliminary decomposition;** and because, for the same reason, if we employ hydraulic lime, it is only the excess of caustic lime in it that combines advantageously with the pozzuolana. The operation in the mortar of two dissimilar powers, one *composing,* and the other *decomposing* in character, might operate disadvantageously. The conditions should be such, that the different combinations of the lime with the silica and alumina, no matter how, when or where formed, should become hydrated **simultaneously.**

[There is much more in Gillmore of value and interest].

Hitchcock E, et al (1861) The Geology of Vermont). Claremont. Claremont Manufacturing Co.

"To obtain lime for water cement, the impure limestone should be broken into small pieces and subjected to a heat sufficient to expel the carbonic acid…care must be taken that the heat is not too intense, for if it is, the rock will become partially fused, and a glassy substance will result from the alkaline and silicious constituents of the rock. After calcination, the rock should be thoroughly pulverized and mixed with sharp sand, after which water may be applied until the mass assumes the consistency of common mortar, when it should be used immediately, especially if it possesses the setting property of some cements. The proportion of sand to be used with the cement, varies with the composition of the lime"

Meagre Lime. Although this kind of lime often slacks slowly and less perfectly than fat lime, and when water is added, forms a less perfect paste, and therefore, **does not work so well with the trowel; and as it takes up less water and bears less sand, is therefore more expensive, yet after all, it hardens with greater certainty, and to a greater degree, and forms a more enduring and stronger cement. It is especially valuable for the property which much of it possesses, of hardening in damp as well as in dry places; and where mortar is exposed to the weather, it is by far the best.** Nevertheless many of the circumstances mentioned above, **produce a prejudice against this sort of lime, especially among bricklayers….**

Having occasion to plaster a building upon the outside it seemed to me that this lime would be well adapted for the purpose. **I tried it by mixing one part of unslaked lime with one part of sifted ashes, and one part of sand, and found it to produce a cement that spread well and became very hard.**

Scott Captain H(1862) Observations on Limes and Cements; their properties and employment. Papers on Subjects Connected with the Duties of the Corps of Royal Engineers Vol. XI. Woolwich. Jackson

…In this paper an endeavour will be made to point out the limes and cements best fitted for mortar; some of the fallacies commonly entertained respecting them; and the advantages which would result from removing their manipulation from the influence of the prejudices and of the convenience of workmen.

On the Action of Lime and Cement Mortars.

It is frequently supposed that, except in wet or damp situations, pure (or " fat") lime mortars attain great strength, and that there is no advantage in employing hydraulic limes excepting where the presence of wet or moisture renders a water setting material necessary. It is still more frequently, indeed generally, believed that though the limes do not set at first as rapidly as the cements, yet, that ultimately, they attain an equal or greater degree of hardness, and that the cements offer so much uncertainty in their use, as to make it advisable to use them as little as possible. A consideration of the causes which influence the setting of mortars will show that **these ideas are probably erroneous**, and this will be made quite evident by the proofs which will be adduced in the second paper, from observations made on their induration in actual constructions and in experimental trials.

Pure limestone, or carbonate of lime, when heated to redness is reduced to the condition of lime by the expulsion of its carbonic acid gas. The lime, when moistened with water, slakes with great violence, evolving much heat and crumbling to a soft, white, very bulky powder. By a fresh addition of water, the bulk of the powder is considerably reduced, and the paste thus formed, if allowed to dry, shrinks and forms a porous mass of no great hardness. If the hydrate of lime were placed in a hermetically sealed vessel, either in the pasty or in the dry state, it would never, as far as we know, change its condition; the paste would remain a paste, and the dry hydrate always remain porous and friable. The hydrate of lime does not contain within itself any property by which a further solidification can be produced. When exposed to the air, however, both the dry and the pasty mass (which in the air soon becomes dry by evaporation) will **gradually harden from the surface inwards, but always at a slower and slower rate, until, after the lapse of some years, no further perceptible progress is made.** The hardening is due to the small proportion of carbonic acid gas which the atmosphere contains, and which restores the lime to its original condition of a carbonate. So far as this gas can penetrate, the pure limes, if used without foreign admixture, will harden and no further….

It is stated by Jahn that in removing the ruins of the Castle of Landsberg, in order to lay the foundations for a new building, a lime pit of considerable dimensions was found in one of the vaults. The surface of this mass of lime was carbonated to the depth of a few inches, but all below that was in the state of freshly slaked lime, only somewhat more dry. This lime, which was certainly more than 300 years old, and valued at several hundred florins, was consequently used in constructing the new building.

"We cannot admit then," says Treussart, " that carbonic acid penetrates far into the interior of masonry, and it is proved by multiplied observations that moisture remains during a very long time in the interior of certain walls. Dr. Jahn reports on this subject that about ten years ago they demolished the piers of the Tower of St. Peters, at Berlin; this tower had been built 80 years, and the pillars were 27 feet thick, the mortar on the outside was hard and dry, but that in the middle was as fresh as if it had been lately placed there. I can state that in 1822, the lower part of a bastion, at Strasburg, being under repair, the mortar was found to be as fresh as if just laid, and **nevertheless, this bastion was erected in 1666**; the revetment was only about seven feet thick, but the moisture of the earth resting against it prevented the lower part from drying. Similar facts are observed in constructions still more ancient. "If then," says Vicat, " in what follows, we treat of ordinary mortars, or the mixtures of sand and rich limes, it is because we are compelled to do so to complete the history of the phenomena we have to describe. For it is our most decided opinion that their use ought for ever to be prohibited, at least in works of any importance."

Sir Charles Pasley's testimony is characteristic, and the more valuable because he once held a different opinion — " I had ascertained," he writes, " more than 12 years ago, that the pure limes, such as chalk lime, Carrara marble, &c., were utterly unfit for the purposes of hydraulic architecture, as they dissolved away on the outside, and never set at all in the inside of walls exposed to the action of water. But **I was of opinion at that time that the mortar of these limes was good for dry situations and for inside work, provided that the external joints were protected against the effects of beating rains, by pointing them either with cement or some superior sort of lime…**Having, however, acquired much more experience, partly from experiments, and partly in consequence of continual observations of new buildings in progress, or of old buildings being pulled down, since the first sheets of this work were sent to press, I am compelled to retract the above opinion in favour of chalk limes, **which I now consider bad under all circumstances, even in the driest situations, as it never attains any great degree of adhesiveness, even when only exposed to the atmosphere, and its resistance is so insignificant, that it rather dries than sets in air.** All that can be said in favour of chalk lime mortar is, that it is better than none; and that **walls built with it will not fall to pieces in process of time, as General Treussart asserted, without external violence"** .... and so, he continues, summing up his ideas on the subject in this pithy remark, which is almost the last of his valuable treatise. **" Thus chalk lime mortar, when wet, is a pulp or paste, and when dry, it is little better than dust." (Pasley on Cements Appendix CX)**

" **We are in the habit of composing our mortars," says Treussart, " of fat lime and sand, our mortars consequently have little durability. We shall not obtain durable masonry in the air until we can make use therein of hydraulic mortars.** In countries where good hydraulic lime is to be had, no other kind should be used for any purpose whatever." (Memoir sur les mortiers, section 2 Chapt 14)

It might have been supposed that testimony so strong and unanimous, and from such reliable authorities, would have quite settled the question as to **the unfitness of pure limes for fortification works at least,** but so firmly rooted in the minds of our engineers was the old notion that good mortar could be made from pure lime (a notion by no means confined to Military Engineers) that we have, notwithstanding, used the fattest of limes for all the masonry at Gibraltar not exposed to the action of the waters of the bay, and within the last few years the pure Plymouth lime has been used for works at Devonport. At Gibraltar when it became necessary recently to make some alterations in work which was 6 years old, and a portion of it was fired at with a 68-pdr. gun — the mortar, as was to be expected, was found to be set on the exterior surface only, and to be quite in a friable pulpy state inside. " We however think," says Colonel Owen, "that the parapet would have presented more resistance had the mortar been of better quality; far from having attained any peculiar hardness, as was expected by Sir John Jones, it was very friable, and had the appearance of having been imperfectly mixed."

It is to be remarked that General Treussart was unacquainted with the superior results to be obtained by cements, and believed the results he obtained with strong hydraulic limes to be the best possible. His own experience of cements was confined to a few trials of Boulogne pebbles, which in character resemble the Roman cement stones of Sheppy and Harwich, and should have given a mortar of equal or nearly equal strength, but having calcined them in a very imperfect manner, he endeavoured to slake them in the same way in which he slaked his limes; and Vicat also, as Sir Charles Pasley remarks, " treats of natural cements in a manner which sufficiently proves his total want of practical knowledge of those cements."

It will appear hereafter that Sir Charles himself, though he advocates so strongly their use **whenever strength is required**, asserting that their employment " does away with the thrust of arches," had no conception of the resistance of which the cements now manufactured are capable. We have now to explain in what consists the superiority of the hydraulic mortars recommended by General Treussart, and of the cement mortars which General Pasley advocates, over the pure lime mortars. These, it will be remembered, have in themselves no property which can produce " setting " in the absence of the carbonic acid of the atmosphere; and that, therefore, where protected from this action, as in the foundations of a building, or in the heart of any heavy masonry, no solidification can ensue. The hydraulic lime mortars, however, do contain within themselves, to a greater or less degree, the property of solidifying without the assistance of the atmosphere…

The hydraulic limes are intermediate between the cements and the pure limes, and partake of the character and mode of action of each class of substances. The proportion of clay in them is generally smaller than in the cements, and the lime sufficiently predominates to produce by its violent affinity for water the degree of heat, expansion, and amount of vapour requisite to throw them into powder. When the quantity of clay, as compared with the lime, is small, the violence of the slaking is scarcely less than that of the pure limes, but in proportion as the clay is relatively larger in amount, the heat generated in combining with water is less, and the lime slakes to a powder more imperfectly and with less increase of volume; until at last, on reaching the boundary of the cements, the slaking must be urged on by confining the heat generated, and the lime be allowed to lie longer to ensure the completion of the action before it is mixed with sand and made into mortar. The volume of the paste produced from the slaked powder of argillaceous limes is also less, generally, in proportion to the amount of clay present, and a smaller quantity of water is necessary to slake and bring them to that state.

Some portions of hydraulic limes, in ordinary kiln burning, are of necessity brought, by the too great heat of parts of the charge, to that condition in which the silicates formed combine with water very slowly, **and such portions remain as unslaked concretions in hand-made or badly mixed mortar**. These, by passing into the state of hydrate after the mortar has been laid in work, expand and frequently do much mischief, throwing down arches and even lifting large masses of heavy masonry.

The slaked powders of such limes consist of hydrate of lime, and of silicate of iron and alumina which have been converted in the burning into that condition in which, through the silicic acid having undergone a great modification, they can unite with the lime to form new hydrated compounds similar to those which result from the action of cements; the only difference appearing to be that, whereas in the case of the cements the formation of the silicates takes place previously to the slaking of the lime, or simultaneously with it; **in that of the hydraulic limes their formation is a subsequent process, and occurs after comparatively long periods which may be measured by weeks, months, and years, instead of minutes, hours, and days.** The solidification is assisted by the presence of water, as this dissolves portion after portion of the lime, and thus brings it into more intimate contact with the silicic acid. It is often observed that the induration of the best hydraulic limes, when immersed in water, proceeds most quickly on the outside, and that **when they are allowed to dry rapidly, they never harden properly.**

When the first stage of calcination only is reached, and the lime slakes readily, the iron and alumina still assist greatly in expediting the subsequent formation of the silicates, and consequently there would be found wide differences in the rapidity of set between specimens of lias lime, grey chalk lime, and Dublin limestone, though they might each contain the same absolute amount of clay, because the composition of the clay in the three cases varies so much. The lias containing the largest amount of iron and alumina would yield the best result, and the Dublin limestone, in which the amount of these ingredients is particularly small, the worst. Many of the Dublin beds contain 20 per cent of clay, and yet yield poor hydraulic limes. Much of the Sheppy cement stone contains no more.

When the second stage of calcination is reached, such limestones as stand on the confines between limes and cements will yield cements, though at the lower degree of heat they produce only limes.

As the cements may, and practically always do, partake of the slow solidifying action of the hydraulic limes, so the hydraulic limes partake, when exposed to the air, of the hardening action of the carbonic acid gas of the atmosphere to which the pure limes owe their external hard crust. From this action indeed the cements are not free, but neither in their case, nor in that of the best hydraulic limes, is this action of notable advantage. **We may, however, have limes containing so little clay as to yield mortars hardly stronger than the pure limes, for the silicic acid can only combine with, and render insoluble, a certain proportion of lime, and whatever setting takes place beyond this must be due to the same ineffectual cause as that, to which the pure limes owe their hardening. Much of the lime that goes into the London market under the name of Dorking, Halling, and Merstham limes, is of this character, and though tinged with iron sufficiently to give it the buff tint which has procured for the better sorts the appellation of " grey lime," yields no stronger mortar, practically, than what might be obtained from the whitest chalk pit.**

The pure and feebly hydraulic limes (and indeed good hydraulic limes) are sometimes improved, as is well known, by the addition of puzzuolana, trass, &c. The action of such substances is similar to that of the clay found naturally mingled with the carbonate of lime in hydraulic limestones. They have been calcined by volcanic heat, and by this means the silicic acid has been brought into that condition in which it will enter into combination with the lime. Burnt clay will produce an effect similar in kind but rarely so perfect, and both with it and puzzuolana or trass, **finer grinding and more intimate mixing, than can be accomplished with ordinary means in actual practice, are necessary to attain such results as have been arrived at experimentally in small samples.** The fitness of such substances for preparing hydraulic mortars may be judged of by the quantity of silica which has become soluble in potash, after they have been acted upon by hydrochloric acid; for clay, which has been calcined in contact with lime or other metallic oxides, is readily attacked by this acid, and the silica set free assumes the gelatinous condition in which the alkalies can combine with it readily.

The pure and feebly hydraulic limes have, in massive brickwork, a very serious defect beyond that of want of strength, which defect is dependent on their inability to solidify out of reach of the air, and on the great hardness they attain where this comes in contact with them. The exterior joints of heavy masonry thus hardening with time, cease to be compressed by the superincumbent weight; but in the heart of the wall the settlement continues, and there a heavy pressure is thrown on the headers of the face bricks, which are thereby broken across, and the entire face of the wall becomes detached.

...Another defect attending the use of such weak mortars in revetment walls arises from the mortars in the joint retaining sufficient water, or imbibing it again from time to time, to throw off the outer crust when it freezes. When this has happened a good hold is ready for vegetation which rapidly makes the mischief worse. Pointing is then resorted to, and this, as often as not, fails in the first winter from the freezing of the pulpy mortar behind, and in a few years the outlay in repointing amounts to a sum which would have covered the extra expense of building, in a good hydraulic mortar or cement, in the first instance. " There is no economy," says General Treussart, " in putting up cheap masonry, which will require to be rebuilt at the end of a few years, and will need constant repairs annually ; it is much better, and really more economical, to encounter at once the expense which will secure to the work an indefinite extension and exemption from all but trivial repairs." It would be a curious point to ascertain how much has been spent on Tilbury Fort in the items of pointing and rebuilding since it was first erected. In some places the joints, from constant rescraping and the lifting effects of frost, which permitted the entry of dust after each repointing, have grown two inches, at least, in thickness.

It is necessary here to notice a very common error concerning **the effect of sand on mortars. Doubtless there are cases in which sand of a peculiar kind, within certain limits, improves mortars; but, as a general rule, the action of sand must be injurious to their strength, and the only valid reason that can be given for its employment is the advantage gained in the first cost of a structure by the saving effected in material.** In estimating the probable effect of sand upon mortar four points present themselves for consideration .. **the cohesion of the particles of the cementing material; their adhesion to the surfaces of the sand; the increase of strength that may arise, when the sand is stronger than the cementing material from the fracture having to take a longer path than it would, where no sand intervenes to break the direct passage in one plane; and the possibility of weak points occurring from several particles of sand remaining in contact without a sufficiency of cementing material to envelope them, and completely fill up their interstices.** The latter consideration affects all descriptions of sand — whether granitic, calcareous, or argillaceous — pretty equally, and so far as this cause of weakness exists, the strength of mortar must suffer deterioration. So far as the particles of sand break joint, as it were, and thus lengthen the path of the fracture, something doubtless is gained by its use, especially when the sand is intermixed with gravel, and its grains are of various sizes. In respect to the question of adhesion as compared with cohesion, wide differences may be supposed to exist, according to the nature of the surface of the sand, whether rough or smooth, and according as the lime is capable or not of exerting a chemical action upon it.

Now, as far as is known, the lime of mortar has no practically appreciable action upon quartz sand; and, therefore, as the greater part of our sand in this country is granitic, the adhesion of the lime to it must be independent of chemical effect, meaning by this term the formation of any new compound**. In France, however, a sand is found, termed an arene, which is a description of puzzuolana, and the employment of this sand has a decidedly beneficial action upon lime mortar.** A ferruginous sand, found in the gravel pit close to Prince Frederic's Bastion, on the Chatham Lines, possesses similar qualities, and it is probable that brick dust and burnt clay, as in some instances they form fair substitutes for puzzuolana, **would also, in a coarse state resembling sand, have also a beneficial effect both on pure and hydraulic limes,** though not, perhaps, on cements, because these naturally contain all, or nearly all, the clay which the lime can chemically combine with.

But with the majority of sands such chemical action is wanting, and the sand and lime particles hold together by the force of adhesion only. Experiments show that with most surfaces this force, as can readily be conceived, is less than that of the cohesion between the particles of lime. **The addition of sand, therefore, generally introduces an element of weakness into mortars in this way also. The loss of strength in respect of this will be greater in proportion as the sand is finer, and as the quantity is increased, for by enlarging the extent of surface over which adhesion takes the place of cohesion, not only is something absolutely abstracted from the resistance of the aggregate mortars, by a lesser force being substituted for a greater, but the chance of weak points, from a deficiency of cementing material between the particles of sand, is increased.** We introduce, then, into lime pastes three elements of future weakness when we add sand to them, arising from imperfection of mixture, and from the substitution of the weaker force of adhesion for that of the cohesion of their particles. We give them one element of strength by interposing, in the direct path which fractures might otherwise take, grains of a material stronger than themselves**. It seems probable, however, that the advantage thus gained does not counterbalance the sources of weakness introduced,** and it will be seen hereafter that experiment proves this to be the case. Experiment shows, too, that there is **little difference of resistance between mortars made of fine, coarse, and mixed sands, though as the sand approaches the size of gravel the diminution of strength from its addition becomes notably less.**

It was Smeaton who first pointed out the error, then upwards of 2000 years old, that the superiority of lime consisted in the hardness and whiteness of the stone from which it was prepared. The fallacy about whiteness is exploded, **but the**

idea of the connection between the goodness of mortar and the density of the limestones yielding it, is still entertained by many practical men; and when the Dorking and Halling grey limes were first brought into the London market, it was considered necessary to call them " stone limes " to procure their introduction. In many of the builders' price books they are still so termed.

Pure mountain limestones and chalk yield mortars of precisely similar quality though the stones are of very different densities; and the reason of this can readily be understood**. The pure mountain limestone, though a cubic foot of it may weigh 173 lbs., produces a paste of lime no denser than that of chalk lime, which weighs only 140 lbs. the cubic foot …** that is to say, all other things but the density of the limestones being similar — such as the purity of the limes, their freshness, the mode of slaking, and the proportion of water employed — the quantity of paste produced will be in proportion to the actual quantities of lime contained in a given bulk of the limestones, and the density of the pastes will be equal.

….Dr. Bryan Higgins, who wrote 20 years before Rondelet, prescribes, that no more than 1 part of lime to 7 of coarse sand, ought to be used in mortar to dry quickly; and less lime may not be used, because it does not render the mass sufficiently plastic for building or incrustation. He subsequently states that this is the best proportion, whether the mortar is to be quickly dried or not. Dr. Higgins **measured his ingredients by weight**; and, according to Smeaton's calculation, Thames sand weighs 4 ½ times as heavy as the slaked powder of common lime; the above proportion, therefore, is **somewhat under 1 ½ parts sand to 1 of lime, in slaked powder, or 3 parts sand to 1 of lime, measured in paste.**

….In concluding that **those mortars must of necessity be the best, which have as much sand as they can carry without losing the toughness and plasticity which the workman has reason to prefer,** Smeaton must either have lost sight of the influence which the relative forces of adhesion of the lime paste to the sand, and of the cohesion of the particles of paste amongst themselves, must have, after setting, upon the resistance of the compound; or he must have assumed that the former was of necessity the greater, and that each grain of sand would be perfectly coated.

….(There is) a common opinion amongst the builders of the metropolis, which is, that the Dorking and Halling limes, as being stronger limes, will, when made into mortar, bear more sand than common chalk lime…

The reasons for the London builders' notions on the subject can be accounted for by the fact of the misnomer of grey chalk lime already alluded to, for stone limes slake to a bulkier paste than chalk limes as they contain more lime in a given measure; tunnel burned lime, also, such as the white chalk, contains more core than the flare-burned grey lime….

When the means of two or more experiments are taken, **there is a loss of strength with each addition of sand,** excepting in one single instance, and then the difference in favour of the larger proportion of sand is quite insignificant. **According to experiments made by Colonel Nelson, in Bermuda, 1 part of lime powder barely filled up the interstices of 3 parts of sand.** Now with 2 ½ parts sand, on the means of Nos. 7, 8, 9, and 10, there is the loss of nearly one half the strength of which the limes were capable when used without sand, and, when 3 parts of sand were used, of nearly two-thirds, the lime being measured always in paste. Again on the means of the three results given in Nos. 17, 18, and 19, an increase of sand from 2 parts to 3 parts occasioned a loss of considerably more than one half of the resistance which the prisms had when used with the lesser quantity. Bearing in mind that these experiments were made by one who entertained, to the last, the notion that sand had generally a beneficial action on the strength of mortars, we can hardly resist the conviction that the building world must be mistaken in its theories on this question….

Before leaving this subject it may be advisable briefly to recapitulate the contradictory evidence of writers and experimenters who hold to the beneficial effect of sand on mortars, and to contrast this with the simplicity of the view here advocated. **Pasley thought, with Belidor and Rondelet, that hydraulic limes would carry with advantage less sand than the fat limes, because they worked short with a smaller proportion of it.** Vicat decided by experiment that they would carry more. Writers, generally, have asserted that the fat limes are benefitted by a considerable quantity of quartz sand. Vicat and Raucourt de Charleville assert that they are injured by a small proportion of it, and consider they have proved the point by experiment. Raucourt explains why it is that " cements," in which term, as already explained, he includes all argillaceous limes, are peculiarly benefitted by making mortar of such proportions as will enable the "cement " to fill up the voids of the sand. General Pasley asserts that cement is injured by any proportion of it. At the same time, on examining the results of the only experiments which have been given in a satisfactory form and are free from objections, we find the views advocated in this paper fully borne out, for not only do **they show that the theoretic rule of just filling the voids of sand is founded in error, but that, as regards strength in heavy structures, where cracks from shrinkage or drying are not to be apprehended, all limes are weakened by even small proportions of it.** The limes tried by Treussart after one year, without sand, and with the theoretic quantity, lost (some) their strength in the latter case. The trials of Colonel Totten after 4 ½ years, with 1/6 and 4/6 of the theoretic proportion, showed a resistance in the case of the larger proportion little greater than ½ of that which it showed with the less. The tendency of both their experiments **points unmistakeably to a loss of strength by each addition of sand in the case of limes, and Table XVIII shows the same rule to hold good with cements.** From the one view all is confusion and uncertainty, from the other, the view here taken, there are no unaccountable anomalies to be reconciled, and there is a **gradual decrease of strength with each addition of sand throughout the whole range of calcareous mortars** — in the fat limes, as asserted by Vicat and Raucourt de Charleville, and as shown by the results obtained by Colonel Totten — in the cements, as established by Pasley — and in the intermediate sorts of hydraulic limes, as satisfactorily decided by the careful experiments of General Treussart….

Enough has now been brought forward to show how unsatisfactory and contradictory are the statements made and the rules followed, by the theorizers on the effect of sand on mortars used in brick and stone masonry, and it is hoped a consideration of all the evidence **will lead to the conviction that this is not a question to leave to be resolved by the convenience of the workman and the interests of the builder. Exception is taken, not so much to the proportion of sand specified for works, (for this is generally moderate, and would cheapen the mortar without materially detracting from the resistance of the masonry) as to the practice which permits a departure from the specification, and any quantity to be introduced that does not render the mortar " short," on the supposition that <u>the plasticity which best satisfies the skilful workman is the surest criterion by which to judge of the proportion of sand and lime to secure the greatest resistance,</u>** and on a fanciful theory derived from the composition and hardness of granite.

(After discussion of others's thoughts on sands)… On considering all the evidence brought forward, and its very contradictory nature, it may be considered that our present knowledge and experience would not justify expense, in order to obtain for brickwork or masonry, quartz sand of any particular colour, size of grain, or from any particular source, **though it may be assumed that such as is rough and sharp will be preferable to smooth grained sands….**

On reviewing…opinions concerning the action of **salt**, and bearing in mind that some of the builders named were dealing with limes which set best when kept damp, and that others may have been dealing with fat limes, with which damp would occasion a retardation of the set; it seems reasonable to conclude that the observers were not mistaken in either instance, but that **for hydraulic limes, either sea sand or sea water may be used in brickwork and masonry, generally, without injury, if not with advantage.** *[Smeaton concluded the same].*

For plastering internally it is universally agreed that sea sand should be either rejected or washed, as the presence of salt will always keep the plastering damp and unfit to receive either paper or painting — of course to use sea water would be still more objectionable. For the internal parts of magazines and stores, also, sea water, and perhaps unwashed sea sand, may retard the drying and attract moisture sufficiently to render their use unadvisable.

In one point all writers excepting Rondelet, who may have been dealing with an arene, are agreed. **They all have decided that the sand must be clean.**
…Peter Nicholson complains that " to complete the hasty hash which was called mortar in his time, screened rubbish and the scrapings of roads, also, are used as the substitutes for pure sands; " and it may be truly asserted that at

Chatham, at least, clean sand is the exception and not the rule both in Government and Civil Buildings. For the Admiralty works, however, clean sand is procured. Here we find no disagreement sufficient to leave any doubts as to the validity of the common opinion against the common practice. **It is stated that one- seventh or one-eighth of clay in the sand used in making mortar causes the mortar to moulder in winter like marl, for clay absorbs water to a much larger extent than lime and sand.** There seems, then, the best ground for great stringency on that item of all specifications which prescribes that **the sand shall be clean as well as sharp, but which, at present, is a dead letter**. Few of us have ever seen a vat for washing sand, or indeed any sand washed at all, excepting for the finishing coat in plastering, and even in this case it is often dispensed with.

The Slaking of Lime

The next point to be considered is the mode in which the lime should be slaked. Many opinions have been expressed on this subject also, but **fortunately, the most generally approved is also one of the simplest of execution.**

The methods employed have been generally divided into three — **ordinary extinction**, immersion, and spontaneous or air slaking. **The first, which is most commonly used on the continent and often in this country, consists in throwing on the lime, as it comes from the kiln, enough water to reduce it to a thin paste. Too much water is in this method generally added in order to facilitate the mixture with the sand. The lime is, as it is termed, drowned, and the slaking is checked.**

The second method of French writers consists in plunging quick lime into water for a few seconds, and then throwing it into a heap and allowing it to fall to a powder. The operation is performed in baskets, the lime being broken to the size of an egg before immersion. M. de Lafaye proposed this method towards the end of the last century as a secret recovered from the Romans. There are various difficulties in this mode of slaking lime, **the chief being that the workman cannot be made to hold the lime in the water the requisite time.**

A modification of this process is much used in this country**. Enough water is thrown on the lime to slake it to a powder, and then sand is heaped over it to cover it all up and retain the warmth and moisture. The quantity of water necessary to bring the ingredients to a paste is added subsequently.**

Writers are not at all agreed as to the best method of effecting the operation of slaking, or on the absolute resistances obtainable according as the one or the other method is employed.

In his first memoir Vicat writes, " Such are the three modes of slaking lime; the first," **(the ordinary method) " is generally used;** the second," (by immersion), " has scarcely been employed except by way of trial on several works ; the third," (or spontaneous method), " is proscribed and represented in all treatises on construction as depriving the lime of all energy, to such a degree that those portions which the air has thrown quite abroad to a powder, are regarded as lost. We shall see hereafter, as regards spontaneous slaking, how much one should mistrust general assertions arising from inaccurate observations, and accredited by authors who, believing everything, repeat without examination the errors of others." In his subsequent work on limes and cements he says**, that the hardness acquired by mortars varies with the mode of slaking made use of,** and that the three common processes bear the following relation of superiority to one another.

With the Rich Limes. 1st. Ordinary Extinction. 2nd. Spontaneous. 3rd. By Immersion.

With the Hydraulic Limes. 1st. Ordinary Extinction. 2nd. By Immersion. 3rd. Spontaneous.

Treussart remarks in allusion to Vicat's observations concerning air slaking, given in his earlier work — " The results I have obtained have been far from confirming what Vicat says."

Treussart found the method of air slaking to be the worst both for fat and hydraulic limes, **and he preferred sprinkling the lime as it came from the kiln, much in the method adopted for hydraulic limes in this country, to either of the other plans.**

Colonel Raucourt de Charleville says, that the methods by immersion and by air slaking retard the set of hydraulic and eminently hydraulic limes, but suit the feebly hydraulic and pure limes better than the ordinary method .. and he gives many minute directions to be observed under different circumstances.

General Pasley says, — " Not having myself tried the strength of what M. Vicat calls fat, hydraulic, and eminently hydraulic limes, after slaking them in various modes, I cannot say more upon his nice distinctions in respect to the slaking of limes, than to express my doubts as to the accuracy of his opinions on this head, which do not carry conviction to my mind, except so far as his objections to excess of water extend, for **both in cement and in lime I have found by experiment, that what M. Vicat aptly terms drowning is prejudical to them."**

In this last opinion all writers are in accord, and since the first method is allowed to lead to this abuse, and it does not secure the perfect slaking of over burned particles of hydraulic lime, it should be proscribed for making mortar for heavy masonry.

The third method would be extremely costly in a large way, — the majority of writers think badly of it, — and chemically, there are reasons against its employment, **though at Lewes excellent outside stucco work is executed with lime so slaked.**

The second method, as modified in our own general practice, has in its favour the authority of Treussart, who was an eminent practical experimenter as well as builder. **It is certainly less open than the first to injurious treatment and is far better adapted than it, to obviate the effects arising from the sluggish slaking of the over burned particles of hydraulic limes.** In its application to the pure limes, it little matters whether large or small quantities are slaked at one time, **but with the hydraulic limes only so much should be slaked at once as can be worked off within the next eight or ten days.** Flare burned and feebly hydraulic lime should be left covered for a period varying from twelve to twenty-four hours, as convenience may dictate, but it will be **safer to leave the hydraulic and eminently hydraulic limes for 24 or 48 hours before making them into mortar.** The quantity of water required to be thrown on the lime will vary with the density and purity of the lime and its freshness; but it may be assumed generally that the quantity necessary will lie between ± and £ the bulk of the lime. With pure and fresh burned lime, more water is evaporated by the heat produced, than with a staler or a hydraulic lime.

7. — On Mixing the Ingredients of Mortars.

The sand and slaked lime have now to be mixed. This can be done either by hand or by machine. The great object to be accomplished is the perfect admixture of the sand and the lime; but according to some writers continued working and beating is essential to the making of good mortar independently of the thorough intermingling of its components. **M. Felibien observes, " that the ancient masons were so very scrupulous in this process that the Greeks kept ten men constantly employed for a long space of time to each basin**…; this rendered the mortar of such prodigious hardness, that Vitruvius tells us, the pieces of plaster falling off from old walls served to make tables. The same Felibien adds, it was a maxim among old masons to their labourers, that they should dilute it with the sweat of their brow, i.e., labour at it a long time, instead of drowning it with water to have done the sooner.

M. Rondelet states that he had assured himself by many trials, that **the more a mortar is beaten the harder it eventually becomes and the quicker it sets** — but he seems to attribute this to the more intimate union and admixture of lime and sand which is thus brought about, than to any chemical change. M. Vicat asserts that in whatever way the lime has been slaked, it should be brought to the condition of a homogeneous paste before the sand or other ingredients are mixed with it. Colonel Raucourt de Charleville recommends that when sands of different degrees of coarseness are to be used, the lime should first be mixed with the finest sand; that then a sand of coarser grain should be added, and so on. This mode of operating, he states, diminishes the labour, and gives the best and most homogeneous mortar. **He considers that to grind, or pound (" broyer ") the mortar is of the greatest value in the case of the hydraulic limes**; <u>that the</u>

inert portions of such limes have frequently the strongest setting properties, and that where grinding is not employed, these sluggish parts must be raked out and rejected. He states, however, that sand must not be added before grinding. That " **it is admissible to grind the limes and the puzzuolanas (" terres ") apart or together;** that a small amount of force can break these down, and produce important results, but as to the sands, what necessity can there be to reduce them to (" sablons ") powders? If we must have these in our mixtures, it would be better to take them in this natural condition and add them to the mortar, than produce them at a heavy expense."

Treussart says, " Experiments which follow will show that it is an error to insist that mortar should be mixed with the " sweat of the labourer," **it is enough if the sand be well mixed with the lime."** Again, he says, a great deal of trituration is useless either with hydraulic or common limes. **It is enough if the mortar be homogeneous,** which is the case when a heap of about 35 c. f. has been passed under the rab five or six times by four men. **Mortar made of ordinary consistence and even rather thin, is easier to mix thoroughly, and gives better results than when it has been mixed in a stiff state**."

Peter Nicholson complains of the hasty manner in which in his day the London workmen compounded mortar, and attributed to beating something further than the advantage derived from a more perfect mechanical mixture; he states it to be of the utmost consequence to its durability .

All are agreed then as to the necessity of an intimate mixture of the ingredients of the mortar, the only doubt being whether there is any further advantage attending it.

Neglecting the advantage, aimed at by Smeaton, of introducing more sand without depriving the mortar of its plasticity, it seems probable that beating does approximate the particles of lime pastes and particularly of the bulky pastes of rich limes, and **thereby impart greater density to their mortars and greater resistance, consequently, after induration.** There is room for doubting, however, whether the increase in the hardness so produced would of itself, and without reference to the more perfect intermingling of the particles of lime and sand which beating must occasion, compensate for the labour of the process, **unless done by machinery**.
Colonel Raucourt de Charleville has given a good reason for grinding or pounding being beneficial with hydraulic limes, and especially with puzzuolanas and other earths of a like kind. The remarks made above **on the wretched mixing of the mortar used at Eastbourne, where particles of lime larger than peas, and in great abundance, escaped slaking before the mortar was introduced into the work, or the inspection of any hard made mortar, after setting, will show how little the sweat of the labourer has done towards moistening it, and how important it is not to trust to his care and diligence, or even to his powers of making a good mixture, whatever his will.**

Davy indeed prefers the ordinary or larrying method of making mortar, because the mixture of lime and sand can thereby be made more perfectly, **whereas by the method of sprinkling, recommended in this paper, there are, he states, always small particles of the lime that cannot be properly mixed, however much it may be chafed up**.

We may then assume that **wherever the work is of sufficient extent to justify the first outlay on machinery, hand made mortar should not be allowed. The cheapest good method of mixing is probably that, now commonly adopted on large works, of grinding the ingredients together under an edge stone.** This is recommended, **not with the view of reducing the sand to a powder, but of breaking down all unslaked particles, and of perfectly incorporating and condensing the ingredients.** If the edge stone system is too expensive to adopt, **a pug mill** forms the best substitute for it. The safest plan with strong hydraulic limes is undoubtedly to grind the lime to a fine powder before mixing it with the sand.

Puzzuolana, and other like substances, absolutely require to be ground very fine as well as to be intimately mixed with the lime in order to develop their properties, as has been already remarked.

When the lime is first ground to a powder, and is then partly mixed with the sand <u>before any water is added</u>, as is done with cements, it is probable that much better hand mixtures could be made, but there is danger in permitting lime to be ground before it is brought on to the ground, for reasons hereafter to be explained, and **it is essential that it should be finely ground, for the over-burned particles which generally escape grinding are precisely those which most require it.**

it. 8. — On Estimating the Ingredients of Mortar.

We have now to consider the best method of estimating the components of mortar. With the sand there is no difficulty. It can most conveniently and accurately, as far as mortar making is concerned, be measured by volume, and though this varies according to the degree of moisture in it, **such variation is unimportant in practice.**

With the lime, however, there is much uncertainty unless the weight, the entireness of the calcination, and the freshness of the lime, be considered as well as volume. The size of the lumps, if the lime is delivered from the kiln, also influences the question. Taking lumps of the extreme size produced by flare burning, and comparing these with an equal volume of the same lime from a tunnel kiln, Pasley estimated that the latter would give the greater weight by 10 per cent. Again if the measurement, with the same description of lime, was sufficiently certain to give always the same weight per given volume, **there is an immense difference in the absolute quantity of lime in the same bulk of different sorts of lime.** A bushel of grey chalk lime weighs only 50 lbs.; a bushel of Plymouth pure lime about 70 lbs.; and a bushel of Keynsham lias lime, 80lbs. It manifestly, therefore, **would be an inaccurate mode of proceeding to estimate the quicklime by volume alone, without reference to weight. If the lime is delivered ground,** the time which may have elapsed since the lime left the kiln, the degree of exposure to which it has been subjected, the degree of compression given to it, and the season of the year, will greatly affect the amount of lime in a given volume.

The best method would appear to be to determine the weight of a given volume, and then, with reference to this weight, to calculate the requisite volume in lump to supply the required actual or absolute amount of lime for a certain bulk of sand. The proportions for the two in volume being thus determined on, measures of wood may be made to allow of the two ingredients being added in the requisite quantities without the necessity of fractional estimations….

It may appear to some, that the value of modes of procedure, sufficiently obvious, has been insisted on unnecessarily, but all those who have had practical experience in works will be aware, that **though their importance is recognised in words, it is not in practice. The workman compounds his mortar pretty much as he chooses, or as his own immediate employer may direct, if by so doing he does not increase his own labour**; and as Sir Charles Pasley states, **"actual measurement is not employed at all, the proportions of the ingredients being left to the tact or sagacity of the labourers who make the mortar**, or if measure be used the rudest sort only is employed, that is, shovelsful or barrowsful." He considered that greater precision both in specifying and compounding mortar was much to be desired.

…9. — On Proportioning the Ingredients of Mortar.

It has been shewn, that so far as can be judged from the contradictory opinions of men eminent as builders and writers on constructions, and from the few experiments made on the point, **it matters little whether the sand employed for mortar is course or fine, or obtained from pits, or the beds of rivers, or from the sea; but that it ought to be free from all dirt and clay; and that of two sands equal in other respects, the more angular will make the stronger work.** It appears, too, that **the only accurate mode of estimating the lime to be mixed with a given quantity of sand is by weight — or at least with reference to weight, though the actual measurement may be effected by volume.**

It was necessary to decide on these points before considering the proportion of sand, which, for economy's sake, could be added to mortar without depriving it of resistance to a degree not compensated for by the saving to be effected….

Davy admits that the French are considerably in advance of us in researches on this subject; but he says "the reputation of the English builders for practical experience in the manipulation of mortars is, on the other hand, well known and appreciated by all those whose attention has been directed to these important investigations." He considers that the proportions given from his work …exhibit a tolerable agreement with each other, and that they are grounded upon careful observation and great practical experience. Since, however, with one and the same lime the proportions vary from one and a-half sand to three sand for one of lime; and it was according to his own statement found that it required five and a-half parts sand to one of lime, to make good " larried mortar," we may reasonably hesitate to yield at once to the conviction that the specifications of our English architects and engineers are based upon the close observation for which he gives them credit, and it may, perhaps, be thought somewhat hard on those who contracted for University Hall, that they were not informed by its eminent architect whether they might adopt the theoretic proper proportions, ranging from five to seven of sand to one part of lime from the kiln, or whether they would be certainly confined to a range of one and a-half to three parts sand, and within these limits have to conform to the view his clerk of the works might take of the matter.

In deciding on the proportion of sand which may be ventured on with different limes we should **consider the effect which will be produced on the strength of the brickwork by variations in the resistance of the cementing material.** So long as the joints of masonry and brickwork are weaker than the stones or bricks which form the bulk of a revetment, the strength of the wall (using that expression in a general sense) will increase proportionally with the strength of the cement employed, until they are nearly equal in resistance, when any further increase in that of the binding substance will be comparatively of smaller value. We say nearly equal, because when a bonded wall, built in mortar much weaker than the brick, is broken, the fracture is constrained to follow a longer path than when the work is put together without breaking joint. The aim of the engineer should therefore be to approximate by the cheapest mode to such an equality of resistance between the components of his structure (between the material in which the blocks of stone or brick are bedded and the blocks themselves), as will produce a straight fracture when subject to a transverse strain, and when that point is reached to improve them conjointly. It must be borne in mind, however, that as the proportion of sand is reduced from four to three, from three to two, and from two to one, the expense of the mortar is generally increased in a largely augmenting ratio.

(A fat lime mortar, made) by adding 3 parts sand to the lime instead of 1 (will) be reduced some 38 per cent. If the lime were of the Dorking or Halling quality, …the saving effected by using 2 parts of sand instead of 1 would be upwards of 30 per cent, the use of 2 parts can hardly be objected to, and it will be seen that this is the quantity specified in the London and Woolwich War Department schedules. The same remark would apply to the best Sussex lime of Lewes, in a less degree, however, because the mortar of that lime would approach, with 1 of sand, within one-half of the resistance of the bricks, and an extra dose of sand might reduce it to nearly one- third….The Lias lime, as it contains within a given volume one-half more lime than grey chalk lime, and is a stronger lime than that of Lewes, might be used with 2 parts without too great a loss of strength.

To be precise **we may conclude, that with hydraulic limes such as the Lias (weighing 501bs. the cubic foot), 2 cubic feet of sand may be added to 1 cubic foot of lime; that with feebly hydraulic limes, such as the Dorking and Halling grey chalk limes, 2 ½ cubic feet of sand may be added to every 50lbs. of lime ; and in the case of pure limes, if we are compelled to use such miserable stuff, we shall not be losing much in resistance if we increase to 3 cubic feet of sand for every 50 lbs. of the lime.**

With respect to the cements, the Roman cement… the proportion should be either 1 or 1 ½ parts sand to 1 of cement powder. Scott's cement will equal the strength of the weaker bricks with 4 parts sand; and the best Portland cement would probably equal it with 5 or 6 parts, but only the best. So long therefore as bricks having no more resistance than ordinary London bricks are used in building, Scott's cement may be used with 4 parts; Portland — of the quality obtainable from Messrs. Lee, or Boorman, or White — with 5. If the bricks were made stronger or a compact stone used, these quantities of sand should be decreased for the cement to 2 or 3 parts. It is not recommended, however, that a less quantity than 2 parts shall be used, because with 2 parts sand the loss of strength is small, and probably what is lost in this way is compensated by the greater certainty of the joints being good.

The proportions here recommended apply only to works above the surface of the ground or free from the action of a body of water. For hydraulic purposes and foundations, 1 part sand to 1 part lime is as much as should be admitted; but with cements the proportion may be increased to 2 parts, unless actually in contact with water, when 1 part should be the limit allowed. As compared with the practice of our leading architects and engineers in drawing out their specifications, the proportions here recommended are not such as to call forth objections, but doubtless the quantity of sand proposed is very small as compared with that which would result from using only a sufficient paste of lime to fill its voids, or as compared with the excessive quantities which it has been customary, since the commencement of our railway constructions, to introduce into mortar. This much, however, must be allowed, that if it is proper to specify 2 sand to 1 lime it is also proper to enforce that these proportions shall be adhered to.

10. On the Proper Employment of Mortars. We must now proceed to the consideration of the manner in which mortar should be employed. The first point, to which attention must be directed in its use, is **the necessity of thoroughly wetting the materials it is intended to bind, particularly if they are of a dry absorbent character.** The second point, that **the mortar shall be as stiff as it can be used without inconvenience, and without danger of the joints remaining unfilled when the bricks and stones are forced home.** The third, **to**

prevent rapid desiccation which, with hydraulic limes, produces very injurious results. It is sometimes thought that the precaution of wetting bricks is unnecessary with lime mortars, and excepting in very hot weather, when the bricklayer finds their warmth and dryness inconvenient, it is rarely done. Cements, on the other hand, are supposed to suffer in their adhesion if the bricks are not wetted, and consequently it is usual to specify that they shall be so treated. The following Table, however, will make it clear that if the hydraulic lime mortars require to be kept moist to secure their induration, as all writers assert, it is nearly if not quite as necessary to make the proviso, that the bricks shall be wetted when used with lime mortars, as when used with cement.

Partington in his " Complete Builders' Guide " says that " few workmen are sufficiently aware of the advantage of wetting bricks before they are used, but experience has shown that works in which this practice has been attended to, have been much stronger than others in which it has been omitted." Amongst the circumstances which contribute to the speedy ruin of modern buildings he places the use of mortar " with dry bricks, and not unfrequently with warm ones." Rondelet, in his " Treatise on the Art of Building," says, " that in order to make the mortar unite better with the stones, it would be of advantage that the workmen should have near them a great bucket or trough of water, in which they should soak the stones before laying them, **and a basket with open wicker-work for the spalls, which should be soaked in the same manner before mixing them with mortar.** This mode of proceeding, which I have seen practised in many parts of Italy, is excellent for works which are to contain water, &c." Vicat writes, " the whole secret of good manipulation and right employ is condensed in the following precepts ... " stiff mortar and materials soaked." Our bricklayers, on the contrary, seem to have taken for their motto, " dry bricks and drowned mortar." In an appendix he adds — " It is true it is sufficient to water the compact stones, such as granite, quartz, mill stone grit, limestone, marble, &c., at the moment of using them; but a mere aspersion will not answer in regard to spongy and absorbent surfaces, such as bricks, the soft or arenaceous limestones, sandstones, &c.; when we have such materials it is necessary to moisten them without ceasing, and to keep them in a permanent state of imbibition."

Or to come to later authorities, Drysdale Dempsey in his " Builder's Guide," published in 1851, says — "One other rule has to be observed, and we reserve it for this last and separate and emphatic statement, to show our estimate of its importance, in order to produce good brickwork, which is this ... — that the mortar should be as thick as it may be, or nearly approaching the solid form, as is consistent with the degree of plasticity essential for its proper distribution and penetration into the joints, while the bricks should be thoroughly wetted on the surface. By these means the adhesion between them is rendered the more perfect, and the subsequent amount of shrinking and settlement is reduced to a minimum."

There is, however, another and equally strong reason for thoroughly wetting bricks in buildings which likewise affects lime as much as cement mortars. New bricks are always covered with a coating of dust and fine sand; and unless this coating is washed off, it intervenes between the bricks and the mortar, and frequently entirely destroys the adhesion. **Strong brickwork cannot, therefore, be executed either in lime or cement mortar, unless the bricks are not only damp, but have actually been washed.**

…A specification, therefore, should provide for wetting the bricks whether lime or cement mortar is to be used; yet there is a difference between them in respect of water, which should be well understood by every builder. It consists in this ...- — the " limes," when reduced to powder, as already stated, and made into a stiff paste with water, slake and fall abroad more or less perfectly, generally becoming a fine bulky powder, which requires a fresh addition of water to make it into mortar; and the cements, when similarly treated, consolidate with the water first added, and must be used before the slaking takes place. In the one case the slaking, as a general rule, takes place immediately, or shortly after the water is added, and the setting occurs subsequently, perhaps, many months after the mortar is used; in the other, the slaking and setting are simultaneous, and take place after comparatively short intervals. **With the limes it will be seen there is a supply of water in the mortar (all, in fact, necessary to bring the slaked dry lime powder and sand to a paste) over and above that which has chemically combined with them in the act of slaking; with the cements, a portion of the water used in making them into mortar is required to satisfy their chemical wants.** The first description of mortar when a drain is brought upon it by its being placed in contact with a dry absorbent surface, loses water, which has to perform a secondary part in the induration; **the cement mortar, under such circumstances, loses water absolutely essential to its consolidation, and without which it perishes.** In neither case will there be proper adhesion ; and in neither case, if the lime is a strong one, will the induration of the mortar itself become perfect in the absence of moisture over and above what will be required to unite chemically with it**; but comparatively, the cement will suffer most since there is neither a reservoir of what, for the time at least, is spare water, to draw upon, nor, with its somewhat gritty particles, that strong retention of water which is found with the unctuous and plastic lime mortar.** The result of this is that a bad lime mortar joint may show fair outwardly, when the bad cement joint will grow crumbly, and betray the mischief done; or should any of the work executed in lime mortar be pulled down in the progress of a building, the want of the wetting is not perceived, for the mortar takes a long time to set, and no adhesion is expected, after short periods; but with the cement joint a failure is evident at once, because a few hours or a few days should impart to it a respectable resistance. It would seem, indeed, that little resistance can be expected from our lime mortars in this country, however long they may have to set, or provision would not so often be made for cleaning old bricks…

In illustration of the other cause, rendering wetting necessary, may be mentioned also the brick masonry of an old wall now being destroyed in Chatham Dockyard; it formed the North boundary of the original enclosure, and was probably built in 1622. Though the mortar is good and of an expensive kind, being mixed with a large proportion of excellent puzzuolana, instances of non- adhesion from the effect of the dust on the brick are easier to find than instances of good adhesion, and the same defect is noticeable in most walls.

The next point to be considered is the degree of consistency which mortars should have when used. Treussart preferred that they should be rather thin than stiff, but experiment indicates that, so far as the resistance of a good joint is concerned, the stiffer the mortar the stronger will be the joint.

The danger to be apprehended in using very stiff mortar is that the mason will be less likely to fill all the joints with it. Mr. Page, consequently, in his specification for the New Westminster Bridge, provides that " **the bricks shall be soaked in water, used clean, shall be closely bedded, and the mortar used sufficiently thin in the interior of the work to enable the workmen to flush the joints full without grouting, which is not to be used without the special directions of the engineer."** Though, then, the stiffest mortars will give the best results if the joints are properly filled, yet to secure that there shall be no vacant spaces left, they must be sufficiently fluid to be worked with ease….

It may… be assumed that whenever grout can be dispensed with, and all interstices be filled with stiff mortar properly applied, it is better to employ the latter. A large quantity of water has the double disadvantage of causing cracks by the shrinkage of the mortar from its subsequent evaporation, and of leaving it very porous….

The table not only shews the extent to which mortars will suffer from a rapid desiccation, but that the injury is greater in proportion as the lime used is more hydraulic….The purely lime mortars suffer less because in the internal parts they merely dry under any circumstances, and a rapid desiccation only interferes with the crystallization of the carbonate of lime where the air reaches them. It will be seen then that in hot weather, and especially in hot climates, the prevention of too rapid a desiccation becomes a point of great importance, especially where hydraulic limes are employed. Colonel Raucourt de Charleville recommends the use of straw mats for the purpose, which are to be suspended over the newly built masonry, and watered night and morning.

(Summary)

1st. Cements should be used in preference to hydraulic limes, and hydraulic limes in preference to pure limes for dry masonry, as well as for hydraulic purposes; and in making a selection between them, first cost alone should not decide the question, where 1 or 1 ½ per cent. extra on the cost of the building will procure a great increase of strength. 2nd. That though there is not much

difference in the results to be obtained from sands from different localities, they should be freed from all clay and dirt. 3rd. That in mortar for dry situations, for every 2 cubic feet of sand, 50 lbs. (equivalent with stone lime generally, to 1 cubic foot) of hydraulic lime from the kiln shall be employed; but that with cements of certain character, this quantity may be considerably increased, without notable loss in the resistance of a construction in ordinary bricks. It may also be increased to 3 cubic feet with pure limes without much injury to the strength of the brickwork. 4th. That for damp foundations and hydraulic works the above proportions of sand should be reduced according as the exposure to the action of water is more severe. 5th. That strong hydraulic limes, after the water for slaking them has been added, should be left covered with sand for 24 hours, at least, to complete the process on the overburned parts.
6th. That strong hydraulic limes, if not ground to a fine powder before slaking, should be ground either alone or mixed with sand under an edge stone; and that if ground alone, they should be afterwards mixed into mortar in a pug mill, though like the cements, they might, when first brought to a fine state of division by grinding, be efficiently mixed by hand in small quantities.
7th. That the materials with which the mortar is used shall be well wetted, and that bricks having a coating of slightly cohering sand or dust upon them, should have this coating washed off before being laid. 8th. That the mortar shall not be more fluid than is requisite to fill the joints and crevices, and that the miserable expedient of grouting should never be resorted to. 9th. That the brickwork or masonry in hydraulic mortar or cement should not be allowed to dry quickly.

Mr. Burnell, in the preface to his work on Limes and Cements, says, " That which is to be desired above all things is to rouse the professions of engineers and architects from the apathy with which they treat such subjects as the one before us — the very alpha and omega of their business." His representations, however, have been as ineffectual as those of the distinguished men whom he follows. **Smeaton long since explained, " It is not to be wondered at that workmen generally prefer the more pure limes for building in the air, because being unmixed with any uncalcareous matter, they fall into the finest powder, and make the finest paste, which will of course receive the greatest quantity of sand (generally the cheaper material) into its composition, without losing its toughness beyond a certain degree, and requires the least labour to bring it to the desired consistence; hence mortar made of such lime is the least expensive; and in dry work the difference of hardness, compared with others, is less apparent."**

The workman, however, preserves his empire. Messrs. Ellis and Sons, of Barrow, sending some samples of their lime, at our request, remarked of one, that it did not command a ready sale, as **the builders did not like it; yet it was the best lime we have met with in this country.** A very excellent lime, **far superior to the grey lime ordinarily met with in the London market, can be prepared from certain beds of chalk in this neighbourhood; but these beds are rejected as useless, because, like the Barrow lime, the lime from it does not**

slake readily, and loses its plasticity with a smaller proportion of sand than that from the purer beds.

It is a difficult matter to alter the practice of those who have grown grey in exalting " practical experience," and in the comfortable persuasion that the bricklayer knows best how to make good mortar, and can be trusted to make it. " Old impressions," as Reaumur has well observed, " are with difficulty effaced. They are weakened, they appear unjust even to those who feel them when being attacked by arguments which are unanswerable; but the next instant the proofs are forgotten, and the perverse association resumes its empire." Notwithstanding, however, all the obstacles in the way of better practice, **I look confidently forward to the day in which we shall feel quite independent, as respects mortar making, of the workman's traditions.** We have, indeed, already taken a long step towards it. Though brought up in the notion that mortar making was a mystery which required a long practical apprenticeship to master, we Military Engineers now gladly call in the assistance of the chemist, and consider his opinion a very useful check on that of the practical builder; and our younger brethren, commencing with an accurate knowledge of the principles which should regulate mortar making and mortar using, will feel still more strongly the necessity of insisting on the observance of the rules to be deduced from these principles, if they desire that their works shall prove lasting monuments of their skill in construction.

PAPER XIV.

ON CONCRETE AS A SUBSTITUTE FOR BRICK AND STONE MASONRY IN WORKS OF FORTIFICATION. By CAPTAIN SCOTT, R.E.

" The most costly part of permanent fortifications is the masonry, which is, therefore, always kept at the lowest point consistent with a tolerable security. Scarps are frequently kept at a reduced height, and casemates and bombproofs omitted, in order to avoid as much as possible the expense of masonry." " The masonry of a fortress is also the most tedious part of its construction, and is for this reason, of necessity, omitted in all works where expedition is a sine qud turn." " If we inquire into the reason of this twofold objection to the use of masonry in situations where it would otherwise be most desirable, it seems to be, that while the earthwork can, by means of rails and trucks, be almost, as it were, done by machinery, the whole of the masonry must remain as completely hand labour (and skilled labour too) as in the erection of the smallest edifice. Is it then possible to give to the masonry of the scarps and casemates of a fortress such a character as shall take it out of the category of tedious and costly hand labour, and render it capable of being executed in gross by the aid of machinery and unskilled labour?"

An attempt will be made in the following paper to shew that this is possible to a large extent by substituting for the brick and large stone masonry of our fortifications, a cheaper description of rubble work, such as we now term concrete. At the present moment there seems to be a strong feeling abroad in the country that soldiers might, with advantage to themselves and the state, be employed on works of construction, and a committee has recently enquired into the advisability of teaching them trades, in order to give them occupation. The substitution proposed would not only effect a great saving in point of material, but, from requiring little skilled labour, would provide our men with a description of work which they could execute without previous instruction. There is nothing new in the idea of using concrete for revetments, magazines, and bombproofs.

At the pass of Thermopylae some of the walls are constructed of small stones and mortar. At Tharsalia and Messene there are many instances of the use of a shell of masonry, filled in with pounded bricks or tiles, rough stones or flints, and lime, well incorporated. At Messene, indeed, the wall surrounding the town is wholly of this description of work. The method of building was termed " emplecton," and it is found that it was employed in most of the ruins of the ancient buildings of Rome, the stones used being small shapeless pieces not bigger than the fist, such as we should reject for our most ordinary constructions. Of such materials, however, as we learn from Rondelet and other writers, were built the Palace of the Emperors, the Golden House of Nero, the Temple of Peace, the Pantheon of Agrippa, the Temple of Augustus, the Colosseum, the Baths of Agrippa, of Titus, of Dioclesian, the aqueducts of the city, and the greater part of the theatres and amphitheatres; indeed, so generally was it used, " so favourite a mode of construction did it become from the astonishing solidity which it conferred, that there are few remaining Roman monuments in which, either in the foundations, in the shape of walls, of pavements, or of water tight linings to tanks, &c., which endure remarkably well to this day, it may not be found." Where parts are gone it is evident, says Rondelet, that violence has been used to destroy the walls, since those which have been deprived of their facings have remained in this condition for nearly 2,000 years.

The Romans brought their mode of building to England, and the Saxons and Normans followed the examples they found. Among Saxon buildings, Godwin names as being built of what may be termed concrete, portions of Richborough Castle; the walls of Aldborough Church, Yorkshire; the towers of Earls-Barton Church, that of St. Peter's Church at Barton-upon-Humber, Lincolnshire; and a building at Warnford, near Southampton; and they are still, the same author states — " of amazing solidity and appear to defy time." He says, " that they are composed some of round pebble stones united by mortar, and some of rubble stone and flints well grouted, and that the Normans often constructed buildings entirely of rubble stone or pebbles rendered into a mass by lime." * Sir Charles Pasley confirms this. " It must be allowed," he writes, " that not only the ancient Romans, and after them the Moors, but even the Norman Barons of England in their feudal castles used concrete, of which Kendal Castle is one of the most striking examples."

*Footnote: Godwin on Concrete. Transactions of Institute of British Architects, Vol. I., part 1. The concrete, according to Vitruvius, consisted of a cement of five parts pure sand and two parts lime, with which, when well incorporated, were mixed pieces of stone weighing each about l lb. Pliny says, to make good cisterns the cement should be composed of five of fine sand and gravel to two of lime, none of the stones exceeding 1 lb. in weight. To increase its solidity he recommends beating. These materials were sometimes rammed in an encasement, such as is used in Barbary and Spain for Phi work, and sometimes thrown at random between castings of brick and stone.— H. S.

Smeaton having observed a portion of the outer wall of Corfe Castle in a remarkably leaning position, like the tower of Pisa, was induced to examine it, and found the interior filling of the walls to be of rough rubble and fragments from the quarries cemented with a mortar composed of lime, " doubtless originally of good quality," and a considerable admixture of sharp sand and pebbles, which had evidently been poured in in a fluid state. From what he saw here he adopted a similar method of building the rubble backing of the first lock on the river Calder.

According to Sir William Reid, the walls of the fortress of Ciudad Rodrigo, in Spain, are of concrete, the marks of the boards, which retained the semifluid matter in their construction, being everywhere perfectly visible. Besides sand and gravel, round boulder stones were employed. These were from 4 to 6 inches in diameter, procured from the ground around the city, which is everywhere covered with them.

Treussart relates that the Italians at Alexandria make very good concrete blocks with the Casal lime, and employ them in angles; they are 4 feet 8 inches long, 2 feet 8 inches wide, and 2 feet 8 inches high; they are buried under ground for two or three years, and there attain great hardness….

A row of houses was also constructed…according to Mr. Ranger's patent process, the peculiarity of which consisted in using hot water. The walls are 50 feet high from the bottom of the cellars to the top; they are 20 inches thick at bottom, the greater part being of the patentee's artificial concrete blocks; but much is also made like the sea wall between two sets of boards. The arches of the cellars are all of concrete made of sea gravel. The lime used was from Lewes.

About this time Mr. Taylor, then architect of the Admiralty, proposed to the Lords Commissioners to build not only docks but wharf walls with Mr. Ranger's concrete. Their Lordships having approved of the trial being made, the experiment was carried out both at Chatham and Woolwich. The docks were faced with granite, but the concrete of the wharf walls was exposed to the action of every tide. The Woolwich wall was in part built with concrete thrown in in mass, as with the sea wall at Brighton, and in part with concrete formed into blocks, which were allowed to set and harden before being built into the wall. At Woolwich, both the blocks and the rough concrete were composed of lime and gravel in the proportion of 1 to 7, brought to the proper consistency with boiling water; but the blocks were supposed to be made of Aberthaw lime, while Dorking lime was to be used for the rest of the work. " During the hard frost in the winter following, evidences of failure began to shew themselves; and as soon as the thaw allowed a thorough inspection of the face of the wall to be made, it was found that hardly a single block had escaped without some damage; in many instances the whole face had peeled off to the depth of half-an-inch, and at one spot, where a drain discharged itself into the river from a height of about 6 or 8 feet, the back action of the water after its fall had worn away the lower courses to the depth of some inches; these were the evidences of the action of frost and water combined upon the best constructed wall at Woolwich. At Chatham they were of the same character, but the damage done to the wall was much greater….

In the following May (1835) the bombproof (in Woolwich Marshes) was fired at both with shell and shot; and a committee of Artillery and Engineer officers reported to the Master- General that, " considering the disadvantageous ground on which it was constructed, which had occasioned some degree of settlement, it sustained the effect of the vertical fire directed against it in a very satisfactory manner, and they entertain every hope that Mr. Ranger's concrete will be found available for magazines of small dimensions, casemates, and those parts of revetments in fortresses which are least exposed to the effect of shot; but with the limited scale on which this experiment has been carried on, the committee do not think, at present, they would be justified in recommending its application in the construction of large powder magazines." **The lime used in this experiment was from Dorking, and the concrete when fired at was still damp and friable, except on the surface.**

The river wall of the Chelsea water works, at Kingston, is constructed of concrete made of 1 part Dorking lime and 11 sand and washed shingle. The wall is 1,200 feet long and 25 feet high. *[which is to say, feebly hydraulic lime in lump, so that the proportion something like 1:6]*

" In concrete pise an engine house, 20 ft. X 12 ft. on plan, was built of the same cement concrete; the walls were 9 inches thick, and were carried up perpendicularly to a height of 6 feet from the ground, at which height a semi-circular arch, 6 inches at the haunches, diminishing to 6 inches at the crown (also of concrete) was thrown across, and this is now standing without outward thrust or settlement. Ordinary brickwork would not have stood this test, and would have cost more than double the price."

The writers who have until the past year most strongly advocated in published works the general employment of concrete, are Fleuret, Rondelet, Colonel Raucourt de Charleville, and Treussart. The writer who has most discredited its general employment was our own Sir Charles Pasley, whose opinions must carry great weight wherever his name is known; but I hope to shew that on this point he was mistaken….

In the opinion of Colonel Raucourt de Charleville, it is the want of good mortar which has most prevented the general employment of concrete in the north of Europe, and he considers that if the lime is of the proper sort there is scarcely any description of work which may not be economically and solidly executed with it. Treussart is of the same opinion; he considers that concrete may be cast in moulds for coins, copings, doors and window jambs, &c., and used even for piers of bridges over the ditches of fortresses, for the walls of sluices, for columns, obelisks, &c., constructing them on the spots they are to occupy. He thinks that it may be used to the greatest advantage for aqueduct bridges to pass canals over rivers, and to supersede arches of brick or stone; to widen a wharf wall by letting it project over the usual waterway, when that must not be encroached on, the overhanging portion of concrete forming, as it were, one immense stone with the remainder of the wall of which it makes a part. He recommends it also for forming air and watertight granaries for preserving corn in fortified places.

(Summarises Pasley’s objections to concrete and to Treussart’s advocacy of its utility)

1st. After reading M. Fleuret's instructions on making concrete, Treussart was led to make conduits and caps of arches of fat lime, for M. Fleuret gave no rule as to the quality of lime to be used, and these failed. He subsequently saw through the cause of his failure and Fleuret's success, and he concludes the first Section of his work thus ... " The goodness of the concrete depends on the quality of the hydraulic lime mortar. All the advantages possible have not yet been derived from this mode of construction, its advantages will be better appreciated when its use shall be more extended, and when the manner of perfecting hydraulic mortars shall be better understood."

He had seen the artificial stones made at Alexandria by the Italians for the angles of buildings, Finot's artificial arch at Strasburg, and the arch at Schelestadt; and in repairing, in 1816, one of the dams which sustained the navigable canal of Strasburg in its passage across the ditches of the fortifications, he tells us that he found the facings alone were of freestone, and that all the interior was of concrete of great hardness, which led him to the belief that hydraulic lime must have been used for it, and ultimately to ascertaining the qualities of the Obernai lime, and of many other hydraulic limes of the neighbourhood….

It cannot, then, fairly be said that General Treussart's opinions were almost entirely speculative; on the contrary, he had good precedents for each of his recommendations.

…Where Halling lime is used for brickwork the joint invariably perishes at or near the ground line, and those who are acquainted with mortar of Aberthaw lime know that in trying circumstances the frost attacks it also. And Sir William Denison remarks that, " had sufficient care been used in the selection of the lime, of which the latter (the walls in question) were composed, and that had Aberthaw lime been used throughout, the damage would not have been near so great."…

It will be seen from the preceding table that the quick setting cements are generally unfit for making concrete, the only exception being the Medina.…

But to bring cement, sand, and gravel into a sufficiently wet condition for use, it is not necessary to add to the mixture more than 20 gallons of water per cubic yard, the proportions being 1 cement to 6 ballast, and of this quantity between 7 or 8 gallons will enter into chemical combination with the cement, leaving 12 or 13 gallons, or little more than one-third of the water contained in the brickwork, to be got rid of. Concrete is generally made with far too much water, and its eventual hardness is thereby much reduced. The quantity used should be barely sufficient to make the mortar plastic, and the apparent deficiency made up by well beating the concrete when in place. A face should be given to a concrete wall, not by laying on a coat of plaster after the surface has become dry, but by introducing sufficient mortar, between the boards and the mass of the concrete thrown in in foot layers, to give the wall a fair face. This can readily be accomplished by thrusting down the blade of a shovel, on the inner side of the retaining boards, and pressing inwards to make room for the mortar to be introduced. A few up and down movements of the shovel will then give the work a sufficiently good face.…

The contract price for the concrete retaining wall at Brighton was 3s. 4d. per yard; the price of brickwork in mortar of the lime used would have been about 15s. per yard…..

I believe that the weight of evidence is so much in favour of the strength and cheapness of concrete, when compared with brickwork or large stone masonry, as to justify extensive trials of it in fortification works, and I think that the formation of a breach in a cellular revetment, such as I propose, would occupy a sufficient time to confute the notion that a revetment should be regarded only as a method of retaining the pressure of the earth behind it, and of keeping a work secure against surprise.

From The Architects Journal – Specification No 11 1908-09 quoted at length in Stafford Holmes Hot Limes in a Cold Climate. BLF News Vol 1 number 2. April 1993.

The sources consulted by Holmes in 1993 well illustrate the changes occurring in the industry at this time, with craft practice and preference being relegated by the growing preoccupation of engineers and architects with hard, fast-setting water cements, initially for underwater and underground works, but creeping upwards into above-ground fabric. As crafts ceased to design the mortars, the prejudice against fat limes (and fat limes plus pozzolans even for water works) accelerated under cover of notionally improved durability and 'reliability'. Holmes's inadvertent focus upon architects' and engineering specifications during the second half of the 19thC – as well as upon Vicat's writings upon the subject of mortars (albeit all of the quoted sections being primarily to do with civil engineering projects) unwittingly gave the impression that hot mixing was something reserved for natural hydraulic limes, and blue lias in particular, which had been much used in London for 'hot mixed' concrete after the arrival of the railways. His other focus, upon the use of hot mixed mortars, used hot for winter working, gave an impression of 'exceptionalism' to this method. The method of slaking more hydraulic limes – sand-slaking and leaving to cool, as well as to 'sour', allowing for late-slaking, also inadvertently created the impression that this was how hot mixes were generally prepared, though such a method would not facilitate hot use. The understandable confusions of this paper gave some impetus to the drift towards imported NHLs after 1993. This drift became a rush after the publication in Lime News and elsewhere in 1997 of John Ashurst's 'clarion call' for general use of both British and imported NHLs.

Brick Laying in Frost

The following is an extract from a report by M. Paul-Duc, a leading architect of Christiana, to HM Console-General there: ' In the use of unslaked lime lies the whole art to executing bricklayers' work in frosty weather. The mortar prepared with it is made in small quantities immediately before being used, and the proportions of such lime is increased…as the thermometer falls. Warmth being developed by the use of unslaked lime, it is only a question of utilizing so handily and quickly as to enable the mortar to bind with the bricks before it cools.' …

Workmanship Clauses for Special Works

Brickwork During Frost

<u>Mortar</u>

The water, sand and lime for the mortar are similarly to be kept undercover free from frost. The lime is to be ground unslaked lime, mixed with the sand in the proportion of 1 part of lime to 2 parts of sand. Where the temperature is under 26 degrees F (-3.3 C), the proportion shall be 1 part of lime to 1 part of sand. The mortar shall be mixed in a shed having a temperature of not less than 34 degrees F (-1 C) in small quantities as required and used immediately.

Brickwork.

The brickwork is to be executed as rapidly as possible consistent with good workmanship, and the course shall be immediately covered with sacking as the work proceeds.

Cessation of Work.

If the temperature shows the presence of more than 12 degrees of frost, ie a temperature less than 20 degrees F (-6 C), the work shall be immediately stopped…

Bricklayer-Mortar-Limes

Fat Limes. Must on no account be used for mortar

Stone Lime, though feebly hydraulic, will make a fair mortar, but it should not be generally used for work below ground. It may be used for tall chimneys or spires, as it 'gives' slightly and will allow a moderate rocking under a high wind without fracture. Proportions: 1 lime to 2 or 3 of sand.

Hydraulic Lime (lias lime) should be used in first-class work. Its use is a necessity for foundations, etc, where cement mortar is not employed. Proportions for work below ground, 1 of lime to 1 of sand; for work above ground, 1 of lime to 2 of sand.

Lime Mortar.

Lime Slaking. The lime should be thoroughly slaked at the scene of the operations by the addition of sufficient water. During the process it shall be effectually covered over with sand to keep in the heat and moisture. All lime must be used within 10 days of slaking.

Mortar Mill. The contractor shall at his own expense provide a proper mortar mill, worked by steam or other approved power, for the due incorporation of the materials…

Screening Materials. If a mortar mill is not provided for the making of the mortar, the contractor will be required to thoroughly screen the materials before mixing to get rid of any dangerous and refractory lumps.
Fat Lime Mortar. Fat lime mortar must not under any circumstances be used…

Stone Lime Mortar. The stone lime mortar for brickwork above ground level shall be composed of 1 part of grey chalk lime, and 2 (3) parts of sand, mixed with a sufficiency of water and thoroughly incorporated together (in a mortar mill). (The lime shall be mixed together in their dry state before being put into the mortar mill).

Lias Lime Mortar. The lias lime mortar shall be composed of 1 part of blue lias lime and 1 part of sand, mixed with a sufficiency of water and thoroughly incorporated together (in a mortar mill). The lias lime mortar for brickwork above ground level shall be made in the same manner, but in the proportions of 1 part of lime to 2 parts of the sand.

Extracts from Architects' Specifications for Completed Buildings.

Cloth Worker's Hall, Mincing Lane. 1856-9. Architect Samuel Angel.

Plasterers Work. All the lime to be the best well burnt chalk lime from Dorking….

The concrete to be composed of clean Thames ballast and best fresh ground stone lime, and mixed in the proportion of 1 of lime to 6 of ballast, the whole to be thrown in to form a bottom from a staging 10 feet clear height above the top surface of the concrete, which is to be 4 feet in thickness over the entire area of site.

Three Dwelling Houses, Cavendish Square. 1856. Thomas Donaldson.

Cement Front – cover the street front…with blue lias cement, with several strings, cornices and moulded architraves etc. Continue the blue lias cement over the blocking course and down the parapet to the gutter.

Iron Bedstead Manufactory, Birmingham. Yeovill Thomason 1854.

The mortar to be fresh burnt Dudley or blue lias lime and clean sharp sand in equal proportions of lime and sand and tempered together….

The concrete to be a mixture of one fifth ground blue lias lime, one fifth clean sharp sand, and three fifths small stones not exceeding 1 ½ " in diameter; the whole to be mixed up and thrown from a stage at least 10 feet in height.

Warehouse at Newcastle Upon Tyne. 1849. John Dobson.

The mortar to be composed of the best Fulwell stone lime, or other stone lime of equal strength and quality…slaked, screened and mixed with a proper proportion of clean, sharp river sand, from the mouth of the River Team, or elsewhere of an equally approved quality. And the mortar for the rubble work and interior walls and foundations to be composed of a proper admixture of lime, sharp sand and smelt furnace scars or iron scales. And all the mortar for every description of the works to be well ground and compounded in an approved mortar mill.

New Bridge at Westminster. Thomas Page, engineer. *(Opened 1862)*

Of Lime – the lime used on the works shall be the best blue lias lime…The lime shall be thoroughly burned, but quite free from core, and shall be used hot from the kiln, where practicable. In other cases, where it may remain a short time on the works, it shall be thoroughly protected from the air and moisture. If any lime core be found after the slaking of the lime, it will subject the contractor to the rejection of the whole of such lime which he may have provided for the works.

The mortar shall be composed of blue lias lime in one part, with three parts of clean, sharp river sand, free of all vegetable substance and screened, the lime being properly slaked, and thoroughly mixed up with the sand, with no more water than is requisite to bring it to a proper consistency; it shall be mixed as it is required for the work, and on no account should any be used which has become partially set, nor is any water to be added to the mortar after it is once mixed *(these are typical proscriptions when hydraulic lime is used).*

The mortar shall not be mixed in a pug mill, but shall in all cases be beaten up to the proper consistency, as practice in former times *(pug mills were disapproved of by some for crushing the aggregate too finely).*

The concrete for the piers below high water mark shall be composed of four parts clean gravel dredged from the river, no smaller in size than shall be approved by the Engineer, and one part of well burnt blue lias lime, properly slaked under sand, and well mixed with the gravel, the water being supplied from a rose-headed pipe or water spout, and no more water used than is sufficient to render the concrete solid. All other concrete for the filling in of the spandrels of arches on the Surrey abutment shall be composed of five parts of clean river gravel and one of lime. The concrete shall be shot, as soon as mixed, into its place in all cases from a height not less than 12 feet, and shall be rammed with broad heavy pinners where the engineers may direct, and in all cases brought to a true level surface…at the completion of any part of the work. No concrete shall be mixed or thrown into place during frosty or very wet weather…In cases where the Engineer may direct, heavy stone or iron slag to be used with the concrete…

Austin J G 1862. Published in New York, summarizing Eastern US urban practice mid 19th C.

ON THE PREPARATION OF COMMON MORTAR

The Lime when properly prepared or burnt in the kiln should be speedily withdrawn, and packed for transportation to its intended destination, in sound casks or air-tight vessels well closed down, and should be kept entirely free from all moisture; and when received by the builder should be deposited until required for use (which should be as early as possible) in a shed or other dry building, or if left out of doors should be closely covered down with a tarpaulin, or boards, and each cask should be unheaded and opened only as required.

Lime in this state is termed *caustic* or *quick lime,* and in order to make it fit to be incorporated with the other ingredients it must be reduced to a 'hydrate', a change which is effected by the application of water, which process is termed 'slaking' and after which operation the lime is called *slaked lime*.

Of this operation, **there are three methods in use.**

The 1st **and most usual** is by pouring or throwing the necessary quantity of water **over the lime after it is spread out into a shallow heap, surrounded by the whole or a portion of the sand with which it is to be incorporated.**

The 2ndly **By immersion,** or plunging the lime when deposited in a basket or other suitable receptacle **for a few moments into water** until the surface lime begins to effervesce or boil and then turned out into heaps to afford time and opportunity for the slaking to be completed. *[this is not lime putty, but dry hydrate. Other sources will take to a putty of 'dough-like' consistency and mix this with sand, probably whilst still hot/warm].*

3dly , by **mere exposure to the atmosphere,** the lumps of lime having been previously broken up to about the size of a pigeon's egg, or somewhat smaller, so as to secure a more speedy and effectual calcination of the whole, but this operation must not be performed in wet weather, nor in too damp an atmosphere; it must be carefully watched, and **so soon as the slaking is complete,** the quicklime **must be immediately used or deposited in close casks till required.** This method is **seldom adopted except for plasterers,** who consider lime made in this way preferable for their work, as it is said to make the lime stronger. This mode suits *fat* limes (such as slake freely) better than poor limes. Lime slaked by the second process will keep well for months in a dry, sheltered spot.

But **in every case** where water is employed for slaking lime or mixing the mortar subsequently, **care must be taken not to 'drown' the lime…**and also not to go to the opposite extreme, but to put the *quantum suff*. at once, which is usually computed at about one and a quarter of the weight of the lime…, for if the water be applied tardily or sparingly, the lime will be benumbed, or imperfectly calcined, and gritty. (exact water requirement will vary according to the quicklime)…*[modern methods of making putty lime, by implication, 'drown' the lime].*

Limes become *effete* (difficult to slake) after much exposure to the air, so that speedy calcination is important to their subsequent use or value. …

The slaked lime must be passed through a sieve or screen, the meshes or orifices of which should be small…so as to give passage only to the *powdery* particles of the lime or that which is perfectly calcined, leaving all the core or indissoluble portions of lime behind, which must be thrown out; and if, after a further addition of water and lime, it should prove obdurate, and will not slake, it must be abandoned altogether.

The operation of screening the lime is sometimes performed before its admixture with the sand, and at other times with it; of these two methods, we prefer the latter, for the following reasons, viz because it effects a saving of time, and because it insures a better and more equable amalgamation of the ingredients, and because the lime is not thereby so much exposed to injury from the atmosphere.

[In general, it seems clear, the limes so slaked will be used almost immediately, rather than stored, although this is possible with the exclusion of air].

Upon the perfect completion of the above-described operation, the combined mass should be spread out in the form of a hollow cone, and the **final complement** of the (water) should be speedily but uniformly added; the whole mass being at the same time effectually stirred up and about, to promote the proper combination thereof; or what is better, the mass should, so soon as it is brought to a proper consistency, be passed through a **'pug mill'**, which is a machine well known, and employed in the preparation of clay for the manufacture of bricks; but where this desideratum cannot be obtained, **it should be well-tempered with wooden beaters, and also well turned over and incorporated together**, as it is very important for the solidity of the work for which it is to be used, that the mortar be well mixed and quite uniform throughout.

Mortar should be prepared to a medium consistency, not too 'tough', that is, not too *dry*, nor yet too 'short', that is not too *wet* – for in the former case the beds and joints will be rigid and difficult to regulate, from the absence of sufficient moisture, and what there is will be speedily absorbed by the brick or stone, and the mortar will indurate too speedily; and in the latter case, the joints will *settle* too much, and the quality of the mortar be deteriorated.

The *induration* of mortar is dependent upon its due absorption of carbonic acid gas from the atmosphere, and it is necessary in order to effect the re-union of carbonic acid with the lime that the latter should have received, previously, **not less than one-third of its weight of water…**

Rich limes emit a strong hissing noise and great heat during the process of slaking, but the poor or meager limes, **which nevertheless are the most valuable,** undergo the operation with less apparent excitement; and in proportion to the extraneous or foreign matter which they contain, and with some varieties of hydraulic limes, no visible effect will be observable in them until after the lapse of several hours.

The *purest limes* require the largest proportion of sand, and require the most water in slaking, **and harden in less time than the common limes** *[Austin seems the first to make this important, counter-intuitive point. Pure limes the most likely to be hot mixed straight to a mortar, though he doesn't say this].*

…In the before-mentioned experiments, Dr Higgins determined that the best proportion of lime and sand is **one measure of (quicklime) to six or seven of (sand)** ***[delivering between 2 and 2.5 slaked lime to 6 or seven, roughly 1:3]*** **but in England the tradesmen usually combine…150 pecks or 37 ½ struck bushels of chalk lime with two loads (60 bushels) of sand; and with the like quantity of stone lime [feebly hydraulic], they usually put 2 ½ loads of sand, or 75 bushels** ***[the chalk lime volumes seem the wrong way around, though the less expansive 'stone lime' at 1:2 is more likely. These proportions are taken from Higgins – they are rarely seen in historic samples tested – the first would deliver a mortar around 75 lime to 60 sand; 6 ¼ : 5, very lime rich and which would shrink uncontrollably],*** which are very erroneous, as the said experiments clearly show, and as our own experience has often testifies.

The above-mentioned quantities are each sufficient to do a rod of **brickwork,** which is equal to 272 ¼ feet of one and a half brick thick or 408 ½ feet of one brick thick *[the mixing methods above mainly for brick work, therefore].*

Various substances are sometimes added to mortar to increase the tenacity, and they impart thereto the principles of hydraulic cements to a greater or lesser degree.
These chiefly consist of **burnt clay, ashes, scoriae, iron scales and filings, pulverized broken potter's ware, bricks, tiles, etc,** all of which are very useful for mixing with lime or mortar to increase their hardness, but these must be very pure and dry, and reduced to a fine powder before being mixed with the lime.

Common mortar of ashes is prepared by mixing **two parts of fresh slaked lime with three parts of wood ashes together, <u>and when cold,</u>** to be well beaten two or three times previous to using it, will be found to improve by keeping…this mixture is by some persons thought to be superior to terras mortar, but not nearly equal to it when applied quite under water.

VARIOUS RECIPES

Beavans mortar, or building cement is composed of **marble, flint, chalk, lime and water,** and when dry, is capable of a high polish. Its proportions are **equal parts of marble, flint and chalk; pulverized,** mixed together and passed through a very fine sieve; add to this **one part of lime which has been slaked three months,** and sufficient water to make the whole into a thin paste; and in this state to be applied over a coarse ground (or previous coat), as thin as possible, and rendered smooth on the surface; and when dry may be polished by Venetian talc. If buildings are to be covered with it, a preparatory rough ground should be attached, formed of **river sand and lime….**

Smeaton's cement, used in the construction of the far-famed Eddystone lighthouse…was composed of equal quantities of Puzzolana and Aberthaw (Blue Lias) lime…

Two bushels of slaked Aberthaw lime, one bushel of Puzzolana and three of clean, sharp sand will form a good water-cement.

Dutch trass, terras or tarras…(is) abundantly used in the construction of mounds, weirs and other aquatic works. The celebrated mortar is made by **covering a previously prepared mass of quicklime of about a foot in thickness (and sprinkled with water), with an equal quantity of of powdered terras,** and then left for two or three days, after which the quantity required **for immediate use is…**beaten up to a proper consistency.

One measure of quicklime, and two of slaked lime, <u>in powder</u>, and one of terras, well mixed and beaten together to the consistence of a paste, with as little water as possible, forms the terras mortar **in general use;** and a cheaper kind is made by mixing **two parts of slaked lime, one of terras and three of coarse sand** together. These cements indurate very quickly under water and remain very firm.

The tufa stone, which when ground, forms trass or terras, contains 57.0 silica, 16.0 clay, 2.6 lime, 1.0 magnesia, 7.0 potash, 1.0 soda, 5.0 oxide of iron and titanium, and 9.6 water; **it is found abundantly in the north of Ireland,** among the schistose formations on the banks of the Rhine, and at Mannheim in Bavaria.

The fatter the lime, the less of it must be added to the trass to make hydraulic cement…when it hardens too soon (as in twelve hours) it is apt to crack, but if it takes **6 or 8 days to indurate, it is better.**

Meager or poor limestones are best suited for hydraulic mortar, such as contain **from 8 to 25 per cent of foreign matter,** such as slica, alumina, magnesia etc; these, though calcined, do not slake when wetted, but when pulverized, will absorb water without heat or swelling and form a paste which will harden under water in a few days, **but will never become greatly indurated by simple exposure to the air.**

All sorts of lime can be made hydraulic by mixing slaked lime with solutions of common alum, or sulphate of potash to mix with the lime or lime and clay.

…*Beton* (French), used for constructing marine works, consists of 12 parts of puzzolana or Dutch trass, 6 parts of sand, 9 parts of **unslaked lime,** 13 parts of stone fragments, about the size of an egg, 3 parts of tile dust, cinders or scales from a forge; the whole well worked and beaten together.

Plaster of Paris, with an admixture of one tenth part of rust of iron, or iron scales or filings, makes a water-cement which sets very quickly and is of great hardness, and if **boiled potatoes** be incorporated with mortar of lime and sand or with mortar containing burnt clay, these compositions will be much improved.

A composition said to equal Roman cement is made by dissolving 3 ½ pounds of **sulphate of iron *[copperas], and mixing them with a bushel of lime and half a bushel of fine gravel sand, previously made into mortar.***

Parker's Roman cement, for incrustations and general building purposes, is a composition forming an artificial stone, and being impervious to water is very valuable. This material, when incorporated with an equal quantity of clean sharp grit sand, well beaten up with a sufficiency of water, and applied quickly, forms a handsome and durable covering for fronts of houses….

…a cement of gray colour, found…to be composed of an admixture of **unslaked lime, pulverized charcoal and powdered sandstone,** was discovered in the construction of a mausoleum of some of the Tartar princes. The space between the bricks were about an inch broad, and the cement had acquired such a solid consistence that it was found **easier to break the well-burnt bricks than to separate of detach the cement.**

M Berthier…concludes that a lime stone which contains **six per cent of clay affords a mortar precisely 'hydraulic'.**

Lime possessing from 15 – 20% of clay, is very hydraulic, and when from 25 – 30, it sets almost instantly and may, therefore, be held to be a perfect Roman cement.

…(Austin turns to Pasley)…

DIFFERENT MODES OF MEASURING LIME

1st In lumps as it comes from the kiln. This is the **customary mode,** which, if any large compact measure, such as one containing a cubic yard, or even 10 cubic feet only, be used, will afford a **tolerable fair estimate** of the quantity, but not so much if small measures be used.

2nd In slaked lime powder. This mode was **first adopted by Smeaton**, at the building of the Eddystone lighthouse, and recommended by him **for all hydraulic mortars;** and the term applies to lime broken small and slaked by a moderate quantity of water, sprinkled over it with a watering pot, after which it should be covered up, until it falls into a powder, for which more or less time will be required, according to the quality of the lime, but from 18 to 24 hours will be sufficient, as even the blue lias limes, which are the slowest slaking of our English limes, from **possessing the strongest hydraulic properties,** do not usually require more than 18 hours.

3rd In quicklime powder. For this purpose the lime is reduced to a fine powder, by being pounded in a mill, or by manual labour; this mode, however, is **seldom adopted.**

4th In slaked lime putty or paste. This mode was adopted in preference by Col Pasley in his experiments at Chatham, and applies a quicklime fresh from the kiln, pounded in a mortar, and afterwards thoroughly slaked with a moderate quantity of water, **gradually applied**, until the lime, throwing out more or less heat, shall become quite cool, and then re-mixing it with more water into a **stiffish paste,** in which state it is to be measured. *[this is not lime putty as we know it, either in form or method of manufacture].*

OF THE BURNING OF LIMESTONE

In England, the operation of calcination is left almost entirely to the lime-burner, and the engineer receives his material in the state of quicklime, the virtue of which is generally **so well known,** that he mixes it up for extensive use without previous trial of its virtues. This, however, would not be the case in new countries, or in those districts removed from spots where lime-burning is carried on as a trade; he must then be his own lime burner, and the knowledge of the best processes followed, both as to fuel and from of kiln, must be studied by him….

STRENGTH OF MORTARS.

…The only published experiments on this subject made in this country (USA) are those of Colonel Totten, appended to his translation of General Treussart's work.

From experiments, Colonel Totten deduces the following general results:-

1st That mortar of hydraulic cement and sand is the stronger and harder as the quantity of sand is less.

2nd That common mortar is the stronger and harder as the quantity of sand is less.

3rd That any addition of common lime to a mortar of hydraulic cement and sand weakens the mortar, but that a little lime may be added without any considerable diminution of the strength of the mortar, and with a saving of expense.

4th The strength of common mortars is considerably improved by the addition of an artificial puzzolana, **but the more so by the addition of a hydraulic cement.**

5th Fine sand generally gives a stronger mortar than coarse sand *[this contradicts the observations of others].*

6th **Lime slaked by sprinkling gave better results than lime slaked by drowning.** A few experiments made on air-slaked lime were unfavourable to that mode of slaking.

7th Both hydraulic and common mortar yielded better results when made with a small quantity of water than when made thin.

8th mortar made in the mortar mill was found to be **superior** to that mixed in the usual way with a hoe.

9th Fresh water gave better results than salt water.

…
CONCRETE – This term is applied by English architects and engineers, to a mortar of **finely pulverized quicklime, sand and gravel.**

BETON – The term beton is applied by French engineers to any mixture of hydraulic mortar with fragments of brick, stone or gravel, and it is now also used by English engineers to the same sense.

From experiments made by Colonel Totten on beton, the following conclusions are drawn:

That beton made of a mortar composed of hydraulic cement, common lime and sand, or of a mortar of hydraulic cement and sand, without lime, was **the stronger as the quantity of sand was the smaller…**

Beton made with just sufficient water to fill the void spaces between the fragments of stone was found to be **less strong than that made with double the bulk of mortar.**

…The strongest beton was obtained by using quite small fragments of brick, and the weakest from small, rounded, stone gravel.

A beton formed by pouring grout among fragments of stone or brick **was inferior in strength to that made in the usual way with mortar.**

Comparing the strength of the betons on which the experiments were made, which were eight months old when tried, with that of a smaple of sound red sandstone of good quality, it appears that the strongest prisms of beton were only half as strong as the sandstone *[BUT the hydraulic limes used still a long way from their initial strength at 2 years, which would likely be around twice that at 8 months].*

Dempsey (1857) Architectural Practice, Containing Detailed Working Drawings, Specifications, Bills of Quantities, Estimates, Tenders, etc etc. London: Archly and Co.

In thick walls the use of **grout** (that is, liquid mortar) is the best safeguard against the too frequent carelessness of workmen. **This composition should not be merely the mortar thinned with water, but should be mixed separately in large tubs, in the same proportions as mortar; and should be used moderately hot, so that it may not impoverish the mortar with which it comes in contact, and that it may set more quickly.**

GILLMORE Q A (1864) PRACTICAL TREATISE ON LIMES, HYDRAULIC CEMENTS, AND MORTARS. CONTAINING REP0RTS OF NUMEROUS EXPERIMENTS CONDUCTED IN NEW YORK CITY, DURING THE YEARS 1858 TO 1861, INCLUSIVE. NEW YORK: D. VAN NOSTRAND, 192 BROADWAY.

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METHODS OF SLAKING LIME.
317. Lime is usually sent to market in barrels, either in lumps, as it leaves the kiln, or, in the case of those varieties that are more or less meagre and consequently difficult to reduce to fine pulp by any of the known methods of slaking, in the condition of coarse powder to which it has been brought by grinding. In either case, it must be slaked before it can be employed as a matrix for mortar.
318. Three methods of slaking lime are usually described in works on mortars; on the continent of Europe, the third method, and in the United States, the second and third are seldom resorted to in slaking lime- practice.

319. The first or ordinary method termed drowning, from the excessive quantity of water sometimes injudiciously employed, It is important that all the water required for this purpose, which, with the different limes, will vary from two and a half to three times the volume of the quicklime, should be added at the outset, or, at least, before the temperature becomes sensibly (p180) elevated. In this condition the lime will remain entirely submerged, and comparatively quiescent, until after an interval of five to ten minutes, the water becomes gradually heated to the boiling point, when a sudden evolution of vapor, a rapid increase in volume, and a reduction of the lime to pulp, ensues. The increase of volume is sometimes denominated the " growth."
320. This process is liable to great abuse at the hands of workmen, who are apt to use either too much water, thus conferring upon the slaked lime **a condition of semi-fluidity, and thereby injuring its binding qualities**; or, not having used enough in the first instance, they seek to remedy the error by adding more after

the extinction has well progressed, and a portion of the lime is already reduced to powder, thus suddenly depressing the temperature, and chilling the lime, which renders it granular and lumpy.

321. As soon as all the water required has been poured upon the lime, it is recommended to cover up the vessel containing it with canvas or boards, in order to concentrate the heat and the escaping vapor, and direct their action upon the uppermost portions deprived of immediate contact with the water bv the swelling of the portions at the bottom. When it is not practicable to apply this covering, a tolerable substitute is found in the sand to be subsequently added to the mortar. This can be spread over the lime in a layer of uniform thickness, after the slaking has well progressed. Another precaution of equal and perhaps greater importance is, not to stir the lime whilst slaking; but to allow it gradually to absorb the water by capillary attraction and its natural avidity for it, taking care that all portions are supplied with it to that degree requisite to produce a paste of the slaked lime, and not a powder. When the lime is to be used (p181) for whitewashing or grouting, the water should be added at the outset in larger quantities than specified above, and the whole mass should be run off whiie hot into tight casks, and covered up to prevent the escape of water.

322. In slaking, the essential point is to secure, if possible, the reduction of all the lumps. It will be found difficult to obtain this result with the hydraulic varieties, and the difficulty increases in a direct ratio with the hydraulic energy, until we reach the intermediate limes, or the inferior limit of cement, when the reduc-tion must be effected by mechanical means. Even with those hydraulic limes that do slake, it is often necessary to employ a mortar mill to reduce the lumps, — Mechanical means which should always be secured, as these lumps constitute not only a dangerous substitute for sand, if left intact, but furnish when pulverized, the most energetic portion of the gauge.

323. Slaking by Immersion. — The second method of slaking (by immersion), consists in suspending the quicklime, previously broken into pieces of about the size of a walnut, and placed in a basket or other suitable contrivance, in water, for one or two minutes, **taking care to withdraw it before the reduction commences.** The lime should then be quickly heaped together, or emptied into casks or bins, and covered up, in order to concentrate the heat and prevent the escape of vapor. In this condition it soon begins to swell and crack, and finally becomes reduced to a fine powder, which may be preserved several months without serious deterioration, if packed in casks and kept from direct contact with the atmosphere. The expense which would ordinarily attend the practical application of this process, and the difficulty, and even impossibility of securing with certainty, at the hands of workmen, the period of immersion, have led to (182) a modification of it, which consists in sprinkling the broken fragments formed into heaps of suitable size, with one-fourth to one-third of their volume of water. This should be applied from the rose of a finely gauged watering-pot, after which the lime should be immediately covered with the sand to be used in

the mortar. In this condition it should not be disturbed for at least a day or two, and the opinion prevails in the southern portions of the continent of Europe that the quality of the lime is improved by allowing the heaps to remain several months, without any other protection from the inclemency of the weather than an ordinary shed, open on the sides. In the vicinity of Lyons this custom very generally obtains, the autumn being usually selected for slaking all the lime required for the following season's operation. In Europe, this method of slaking is applied to the fat and slightly hydraulic limes only, and not to those that are eminently hydraulic, upon which it seems to act disadvantageously, by depriving them, in a measure, of their hydraulic energy.
324. Spontaneous slaking. — Quicklime has a great avidity for water, and when not secured from direct contact with the atmosphere, gradually absorbs moisture from it and falls into powder, exhibiting but very slightly, and sometimes not at all, the other phenomena usually developed in slaking. The lime is then said to be slaked spontaneously, or air slaked.

…(183) A great and insurmountable objection to the process, however, is the expense of storage room or sheds which it necessarily involves, to say nothing of the time required for its completion. Spread out in layers of from ten twelve inches in depth, some varieties of fat lime might become thoroughly reduced in twenty or twenty- five days; others would require as many weeks; while with a few, the process would continue for a whole year. Hydraulic limes are greatly injured by spontaneous slaking. Fat limes slaked to powder by the second or third process, are converted into paste with less water, and undergo a less augmentation of their original volume, than when slaked by the first process.

326. By neither of the three processes of slaking, nor any modification of them, have I succeeded in obtaining as great an augmentation of the volume of fat lime measured in the state of paste, as is stated by M. Vicat to belong to the fat limes of France, viz.: that one volume of the quicklime in lumps, by the absorption of 2.91 volumes of water, will give 3.5 volumes of paste.

327. I have repeatedly tried all the limes offered to any extent, in the New York market. In slaking them, quantities of five to ten pounds were generally employed and the utmost care was taken, in all cases, to obtain perfect accuracy in the weights and measurements (184) and by the use of glass and tin vessels to prevent the waste or absorption of water.

…p187 The same authority (Vicat) says, that the absorption and penetration of this gas proceeds more rapidly in the hydraulic limes than in the fat limes — a statement which not only needs confirmation, **but is believed to be the converse of what is true.** Mv researches lead me to the same results as those enunciated by Geo. Robertson, Esq., in a paper recently read before the " Royal Society of Edinburgh,",viz.: **" The depth to which carbonic acid is absorbed into mortar in a given time, and, to a certain extent, the induration from that cause varies inversely with the hydraulic properties of the lime, which depend upon the silica contained in it."**

332. The incrustation is due in the case of hydraulic limes to the combined influence of reactions, considerably more complicated and obscure than those which obtain with the hydrate of fat lime. The hydrosilicate and aluminate of lime (SiO,4 CaO + 6 HO) and (A1.0, + 3 CaO + 6 HO) are formed in addition to the hydrocarbonate. The formation of these compounds of silica and alumina is not confined to the crust on the surface, but takes place throughout the mass, and is really the principal efficient cause of the induration of this class of limes, when placed under water, or in humid localities excluded from atmospheric influences.

P188) 333. The hardness assumed by the hydrate in the air is intimately connected with the process of slaking, and appears to sustain a direct ratio with the increase in volume. The three modes of slaking arranged in order of their superiority in this respect stand as follows : 1st. For fat limes: ordinary slaking, spontaneous slaking, slaking by immersion. 2d. For hydraulic limes: ordinary slaking, slaking by immersion, spontaneous slaking.
334. The hydrates of fat lime, drying in the air, shrink and crack to such an extent, that they cannot be employed in mortar for masonry without a large dose of sand.

(189) … 336. For fat limes, the second and third methods have been supposed by many engineers to possess some supposed advantage; the former, in conferring increased hardness and tenacity upon the mortar; the latter as a means of securing hydraulic properties in a moderate degree; but as there are some doubts upon these points, particularly as to the alleged superiority of air-slaking, and as any requisite degree of strength, hydraulic energy and quickness maybe conferred upon lime mortars with **more certainty** and with equal economy, by the judicious use of hydraulic agents, either natural or artificial hydraulic lime, pozzuolana, or cement, (particularly the latter in the United States,) the first, inasmuch as it is attended with less original outlay, gives more certain results, and requires fewer precautions at the hands of the workman, the first process may be regarded as the most advantageous in nearly every case, provided the precaution is taken to pour on at the outset all the water required to produce a stiff paste, but no more.

338. General Totten announced the following as the results of experiments made at Fort Adams, upon the different modes of extinction: 1st. Slaking by drowning, or using a large process quantity of water in the process of slaking the lime **affords weaker mortars than slaking by sprinkling**. (190) 2d. Experiments with air-slaked lime were too few to be decisive, but the results were unfavorable to that mode of slaking.

339. Preservation of Lime. — The paste of fat lime, whatever may have been the mode of extinction, may be preserved intact for an indefinite length of time, if kept from contact with the air. **It is usual to put it in tight casks, or in reservoirs or trenches covered up with sand**; or, when shed-room is available, to form it

into rounded heaps similarly protected and under cover. 340. The powder derived from the second and third modes of extinction may be preserved for several months, without sensible deterioration, in covered casks or bins, or if heaped up in dry sheds, and covered over with straw, cloth, or dry sand.

341. Until quite recently, opinions among engineers were divided as to the effect of time upon the quality of paste of fat lime, preserved with suitable precautions for future consumption. General Treussart entertained the opinion that they should be made into mortar and used soon after their extinction. This idea finds few advocates at the present day, **although the practice in this country conforms to it with singular unanimity**. As before observed, it is customary in some parts of the continent of Europe to slake the lime the season before it is to be used.
342. Fabrication of Mortars. — The relative quantities in which sand and the cementing substance, whether the latter be derived from common or hydraulic lime, or cement, should exist in mortar, depend in a great measure on the character of the work in which it is to be used; its locality and position with regard to a state of moisture or dryness; and, if subjected to alternations in this respect, the character of the moisture, depending on its proximity to or remoteness from (191) the sea, the nature and magnitude of the forces which it will be required to resist, the peculiarities of the climate, and the season of the year in which the work is to be performed. 343. In practice, the actual quantities of the different ingredients to be portioned out "depend on the varying conditions of dampness and dryness, looseness and compactness, powder and paste, in which they may be measured."
344. The following data, derived from the work of General Totten and from direct trials, will be found useful in estimating the amounts of the different ingredients necessary to produce any required quantity of mortar.

P201
359. **Extensive operations requiring large quantities of mortar are frequently carried on by experienced engineers, without the aid of a mortar-mill of any kind. When Making mortar ordinary lime mortars are thus made by hand, it is customary and convenient to slake the lime by the first method described, and in no greater quantity than may be required for immediate use. The operation should be conducted under a shed. The measure of sand required for the " batch" is first placed upon the floor, and formed into a basin for the reception of the unslaked lime. After this the latter is put in, and the larger lumps broken up with a mallet or hammer; the quantity of water necessary to form a stiff paste is let on, from the nozzle of a hose, or with watering-pots, or even ordinary buckets. The lime is then stirred with a hoe, as long as there is any evolution of vapor, after which the ingredients are well mixed together (p202) with the shovel and hoe, a little water being added occasionally if the mass be too stiff.** At this **stage of the operation, it is customary to heap the mortar compactly together, and allow it to remain until required for use. When circumstances admit, it should not be disturbed for several days, and during**

the p riod of its consumption should be broken down and " tempered" in no larger quantities than may be required for use from day to day.

360. It is believed that certain slight modifications of this common method of procedure can be made, with decided advantage in the final results. They may be indicated as follows :
361. First. All the lime necessary for any required quantity of mortar should be slaked at least one day before it is incorporated with the sand.
362 Second. The sand-basin, to receive the unslaked lime should be coated over on the inside with lime-paste, to prevent the escape of water.
363. Third. All the water required to slake the lime to a stiff paste, should be poured on at once. This will completely submerge the quick lime. The heap should then be covered over with tarpaulin or old canvas, and left until next day. 364. Fourth. The ingredients should be thoroughly mixed, and the mortar heaped for future use.

P204… 380. Composition of Mortar used at Fort Warren. — The mill-made mortar for the stone masonry at Fort Fort Warren was composed of lime, hydraulic cement, and sand, in the following proportions, viz.: (p205) These ingredients being well mixed, make eighteen and a half cubic feet of good mortar. For mortar for brick masonry, the same quantities of lime and cement received but fifteen and three-quarters cubic feet of loose sand, equal to twelve cubic feet well compacted, giving sixteen cubic feet of good mortar….

381. Some engineers object to the use, in works of importance, of mortar containing so large a proportion of sand as that adopted at Forts Richmond and Warren; others again very seldom add lime to their cement mortars. Touching this last-mentioned point, recent experiments show, with a uniformity quite satisfactory, that most American cements will sustain, (p205)without any great loss of strength, a dose of lime paste equal to that of the cement paste; **while a dose equal to the volume of cement paste may safely be added to any energetic Rosendale cement, without producing deterioration in the quality of the mortar,** to a, degree requiring any serious consideration. Neither is the hydraulic activity of the mortars so far impaired by this limited addition of lime paste, as to render them unsuitable for concrete, under water or other submarine masonry; while, for constructions not subject to immediate submersion, or the action of the returning tide, it is to be preferred on many accounts. **By the use of lime, we secure the double advantages of a rather slow mortar— one that is in no danger of setting before it reaches the mason's hand — and a cheap mortar**. **We also avoid the principal serious objection to the use of a quick-setting mortar, due to careless and tardy attendance on the masons, and consequently the constant breaking up of the incipient set on the mortar-board, whereby cements are degraded in energy to a level with ordinary hydraulic limes.**

P207

POINTING MORTAR.

384. In laying up masonry of any character, whether with common or hydraulic mortar, the exposed edges of the joints will naturally be deficient in density and hardness, and, therefore, unable to withstand the destructive action of the elements; particularly variations in temperature, producing extremes of heat and cold. It is therefore customary, to fill the joints as compactly as possible, to the depth of about half an inch, with mortar prepared especially for the purpose. This operation is called "pointing," and the mortar, "pointing mortar." The cleaning out of the joints to the requisite depth should take place while the mortar is new and soft; and (in stone masonry) when the stones come in contact, or nearly so, the joints must be enlarged, to the width of about three-sixteenths of an inch by a stone-cutter.

385. Pointing mortar is compounded of a paste of finely ground cement, and clean sharp silicious sand, in such proportions that the volume of cement paste shall be very slightly in excess of the volume of voids in the sand. These voids should be carefully ascertained. The measure of sand will generally vary between 2 ½ and 2 ¾ that of the cement paste; or by weight, one of cement powder to from 3 to 3 ½ of sand. The mortar, when ready for use, should appear rather incoherent and quite deficient in plasticity. The mixing should take place under shelter, in an iron or stone mortar, or some other suitable vessel, and in quantities of not over two or three pints at a time.

386. Before pointing, the wall should be thoroughly saturated with water, and kept in such a condition, that it will neither absorb water nor impart any to it, — two conditions of special importance, the first being paramount. Walls should not be allowed to dry too rapidly after pointing, but should be kept moist for several days, or better still, for two or three weeks. Pointing in hot weather should therefore be avoided, if possible; or else some temporary shelter from the direct action of the sun's rays should be provided.

387. For pointing masonry in courses, the tools required besides an ordinary mason's trowel are, a straight-edge, about six feet long; a caulking iron, measuring three inches by one-eighth of an inch on the edge; a hammer, and some conveniently shaped iron or steel instrument for polishing the surface of the joint in the last stage of the operation. The mortar is put in the joint with the trowel, the straight-edge being placed (209) against the wall, just below the joint, as an auxiliary. The joint is then well caulked with the caulking iron, by repeated blows of the hammer, until a film of water shows itself on the surface of the mortar; after which, mortar is again put in, and the caulking repeated. In using the straight-edge, two men, one at each end, can conveniently work. The operation is continued until the joint is entirely full. The mason then rubs and polishes the joint, under as great a pressure as he can exert, and finishes off by using the straight-edge and trowel point, to remove any mortar spread out upon the stones on either side, make the pointing straight, and give the appearance of exact equality in the thickness of the joints.

388. In pointing rubble masonry, the same general directions are applicable, but the use of the straight-edge has to be dispensed with.

NELSON, Captain R. E. (1865) VII Memoranda on Transition Lime and Limestone as obtained from different Quarries at Plymouth. Papers on SUBJECTS CONNECTED WITH THE DUTIES OF THE CORPS OF ROYAL ENGINEERS. Vol VII London. Weale.

First Quarry. The works at which these Notes were made consist of quarries chiefly for raising limestone in blocks of from ¼ cwt. to l cwt., either to be burned on the spot, or to be shipped for different places in the neighbourhood where no lime is to be found.

The burning establishment is a block of four kilns; to these, the stone is brought from below in tip-carts on railroads, by a 16 horse-power steam engine, up an inclined plane….

Spallings, not less than a man's fist, are collected for the kiln; under this, they are wheeled off as rubbish for made ground ….

Fuel used in burning: Swansea culm (Anthracite), coal being in general too sulphurous to allow the burner to work….Mode of filling the kiln: Two bundles of reeds; 10 cwt. or 12 cwt. chips, larger above; thus far filling up about 4 feet deep; then 3 cwt. rather large culm, 2 courses of stone, say 6" thick together; 7 2 cwt. culm, 7″ stone; 1 ½ cwt. culm, 8″ stone; 1 ½ cwt. culm, 9″ stone; and from thence, alternate with 1 ½ cwt. culm and 9″ stone, until the kiln is filled….

Proportion of culm to lime: 1 ton of culm should give from 3 ½ to 4 tons transition lime. 1 ½ ton of culm should give from 3 ½ to 4 tons lias lime. Time of burning one charge: From 1 ½ to 2 days, according to the wind. Net produce of kiln per day: From 32 to 33 tons, each 'ton ' containing about 9 bushels.

Second Quarry.

A man will turn out and break up for rubble stone 4 'tons' or 56 cubic feet per day. If he has not to break up, then about 6 tons per day. When thus broken up into pieces of from ½ to ¾ cwt., and delivered at the kiln (close to the quarry), he will further break it up for burning at 1 load = 16 'tons' = 224 cubic feet per day. The proportion of culm burned to quick lime yielded was 1 : 3; of slaked lime, 1 : 6. In burning Aberthaw limestone, culm : quick lime: l : 4, or culm : slaked lime: l : 6 only.

Henry Reid A Practical Treatise on Concrete and how to make it, with observations on the Uses of Cements, Limes and Mortars 1869 Spon London

When used as mortar for building, its value is measured by the amount of certain impurities which it contains ; and the following classification has been adopted to distinguish the several descriptions. First : Eich limes, having 100 per cent. carbonate of lime. Second : Poor limes, 70 per cent. carbonate of lime, 3 per cent. silica, 26 per cent. sand, 1-5 per cent. alumina. Third : Slightly hydraulic, 80 per cent. carbonate of lime, 3 per cent. alumina, 5 per cent. silica. Fourth : Hydraulic, 82 per cent. carbonate of lime, 6 per cent. alumina, 11 per cent. silica. Fifth : Eminently hydraulic, 80 per cent. carbonate of lime, 6 per cent. alumina, 14 per cent. silica : — indicating as they diverge from a pure carbonate of lime an increase of silica and alumina, the two ingredients that give value to hydraulic limes. The first and second classes are inert, and possess a minimum degree of setting energy. The third, fourth, and fifth classes improve in value, and set with moderate energy either in or out of water. The time of setting of these five classes of limes ranges from three to fourteen days, without an admixture of sand or gravel. In selecting lime for concrete, it is advisable to reject that which is obtained from limestones having by analysis a less amount of silica and alumina than those of the second class. The use of pure limes is not advisable, from their extreme liability to absorb moisture ; and when being slaked great care is neces sary so as to obtain the utmost amount of comminution of their particles. The Eomans overcame this difficulty in using rich limes by the introduction of foreign materials ; they used puzzolana in Italy, trass in Germany and pounded bricks in England and France. Whatever quality of lime may be used it is necessary that it should be reduced to the finest powder, •either by slaking or mechanical pulverization. In preparing it to mix with sand or gravel it is necessary to impart suffi cient moisture to ensure the maximum amount of cementa tion….

In consequence of the indifference of builders to the quali ties of mortars they use, no very satisfactory progress has been attained in their preparation in this country.

GENERAL OBSERVATIONS. The suitability of Portland cement concrete, especially for house-building purposes, is now so generally acknowledged that it is almost superfluous to describe or enumerate its many advantages over bricks and stones for ordinary erections. It is, however, desirable to explain more fully the leading benefits to be derived from its use : —
First. Increased strength.
Second. Reduced cost.
Third. Additional facilities for the flue, and heating or ventilating arrangements.
Fourth. Resistance to atmospheric influences, and from its comparative non-absorbance, the capacity of resisting damp whether internal or external.
Fifth. Reduced cost in details of construction, more especially in plastering, carpentery and joinery.

Sixth. Durability from its ultimately becoming crystallized, and instead of deteriorating with age becomes harder and stronger.
Seventh. Flat roofs with inexpensive covering may be con structed owing to the increased strength of the walls.
Eighth. Fire-proof when the timber necessary in construction is judiciously arranged.
Ninth. Impermeability to sound.
Tenth. Possibility of adopting non-skilled labour in the preparation of the concrete and placing it in the walls.
Eleventh. Capacity of resisting attacks of vermin.
Twelfth. High and equable internal temperature secured by reason of the non-absorbent nature of the materials.
Thirteenth. Purity of atmosphere in the rooms in consequence of the walls being able to resist the absorption of the animalised gases.
Fourteenth. Advantageous condition of the walls to obtain the most economical application of heat for warming, as no waste of fuel is incurred in first evaporating the moisture — a common source of expense in ordinary brick structures.
Fifteenth. Expedition in construction, as a house built of Portland cement concrete may be inhabited when the walls are completed. No delay need arise in drying, as the cement concrete possesses the property of exuding the water of mixture so soon as it sets.
Sixteenth. Avoidance of dust from the disintegration of mortar. This is a fertile source of annoyance in all brick- built houses, with their innumerable joints made of bad lime-mortar.
Seventeenth. Facilities for warming or ventilating floors of concrete.
Eighteenth. Cheap form of roof may be made of concrete.
Nineteenth. General improved facilities for the most advanced sanitary appliances for comfort and health.

The above list of advantages has special reference to construction of dwellings ; but there are other and many varied uses to which Portland cement concrete may be applied, such as improved walls for gardens and other inclosures. Pavements and roadways of all descriptions may be made with good Portland cement concrete. For such, or, indeed, for any purpose where such a material is applicable, it is necessary that the cement should be of first-rate quality, and its mixture or combination with the gravel, shingle or other aggregate, should be carefully performed.

Anonymous (1870) Specifications for Locust Grove Schoolhouse, Poposcon, West Chester, Pennsylvania http://locustgroveschoolhouse.org/articles/draft-specifications-renovations-late-19th-century

The walls partitions and sealings [ceilings] to be lathed and plastered with two coats of brown mortar and one hard white finish. The brown mortar to be composed of fresh wood, burnt lime, and clean sharp sand, well haired. The lumber to be of the best quality and properly seasoned, and all the hardware nessary [necessary] to complete the building to be of the most approved kind and all other material and the workmanship required to carry out the specifications to be of the best quality and all to be done to the satisfaction of the director of the proper committee.

the partition and ceiling to be well lathed and with the wall to be plastered with two coats of brown mortar and with one of white hard finish. The brown mortar to be composed of fresh wood, burnt lime, and clean sharp sand well hared [haired] -

The portico to be build [built] over font [front] door 7 by 8 feet, the walls to be 18 in. thick, and the foundation to be 2 ft deep- to be of good building stone and good mortar, the walls to be built on three sides of sufficient hight [height] that the floor when laid well be on a level of underside of door. Sill to be filled in between the walls to the depth of 1 foot with small stones well laid in the floor. to be laid with large flat stones solidly laid in mortar and to extend over the wall 2 in. all around the posts. The in iron common water pipe securely fastened at bottom.

Gillmore Q A (1871) REPORT ON BETON AGGLOMERE; OR, COIGNET-BETON AND THE MATERIALS OF WHICH IT IS MADE. PROFESSIONAL PAPERS, CORPS OF ENGINEERS, U. S. ARMY. Government Printing Office, Washington

P7 BETON AGGLOMERE

MORTAR.

Calcareous mortar is compounded of one or more of the varieties of common lime, hydraulic lime, or hydraulic cement — natural or artificial — mixed with sand and water into a plastic condition.

The degree of strength and hardness, and consequently the durability, attained by mortar in setting, is dependent on the quality of the lime or cement employed, the kind and quantity of sand, the method and degree of manipulation, and the position, with respect to moisture or dryness, in which it is subsequently placed.

A mortar, of which the matrix is common lime only, will never harden under water, or to any considerable extent if kept in damp places, excluded from the air. A condition of constant humidity, on the contrary, is favorable to the induration of all hydraulic mortars.

CONCRETE OR BETON.

These terms, by no means originally synonymous, have become almost strictly so by usage. As generally received and understood in modern practice, they apply to any mixture of mortar, generally hydraulic, with coarse materials, such as gravel, pebbles, shells, or fragments of tile, brick, or stone. Two or more of these coarse ingredients, or all of them, may be mixed together.

The matrix of beton was formerly understood to possess hydraulic energy, while that of concrete, being derived from common lime, did not. A concrete, destitute of hydraulic energy, is seldom used in works of importance at the present day.

As lime, or cement paste, or a combination of the two, is the cementing substance or matrix in mortar, so mortar itself occupies a similar relation to concrete or beton. The proportions of the ingredients, in either case, should be determined on the principle that ***the volume of matrix should (p8) always be somewhat in excess of the volume of voids in the materials to be united,*** the excess being added as a precaution against imperfect manipulation.

BETON AGGLOMERE. 3. This name is given to a beton of very superior quality, or, more properly speaking, an artificial stone, of great strength and hardness, which has resulted from the experiments and researches, extending through many years, of M. Francois Coignet, of Paris.
The essential conditions which must be carefully observed in making this beton are as follows :
First. Only materials of the first excellence of their kind, whether common or hydraulic lime, or hydraulic cement, can be used for the matrix.
Second. The quantity of water must not exceed what is barely sufficient to convert the matrix into a stiff, viscous paste.
Third. The matrix must be incorporated with the solid ingredients by a thorough and prolonged mixing or trituration, producing an artificial stone paste, decidedly incoherent in character until compacted by pressure, in which every grain of sand and gravel is completely coated with a thin film of the paste. There must be no excess of paste when the matrix is common lime alone. With hydraulic lime this precaution is less important, and with good cement it is unnecessary.
Fourth. The beton or artificial stone is formed by thoroughly ramming the stone paste, in thin, successive layers, with iron- shod rammers.

MATERIALS SUITABLE FOR BETON AGGLOMERE.

The materials employed in making this beton are as follows:

Sand. — The sand should be as clean as that ordinarily required for mortar, for stone or brick masonry of good quality. Sand containing 5 or 6 per cent. of clay may be used without washing, for common work, by proportionally increasing the amount of matrix. Either fine or coarse sand will answer, or, preferably, a

mixture of both, containing gravel as large as a small pea, and even a small proportion of pebbles as large as a hazel nut. There is an advantage in mixing several sizes together, in such proportion as shall reduce the volume of voids to a minimum. Coarse sand makes a harder and stronger beton than fine sand. The extremes to he avoided are a too (p9) minute subdivision and weakening of the matrix, by the use of fine sand only, on the one hand, and an undue enlargement of the volume of voids, by the exclusive use of coarse sand, on the other.
The silicious sands are considered the best, though all kinds are employed. When special results are desired in the way of strength, texture, or color, the sand should be selected accordingly.

Common or fat lime. — The lime should be air-slaked, or, better still, it may be slaked by aspersion **with the minimum quantity of water that will reduce it to an impalpable powder**. It should be passed through a fine wire screen to exclude all lumps, and **used within a day or two after slaking**, or else kept in boxes or barrels protected from the atmosphere. It is scarcely practicable, under ordinary circumstances, to employ fat lime alone as the matrix of beton agglom6re, particularly in monolithic constructions, in consequence of its tardy induration. Even when used in combination with hydraulic lime or cement it acts as a dilutent.

M. Coignet claims, with great confidence, if not with correct judgment, that good beton can be made with sand and fat lime alone, but it is not so employed in his artificial stone manufactory at St. Denis, and it is believed that all the works executed in beton by the company of which he is the head have contained hydraulic lime or cement. Attempts to make beton of even average quality, without good hydraulic ingredients, have failed in the United States; and it is extremely doubtful whether any characteristic excellence can be attained, after the lapse of weeks or even months, by a mixture of this character. When a matrix of fat lime alone must be employed for want of a better material, the manipulation should be conducted with watchful care. The quantity of water must be limited strictly to what is necessary to convert the lime powder into a stiff paste; and of this paste only enough must be used to cover each grain of sand and gravel with a thin, impalpable coating. The other conditions of prolonged trituration and thorough ramming, already referred to, are common to all varieties of this beton.

Hydraulic lime. — The most suitable limes are, like those of Theil, Seilley, and other localities in France, derived from the argillaceous limestones, in contradistinction to the magnesian or argillo-magnesian varieties. These limestones contain (p10) before burning from 15 to 25 per cent. — generally less than 20 per cent.— of clay. After burning, **the lime is slaked to powder by aspersion with water, and sifted to exclude unslaked lumps. Hydraulic lime cannot be considered an essential ingredient of beton agglomere, except in comparison with common lime. It may be altogether replaced by good hydraulic cement, or it may be used alone, or mixed with common lime, to the**

entire exclusion of cement. A stiff paste of this lime should set in the air in from ten to fifteen hours, and sustain a wire point one-twenty-fourth of an inch in diameter, loaded with one pound, in eighteen to twenty-four hours. Its energy, and therefore its value, varies directly with the amount of clay which it contains, which generally will not exceed 20 per cent. before burning, although it may reach 25 per cent. Beyond this point the burnt stone can seldom be reduced by slaking and becomes a cement. No hydraulic lime of this variety has ever been manufactured in the United States. It is not known that stone suitable for it exists here.

(Portland cement is suitable). *(The Portland Cement discussed is early and more akin to an eminently hydraulic lime. Some is made directly from impure limestone; other by artificially blending the necessary ingredients).*

P13 MATERIALS NOT SUITABLE FOR BETON AGGLOMERE. As a rule, all hydraulic cements **produced at a low heat**, whether derived from argillaceous or argillo-magnesian limestones, are light in weight and quick-setting, and never attain, when made into mortar or beton, more than 30 to 33 per cent. of the strength and hardness of Portland cement placed in similar circumstances. They are also greatly inferior to good hydraulic lime. This is true of all cements made at a low heat, including even those derived from limestones, **that might, with proper burning, have yielded Portland cement.** The celebrated Roman cement, the twice-kilned artificial cements, the quick- setting French cement, like that of Vassy, and all the hydraulic cements manufactured at the present day in the United States, belong to this category. They are **incapable**, under any known method or degree of manipulation, of producing a matrix suitable for beton agglomere of good quality.

P14 THE INDURATION OF MORTARS. 17. The setting or hardening of mortars, except so far as it is due in some degree to the absorption of carbonic acid from the atmosphere, is a species of crystallization induced when water is added to the compounds found in the kiln by the agency of heat. Mortars of common lime harden by the absorption of carbonic acid from the atmosphere, by which a sub-carbonate of lime is formed. The lime never takes up its full equivalent of carbonic acid. If the limestone be siliceous, the calcination produces silicate of lime. Si O3 3 Ca O, which **becomes hydrated by combining with six equivalents of water,** producing hydro silicate of lime, Si O3 3Ca O+6 H2O.

If the carbonate of lime be in excess in the stone, the burnt product will contain both silicate of lime, and quicklime, or protoxide of calcium. It will slake to powder by the suffusion of water, if the quick lime be present in sufficient quantity, producing a species of hydraulic lime, of which the hydraulic energy will depend on the amount of silicate produced during the calcination. If the limestone be argillaceous — that is, if it contain alumina as well as silica — a calcination **at a low heat** produces both silicate and aluminate of lime. The latter becomes hydrated by taking six equivalents of water, and is then represented by the formula Al O3 3 Ca O+6 H2O. If the silica and alumina be present in the form of homogeneous clay, and in suitable quantity, say less than 20 per cent, the burnt stone will slake, yielding hydraulic lime resembling more or less those of Seilley and Theil, France. If more than 20 per cent. of clay be present, the lime will be so little in excess that the burnt stone may not slake, but must be reduced to powder by grinding. The result, if burnt at a low heat, is light, quick-setting cement, like the Roman.

If this stone be burnt at a high heat, the reactions in the kiln are somewhat more complicated, particularly when the point of incipient vitrification is reached, a variable point, dependent in a great measure on the fluxes present in the stone. The compounds formed under these conditions, however, require but (p15) three equivalents of water for their hydration, their formulas being Al O3 3 Ca O+3 H2O, Si O3 3 Ca O+3 H2O. **Herein lies the probable cause, in a great measure, of the superior strength and hardness attained by Portland cement over the quick-setting varieties burnt at a low heat**, in which the compounds take six equivalents of water to form hydrates.

TREATMENT OF THE MATRIX. 19. It is impossible to produce a cementing material, of suitable quality for beton agglomere, by the ordinary methods and machinery used for making mortars; for if we take the powder of hydraulic lime or Portland cement, and add the quantity of water necessary to convert it into a paste by the usual treatment, it will usually contain so much moisture, even after being incorporated with the sand, that it cannot be compacted by ramming, but will yield under the repeated blows of the rammer like jelly. If the quantity of water be reduced to that point which would render the mixture, with the usual treatment, susceptible of being thoroughly compacted by rammers, much of the cementing substance will remain more or less inert, and will perform but indifferently well the functions of a matrix.

To prepare the matrix, there is taken of the hydraulic lime or cement powder, say one hundred parts, by measure, and of water from thirty to thirty-five or forty parts, which should be the smallest amount that will accomplish the object in view. These are introduced together into a suitable mill, acting upon the materials by both compression and friction, and are subjected to a thorough and prolonged trituration, until the result is a plastic, viscous, and sticky paste, of a peculiar character, in both its physical appearance and the manner in which it comports itself under the subsequent treatment with rammers. There would appear to be no mystery in this part of the process, yet the excellence of the beton agglomere is greatly dependent on its proper execution. **If too much water be used, the mixture cannot be suitably rammed; if too little, it will be deficient in strength.**

TRITURATION. 21. The matrix in paste, and the sand, having been mixed together in the desired proportions, (given hereafter,) are then introduced into a powerful mill, and subjected to a thorough and energetic trituration until, without the addition of more water, the paste presents the desired degree of homogeneity and plasticity. When, for any special purpose, it is desired to

introduce into the mixture a quantity of Portland cement, in order to increase the hardness or the rapidity of induration, it had better be added during the process of trituration, mixed with the requisite increment of water, so that after proper mixing the whole material will present the appearance of a short paste, or pasty powder, which is quite characteristic of this process of manipulation. **In ordinary practice, when sand and hydraulic lime only are employed, it will be found to answer very well to mix the two together dry, with shovels, and then spread them out on the floor and sprinkle them with the requisite minimum amount of water. The dampened mixture is then shovelled into the mill and triturated, as already described.** *(This is hot mixing, insofar as the hydraulic quicklime will exude heat)*. When a portion of Portland cement is used, it may also be incorporated with the other ingredients **before the water is added**, or introduced into the mixture in the mill, as may be preferred. When Portland alone is used for the matrix, the process is the same as when lime alone is used, except that the trituration should be more prolonged, especially if the cement be rather light and quick-setting.
The market value of Portland cement per ton is generally not far from double that of good hydraulic lime. Having both equally at command, the following proportions are employed for divers purposes, according to circumstances and the quality of the materials:

Sand by volume	6	5	4	5	6	4	4	5	5	5
Hydraulic lime in powder by vol	1	1	1	1	1	1	1	1	1	1
Portland cement in powder by vol	0	0	0	¼	½	½	½	1	1 ½	1 ½

It will rarely occur that the proportions given in the two columns on the right of the above table need be used. They are suitable for ornamented blocks, requiring removal and handling a day or two after being made.
23. It may sometimes happen that too much water has been introduced in the preparation of the paste. A proper corrective, in such case, is the introduction into the mill of a suitable quantity of each of the ingredients, mixed together dry in the required proportions. By employing none but white sand and the lighter-colored varieties of lime and cement, a stone closely imitating white marble may be made, while, by the introduction of coloring matter into the paste, such as ochres, oxides, carbonates, &c, or fragments of natural stones, any variations in shade or texture may be produced, from the most delicate buff and drab, to the darkest grays and browns. In some cases it may be found more convenient to measure the ingredients directly into the mill, alternating with the different materials, in regular order, using for the purpose measures of various sizes, corresponding with the required proportions. When it is specially desirable to obtain stone of the maximum degree of strength and hardness, the paste may be returned a second or even a third time to the mill, but in all cases the mass must be brought to the characteristic state of incoherent pasty powder, or short paste….

47. All attempts to cheapen a matrix of Portland cement, by the substitution of common lime for a portion of the cement, result in a sacrifice of strength in

proportion to the extent of the adulteration, and the ratio of loss is not materially changed by the increased induration due to age. This is specially true in thick walls or other large masses of masonry, of which the portion which hardens by desiccation, and the absorption of carbonic acid at the surface, forms but a small proportion of the entire mass. When, however, the matrix is cement alone, and the proportion of sand is so huge that the grains are not all coated, and the voids not all filled or nearly so, **increased strength of the mortar beton is secured by adding a small quantity of common lime. The result is that both the strength of the matrix and the porosity of the mixture are diminished**. The aggregate volume, however, remains the same, while the section of rupture upon the same area, and the rupturing force, are both augmented. In other words, with large doses of sand and a cement matrix — for example, when the volume of the sand exceeds five times that of the cement loosely measured — there is an advantage in increasing the volume of the matrix at the expense of its strength, by **adding common lime powder, within the limits generally of one-fourth of the weight, or eight-tenths of the volume, of the cement.**

P57 MANUFACTURE OP HYDRAULIC LIME. 98. **In France, the practice of using lime that has been slaked in large bulk to a state of paste, by a copious use of water, has been entirely discontinued within the last few years, for the reason that only the fat or feebly hydraulic limes can be so treated.**

The presence of a sufficient amount of clay to confer eminently hydraulic properties upon the lime, engenders the presence of lumps and portions not susceptible of thorough extinction by the ordinary means, which would not only render the mortar heterogeneous, but might endanger the stability and safety of the masonry, by subsequent slaking within the work. Hence, whenever the advantage of employing hydraulic lime, either alone or mixed with cement, in order to confer energy and strength upon mortar, has been recognized, the lime is invariably used **in a state of freshly slaked, impalpable powder**. The use of fat lime has been very generally discontinued upon important works.

99. The following method is the one commonly practiced for obtaining hydraulic lime from argillaceous limestones containing from 12 to 24 per cent. of clay, the latter being composed of about 2 of silica to 1 of alumina.
There is no advantage in a high heat, like that necessary for burning Portland cement. **While still warm from the kiln, the stone is sprinkled with from 15 to 20 per cent. of its own weight of water, care being taken not to use enough to convert any portion of it into paste.** The slaking soon begins, and the stone falls to pieces, a portion of it in the condition of fine powder, while the rest remains in unslaked, or partially slaked, lumps of various sizes. The whole mass is then thrown together in large heaps, where it remains undisturbed for **six or eight days,** in order to complete the extinction as far as possible, and is then screened with a sieve of twenty -five to thirty fine wires to the lineal inch. **The portion which passes the screen is hydraulic lime of first quality,** if the stone be capable of yielding such, and, when used, requires only sufficient water to convert it into a stiff paste, in order to furnish an excellent matrix for mortar,

beton, or concrete**. The lumpy portions which do not pass the sieve either contain too much clay,** or have been burnt at too high or too low a heat to be susceptible of thorough extinction by exposure to the air, or aspersion with water. **The quantity of this lumpy residue will be great in proportion to the amount of clay in the stone, or the extent to which the heat in burning has been improperly regulated.** In some localities this residue is thrown away, as dangerous or worthless, **while in others it is the custom to grind it up separately, and mix it with the powder previously obtained by aspersion.**

When the burning has taken place at a heat suitable for making common lime, the residue owes its origin to the presence of clay, and may be a light, quick-setting cement, like the Roman. If so, its incorporation with the lime powder will augment the hydraulic activity of the latter, though perhaps not its ultimate strength and hardness. When the residue is too much under-burnt to slake readily, it may cause damage by a tardy extinction in the mortar, and should be rejected. **When burnt at a high heat, the residue may be Portland cement, if the stone contain from 20 to 22 per cent. of clay; or it may be inert clinker, partially or wholly vitrified, depending not only upon the amount, but also upon the form in which the silica and alumina exist in the clay.** The character of the residue, when ascertained, will determine whether it would be advantageous or otherwise to add it to the lime powder produced by slaking. (p59) and watchful care, in order that the introduction of ingredients that are worthless, or perhaps both dangerous and worthless, may be avoided….

…light, quick-setting cements are also produced by a moderate burning, from stone containing as high as 27 per cent., or even 30 per cent., of clay. Indeed, the amount of clay may reach, exceptionally, as high as 35 per cent. The cement made at Vassy, in France, the English and French Roman cements, and all of the American cements, (the Rossendale, Shepherdstown, Cumberland, Ooplay, and others,) belong to this class. In Austria the name of hydraulic lime is given to cements of this description. The Roman cement, made from the nodules of septaria derived from the Kimmeridge and London clay, is the best of the cements here referred to, though greatly inferior in strength and hardness to the Portland.

P61 Experience has fully proved that the heavy, slow-setting cements (the class upon which the name of Portland has been conferred, from the resemblance of the English variety to natural Portland limestone) **can only be obtained by burning, at a high heat, either limestones containing at least 20 and not more than 22 per cent. of clay, or an artificial mixture of the ingredients in similar proportions.**

Natural stone, suitable for this purpose, is found in Europe in the first range of the Jura formation, and on the lower slopes of the Alps in France and Austria, it generally occurs in numerous layers, which are very variable in the amount of clay which they severally contain, not exceeding from 10 to 15 per cent. in some, and reaching as high as 20, 25, and even 30 per cent. in others. The

layers are generally thin, and there are but very few of them in which the desired proportion of 20 to 22 per cent. of clay exists, homogeneously distributed. By far the greater number contain either less or more than this amount. In whatever manner apparently homogeneous limestones may be exposed to burning, at a high temperature, it is impossible to avoid the complete vitrification of some layers containing too much clay, while others, not containing enough, or less than 20 to 22 per cent, produce cements having lime in excess.

P62 107. It is to be borne in mind that Portland cement can only be made from a mixture, natural or artificial, of 20 to 22 per cent. of clay and 80 to 78 per cent. of carbonate of lime, and that the calcination must take place at a temperature sufficiently high to produce that peculiar softening which precedes incipient vitrification, it being at this stage alone that those silicates, upon the crystallization of which, in the presence of water, this cement depends for its peculiar merits, can be formed.

P65
ARTIFICIAL PORTLAND CEMENT.
113. Fully nineteen-twentieths of all the Portland cement made at the present day is artificial. In its manufacture, either the wet process of England, used also in making the natural Boulogne Portland, or the dry process of Germany, may be followed. A brief and very general description of these two processes is given below.

THE WET PROCESS. 114. The works in the vicinity of London employ both the white and the gray chalks of that neighbourhood. Exclusive of the flint contained in them they are nearly pure carbonate of lime. The clay is procured from the shores of the Medway and Thames, and the adjoining marshes and inlets. It contains about two parts of silica to one of all the other ingredients, comprising alumina, oxide of iron, soda and kali, carbonate of lime, &c.

First. The clay and the chalk are mixed together in the proportion of about 1 to 3 by weight, in a circular wash mill, provided with heavy harrows revolving on a vertical shaft, to secure the perfect reduction of the particles of chalk to an impalpable paste. The chalk is not allowed to mingle with the clay until it has passed a fine wire sieve.

Second. When a thorough mixture is thus effected, the liquid, resembling whitewash in appearance, is conducted to large open reservoirs called backs, where it is left to settle. The clear water, as it rises to the surface or the heavier materials subside, is drained off. A portion of that which remains mingled with the raw cement goes off by evaporation. During the time the mixture remains in the backs, samples are taken of it constantly and made into cement in sample kilns, to test the accuracy of the proportions. If any error in this respect is discovered, it is corrected by new material washed into the backs, or by mixing together the contents of two or more backs. The time required for the contents of the backs to obtain sufficient solidity to bear transportation to the drying stoves varies with the wetness or dryness of the season.

Third. When the raw cement mixture has attained the consistency of butter, it is taken out of the backs by shovelfuls, like stiff mud, and, in that form and condition, is removed to stoves heated by flues, and dried.

Fourth. After being dried — although it is not necessary to expel all the moisture — it is burnt with gas coke in perpetual bell-shaped kilns, which are fed daily from above and drawn below. The coke and raw cement are put into the kiln in alternate layers, in the proportion of about one part by weight of coke to two of cement, and the burning must be carried to the point of incipient vitrification. When properly burnt the pieces of cement called clinker, are of a greenish color, and are cracked, contorted, and much shrunken from the effects of the heat.

Fifth. The cement clinker is ground between millstones to that degree of fineness that when passed through a No. 30 wire sieve, of 36 wires to the lineal inch, there shall not be a residue exceeding 10 per cent.

Sixth. The cement powder poured into a measure, and not compacted by shaking or otherwise, should weigh not less than 106 pounds to the struck English bushel. Some engineers exact 110 pounds per bushel.

Seventh. Made into a stiff paste without sand, and immersed in water within twenty-four hours thereafter, the sample, when seven days old, should sustain a tensile strain, varying with the different uses to which it is to be put, of from 178 to 222 pounds to the sectional area of one inch. Few cements weighing less than 100 pounds to the loose bushel will sustain this test.

Lyman C R; Croffut WA (1870) A Helping Hand for Town and Country: An American Homebook of Practical and Scientific Information Concerning House and Lawn; Garden and Orchard; Field, Barn and Stable: Apiary and Fish Pond; Workshop and Dairy…New York. Moore, Wilstach & Moore.

How to set Posts Firmly. — **Take equal quantities of water lime and quicklime, and mix with sand as usual**; put two or three inches of mortar and coarse gravel in the bottom of the hole, so that the end of the post will not come to the ground; then set the post in, top-end down; fill in several inches of coarse gravel; pound it down; then mortar and more gravel, and so on until the cement is raised above the ground several inches around the post. Slant it away from the post in every direction, so as to turn off the water; then take coal tar and a brush, paint around the bottom of the post, and fill the interstices between the post and the cement with coal tar. Only mix enough mortar for one hole at a time. The post will be as solid as if set in stone; it don't heave out with the frosts and sag around and pull the boards off, as the water and air can not get to it.

Gillmore Q A (1871) REPORT ON BETON AGGLOMERE; OR, COIGNET-BETON AND THE MATERIALS OF WHICH IT IS MADE. (1871) PROFESSIONAL PAPERS, CORPS OF ENGINEERS, U. S. ARMY. Government Printing Office, Washington

Common or fat lime. — The lime should be air-slaked, or, better still, it may be slaked by aspersion **with the minimum quantity of water that will reduce it to an impalpable powder**. It should be passed through a fine wire screen to exclude all lumps, and **used within a day or two after slaking**, or else kept in boxes or barrels protected from the atmosphere.

In ordinary practice, when sand and hydraulic lime only are employed, it will be found to answer very well to mix the two together dry, with shovels, and then spread them out on the floor and sprinkle them with the requisite minimum amount of water. The dampened mixture is then shovelled into the mill and triturated, as already described. When a portion of Portland cement is used, it may also be incorporated with the other ingredients **before the water is added**, or introduced into the mixture in the mill, as may be preferred.

SEMPLE G ON LIME, MORTAR, AND GROUT. In The Irish Builder 1875

"I have from my childhood been well acquainted with the nature of lime and sand made in mortar of all sorts that have been used in buildings in these countries, and tried numerous experiments with them, on which, together with what I have observed and learned from old experienced workmen during the course of sixty years, I think I can safely affirm that good mortar made of pure and well-burnt limestone, and properly made up with sharp clean sand, free from any sort of earth, loam, or mud, will within some considerable time actually petrify, and as it were turn to the consistence of stone. I remember I had of my remarks from an old Scotch mason, which I shall give you in his own identical words, that is: "When a hundred years are past and game, Then gude mortar is grown to a stane (stone)."

"My father (who was a workman about the year 1775) often told me, and my own repeated observations convince me, that the method masons practised in former times, in building churches, abbeys, castles, and other sumptuous edifices in this country was to this effect: After they laid the outside courses with large stones laid on the flat in swimming beds of mortar, they hearted their walls with their spawls and smallest stones; and as they laid them in, they poured plenty of boiling grout, or hot lime liquid, among them, so as to incorporate them together as it were with melted lead, whereby the heat of it exhausted the moisture of the outside mortar, and united most firmly both it and the stones, and filled every pore, which (as the masons termed it) set—that is, grew hard immediately; and this method was taught to our ancient masons by the Romish clergy that came to plant Christianity in these countries, and I affirm that in many of such old buildings I have seen the mortar as it were run together and harder to break than the stones were. "But with respect to the matter in hand, I admit that mortar will not set or grow so soon hard in water as upon land; but I am fully convinced that good mortar will in reasonable time grow as firm and as substantial in water as upon dry land. But not dwelling upon mere reports I shall come to facts, and I do also affirm that in pulling down Essex Bridge, and repairing Ormond Bridge, we found the mortar of the lower using of wet bricks is very trying to the hands of workmen, and necessitates the wearing of pieces of leather to protect the inside of their fingers and their palms from being excoriated. There can be no doubt about wet bricks making a better bond with the mortar where it is good, and even with inferior mortar the walls would be the stronger by wetting the bricks before using.] "There are several sorts of limestones: some, indeed, set much sooner and harder under water than others, but any good lime properly mixed, and tempered with sharp clean sand, will bind and cement as effectually under water as above it, as I hinted before. What I mean by good lime, is that which is made of clean close-grained limestone. All marble is limestone, but all limestone is not marble. All marble will take a polish, but all stones that will burn to lime, will not take a polish. For instance, chalk will make lime, but it will neither polish nor make good lime for any purpose; therefore I advise you to choose the closest-grained, the hardest, and consequently the heaviest limestone for any work, but particularly for water-work. I need not explain what by sharp clean sand, but I shall give this caution, that it is better to put too much sand in your mortar than too little. I know workmen choose to have their mortar rich, because it works the pleasanter; but rich mortar will not stand the weather so well, nor grow so hard as poor mortar will do; if it were all lime it would have no more strength in comparison than clay." [We will continue some further extracts from Semple's work in our next, on the above materials. It will be interesting to see how far the practice of a century or a century and a-half ago, differs from the present in the selection of lime and sand, and its manipulation. We will also have occasion to quote the opinions and experiences of another old native architect in sand and mortar—an architect who seems to have had much practice in his day, but about whose time and works very little particulars are accessible. The architect alluded to is spoken of in Rutty's "Natural History of Dublin," thus: "Thomas Covey a most ingenious and experienced architect, having been employed in building many of the noted forts and barracks in this kingdom." Covey seems to have been a contemporary of Semple's; and it occurs to us, that his practice extended farther back in the eighteenth century than the latter. With all the modern chemical knowledge of building materials that exist, yet the greater portion of the building mortar used at present is complete rubbish, and disgraceful in the extreme to architect and builder. The mortar of the old builders tells its own tale to day, and proves that those who made it valued their name and reputation.]

THE OLD BUILDERS: THEIR METHODS AND MATERIALS. [Being Extracts, with Notes, from "Building in Water," by George Semple, Architect.] WE here continue Semple's observations on limestone, sand, mortar, and his account of the experiments he made in testing the nature, qualities, and strength of these materials for certain uses, but particularly with a view to buildings in water.

MORTAR, GROUT, AND CONCRETE; EXPERIMENTS. "As I have desired you to preserve and use even the powder or smallest fragments of the limestone, I shall here assign my reason for it, which is, that the powder of fresh quarried limestone (which you will find to have a sulphureous smell, partaking greatly of the smell of gunpowder) has this petrifying quality to a very high degree, and that calcination heightens that quality, is universally agreed to ; but yet it does operate in that manner used alone. For instance, if lime be left to lie by itself, either on land or in water for thousands of years, it would neither petrify nor come to any degree of hardness, nor would sand alone petrify, but when these two unite, they begin to operate powerfully upon one another. "In order to come at a thorough knowledge of this petrifying quality, I would recommend the following experiment :—**Take ten pounds of limestone, fresh quarried, pound it into very fine powder, and take the like quantity of sharp, clean, and fine sand; get thoroughly burnt roach lime hot from the kiln, the like quantity, put it into a vessel, and pour water upon it leisurely, and stir it gently till you find it is all dissolved, and as it were melted into a hot liquid; rub and thoroughly mix the flour of limestone with the sand, and <u>without letting the lime liquid have time either to cool or evaporate,</u> stir in and most effectually mix and work them all together very stiff, and beat them thoroughly on a clean boarded floor,** and then make this mortar into blocks, about the size of a brick; bury one of these blocks in very damp or wet ground, put another entirely in water, and keep a third in some dry place. Now I am confident that each of these three blocks will, in a reasonable time, actually petrify into stone, and become as much so as if they had been cut or wrought out of a rock, and that they will endure calcination, and become good lime afterwards, but not so rich as that from whence they were derived. And with respect to lime, that which is deposited in the bowels of its own natural mother, will grow the first into stone; that laid in the water will be the second; and that which is kept in a dry place will be the last, and of a short brittle nature. But the first, if in a large block, will not only become hard but stout and stubborn, and would stand and give stout resistance to a hammer or punch. The second would be more free, and the third fly off short. I apprehend that this little experiment is worthy of attention, because by ascertaining the time of these deposits, and trying the blocks from time to time afterwards with a tool or the point of a pen-knife, some useful knowledge might be obtained; but be that as it may, these are some of my reasons for recommending limestone.

However, where that cannot be conveniently got, you must make use of such hard stones as you can get, but be sure to have them broke to the sizes above mentioned, for such will most assuredly cement and unite together with the lime and gravel, and each of the stones will contribute to sustain the confidence reposed in them. Whereas, if one large stone was put in among them, it would not unite, but stand stiff, and thereby be a great means of shifting the weight from itself, and throwing it on the small stones that surround it, and consequently would overturn instead of supporting the weight which it was destined to bear.

For these, therefore, and many other reasons, I must earnestly recommend it to your practice to use no other but small stones in your stuffing. “You are also to take particular care that your sandy gravel is sharp and clean, and of that degree of fineness as may contribate proportionably to the solidity of the whole, **and not to throw your stones in one place, and your lime and sand in another, but let them be all equally mixed throughout the work,** and all this can be easily done, for let the water be what depth it will, or your hurry ever so great, this you may do, and you are not to neglect it ; and, observe also, that this sort of work can be much more effectually done in water than upon dry land, even admitting that it was to be done with wet grout, because these three materials being thrown in proportionably together, each stone and every particle of the gravel and sand will take possession of a place suitable to it, but the sand in particular will continue in quick motion till it finds out a place of rest proportionable to its size, and instantly fill up the most minute vacancy (provided that you observe these directions properly) and immediately become as compact and as solid as a bank of a gravel-pit that has been formed by nature.”

Semple's observations may be deemed old fashioned, but the facts they embody are worthy of attention at this day when worse lime, sand, or mortar in globo is used systematically than has hitherto ever been used in the progress or history of the building art. The making of good mortar does not receive the attention from modern builders that it deserves, and there are but few architects who bother themselves whether their works are carried out by the use of the cement or mortar they specify. Indeed, it is not too much to say that numbers of architects as well as builders do not know the constituent elements of good mortar. The theory of the hardening of mortar is even at present very imperfectly understood—the generally received idea being that a combination of silicate of lime and a compound of the carbonate with the hydrate is formed which, together, set in the solid mass. **Mortar is commonly prepared by mixing one part of freshly slaked lime, and two or three parts of sand with sufficient water to form them into a paste.** These quantities—if the lime be good and the sand sharp and clear—would make mortar of a good quality, but in the speculative buildings of the present day, and even in others where there exists no necessity for “scamping,” the sand that is used is little better than loam or “riddlings,” and the lime is poor and deficient in quantity. **Though these old builders had little or no knowledge of the chemistry of the components of good mortar, yet, by experience, they knew what good mortar was, and made it.** Their works still standing testify the fact, the mortar being harder than the stone. The cause of so many buildings falling at the present day before finished or immediately after being finished, may be attributed, in many cases, to the wretched mortar or cement used, which is a mere make-believe. Tall chimneys topple over, sacrificing many human lives, and putting their proprietors and builders to thousands of pounds expense: The cause may be summed up—bad work and bad materials.

The Irish Builder 1875 Google Books.

From an article entitled "Precautions in Building" in The Australian Town and Country Journal, 4 December 1875, discussing the poor quality of some mortars at the time:

. . . how is it that mortar is often such perishable stuff, that new buildings often require pointing after a few years? Almost invariably the reason is, that loam is used in order to economise the lime, whereas good mortar consists essentially of lime and siliceous sand alone, the lime in the state of hydrate.
The difference in the expense and trouble of making mortar which will last for centuries, and each century become harder; and useless rotten stuff, that would not last twelve months, is so trifling, that it must be from ignorance alone the mistake is now made. . . .

The lime should be fresh, the sand a sharp grit and quite clean, and the water pure and free from salt. The sand is made into the form of a basin, into which the lime is thrown in a quick state; water is then thrown upon it to slake it, and it is immediately covered up with sand; after remaining in this state until the whole of the lime is reduced to powder, it is worked up with the sand, and then passed through a wire screen, which separates the core. More water is then added, and it is well worked up or larryed for use.

Bruce Allen C (1886) Cottage Building, or Hints for Improving the Dwellings of Working Men and Labourers. London Crosby, Lockwood and Co.

Gravel is the best sort of earth for this kind of walling, and it should be of a loamy nature, with a large proportion of stones. It should be used as dry as possible, no cement being required, as it is held together by the force of cohesion alone.

The foundation upon which Pise walling is to be erected is formed of stone or brickwork, rising not less than six inches or a foot above the surface of the ground, and about six inches wider than the thickness of the intended wall. It should be
covered with a layer of Roman cement, stone, or tile, to prevent the rising of damp.
The foundation being completed, frames (p32) formed of planks of any convenient length are fixed by resting them on the edges of the stone or brickwork, on either side they are held together at the top and bottom by iron bolts, and kept apart at the top by pieces of wood called 'guides,' placed about three feet asunder. The Pise gravel is then thrown in, about half a bushel at a time, spread evenly, and rammed down till the surface becomes perfectly hard. The work proceeds in this way till the frame is filled to within an inch or two of the upper bolts. A portion of the wall being thus completed, the lower bolts are

drawn out and the upper ones slightly loosened: the frame is then raised bodily, till the lower holes rise above.
One course may be raised upon another, as thus described, immediately it is finished; but it is found more convenient, and makes better work, to carry on the courses horizontally, and keep them of an equal height. As the work proceeds, the tops of the walls are kept dry by copings or other means; and when completed to the necessary height, the roof (which should be already framed and ready for fixing) is immediately put on and covered in.

The spaces for the doorways and windows are formed by placing partition boards, fastened to the frame-work by bolts, of the breadth of the wall and height of the frame, on either side of the space to be left vacant; and pieces of timber, two or three inches thick, shaped like truncated wedges, are then inserted, with their bases in the wall itself, and with their smaller sides touching the partition boards: to these timbers the door-posts and window-frames are afterwards fastened. If the building rises above a ground story, sleepers or plates are laid on the inner side of the walls, as in the ordinary manner, for the floor-joists to rest on, the bolts are then replaced, and, together the top of the wall with those at the top, screwed up, and the work is proceeded with as before.

*A great improvement in the Pise walling, and which would make it as durable as stone or brickwork, would be effected by forming the angles and door and window jambs of brick or stone. The solid Pise itself is found to be, when well and carefully constructed, so hard, that when struck with a hammer, the flints break rather than start from the work. Pis4 walls, if thus constructed with stone quoins, doorways, and windows, would be well adapted for churches and schools in poor localities. See Wild's 'Cottages for the Peasantiy and for Emigrants,' 8vo.

(p33) The above method of forming Pise walling is different from the mode of building common in Devonshire and the West of England, and known by the name of cob-building, as will be seen, and is greatly superior to it, and far more durable.
The substance of which cob walls are made is loam or clay mixed with straw and moistened with water it is formed in; frames, in the same way as that above mentioned, but in courses of not more than one foot or one foot and a half in height it is then left some time to dry and become consolidated before a second course is imposed. The window and door frames are inserted as the work proceeds, and their respective openings cut out after the work is finished. The strength and solidity of cob walling depends much upon its not being hurried in the process of forming, and, when finished, it must be left some months to dry and settle.

Mud walls, or walls of clay lumps, are thus formed: The clay to be used is first freed from all large stones, and soaked with as much water as it will absorb; it is then well beaten, and a quantity of short old straw added, and the whole well and thoroughly mixed up together, continued by the treading of horses, or otherwise, till the clay becomes thoroughly broken, and of about the consistence of mortar: it is then put into moulds, 18 inches long, 12 inches (p34) wide, and 6 inches deep, without a bottom, and moulded in the same manner as bricks. These lumps are then dried in the sun, and laid in the usual manner with mortar.

(p40) Lime-ash floors are formed in several ways, according to the locality. One of the most approved methods is the following: the sand to be used, after being well washed and freed from earth, is mixed with lime ashes, in the proportion of two- thirds sand to one-third lime ashes, both thoroughly mixed together. It is then, after being suffered to remain for two or three days, tempered with water, and laid on the ground, or other surface to be covered, to the depth of about 3 inches. In two or three days it becomes sufficiently hard to bear treading on, and is then beaten all over with a wooden mallet, till it becomes perfectly hard, using at the same time a trowel and a little water to render the surface as smooth as possible….

In using plaster or stucco for the upper floors, broad battens, or reeds, are laid on the joists (hoop-iron in lengths to stretch from wall to wall would perhaps be found better) the upper surface or floor of plaster is then laid and finished as above described, and the ceiling completed between the joists.

(p96) *Specification of works to be done in the erection of cottages*

The walls are to be executed with sound, hard, and well-burnt bricks, laid in mortar. The mortar to be compounded of one- third, by measure, of well-burnt stone lime, and two-thirds of clean sharp sand, free from salt, both to be well beaten and worked up together. To lay the whole of the brickwork in English bond; the exterior to be worked fair and finished with a neat flat-ruled joint; the interior to be worked fair for colouring, or left rough for plastering. It is to be well bedded and flushed (p97) in with mortar…To thoroughly bed in mortar all the wall- plates, wood-bricks, lintels, bond-timber, and other work requiring to be set in brickwork, and to bed in and point round with lime and hair mortar all the door and window frames.

Darling & Curry (1882) Specifications for Proposed New Parliament Buildings for Ontario. Toronto Public Library.

This, a good illustration of the shift towards Portland cement, with residual lime use, intriguingly, for high status construction in a challenging climate.

Cover the top and footings of all walls with straw manure, and planks loaded with heavy stones, and take all possible precautions for keeping the building secure against rain and frost, from the day the building will be stopped at the approach of winter, until such time as the works will be resumed in the spring….

Provide and lay in cement mortar, cut stone bed plates of Waubaushene limestone…under ends of iron girders, and…cut stone head-pieces over same….Provide and fix under iron columns base stones of Waubaushene limestone, laid perfectly true in cement mortar….All piers in the south front to the ground and basement floors….are to be…properly wrought and laid in cement mortar….Prepare as directed, a damp-proof course of pitch, Stockholm tar and sand, and evenly spread same ¾ inches thick over the whole of the interior and exterior walls…

The whole of the inside surface of the outer external walls to have a wash of Portland cement and fine sand or wood ashes, put on with a brush as the work proceeds

The lime mortar to be composed of fresh well-burnt lime, run in a pan, clean, sharp grit sand and clear pure water, mixed in the proportion of one part lime and two parts sand, and to be freshly mixed for daily use…

The cement mortar to be composed of **one part lime, half part Portland cement, and two parts sand,** to be mixed in the most careful manner with pure, clean water….

If soft spots in the ground under the foundations should be met with, excavate the same, and fill in with concrete, composed of one part of broken stone not more than 2 inches diameter, one third parts of sand and one-sixth part of Portland cement, well-rammed into place.

Lay concrete floors throughout the entire basement, on a foundation of broken stones or hard brick rubbish 6 inches deep and well rammed down. The concrete to be composed of six parts of broken stone, two parts sharp coarse sand and one part of Portland cement, well mixed and rammed. Concrete 3 inches deep…

Lay brick floors…with hard burnt clinker bricks on edge, grouted between with grout composed of Portland cement one part, and sand two parts….

After the stonework is all completed and the roof in position, it must be cleaned down and tape-pointed with cement mortar…

All cut stone work…to be set in putty mortar, with close joints and properly washed, cleaned down, and pointed with Portland cement…rake out mortar joints when setting….

Bricklayer. Build the whole of the walls…with red bricks laid in English bond, well-bedded in mortar….Grout every fourth course with liquid grout….(Outside pressed bricks)…Lay pressed bricks with close joints to all walls in court-yard…The bricks to be laid in putty mortar, with the koints raked out. Dry tuck joint with red or black mortar on completion….(Inside Pressed bricks)…Lay of uniform red colour…with close joints in putty mortar….Rake out the joints and dry tuck on completion….(Vaults)…The vaults are to be built of hard burnt red bricks laid in mortar composed of one part of lime, one-half part of Portland cement and two parts of sand….

Plasterer….Lime to be fresh, clean and thoroughly well-burnt. Sand well washed and as sharp as possible….Mortar to be stiff, and the putty to be run at least one month, before being used. Hair to be dry, clean, long, well-teased and of the first quality….

The lime must be kept in a close air-tight and water-proof lime-house during the progress of the works, and no air-slacked lime will be allowed to be used. (Wire lath)….

The first coat to be composed of 1 part freshly-burned lime, 2 parts clean sharp sand and 1/6 part hair, well scratched to receive the second coat. The second coat to be the same as the first, but only one half of the amount of hair, to be worked to screeds, and made perfectly plumb and true in all respects. This coat to be well floated. The third coat to be composed of Guelph lump white lime, with ¼ or 1/5 part of plaster of Paris, to be thoroughly polished with a trowel, hand-float and brush….

Rough stucco. All the lobbies, corridors, passages, etc are to be finished in rough stucco, consisting of one part of fine stuff and two parts sand, to be gone over with a hand float covered with felt….

The Contractor to state the price per lineal foot for running Keene's cement base to all rooms throughout the building. The base to be 14 inches high, 2 inches thick, moulded; the backing to be of first quality English Portland cement, the face to be finished with second quality Keene's cement….

Hammond A (1890) The Rudiments of Practical Bricklaying (7th Edition). London. Crosby Lockwood and Son

This is an excellent text in its explanation of many aspects of bricklaying craft practice. In its discussion of mortars, their preparation and uses, it well-illustrates the state of flux, as well as the uses of traditional and then 'modern' materials, such as Portland cement, without much critical thinking – the typical characteristics of Portland cement are seen as a benefit, not a hazard, for the buildings they are used upon, though the materials it is displacing, both natural cement and feebly hydraulic limes were more benign. There is no consideration of cement-lime mortars here. Concretes and most ordinary mortars are being hot mixed, including pointing and putty mortars for gauged brickwork. The author recommends the use of 'superior' blue lias lime, whilst acknowledging the rarity of its use in London (and perhaps other metropolitan centres) at this time, where feebly hydraulic grey chalk/stone limes remain the norm, even for concrete. As the more hydraulic limes came to be used in keeping with the author's recommendations, sand-slaking and banking, with the lime allowed to cool before mixing with the sand laid around and over it for use became more common (see Frost, The Modern Bricklayer, 1925, as well as the British Standard 1951), to allow for both slow initial slaking and late slaking of the more hydraulic limes. Lime for plaster mortars is being slaked on site with a minimum of water, diluted after slaking to form a thin paste before being sieved and mixed, probably whilst still warm or even hot. Lime for use on its own as a putty is being slaked and diluted after slaking, but then laid down for a period to stiffen before use. The author advocates such laying down for the lime for coarse stuff also, acknowledging that this was not much done at this time. Its detailed description of the process and materials of tuck-pointing is invaluable.

CONCRETE

The 'limes' generally used for concreting in this country are obtained from Dorking in Surrey and Rochester in Kent, besides other places where the grey limestone is to be obtained.
This lime is ground and mixed with ballast while in a powdered state; it is then wetted and turned over twice, to mix them well together; this is then wheeled in barrows to an elevated position and thrown into the trenches, and afterwards levelled to receive the brickwork. This kind of concrete is mixed in the proportions of **one part of lime *(quicklime)* to six or seven parts of gravel.**

Although this kind of concrete is very much used in and about London, it is considered a very imperfect method, although economical as regards the labour: it proves most expensive in the material, for if the work was properly executed it would not require nearly so much of the latter *(??)*.
The method of concreting which is thought by most engineers to be the best is to reduce the lime to the state of a thick paste, and then it is made into a soft mortar by mixing about an equal quantity of sand with it before it is mixed with the gravel; and instead of shooting it down from a height and leaving it to settle by itself, it ought to be wheeled in upon a level and beaten with a rammer; for it is thought by being thrown from a height the materials separate, and by so doing some parts get more lime than they ought to have, while others get but very little.

LIMES, CEMENTS ETC.

Of limes, *blue lias* is reckoned the best in this country, because it is equally adapted for work below water-level or for moist situations as for dry ones. But it is **not generally used for ordinary building purposes,** principally on account of its taking but a very small proportion of sand before its setting properties are weakened; so it is thought best only to use little more sand than lime in the mixing.
This lime must not be made into mortar a long time before it is required as other limes often are, or else it will get so hard that it will be of very little use for the purpose of laying bricks.

This lime will take less water than the other limes usually do; **and it ought to be slacked several hours before it is made into mortar**, as some parts will take much longer than others. The principal supplies of the lias limestone are obtained from Aberthaw, near Cardiff; Barrow, near Mount Sorrel, in Leicestershire; and Watchet.

Dorking and Halling Limes. These may be considered the **principal limes used in and about London for making mortar,** owing to their taking a greater quantity of sand than any other before their setting properties are weakened, the usual proportions being three or four parts of sand to one of lime. But it must be remembered that very often it is not the quantity but the quality of sand that destroys the lime; for the cleaner and sharper the sand, the better the mortar will be.
These limes are obtained from Dorking in Surrey; and between Rochester and Maidstone in Kent.

Chalk Lime is seldom used in London for outside work, because it sets so slowly, and in damp places never sets at all. But it is used to a great extent for plastering the inside of houses, where there is no dampness; and **although it is not used in London for outside work, it is very much used in many parts of the country, where it is very cheap, and better limes are not so easily obtained.**

Cements. The cements used by the builder are of various kinds, such as Portland and Roman for external, and Keen's and Martin's for internal decorations.

Portland Cement is considered **the best for general use**, owing to its fine setting properties and its cheapness; for it takes a greater quantity of sand than any other before it is much weakened….and will take two or three parts of sand to one of cement for ordinary purposes….

Roman cement, although possessing many good qualities, is greatly inferior to Portland, and therefore is **but little used by the builder….**

FROST

If the brickwork is carried on in frosty weather, all walls must be carefully covered up with weatherboards, straw, or something that will protect them; if not, the frost will penetrate into the work, and greatly destroy the strength of all that which is damp….

Gauged brickwork

…Gauged arches, as a rule, are set in grey lime putty, brought to the consistence of cream. This is put into an oblong wooden box, about 2 ft by 1ft 9″ deep, for the setter to dip that side of the brick where the bed-joint is required. But in doing this, care must be taken that the bricks are neither too wet nor too dry; also that the putty is of such a thickness that it will give the brick just such a joint as the work requires; of course the brick should be held in the putty until it takes up the joint. If each course is bedded regularly throughout its thickness, the joint will be full and even on the face of the arch; and should it project a little, which is often the case, it ought to be left until the building is cleaned down, then they can be rubbed off level with the bricks, and so leave the face of the arch perfectly regular. This method only applies to gauge-work.

Pointing
(two main kinds:) tuck-pointing and flat-joint pointing….

Stock work with the white joint is most general in London; and the first thing necessary is to mix the pointing stuff. It is often thought best to colour the work, even if it is a new building, **to bring all the bricks to a uniform colour;** because some bricks are much darker than others, and therefore have a bad appearance when finished. This colour as a rule is made with green copperas in the proportion of one pound of copperas to five gallons of water…If the work is wetted before the colour is laid on, one gallon of colour will do 100 feet, more or less, according to the bricks and the season of the year.

Yellow Stopping – this is made with grey lime putty, and fine washed sand, in the proportion of one bushel of the former to three of the latter, and will take about 2 lbs of yellow ochre to each hodful of stopping. But…the workman will regulate it to suit the colour of the brick….in all cases let the stopping be a shade darker than the brick when it is dry.

White Putty. This is generally made with chalk lime (because it dries much whiter than grey lime and gives the work a better appearance), and silversand, or marble dust; the latter should be used whenever it can be obtained, on account of its giving a beautiful glaze. **It is usual to heat the pieces of marble until they fall to a powder, then screen it through a very fine screen or sieve before mixing it with the lime.** But silver sand is more generally used. **The lime is slaked and sifted through a fine sieve.** Sometimes oil or size is mixed with it to make it work better; and also to give it greater binding properties; but this **must be done while the lime is hot and dry,** and one pint of either to half a bushel of lime is enough.
If chalk lime is used, one peck of silver sand is sufficient for half a bushel of lime, but if grey lime is used, it will take double that quantity of sand.

If work is to be pointed, it must be well rubbed with pieces of the same brick as the wall is built with; this will give the work a level surface. Brush off all dust, and wet it well, then follow with the colour and give it one coat throughout; if it should require two coats, let one well set before the second is laid on…It s usual to (apply the stopping) in lengths of about 8 feet…and if this is taken for the length and 5 feet for the height, it will be quite enough at one time.
We sometimes see houses stopped in from top to bottom before ever a putty joint is laid on…whenever this is done, the stopping gets so dry and hard that the putty will not combine with it as it ought, and it will fall off in a very short time…When the length as before stated is stopped in, it is usual to rub it well with a piece of dry sacking…to give the stopping and bricks the appearance of being one uniform block. Brush off all dust, and, if necessary, damp it with the stock-brush carefully, so as not to disturb the stopping; then gauge the joints at each end of the rule as a guide for holding it; so that each course is of the same thickness, and each joint perfectly level…this gauging must be applied to all work, whether yellow, white or red…The cross-joints should be perfectly plumb from top to bottom of the building….The fine stuff is spread upon this rule, and afterwards taken off it with the jointer and laid on the work that is stopped in…after this, the rough edges are cut off with a knife, or ‘Frenchman’…This is the process for yellow or stock-work pointing.

Red brickwork is treated in many respects quite differently. The colour used for this is composed of 1 lb of Venetian red and 1lb of Spanish brown to 1 ½ gallons of water…This colour has no setting properties, therefore it is necessary to mix something with it that has…One of the best things to use for this purpose is white copperas. This must be dissolved in warm water, and 1 lb will set about 3 gallons of colour. Alum is also used in the same proportions; and sometimes half a gallon of stale beer to the same quantity of colour for setting.

Red Stopping is composed of 1 part of grey lime to 3 parts of fine washed sand (red sand would be better, as it would take less colouring). This is coloured with Venetian red and a small portion of vegetable black. (Proportions will vary according to the tone of particular bricks)….Red work is coloured throughout first, and then a second coat is laid on *after it has been stopped;* this is done very lightly, so as not to rub up the stopping.

White Brickwork…(only requires) rubbing down before pointing; but should there be any flesh-coloured ones among them, it is best to leave the dust on the face after rubbing it, and give the whole a coat of alum-water; this will set the dust so securely on the face of the bricks, that no quantity of water will wash it off, and will give the whole front a regular appearance. This is made with 1lb of alum dissolved in three gallons of hot water; and if it can be laid upon the work when warm, so much the better….

There are three sorts of putty used for this work, white, black and sometimes red….

Black putty requires ½ bushel of grey lime, slaked and finely sifted: 1 ½ bushels of very fine washed or silver sand and 12 lbs of lanp-black or vegetable black; the last named is much easier to mix with the lime and sand….

Red putty. (as above, but with Spanish brown pigment).

It is not always necessary to colour brickwork; and if the bricks are all of one colour, such as Suffolk whites, best reds, or malms, it is much better not to do so….

The putty joint in all tuck-pointing ought not to exceed a quarter of an inch in thickness.

Old Brickwork

When this is repointed, all the old mortar must be raked out of the joints. The whole front is then well rubbed with pieces of brick to clean off the grease and dirt, and well swept down with a hard broom perfectly clean, so that the colour may enter the face of the brick, and after this, it is given two coats of red colour or green copperas as the case may be…**the stopping in old work is generally smoothed down level with the face of the bricks with the trowel, and not rubbed in the way that new work usually is,** for very often it is stopped with brown or black stopping, if it is stockwork, and, of course, it would never do to rub it.

Flat-joint Pointing. This is of three kinds. The first is laid on with a trowel and cut off at the top only with the Frenchman…the second kind is cut off top and bottom…and the third is simply done by filling up each joint flush with the brick; then rub it over with a stock-brush or a piece of sacking, and next run a line in the centre with a jointer or anything that will mark it. Inside work which is to be whitewashed or coloured is the only work which is done with this kind of pointing. Washed sand and lime made into a stiff mortar is the only pointing ,aterial required for flat-joint pointing, but the darker the sand the better…in all kinds of pointing, the work should be kept well damped, for upon this depends the soundness of the pointing….

Plastering

…All internal plastering, as a rule, is done with chalk lime, hair, plaster of Paris, and Keen's and Martin's cements. The following are the different methods of mixing them:

Lime and Hair, or Coarse Stuff. For this purpose the sand should be clean, sharp and screened. Then form a pan to receive the lime. This is slacked in a tub, and sufficient water is **afterwards** added to bring it to the consistence of cream, and is then run through a fine sieve into the pan formed with the sand *(this will still be warm to hot)*. After a sufficient quantity is run out to carry the sand, the hair is thrown into the lime and thoroughly raked about with a two-pronged rake, so as to part the hair and mix it well with the mortar; but it would be better to run the lime into putty, **as for fine stuff**, and **when cold**, mix the hair with it; this will not be so apt to rot the hair, and so add to the stability of the work.
For this purpose bullocks' hair is generally used, and this should be well beaten with small laths, or else laid in water a day or two before it is mixed with the lime. The whole is then mixed and allowed to stand for a short time.

Fine Stuff or Putty, is made of pure lime, and is **mixed in the same way as lime used for coarse stuff;** but instead of running it into a pan of sand, this is run into a 'putty bin' built with bricks according to the size required, and allowed to remain there until the evaporation of water has brought it to a proper thickness for use; if the water rise to the top, it can be drawn off if required, and the putty will get dry the sooner.

For lime stucco the sand is mixed with the putty according to the quantity required. This stucco, when left for painting, is left smooth from the trowel….

Portland, Roman and lias cements are those generally in use for all external plastering; and as regards quality and cheapness, Portland is decidedly the best.

Walker F (1891) Brickwork: A Practical Treatise. Third Edition. London. Crosby, Lockwood and Son

The Metropolitan Building Act requires that the concrete shall not be less than 9 inches in depth, nor have a margin of less than 4 inches outside the first course of footings ; 6 inches is the usual margin in good work.

The following is a specification to govern the supply of materials, the mixing, and the putting into place of cement concrete. The whole of the cement to be Portland of the very best quality, very finely ground…

The mixing to be carried on upon a clean platform made of 9 inch X 3 inch deals, bedded solidly on sand, that the cement may not run off through the joints in the process of mixing. The concrete to be composed of four parts of broken bricks, broken porous stone, or Thames ballast; two parts sharp clean sand, free from loam or other impurities; and one of cement of the specified quality….

The concrete to be tipped from a height not exceeding 4 feet, and to be steadily rammed or struck with the back of a shovel until the cement or matrix flushes to the surface.

With regard to the acting properties of Portland cement when used with salt sand, or salt water, an experiment proved the use of salt water and salt sand perfectly satisfactory, both with Portland cement and lias lime, but there was no question as to their setting being retarded by their use." *Brunel.*

When blue lias is used for concrete, the proportion of parts and the mixing is the same as described in cement concrete….

MORTAR.
Mortar used by the bricklayer is made either from stone lime, lias, or Portland cement, mixed with a proper proportion of sand. Chalk lime should not be used, as the only setting that takes place in it is the formation of a surface crust, bearing a small proportion to the bulk. Stone, or gray chalk lime, as it is sometimes called, is generally used; it possesses slight hydraulic power, and will set if secluded from the air or in damp situations, and is capable of bearing three parts of sand to one of lime. For damp situations blue lias will be found to make the best lime-mortar.

It is eminently hydraulic, and becomes very hard, especially in damp places; but it will not bear so much sand as stone lime. The amount of sand should not exceed twice that of lime. **Lump lias is used for mortar; it should be well wetted, covered over with sand, and allowed a day to slack before being ground in the mortar mill.** The sand used for all mortars should be a clean, sharp, angular grit….

FLAT-JOINT POINTING.
This is the most general and durable kind of pointing. It should be made up of washed sand and stone lime several days at least before using it, that it may by the process of retempering acquire toughness, which will add very much to Its durability and facility of working. The joints should be finished flush with the work…and neatly cut off top and bottom with the Frenchman, and brushed off.

To ensure good pointing, the work should be well raked out and wetted not sparingly….

Copperas is very much used in connection with stock work, especially when the bricks are inferior or of a bad colour. One pound of green copperas is melted down with every 5 gallons of water. It should be mixed several days before required, and enough made to finish the job, that it may be all one colour. A small nob of lime mixed with the copperas very much heightens its colour. The copperas should be tried on the work to match it before being generally used, and weakened down by the addition of water if found necessary.

Richardson C (1897) Lime, Hydraulic Cement, Mortar and Concrete. Part I. The Brickbuilder Vol 6 April. Rogers and Manson Boston.

The Foundation of Cements.

The foundation of all cements, except those of a bituminous nature, which are used for binding together materials in masonry and concrete, is lime, the oxide of the metal calcium, which, although never found in the free state, is, in its various combinations, so widely diffused in nature.

Occurrence.
It occurs as carbonate in marble, in limestone, in chalk, in marl, and in shells, as sulphate in gypsum, as silicate in many minerals and rocks, and as phosphate in a few.

Forms of Importance.
Carbonate of lime in its purer forms and, when mixed with clay, in argillaceous or hydraulic limestones and some concretions, is of the greatest importance to the engineer and builder. From those forms in which there is but a small admixture of other substances lime is made. From those which contain clay or from a mixture of the pure carbonate with clay, hydraulic lime and cement are made.

CAUSTIC OR QUICK LIME.

The product of the expulsion of carbonic acid from the purer forms of carbonate of lime at a red heat is caustic or quick lime. It is the more or less pure oxide of the metal calcium, of which it contains about 95 per cent, when of the best quality. The process of making lime in this way is called lime burning. It is conducted in kilns of various forms in which a suitable temperature can be maintained.

Lime Kilns.
The kilns in use in lime burning are of both the intermittent and continuous types, and these again may each be divided into two classes, one in which the

fuel is mixed with the limestone, the other where the combustion is carried on in a separate chamber or furnace, apart from the stone.
Whatever the method of burning, the product is much the same, the advantage of one form over another being purely one of economy of fuel and completeness and regularity of burning. In the United States almost all the lime burning is done in kilns of the continuous type, with the fuel, either coal or wood, mixed with the stone. Wood is supposed to produce a better lime, as the ash is smaller in amount and not so siliceous. Where fuel oil, or gas is available, one of these sources of heat is the most satisfactory for lime burning.

Lime Burning.
Lime burning consists of raising limestone to that temperature at which it will lose its carbonic acid. It is usually carried on at a bright-red heat or about 1,700 degs. Fahr., although carbonate of lime begins to decompose at a lower temperature. **Too high a temperature is undesirable**, as this may produce a chemical combination between the lime and the impurities which all limestones contain to a greater or less degree. **If these impurities are siliceous, silicates of lime are formed which fuse and prevent the lime from slaking properly**. The formation of such silicates **may also take place with the ash of coal. This is known as clinker and is carefully thrown out in drawing the lime from the kiln.** .Smaller particles, however, cannot be separated and injure the quality of the lime.

It is necessary that a current of air should pass through the kiln, when lime is burned, to carry off the carbonic acid, as carbonate of lime, when heated in a vessel from which the gas cannot escape, is not decomposed and no lime is formed. A current of steam is even more desirable than air, but this is never used in practice, as it is hardly economical. **The limestone is, however, often sprinkled with water which has, to a small degree, the same effect.**

SOURCES OF LIME.

Limestone and marble are the usual sources of lime, but it can also be made from chalk, some marls, and oyster shells. Chalk is not found in this country, marl is used only for Portland cement, and oyster-shell lime principally for fertilizers and purifying gas. **Stone lime is preferable for building purposes to any of the other forms.**

CHANGES IN LIMESTONE IN BURNING.

The changes which a limestone undergoes in burning are loss of weight by the removal of carbonic acid, water, and organic matter if present; change of volume, of density, of color, and of hardness.
Massive limestones, or marbles such as are used in making lime, have a specific gravity and density of from 2.65 to 2.75. Lime in the form of the stone from

which it is made, that is, in lumps, is porous owing to the loss of carbonic acid and water. It has, therefore, a density of only 1.5 to 1.85, although the specific gravity of the lime is usually about 2.8 to 3.1, and that of the pure oxide 3.16. The color of many limestones is due to organic matter which burns away and leaves the caustic lime white. If it does not burn away it is due to mineral impurities which are undesirable.

The hardness of lime is of course inferior to that of the stone from which it is made owing to the porous condition in which it is left, and there is a slight increase in volume due to the expansion of the gas in the stone.
From pure carbonate of lime exactly 56 per cent, of oxide or caustic lime should be obtained, but owing to the loss of water and organic matter, as well as carbonic acid and to waste, this figure is never reached except when there are admixtures of clay or silica. Then the loss of carbonic acid is not as great as from pure carbonate of lime. When the limestone contains much carbonate of magnesia the product of burnt lime may be considerably reduced, as this carbonate contains more carbonic acid than carbonate of lime. **Such a limestone is known as dolomite and is of inferior value for making lime.**

Effect of Impurities.

We find limestones which are nearly pure, having 97.2 per cent, of carbonate of lime, in the form of white marble, and 96.0 per cent, in a blue limestone. In contrast are stones which contain silica or clay as well as silica, as shown by the presence of iron and aluminum, and those which are mixed with carbonate of magnesia. All the forms have their peculiar properties. **The purest should be, of course, selected for lime burning**. **The impurities in a limestone have an important influence on the character of the caustic lime made from it.**
A quicklime prepared from a limestone comparatively free from impurities and consequently nearly pure calcium oxide is called a rich or fat lime. With the increase of admixture of other substances the lime becomes poor, that is to say, it does not slake easily, and **when this exceeds 10 per cent, the burnt stone begins to slake with more difficulty or fails to do so at all, and can be no longer regarded as a mere lime, but is hydraulic or magnesian lime depending upon whether the admixture is clay or carbonate of magnesia.** Already with from 5 to 8 per cent, of clay in the limestone, the lime has **hydraulic properties**, and these increase until it is very highly hydraulic with 25 per cent.

When the admixture is magnesian and the rock is composed of carbonate of lime and magnesia, without clay, the **resulting lime does not attain hydraulic properties, but merely becomes poor and fails to slake readily.** With even 10 per cent, of magnesia, lime becomes poor, and with a larger amount still more unsatisfactory. Lime from dolomite, or magnesian limestone, which is very common in the United States, contains about 21 per cent, of magnesia, **and is of inferior value for building purposes. Too much of this lime is used in the country, and it should be avoided as far as possible under all circumstances.**

Lime containing a large amount of magnesia, if free from impurities may be used, however, for furnace linings as it resists heat well and is very basic, not fusing as readily as pure lime in presence of silica.

COMPOSITION OF CAUSTIC LIME.
The composition of commercial quicklime is varied, depending on the kind of rock from which it is made. The following are analyses of some typical limes, found in our markets: —

1)New York, from limestone: Lime 95.6%; Magnesia 0.6%; iron and alumina 0.8%; silica and silicates 1.2%
2) Baltimore County, from marble: Lime 95.3%; Magnesia 0.8%; iron and alumina 0.9%; silica and silicates 2.2%
3) Washington DC, from dolomite: Lime 73.3% Magnesia 21.4%; iron and alumina 4%; silica and silicates 0.9%
4) Connecticut, from limestone: Lime 85.1%; Magnesia, iron and alumina 5.8% silica and silicates 2.8%
5) Connecticut, from dolomite: Lime 55.3%; Magnesia 36.4% iron and alumina 3.2%; silica and silicates 1.4%
6) West Virginia, from limestone: Lime 89.9%; Magnesia 2.2%; iron, alumina, silicates 5.8%
7) West Virginia, from limestone: Lime 74.2%; Magnesia 2.4%; iron and alumina 1.5%; silicates 3.9%

It appears that limes which are 95 to 96 per cent, pure are the best that are attainable commercially and that they are frequently less pure. When fresh from the kiln lime would, ofcourse, show no loss on ignition, but on storage it absorbs water with great avidity from the air until, as in that numbered seven, it has reached 17 per cent., when it is nearly half air slaked. **Fresh lime, or that which has been carefully protected from the air, is of much greater value for building purposes, although too often this is unattainable.**

IBID April 1897 part II

CHARACTERISTICS OF GOOD LIME.

PURE calcium oxide consists of 71.4per cent of calcium and 28.6 per cent of oxygen. Its ordinary form is that of a more or less porous earthy white solid which, in a pure condition, is very resistant to heat. It has, as has been shown, a great affinity for moisture and must be preserved out of contact with air from which it absorbs water and carbonic acid.
Caustic lime, for building purposes, should have the following properties — :
Except when made from coarsely crystalline marble, or from marl or shells, it should be in hard lumps.
It should be white, or nearly so, in color. Lime of a yellow or brownish color, with veins of silicious matter, is inferior.

It should be free from semi-fused or fused stone, showing over-burning, and from unburnt ash of fuel or clinker.
It should contain less than 10 per cent, of impurities, but often has more.
It should slake rapidly, showing that it is rich and fresh.
Good lime in lumps should weigh, as packed, with about 40 per cent of voids, 60 lbs. to the cubic foot, 75 lbs. to the bushel, and from 220 to 230 lbs. to the barrel of 3 bushels. If ground or in powder it will weigh less when packed loosely, but when well shaken down it will weigh as much as 270 lbs. to the barrel. A lump of hard lime, I ft. cube, would weigh about 95 lbs., having a density of 1.52.

THE SLAKING OF LIME.

Caustic lime combines with water with the evolution of heat to form calcium hydrate. **Every 100 parts of caustic lime require 32 parts of water for its conversion into hydrate. If one third of its weight of water is sprinkled on quicklime it becomes very much heated, cracks open, if of the massive variety, swells up and falls to powder.**
The heat developed is sufficient, at times, to ignite wood. The quicklime becomes slaked lime. **This consists of 75.7 per cent, of calcium oxide and 24 3 per cent of water.** It has a specific gravity, when pure, of 2.07. **The increase of volume in the process of slaking is due to the formation of steam, which tears the particles of lime apart and expands the mass.** If a current of dry steam is passed over heated caustic lime confined in a tube it becomes slaked without any increase of volume.
The smaller the amount of impurities the more energetic is the act of slaking and the greater the increase of volume. In rich and pure limes the increase of volume under ordinary conditions will be **over twice** that of the unslaked material, including the voids, while with very poor limes it may be much less. **The statement frequently made that lime increases three volumes in slaking** *(Vicat, amongst others)* **is based upon the increase in volume due to the excess of water often used in slaking.** In this case it may be as great as 3.4. **The amount of increase of volume for the same lime may be very variable, depending on the conditions under which it is slaked.** We have seen that it is a reaction between water and caustic lime where much heat is generated, and that to the steam evolved is largely due the expansion of the lime. **It is evident, therefore, that the provisions for augmenting and retaining this heat are of importance**. If water is added slowly but comparatively little heat is developed, while slaking in an open space will not give as much as when it occurs in a closed box. Cold water also will not accelerate the action as well as warm. **The amount of water used has a marked effect on the volume of slaked lime produced. With an equal volume of water the increase for a good, rich lime is from 2 to 2.4.** An increase or reduction in the amount of water or in the volume weight of the lime may increase or diminish this.
The following experiment shows the effect of different amounts of water on an ordinary lime

Volume of water	Increase in volume
½	1.6
1	2.0
2.5	2.5

With poor dolomitic lime the volume increase was only 2 to 1.7

It appears, therefore, **that the increase of volume to be expected of any lime is dependent on conditions which may be very variable.** For example, a peck of lump lime with 44 per cent, of voids between the lumps gave, on slaking with its own volume of water, 2 pecks of fine powder of slaked lime, which is a fair increase in volume for lump lime. From I peck of closely packed lime, however, 2.5 volumes of slaked lime were obtained. The difference in volume is of course due to the difference in weight of the lime as packed in the two ways.
The proper comparison, therefore, is one of volume from weight 10 lbs. of caustic lime, for instance, should give 6.8 bushels of slaked lime, an increase of volume of 2.25. Gilmore found in some of his experiments increases as great as 2.46, 2.83, 3.21, 2.40, and 2.14, but the weight of lime in his unit volumes was much greater than occurs in practice, and large amounts of water were used in slaking **so that he was dealing with paste instead of dry slaked lime.** …

General Totten found in experiments on slaking limes no increase in volume greater than 2.27 when no more than an equal volume of water was used. The increase of volume is commonly used as a test of the quality of lime.
Air Slaking.
Slaked lime is also produced by exposure of caustic lime to the air, from which it absorbs sufficient water to become hydrated, as well as some carbonic acid. This is known as air-slaked lime. **It is of little value for mortar making, because there has not been enough heat produced in its formation to tear apart and expand the particles which will alone enable it to form a rich paste.** The larger particles have also to a certain extent become hardened on their surfaces by a kind of setting, and by the absorption of carbonic acid from the air.

Practice in Lime Slaking.

In practice, the slaking of lime for mortar is conducted in several ways. **Either sufficient water is sprinkled over the lime to combine with it and resolve it to a powder, providing also an excess for that lost in the form of steam, or an excess is added at once, sufficient to make the finished mortar.**

The first method is in some ways the best, because a finer, looser powder is produced, in the manner already described, and **because the poorer limes are much more easily and thoroughly slaked in this way with the aid of the greater heat evolved. When too large an amount of water is used the development of heat is prevented, and the operation is much less complete.** The particles of lime which are left unslaked go into the mortar in that condition and, being subsequently slowly hydrated by the moisture of the air, expand with injurious effect after it has been used. The popping of mortar, frequently noticed in the walls and ceilings of dwellings, is due to this cause. **For the same reason, given above, all the water which is to be used should be added at once or nearly so. If it is added in small portions the effect is to cool down the whole mass and prevent thorough slaking.**

We have seen that a third of its weight of water is theoretically necessary for slaking lime. **In practice, however, to allow for vaporization as steam, and for the slight excess necessary to bring all the particles in contact with moisture, this amount must be increased to at least an equal weight**. It is difficult to say what volume of water should be used, as this depends on the volume weight of the lime, which is variable. It is ordinarily about that of the lime itself plus its voids. **Practically it is convenient with fat lime to use two and a half volumes of water, which will suffice for slaking and for the production of a paste. Poor magnesian limes require less.**

As heat assists in the expansion of the lime, the operation is best carried on in a covered box. One half of the water is added at first, and as soon as the lime begins to fall to pieces the rest is poured in and thoroughly mixed with the slaking material. The entire mass will thus be raised to a high temperature. The operation thus carried on takes place rapidly, but it can hardly be considered completed until the mass has become cool, or until even after a longer time. In cold weather it is advantageous to use warm water, especially with poor limes.

Water for Slaking and Mixing.
Water used for slaking lime and making mortar should be pure. When it contains salts, such as chlorides and sulphates, the mortar effloresces and gives rise to stains. **For this reason sea water is unsuitable, although it has been used successfully with hydraulic cement.**

LIME PASTE OR CREAM.
The lime paste made in the manner previously described may be too stiff for mortar if a very rich lime has been used, or if a very large volume of sand is to be employed in making the mortar. There is no difficulty in thinning it, however, to the proper consistency, depending on the character of the mortar to be made. **If, however, more than two and a half volumes of water are added to the lime at first the resulting paste will have a tendency to be granular and to contain lumps which, in the thin cream, it is impossible to break up.** In careless practice as much as three or four volumes of water are sometimes used in slaking lime, when it is intended to make a mortar with a large volume of sand. **Stretching the cream in this manner to make a small amount of lime fill a large volume of sand voids makes the resulting mortar very porous when dry.**

Good paste of lime should not contain at the extreme more than three volumes of water as compared to the measured volume of the quicklime.
As there are generally some hard and unslaked particles even in the best limes, **the cream should be run through a sieve if possible, after standing over night,**

before mixing it with the sand. It should be remembered that the longer the paste stands before use the smoother it becomes. As will be seen later, this improvement goes on after the mortar has been mixed.

Part III May 1897

LIME MORTAR.

Mortar is a mixture of some cementing material with sand.
Lime mortar is composed of lime paste and sand, with the addition, for certain parts of plastering, of hair and similar bonding material.

Necessity of Sand in Mortar. —

Good cream of lime might be used alone as cement, as it hardens on exposure to the air by drying, were it not that, under these conditions, it shrinks and cracks very badly. It is, therefore, customary, both on this account and for economy, to temper it with sand. This should be clean, sharp, and rather coarse for masonry, finer for plastering. When discussing hydraulic mortars and concretes there will be occasion for a further consideration of sand and its qualities and proper use.

Proportion of Sand to Lime.

A mortar made of lime paste should, theoretically, contain so much sand that the cream of lime **will more than fill the voids**, that is to say, the volume of the mortar should be greater than that of the sand. **In fact it is necessary that it should considerably more than fill them in order to thoroughly coat each particle and provide for shrinkage. If too much sand is present there is not sufficient cementing material to make a firm bond, while on the other hand, if there is too little the mortar will tend to shrink and crack on drying. If too little lime is used the deficiency must be made up with water, that is to say, the paste is made very thin.**

In ordinary sands the voids are from 30 to 40 per cent, of the volume of the sand. With sand, having 40 per cent, such as that which is used for the best lime mortar, 1 volume of paste would fill the voids in 2.5 volumes of sand with no excess. **As a matter of fact, practice leads to the addition of only from 1.25 to 2 volumes of sand to 1 of paste which, when the caustic lime yields 2.5 volumes of paste, means 3 to 5 volumes of sand to 1 measured volume of caustic *(quick)* lime.** In this way a plastic mortar and one that will not crack in drying is made. **With fat lime and sharp sand 3 volumes of sand to 1 of lime forms a rich mortar and these proportions are often required in the best specifications. The greater part of the mortar used in ordinary brickwork is, however, made with 5 volumes of sand, or more, and is probably satisfactory.**

The experiments *tables omitted here)*, it will be noticed, were carried out with a pure and fat lime. The sand in use was not very coarse, and had 40 per cent, of voids. From the results the following conclusions may be drawn: —

Slaking. — Slaking with a volume of water equal to the measured volume of the lime, with 44 per cent, of voids, or with a weight of water equal to the weight of the lime, gives a volume of paste, after the addition of another volume of water, equal to that of the water used, only. **This paste is very thick.**
Slaking with two volumes of water, with the addition of half a volume, after slaking is finished, making 2.5 volumes of water in the paste, gives 2.56 volumes of paste which is thick and rich.
Slaking with 2.5 volumes of water added all at once gives 2.71 volumes of thick paste suitable for good mortar.
Slaking with 3 volumes of water added at once gives 3.12 volumes of thin paste. Slaking with 4 volumes in the same way yields 4.12 volumes which is too thin to be of value.
It appears, then, that slaking with 2.5 volumes of water added at once is the most advantageous method of procedure, and that but a small departure from these proportions on either side will result in forming a less satisfactory paste.

Density.
The density of the paste naturally decreases with the increase of water it contains.

Volume of Sand for Mortar. —

If but twice the volume of the lime is added to the paste in the form of sand, the resulting mortar is too rich. It contracts and cracks on drying. Three volumes of sand make a very rich and satisfactory mortar such as should be used for laying up fronts and pointing.

Five volumes form a mortar good enough for ordinary brick masonry where not exposed to moisture, while greater amounts of sand furnish mortars which are very porous, but serve for cheap work in absolutely dry situations.

Density of the Mortars. —-The density of these mortars is, of course, proportionate to the amount of sand they contain. Their porosity is larger the more water the paste contains.

Volume of Mortars. — With a small amount of sand the volume of the mortar is, where twice the volume of the lime is sand, 66 per cent more than the volume of the sand; **where the volume of the sand is three times the lime, 46 per cent, more;** where 5 volumes, 1 7 per cent.; with 7 volumes the mortar is less in volume than that of the damp sand owing to its closer compaction.

The amount of water in the paste plays a prominent part in the relation of the volume of mortar to the volume of sand and to the amount of sand which can be added to any paste.

Composition of Wet Mortars. —

Calculation shows that these varied mortars contain from 30 to 15 per cent, by weight of water or from 1.7 to 3.9 per cent, of lime, but the relation of water to lime increases with diminution of the amount of lime, that is to say, with the increase of sand, from 1.7 in the richest mortar to 3.9 times as much water as lime in the poorest mortar with the thinnest cream. These figures show why the richest mortar contracts the most on drying from loss of the largest amount of water, and that the poorest mortars, although not having as large a per cent by weight of water still have not enough lime to form proper cement.

Composition of Dry Mortar.—
The dry mortars contain from 22.6 to 45% of lime, but as the two extremes of combination would never be used in practice, it appears that mortars as ordinarily mixed may contain from **15 to 8 per cent, of lime**. This corresponds to the results obtained by analysis of many mortars actually employed in masonry.

Strength of Dry Mortar. —
The set of mortars acquired **by simply drying out** gives them a tensile strength of from thirty to forty pounds per section of 1 sq. in. *(.20 to .28 mpa)* and a crushing strength of about 85 to 95 in 2 in. sq. section *(.59 to .66 Mpa).* There is not such a difference between the different kinds of mortars at this stage, but with age there would be but little increase in strength with the poorer ones. The physical properties of the latter are also against them as they cannot resist moisture.

Professor Smith's tests, given in the January number of The Brickuuilder, show also that **with a diminution in the cross section of the mortar there is an increase in the strength per square inch of section**. This is due to the liability of shrinkage cracks in tests pieces made with larger cross sections.

General Conclusions. —
It appears that fat limes should be slaked with 2.5 volumes of water, added at once in a closed box, to obtain the best and largest amount of good paste; **that with this, three times the volume of the lime in the shape of moist sand may be mixed for fine work, such as pointing, plastering, and in places exposed to dampness, and that 5 volumes of sand is not too much for ordinary brickwork.**

The amount of mortar which a barrel of lime, of average weight, under the same conditions as in the experiments, would yield is,

Parts sand	parts water	cubic feet

3	2.5	16.5
4	2.5	20.6
5	2.5	24.8

or, 4 cu. ft. of lime with 2.5 parts water, and 4 volumes of sand would yield 22 cu. ft. of mortar, which, according to authorities, is sufificient to lay one thousand brick in ordinary brickwork with coarsely drawn joints. With more compact work one barrel of lime will lay one thousand bricks. A barrel of poor or magnesian lime will not yield more than three quarters of these quantities.

Amendments to lime mortar.

Lime mortar, made of ordinary rich lime, is not suited for masonry where it is exposed to water, dampness, or to the absorption of water by capillarity from the soil. The hardest lime mortar will absorb 15 to 21 percent of its volume of water. **If hydraulic cement cannot be substituted for it, on the score of economy, a certain degree of improvement may be made in the mortar by mixing it with finely ground brick-dust or burnt clay, which yield the necessary silica to make it somewhat hydraulic and less porous; or a certain portion of the lime, one third, for instance, may be replaced by hydraulic cement. This is seldom done, as it is cheaper in the end to use cement alone.**

Effect of Frost on Lime Mortar. —
The most thorough experiments of Tetmaier show that **lime mortar cannot be used at temperatures below freezing, especially with porous materials, and attain any bond.** No additions, such as salt, soda, glycerine, or sugar will prevent lime mortar, when frozen for any length of time, from becoming a friable material.

Mortar can be mixed by hand or machinery. **The latter is of course preferable.** When done by hand, **as is the common custom**, the operation should be carried on in a closed box, or on a surface through which water cannot escape, and with suitable walls of sand. Machine mixing is much more thorough than that done by hand, and is coming into vogue rapidly in our larger cities where there is such a use of mortar as to make it an economy to prepare it on a large scale. Such mortar is more regular in composition than hand made. All the material can be accurately gauged and weighed, which is most desirable.

SETTING OF LIME MORTAR.

The setting of lime mortar is the result of three distinct processes which, however, may all go on more or less simultaneously. **First, it dries out and becomes firm. Second, during this operation, the calcic hydrate, which is in solution in the water of which the mortar is made, crystallizes and binds the mass together.** Hydrate of lime is soluble in 831 parts of water at 78 degs. F ; in 759 parts at 32 degs., and in 1136 parts at 140 degs. **Third, as the per cent, of water in the mortar is reduced and reaches 5 per cent., carbonic acid begins to be absorbed from the atmosphere. If the mortar contains more than 5 per**

cent, this absorption does not go on. While the mortar contains as much as 0.7 per cent, the absorption continues. The resulting carbonate probably unites with the hydrate of lime to form a subcarbonate, which causes the mortar to attain a harder set, and this may finally be converted to carbonate. The mere drying out of mortar, our tests have shown, is sufficient to enable it to resist the pressure of masonry, while the further setting furnishes the necessary bond.

There is also supposed to be a formation of lime silicate in the course of setting. The evidence in favor of this has been obtained by German investigators from the analyses of very old mortars.

It **appears more plausible** that the soluble silica found in these mortars was derived from silica contained in the limestone from which the lime was derived, and which was rendered soluble in the process of burning by combining with lime, than that it was due to any combination of the lime of the mortar with the silica of the hard quartz grains of sand, which seems highly improbable. In these old mortars the amount of carbonic acid is high, and in several cases it is sufficient in amount to have converted the lime and magnesia completely to carbonate, although the percentage of these bases is in most cases much greater than good practice demands.

Millar W (1898) - Plastering, Plain and Decorative Shaftebury Donhead reprint

There are three methods of slaking 'lump-lime' - the first by immersion; the second by sprinkling with water; and the third by allowing the lime to slake by absorbing the moisture of the atmosphere. Rich limes are capable of being slaked by immersion and kept in a plastic state. They gain in strength by being kept under cover or water. All rich limes may be slaked by mixing with a sufficient quantity of water, so as to reduce the whole **to a thick paste.** Lump lime should be first broken into small pieces, placed in layers of about 6 inches thick and uniformly sprinkled with water through a pipe, having a rose at one end…**and covered quickly with sand. It should be left in this state for at least 24 hours before being turned over and passed through a riddle.** The layer of sand retains the heat developed and enables the process of slaking to be carried out slowly through the mass…the quantity of water should be properly regulated, as if over-watered a **useless paste** is formed. If a sufficient quantity is not supplied, a dangerous powdering lime is produced. Slaking by **sprinkling and covering the lime lumps** is frequently done in a very imperfect and partial manner, and portions of the lime continue to slake long after the mortar has been used. Special care must be exercised, and sufficient time allowed for the lime to slake when this method is employed….

In most parts of England the lime for making coarse stuff *[for plastering]* is generally slaked by immersion, and is run into a pit, the sides of which are usually made up with boards, brickwork, or sand, the lime being put into a large tub containing water. When the lime is slaked, it is lifted out with a pail, and poured through a coarse sieve. It is sometimes made in a large oblong box, having a moveable or sliding grating at one end to allow the lime to run out, and also to prevent the sediment from passing through.

In preparing lime *[mortar - for Millar lime and mortar are interchangeable]* for plasterwork, the general practice in the north of England is to slake it for three weeks before using…**Now, while all this precaution is taken in regard to plastering, in making mortar for building, the lime is slaked and made up at once, and it is frequently used within a day or two. But this is not all. Limes which are unsuitable for plasterwork, known as hot limes, and which, when plasterers are obliged to use, must be slaked for a period of - not three weeks, but more - nearly three months before using, and are then not quite safe from blistering, *are the limes mostly used for building purposes.***

MORTAR …for plasterwork it is usually composed of slaked lime, mixed with sand and hair and is termed 'coarse stuff'…In Scotland the coarse stuff is generally obtained by slaking the lump lime…with a combination of water sprinkling and absorption. **The lime is placed in a ring of sand, and in the proportion of one of lime to three of sand, and water is then thrown on in sufficient quantities to slake the greater portion.** The whole is then covered up with the sand, and allowed to stand for a day; then turned over, and allowed to stand for another day; afterwards it is put through a riddle to free it from lumps, and allowed to stand for six weeks to further slake by absorption. It is next 'soured' - that is, mixed with hair ready for use. Sometimes when soured, it is made up in a large heap, and worked up again as required for use. This method makes a sound, reliable mortar. In some parts lime slaked as above is mixed up with an equal part of run lime. This latter method makes the coarse stuff 'fatter' and works freer….

Grinding is another process for making mortar or 'lime', and **if made with any kind of limestone is beneficial.** It thoroughly mixes the material, increases the adhesion, adds to the density, and prevents blistering. When there is a mortar mill, **either ground or lump lime can be used,** and the coarse stuff may be made in the proportion of 1 part lime and 3 parts sand….The process should not be continued more than thirty minutes. Both material and strength is economised if lump lime is slaked before being put [immediately?] into the mill….It should be borne in mind that a complete incorporation of the ingredients is essential **in the slaking and mixing for coarse stuff,** whether done by hand or machine.

…Smeaton found that well-beaten mortar set sooner and became harder than mortar made in the usual way…

…Lias lime should be mixed dry with sand, and damped down for seven or ten days to ensure slacking. It should not be used fresh for floating or rendering.

…Mortar made from Hydraulic Limes should be mixed as rapidly as is compatible with the thorough incorporation of the materials, and used as soon as practicable after mixing, because if put aside for any length of time *[or knocked up later] its setting properties will deteriorate.* ….

…proverb among Scotch masons: "when a hundred years have past and gane, then gude mortar turns into stane" …

….many of our limes are comparatively poor in carbonate, and associated with silica, alumina, magnesia, and oxide of iron, which may either be partially combined in the natural state, or enter into combination with the lime during the process of calcination *[and perhaps during hot mixing, if same present in sands or other aggregates]*, **and these limes might be termed slightly hydraulic.**

Newspaper Cutting: GOOD NEWS FOR SOME WORKERS. 1888.
Hitherto British bricklayers have been on the verge of poverty all through that part of the winter when frosts have been keen. They supposed that whoever else worked, they needs must be idle. Now, however, we learn on the authority of our Consul General in Norway that this all comes of our workers being too conservative in following the methods which satisfied their fathers and forefathers. Norwegian bricklayers rather prefer winter work, because the walls built then dry quicker and better. The advantage is simply the result of using, on dry bricks, unslaked lime as mortar, and preparing the mortar in small quantities immediately before it is used. The remedy for idleness is so plain and simple that it ought to commend itself both to British masters and men.

Powell George T (1889) Foundations and Foundation Walls For All Classes of Buildings. New York. William T Comstock.

New York City Building Laws, 1871

Section 11. **Mortar, of what materials, and how used.** The mortar used in the construction, alteration, or repair of any building shall be composed of lime (quicklime) or cement, mixed with sand, in the proportion of three of sand to one of lime, and two of sand to one of cement, and **no lime and sand mortar shall be used within twenty-four hours after being mixed;** and all walls or parts thereof, below the curb level, shall be laid in cement mortar, to be composed of cement and mortar, in the proportion of one of cement to two of mortar. No inferior lime or cement shall be used. **Sand.** And all sand shall be clean, sharp grit, free from loam; and all joints and all walls shall be well filled with mortar. **Inside plastering....**The proportion for the scratch coat is as follows: one part quicklime, four parts sand and one quarter to one third measure of cattle or goat's hair. It is usually put on from three- eighths to one half inch in thickness.

On the preparation of Common Mortar

The lime, when perfectly burnt in the kiln, should be packed in casks or air-tight vessels, and kept free from all moisture, and should be opened only as required....
The purest limes require the largest proportion of sand and water, and harden in less time than the common limes...
Various substances are **sometimes** added to mortar to increase its **tenacity** (*good word*), and they impart thereto the principles of hydraulic cement **to a greater or lesser degree.** They chiefly consist of burnt clay, ashes, scoriae, iron scales and filings, broken pottery, bricks, tiles etc. They are useful in mixing with lime or mortar to increase their hardness, but they must be pure and reduced to a fine powder...
...Some of the mason builders in New York and vicinity who are large contractors, make building mortar for brick walls of the following proportions: one barrel of lime; six barrels of sand - sharp bank sand, which is calculated to lay 1000 bricks...The proportion of one measure of quick-lime, either in lumps or ground (when lumps exceed three inches each way they require to be broken), and five measures of sand is about the average used for common mortar by many masons. However, architects generally specify one part of lime to three of sand...
Where there is heavy working strain brought on piers, or parts of walls, it would be best to use some proportion of cement as the tenacity or cohesion of some mortars is **not to be relied upon until four to six months after being used. This is only important where structures are heavily loaded or of considerable height....**
Common mortar of ashes is prepared by mixing two parts of fresh slacked lime with three parts of wood ashes and when cold to be well beaten, **in which state it is usually kept for some time... by some it is considered equal to some of the water cements.**

Baker I O (1890) A Treatise on Masonry Construction. John Wiley & Sons New York.

Common lime is used in making the mortar for most architectural masonry, and until recently it was generally employed in engineering masonry; **but the opinion is rapidly gaining ground that only cement mortar should be employed in engineering structures requiring great strength or subject to shock.** On most first class railroads hydraulic cement mortar is used in all masonry structures. This change in practice is largely due to the better appreciation of the superiority of hydraulic cement as a building material. Although it has been manufactured for about fifty years, the amount used was comparatively limited until within the last twenty years. At present large quantities are imported from Europe, and very much more is made in this country. **Hydraulic lime is neither manufactured nor used in this country….**

120. The ordinary method of slaking lime consists in placing the lumps in a layer 6 or 8 inches deep in either a water-tight box, or a basin formed in the

sand to be used in mixing the mortar, and pouring upon the lumps a quantity of water 2 ½ - to 3 times the volume of the lime.
This process is liable to great abuse at the hands of the workmen. They are apt either to use too much water, which reduces the slaked lime to a semi-fluid condition and thereby injures its binding qualities; or, not having used enough water in the first place, to seek to remedy the error by adding more after the slaking has well progressed and a portion of the lime is already reduced to powder, thus suddenly depressing the temperature and chilling the lime, which renders it granular and lumpy. It is also very important that the lime should not be stirred while slaking. The essential point is to secure the reduction of all the lumps. Covering the bed of lime with a tarpaulin or with a layer of sand retains the heat and accelerates the slaking. All the lime necessary for any required quantity of mortar should be slaked at least one day before it is incorporated with the sand.
After the lime is slaked the sand is spread evenly over the paste,, and the ingredients are thoroughly mixed with a shovel or hoe, a little water being added occasionally if the mortar is too stiff. One barrel (230 Ibs.) of lime will make about 8 cubic feet of stiff paste.

121. The common mortar of quicklime and sand is not fit for thick walls, because it depends upon the slow action of the atmosphere for hardening it; and, being excluded from the air by the surrounding masonry, the mortar in the interior of the mass hardens only after the lapse of years,or perhaps never.* Themor- tar of cement, if of good quality, sets immediately; and, as far as is known, continues forever to harden without contact with the air. Cement mortar is the only material whose strength increases with age. Owing to its not setting when excluded from the air, common lime mortar should never be used for masonry construction under water, or in soil that is constantly wet ; and, owing to its weakness, it is unsuitable for structures requiring great strength, or subject to shock. Its use in engineering masonry has been abandoned on all first-class railroads. Cement is so cheap, that it could profitably be substituted for lime in the mortar for ordinary masonry.

127. Lime with Cement. The advantages of a slow-setting mortar can be obtained by mixing common lime with a rich Rosendaie mortar. The lime should be reduced to a paste before being added to-the cement. The addition of the lime gives the double advantage of a rather slow-setting mortar and a cheap one, but decreases the strength of the mortar. No experiments seem to have been made to determine the activity of a mixture of cement and lime; but from practical experience it is well known that the addition of lime somewhat retards the setting of cement mortar. The extent to which the induration of different cements is affected by the addition of lime seems to vary directly with their activity.
It has long been an American practice to reinforce lime mortar by the addition of hydraulic cement. The mortar for the ordinary brick-work of the United States public buildings is composed of one fourth cement, one half sand, and one fourth lime. Of course a cement mortar is better, but it costs more.

Heath AH (1893) Lime and Cement, a Manual on Their Treatment and Use in Construction. London & New York. Spon

Lime, used as a cementing material for constructive purposes, is obtained from natural limestone, to which in some cases is added a siliceous, or silico-aluminous substance….

The rocks utilised for the production of cementing limes are mainly composed of calcium carbonate…or of carbonate of lime and silicate of alumina; in some instances a proportion of magnesia is present in combination. **The use of these magnesian limestones is generally confined to the locality where they are abundantly found, and where better limes cannot be easily procured.**

(when calcined)…the loss of carbon dioxide from a pure limestone is 44%; and that from a magnesian limestone may be still larger…Calcined lime for building purposes can be purchased in the lump or in a powdered state, and is called quick or caustic lime….A cubic foot of ordinary building lime in lumps will make about 1 1/6 cubic feet of slaked lime powder. This fine powder is quite dry, if the proper proportion only of water has been added, about 1/3 by weight, or as 18 to 56.

This property of slaking is most marked with the purer calcium oxide. When silicate of aluminium (clay) is present in small quantity, the action is less intense and slower; it decreases with the increase of the silicate, until a proportion is reached at which the slaking may, for all practical purposes, be said to cease.

The powdered lime is used as an adhesive and cohesive body by mixing it with just as much water as will yield a stiff paste; this paste is inserted between the surfaces of the two bodies to be cemented together, completely filling the space, and is then left undisturbed to harden into a substance resembling a limestone.

The chemical change occurring during the process of hardening of pure lime is mainly due to the absorption of carbon dioxide from the atmosphere. When this absorption takes place in the presence of moisture, the conversion of the hydrate into a carbonate is accompanied by a crystallisation, the crystals adhere closely to one another and to any rough surface with which they are in contact. This is the setting, and induration, of the pure lime mortar.

In pure limes the process of conversion is slow, especially when the area of surface of the lime paste, exposed to the direct action of the air, is small compared with the bulk; and, when the surface is converted, the carbonate forms a coating which hinders the ingress of air to the interior of the mass.

Hence in a large mass of materials cemented together with pure lime, the hardening of the central portion may be delayed for a long period, if not entirely stopped. The thickness of the film of carbonate formed on an exposed surface may be from ¼ to 1/8 of an inch in the first year, and the increase lessens in each succeeding year.
Moreover, the crystalline form of pure calcium carbonate is soluble in water containing carbonic acid, and consequently will be gradually washed away if exposed to rain. Hence pure limes are fit for use only in the form of thin coatings to rough surfaces of solid structures, having a maximum of surface exposed to the air, and at the same time under protection from the weather.

The purest natural limestones contain some insoluble silicates of iron and alumina, varying in quantity from 1 to 6 %. Less pure limestones may contain from 15 to 30 % of similar impurities, and are materially affected thereby; they slake more slowly, and with less intense chemical action, the increase in bulk and the heat generated are less than are found with pure limes.

Some natural limestones contain a sensible proportion of clayey matter (silicate of alumina). When such a limestone is calcined, reduced to powder either by slaking or by grinding, and used as a cement, it is found to be independent of direct contact with the air for the development of the property of hardening, and, moreover, the indurated body is insoluble in water….**These limes therefore are well suited for use as cementing bodies for all constructive purposes; and when the aluminium silicate attains a certain percentage, the cement paste will harden readily even when submerged in still water, and will be perfectly insoluble. Such limes are termed hydraulic limes, and are of great value to the engineer.**

If the aluminous limestone does not contain, or is not mixed with, sufficient clayey matter for the complete conversion, after calcination, of the caustic lime into these silicates, acertain amount of the lime will be left uncombined, which when exposed to the moisture will become a soluble hydrate and be liable to be washed away. The oxide will also expand in the process of hydration, a result which may be harmful.

Limes containing about 8 to 12 % of suitable clayey matter are termed **moderately** hydraulic. When water is added to the calcined lumps, they break up to a small extent, and heat but little, the slaking is incomplete. When used as a cement the paste or mortar sets underwater after…15 to 20 days, but never becomes hard. It hardens satisfactorily when used for building above ground.

Limes containing 15 to 18 % of clay may be termed hydraulic. Slaking begins about an hour after the wetting of the calcined lumps, and is incomplete; the increase in bulk is small. A cement paste sets after 6 to 8 days' immersion in still water and finally hardens to the consistency of a soft stone.

Eminently hydraulic limes contain from 20 to 30 % of clayey matter. The action of slaking in these limes is delayed and the lumps of calcined lime do not readily crumble into powder, sometimes not at all. A mortar paste hardens on the third or fourth day of immersion in still water, and continues to harden for a long period; after the lapse of a month it is hard enough to resist the action of running water.
The property of hydraulicity may be conferred on pure limes by the admixture of substances containing soluble silicates. A volcanic ash, called pozzolana (consisting of about 50 % of silicic acid, 16% of alumina; 12% of oxide of iron, 9% of lime, and small portions of other substances) added to pure lime, confers hydraulicity, and the resultant mortar may be used in engineering construction. Smeaton used Aberthaw (actually Watchet) infra-lias lime, and pozzolana shipped from Civita Vecchia, in the construction of the Eddystone lighthouse in 1756-9.

Pozzolana is found near Pozzuoli, on the west of Naples, at other placeson the flanks of Mount Vesuvius…(and doubtless elsewhere)…it is a volcanic ash. It is partly powder, partly coarse grained, or like pumice stone scoriae or tufa stone, and the colour ranges from white, whitish gray, blackish gray, brown to vilet red. The best is said to be the white to blackish-gray.

It is largely used in the district, and in Rome; sometimes it is mixed with a pure lime only, sometimes the fine powder is mixed with 70 parts (by volume) of pozzolana, consisting of both powder and small stones, which serve instead of sand; the mortar is used for brickwork. The mixture of equal bulk of sand and pozzolana powder can be used for hydraulic work. Pozzolana differs much in quality, analyses give the following range of composition:

Silica from 44-56%
Alumina 10-15%
Sesquioxide of iron 7 to 29%
Lime 1 to 10%
Alkalies 5 to 15%
Sand 0 to 5%
Water 0 to 9%

A similar volcanic ash is found in the Eifel district, between Bonn and Andernach, on the west bank of the Rhine, and is called 'trass'; and another volcanic ash used in the Mediterranean is known as Santorin earth (from Santorini)….Trass is largely used in Holland in fresh-water and marine submerged engineering work; and Santorin earth has a great reputation for conferring hydraulicity on rich limes. Analysis of trass from Andernach…:

Silica 46-57%
Alumina 14 to 20%
Magnesia 1 to 7%
Iron oxide 5%

Lime 2 to 11%
Potash & soda 8 to 15%

Similar volcanic ash is stated to be procured in central France (the Vivarais district); also at Aden (Yemen)…

It is stated that in the neighbourhood of Catania, on the east coast of Sicily, and south of Mount Etna, there are beds of clay which have been covered by deep streams of molten lava, with the result that the clay has been burnt and converted into a small red gravel, or powder. **This material, mixed with a little quicklime and water, furnishes a mortar which** has been used for centuries with excellent results. The buildings of Catania are stated to be constructed of stones of lava cemented together with this mortar, which is also used as an external, and internal, plaster….so excellent is the mortar that house walls are built four and six stories high of this (small and irregular) material, which is, in fact, a lava rubble concrete. It has also been used in athe construction of a harbour breakwater…, the small lava rubble being moulded into large blocks liberally cemented together with this mortar.

(analysis of Santorin earth):

Lime 2 to 3%
Silica 65-69%
Alumina 13 to 16%
Oxide of iron 5 to 5%
Magnesia 1 to 2%
Potash, soda etc 7 to 8%

It is mixed with lime and sand to form mortar. For the Mole works at Fiume the proportions used were

6 cubic feet Santorin earth
2 of slaked lime
1 of sea sand.

(moulded blocks submerged after between 24 and 36 hours after manufacture). If the mortar is to be used under water when newly mixed, **more lime should be added…..**

…Sharp-edged clean broken stone is the best for beton, and the Santorin earth should be washed free from earthy particles:

Broken stone 19 cubic feet
Santorin earth 17.5 cubic feet
Slaked lime 6.31 cubic feet
Sand 1.65 cubic feet.

Used at Pola.

Finely powdered burnt brick, provided that soluble silica be present (that is, the bricks have been made of a plastic greasy clay and not of a snady clay), will also confer this property of hydraulicity on pure limes. The burnt brick, or burnt clay, must be thoroughly burned, at least to the point of incipient vitrifaction; and the crushing must be carried out to the finest possible state of division; the finer the particles, the more effective is the result of the admixture. The caustic lime must also be reduced by crushing, or by thorough slaking, to a similar degree of fineness.
A method sometimes adopted consists in mixing together chalk and a plastic greasy clay in certain proportions; the ingredients are dried and crushed together. Sometimes they are reduced to a moist paste by grinding together in a mill, then the mixture is calcined; this, however, is an imperfect way of making Portland cement….

On the Continent, these expedients are still adopted to a limited extent, in Great Britain they are rarely used, owing to the comparative cheapness of, and the excellent results obtained from Portland cement. In distant countries, where neither good natural limes, nor Portland cement, are so easily procured, these mixtures of the purer limes and the various natural silicates may be used with advantage….

SALE OF LIME AND SAND

In the London district chalk lime is sold by weight and by measure. About 2 cubic yards of ordinary chalk lime in lump make a ton weight; and 16 heaped bushels in the lump make a cubic yard, and 14 heaped bushels of ground lime powder…A measure of lump lime, a London yard, or load, of lump lime is 27 cubic feet and contains a very little more than 21 striked bushels. A cubic foot is about 0.78 of a striked imperial bushel, and this bushel is 1.283 cubic feet. A hundred of lime is 100 pecks, or 25 bushels….
The London yard of lump lime is from 21 to 22 striked bushels and makes 18 striked bushels of ground lime (nine 2-bushel bags)….

The approximate weights of quicklimes are:

Gray chalk lime (ground) 40 to 47lbs per cubic foot
Blue Lias lime, ground 49 to 70 lbs.
The values vary with the quality, condition and age of the lime.

Lias lime is sold by weight and by measure, in the lump, and in the ground state, in 2-bushel, and 3-bushel bags. Of ground lias lime, one ton makes ten 3-bushel bags; of Portland cement, of ordinary quality, about 20 bushels make a ton weight.

Sand...about 18 ½ striked bushels make a ton of dry sand.

LIMESTONE USED IN LIME-MAKING, THE UPPER, MIDDLE AND LOWER CHALK ETC

The upper, or white chalk is found plentifully…in a belt or tract of country running from Dorsetshire to Cambridgeshire and Norfolk, thence to the north of Lincolnshire and into Yorkshire as far north as Flamborough Head….
It is a carbonate of lime, containing from 1 to 6% of silicates and other bodies… When calcined, it loses nearly half its weight and becomes a caustic lime, fit for use, when mixed with water to a paste, in plastering thin coats on rough surfaces protected from the weather. It is called rich or fat lime….

The gray chalk of the lower chalk division is also carbonate of lime, containing a little alumina (from 5 to 15% of silica, iron oxide and alumina); when the silicate of alumina is above 8%, the lime is good for cementing purposes. It is found in the same localities as, and beneath, the white chalkl and it is known in the London district and the southern counties as 'Gray stone Medway', 'Halling' (Rochester), 'Wouldham', 'Burham' (Kent); 'Mertsham', 'Dorking' or 'Guildford' lime. Sometimes it is specified simply as 'stone' lime; the term probably arises from from a fallacy of Marcus Vitruvius, that the harder the stone, the stronger the cement made from the calcined stone. ….Gray chalk limes in slaking do not greatly increase in bulk (??), and only a moderate heat is generated; the time of slaking is longer, and the chemical action is less intense than with white chalk limes (??.

The lumps of calcined lime are heaped up in a hollow formed in sand, the heap is wetted, and is then covered with dry sand, and sometimes also with sacks, to keep in the heat and assist the slaking. This is a good cementing material for ordinary constructive purposes above ground. The chalk is generally burnt in 'flare' kilns…the fuel is not mixed with the stone…
White chalk withstands heat better than the gray; a clayey limestone requires less fuel for burning than the white chalk, but is liable to be overburnt.

The lower chalk marl, of the lower chalk division, is calcium carbonate containing rather more silicate of alumina than the gray chalk, but the proportions are variable and uncertain….From its want of uniformity, it is not an important source of supply of cement. It has been used near Cambridge, and near Hitchin, in the preparation of Portland cement. Chalk marl near Farnham is stated to contain as much as 21% of silica and alumina.

In the Oolitic series are many beds of limestone; some, interspersed between the marls of the Kimmeridge clay, also those in the Oxford clay, may be found to yield a good hydraulic lime, but it is advisable to test the stone, both by analysis and by experiment, before using for any important purpose….

A good lime is furnished by some fissured limestone beds near Peterborough, also near Stamford, the lime is called 'blue and gray stone lime'. In the Corallian beds of the Lower Oolite are the clayey limestone beds in the Vale of Pickering, and along the Howardian Hills, in Yorkshire; they are called cement stones, or 'throstler'.

In Yorkshire also, but of the Lower Greensand formation, are the septaria nodules of the Speeton clay, north of Flamborough Head; these stones were sent to Hull for cement-making.

Where the proportion of alumina in the clayey matter is excessive, the mortar made of the lime is liable to crumble away on exposure to the weather; if the silica be insufficient to convert the caustic lime into a silicate, the mortar is liable to expand in setting, and to produce cracks in the brickwork. To counteract this tendency, care must be taken to ensure perfect slaking of the quicklime before use.

The great beds of oolitic limestone supplying the valuable building stones are generally not of themselves capable of furnishing a good quality of cementing material.

Portland stone about 1.2% silica
Ancaster stone, about 1 to 2% silica
Ham Hill stone contains about 4.7% silica and 8.3% alumina and iron oxide
Barnack stone 0to 2% silica; 1.3% alumina etc
Bath stone 1 to 2% silica
Chilmark of Tisbury stone about 10% silica; 2% alumina etc.

LIAS LIMES

In the Lias series are thin beds of limestone separated by seams of clay. These…contain silicate of alumina in the proportion of from 10 to 30%, with carbonate of lime, and small proportions of other ingredients.

Analyses give as an average..:
Carbonate of lime 68-80%
Silica 20 to 10%
Magnesia about 1 ½%
Alumina about 3 to 4%

An excellent cementing material is procured from these lias beds at Lyme Regis, Watchet, Keynsham, Street and Pylle; also at Westbury, and at Charlton, near Shepton Mallet; at many places in Gloucestershire; from the infra-lias beds of the Aberthaw promontory and at Lliswerry, near Newport (Monmouth). In Warwickshire, the district around Harbury (near Leamington, on the GWR_, also Kineton, Wilmcote, and other places near Stratford on Avon; at Stockton near Rugby; and northwards to Long Bennington, about midway between Grantham and Newark; and near Kirton Lindsey in Lincolnshire, are some of the places where the lime is produced….this useful limestone is found plentifully, though the quality may not be of uniform excellency for cementing purposes. In north Lincolnshire and in Yorkshire, the character of the beds appears to alter. There are also small patches of lias beds near Whitchurch, in Shropshire; near Carlisle, and in Antrim and Argyllshire.

It must always be borne in mind that permanence in the proportions of the ingredients of a natural limestone is not to be expected; not only do the different seams of stone vary widely in the character of their composition, but also there is no certainty of permanent composition in any seam.

The quicklime produced by calcination of **selected lias limestone** is **eminently hydraulic,** its faculty of hardening when submerged in water grows with the increase in the proportion of silica. **It gives good results as a cement for all ordinary work, either above ground or beneath <u>in damp situations, or even in still water….</u>**

The stone is calcined in open topped cup=shaped kilns, the fuel is interstratified with the limestone, about 6 to 7 tons of coal are burnt to produce 25 tons of lime.

The **calcined stone must be thoroughly ground to a fine powder, then spread in a layer of about 12 inches thick on the floor of a dry, weather-proof shed and exposed to the air for two or three weeks before it us used in building.** A good plan is to fit up the aeration shed with shelves, or trays, on which the lime can be placed.

Lias lime can be slaked in the ordinary manner, but ample time must be given – not less than three days, and the slaked lime must be sifted through a fine-meshed sieve, to reject all coarse, imperfectly slaked particles.

If used when freshly ground, it is liable to expand when hardening in the mortar joints, and cause rupture in the masonry. The expansion is due to the delayed slaking of impure caustic lime.

An analysis of Aberthaw limestone gives:

Calcium Carbonate about 86%
Magnesium carbonate abt 2%
Silica abt 8%
Alumina abt 1%
Iron Oxide abt 2%
Water abt 1%

An excellent 'Portland' cement is now made from the lias limestone, and the clay of the beds separating the seams of stone. If due care is taken to mix the lime and clay in correct proportions, (after analysis), the cement will be good;

but the variableness of composition of each ingredient renders the manufacture more difficult than with pure chalk and clay.
MAGNESIAN LIMESTONE

The term…is applied to a carbonate of lime containing upwards of 10% of magnesia; and is also given to a well-defined geological formation beginning in the south near Nottingham and extending northwards…to the sea at Tynemouth.
Some limestones of this formation contain, however, only a small proportion of magnesia…(as little as 1 ¼% to about 98% calcium carbonate…
In some instances it yields a fairly good cementing material, more or less hydraulic according to the % of aluminium silicate present…

Magnesian limestone must be burned at a high temperature to develop its hydraulic properties; if the temperature be low, the caustic lime absorbs water slowly, and seems devoid of hydraulic properties.

A pure magnesian cement hardens in water, but a limestone containing a large percentage of magnesia is likely to be untrustworthy, as the caustic lime absorbs water rapidly, while the caustic magnesia absorbs slowly, so that the lime may have set in a mortar and be hardening while the magnesia is (still) undergoing hydration, and its subsequent setting may cause disintegration of the mortar.

The Rosendale cement, so largely used for engineering works in the US, is derived from an argillaceous magnesian limestone of the Appalachian range. It is stated that there are 17 distinct layers of limestone, which vary considerably in quality. The stone is burned, mixed with coal, in continuous draw-kilns, part of the charge being withdrawn every 12 hours. The calcined lumps are carefully picked over, those underburnt being returned to the kiln. The lumps are first cracked in a roller mill and then ground between stones, the fineness being about 95% to pass through a 2500 mesh sieve. It is packed in paper-lined casks.

CARBONIFEROUS LIMESTONE

…Is composed mainly of calcium carbonate. There is usually…a small percentage of aluminium silicate, from about 2 to 10%...in some cases, a good cementing material is produced.
It is burnt in open-topped kilns, about 1 ton of coal is burned to produce 4 tons of lime….continuous or 'draw' kilns….

In general the carboniferous limestone is suitable for making mortar to be used above ground, and in dry situations; its use is mainly confined to the locality in which it is found.

In the Silurian and Devonian geological system are numerous beds of limestone; some are used for fluxing purposes in the smelting of iron ores, others for

constructive purposes, where accessibility and favourable conditions of working and of transport permit.
Among these beds are the Wenlock limestones, quarried near Dudley and Walsall, the Woolhope limestone; the Ludlow, Aymestry, Bala and Llandeilo limestones, in the Silurian system; and the Petherwin limestone in the north-east of Cornwall, also at Barnstaple, Ilfracombe, and Lynton, of the Devonian system.

Walsall limestone:

76 ½% calcium carbonate
magnesian carbonate 2%
silica 13%
alumina 0%
iron oxide 2 ½%

Woolhope limestone:
Calcium carb 67-76%
Mag carb 2 to 3%
Silica 14-20%
Alumina 4 to 6%

GYPSUM
UK sources: Isle of Axholme (Lincs); Newark, Elton, Orston to Tutbury near Uttoxeter, in Chesire, between Whitehaven and Carlisle, Purbeck beds near Battle. Also Aust (Glos), Droitwich, Syston (Leics) Watchet and Somerton

…Has a normal composition of about 47% sulphuric acid; 33% lime: 20-21% water. 120-130 degreesC firing temp for good quality….absorbs water with great avidity….adheres firmly at first and sets rapidly, but its adhesive strength diminishes with age….

CALCINATION OF LIME

Limestone is sometimes calcined in the open air in heaps built up of alternate layers of stone and fuel, the sides and part of the top of the heap being thickly covered with clay, to prevent loss of heat and to secure some degree of iniformity in burning. The method wastes so much fuel that it is seldom employed, also the ashes from the fuel are liable to be mixed up with the lime….

The dimensions recommended for kilns are, height twice the largest diameter for flare kilns; for running kilns, 3 times, 4 and even 5 times. Diameter of orifice of chimney of flare kiln, 1/3 the largest diameter, hearth opening about ¼. Diameter of top of funnel-shaped kiln, 5 times the diameter of the lower orifice, which is usually about 20 inches.

NATURAL CEMENT

…The London clay nodules from Sheppey and Harwich contain from 60-70% calcium carbonate; 18-20 of silica; 6-10 of alumina; 0-2% of magnesia and a little iron oxide, but their composition is very variable…..In making mortar, about 1/3 by volume of water is added to the powder, and the paste is thoroughly well beaten with a trowel, or shovel, in the mixing; the more it is mixed the better and harder becomes the indurated cement.,,,sets in from 5 to 15 minutes, under water in from ¼ to 1 hour. When mixed with sand the time of setting becomes 1 hour and upwards according to the proportion of sand…

this quick-setting cement is valuable for the protection of mortar joints and of slow-setting Portland cement concrete from the wash of the waves and of tidal or river currents; a coating ¼ inch thick of Roman cement is efficient. It is also used for the same purpose in submerged foundation work, and fo coating damp walls…

The proportions of cement and sand generally used for foundation work are 3 cement to 2 sand; and for plastering, 2 cement to 3 of sand,

(Section of Limes and mortars in India)

Kunkar – impure limestone: 72% calcium carbonate; 15% silica; 11% alumina and iron oxide, but probably the silica is in the form of sand….Clay may be added to the Kunkar before burning…
Highly burned brick, or pottery, crushed to a fine powder, is frequently added to quicklime, and used in the place of sand for mortar making….

It is stated that a good hard hydraulic mortar was made of kunkar, burnt clay, calcined ironstone and sand. The same ironstone mixed with lime and calcined, gave a good hydraulic lime….

For lime concrete…(equal parts of) lime and brick powder (and broken stone to 45-50% of the bulk. – 1 of broken stone:1/4 lime:1/4 brick dust…A weak lime concrete for backing may be made of 6 broken stone to 3 of a mortar composed of 2 sand (or brick dust) to 1 lime, turned over and mixed together at least 7 times…

At and near the western sea=ports of India, volcanic ash and pumice stone is imported from Aden, and mixed with Indian limes in the proportion of ½ or 1 part of pumice to 1 of lime…. It must be used within 48 hours of the time of mixing.

…It is customary in India to mix with the lime, whether for mortar or for plastering, a proportion of coarse sugar syrup, or of molasses. **The effect is to retard the evaporation of moisture, and it is generally considered that the coarsest syrup assists the setting of the mortar, and increases its strength.** For mixing mortar, about ½ lb of sugar syrup is dissolved in 2 gallons of water. Or, from 1/8 to 1 % by weight of syrup is added to the lime. Or, 1lb of molasses to 1 bushel of Portland cement.

Chapter VI Slaking of Limes; quality and proportion of sand and water, hand and machine mixing; cement mortar.

…Calcined limestone is to be purchased either in the lump just as it comes from the kiln, or the lumps have been crushed and ground to a fine powder. Unless implicit reliance is to be placed upon the quality of the powder, it is better to purchase the calcined lumps, and reduce them to powder under inspection when required for use.

Ordinary pure or chalk lime in calcined lumps can be slaked, that is reduced to hydrate of lime in the form of a dry powder, by sprinkling the lumps of quicklime with water….**Pure lime is often slaked by total immersion in water for some days.** Grey-chalk lime is slaked by throwing water over the quicklime lumps, and covering them with sand to retain heat.

Blue lias and other limespossessing a high degree of hydraulicity do not slake readily. Some hydraulic limes will slake if, after being wetted, the heap of watered lime is covered with sand and with sacks etc to retain heat in the mass. Slaked blue lias lime should always be sifted before use, so that all the imperfectly slaked pieces may be separated and again treated.
As it is essential that hydraulic limes be in a finely divided state before being mixed into mortar, and, as they are all more or less inert and slow in slaking, it is better to grind the lumps of calcined lime to a fine powder before the water is added, and thus ensure the complete slaking of every particle.

Ordinary blue lias lime in the lump requires 2.5 gallons of water per bushel for slaking, and about 4.5 gallons for mixing into mortar…In slaking hydraulic limes it is very important to prevent loss of heat, and ample time should be allowed, two days at least for moderately hydraulic limes, up to a week for superior limes….

A larger proportion of sand may be mixed with rich chalk lime, without seriously diminishing its low cohesive and adhesive strength, than can be used with a hydraulic lime produced from blue lias limestone.

Sand is mixed with lime for three reasons:

1. to lessen the quantity of lime used to make a given bulk of mortar; sand is generally cheaper than lime, and the cost of the mortar per cubic yard is thus reduced;
2. to confer on the mortar somewhat greater resistance to crushing, and also to prevent excessive shrinkage during the setting and hardening of the mortar in use;

3. to separate the particles of lime and render the mortar more porous, thus, with the purer limes, facilitating the penetration of carbonic acid, and accelerating the setting of the mortar. It is considered also that the crystallised particles of carbonate of lime adhere more firmly to the sand grains than to each other.

QUALITY OF SAND

Sand should be in all cases clean, free from clayey matter or vegetable earth; when rubbed between the hands should not soil them, and when dropped into water should not cause muddiness; should consist of sharp angular *siliceous* fragments **not less than 1/24 inch in diameter, and not exceeding 1/8 inch;** and should have a rough texture of surface. Calcareous or argillaceous sands are unsuitable, as the former will dissolve, and the latter partly dissolve in acids.

Fine sand may be defined as composed of fragments whose diameters range between 1/24 and 1/16 inch, coarse sand between 1/16 and 1/8 inch….

Coarseness of texture is…of greater importance than size of grains, and sand grains of uniform size do not necessarily make the best mortar. Sands that are much waterworn, and consist mainly of rounded grains, are not so suitable for making either mortar or concrete; they are, however, often used in default of a better material….

Sea sand may be used for mortar making with either hydraulic lime or Portland cement, but the mortar should not be used in the erection of dwelling houses, warehouses, etc, where the absorbent nature of the salt would tend to maintain a dampness in the walls. It is largely used in building dock walls and similar massive structures….If of a suitable quality, and thoroughly washed in a stream of clean fresh water, sea sand can be used in mortar making for all purposes.

Loamy and clayey sands are injurious in cement mortar, and **to a less degree in lime mortar.**

Crushed sandstone, vitreous blast furnace slag, or any vitrified rock…will furnish a good sand for mortar making. For a dense impervious mortar, it is best to use the finer particles as well as the coarse, but with an additional quantity of lime or cement above that which would be mixed with coarse sand only.

PROPORTION OF SAND USED

Gray chalk quicklime can be mixed with nearly three times its bulk of sand, an ordinary proportion is from 2 to 2 ½ times the bulk of the lime before it is slaked.

Blue lias should not be mixed with more than twice its bulk of sand for a strong mortar, and the best mortar is made with equal proportions.

WATER USED FOR MIXING

The amount of water used for mixing good mortar should not exceed the quantity required to make a somewhat stiff and cohesive paste. If too little water be added the mortar will not set properly, and if too much water be used the mortar will be thin and sloppy, the sand is liable to settle and separate from the lime, cavities may be left in the mortar joints by shrinkage during setting, and it is said that a thin mortar never sets as hard as a thicker paste….Due allowance must always be made for the porosity and absorptive nature of the bricks and stones to be cemented together, the mortar paste must not be robbed of any of the water required for setting; and allowance is also made for loss by evaporation in hot weather. It is a good plan to saturate with water all bricks and stones used in building, except in time of severe frost.

(questions virtue and effectiveness of grouting dry laid hearting material)…
a better method is to fill the shallow basin enclosed by the facework with comparatively stiff mortar, softened if need be with a little water, and remixed with a long-toothed rake called a 'larry'. The bricks or stones are then well bedded by hand in the pool of mortar paste. This process is called 'larrying'.

….MORTAR MIXING BY HAND

for small quantities of mortar, the mixing is usually carried on by hand labour, spades or shovels and rakes with long prongs being used. The sand and slaked lime should be well mixed in the dry state, being turned over with spadework three or four times…Then water is sprinkled on while the mixing continues, until the whole is a soft, plastic uniform paste. About 6 or 8 turnings over are the minimum required. Ground blue lias lime is sometimes mixed with sand and water without previous slaking, then left for 6 or 8 hours, or longer, and then remixed, to ensure the complete slaking and wetting of all particles of lime.

MORTAR MIXING BY MACHINE

Roller pan mixers (long description)

The process of mixing in the edge runner mortar mills is to place the slaked lime in the pan and grind it under the runners for at least three minutes in a dry state, then water is added gradually, through a rose jet or a finely perforated tube, and finally the sand is put into the pan. (takes about 30 minutes).

(sand added last to reduce crushing, but) if pozzolana, semi-vitrified brick, or similar burnt clay or forge ashes be added to the mortar, it should be ground for as long a time as the lime, that is, put in the mill pan at the same time as the lime….

Working in severe cold – slake and mix with boiling water…

A method said to be adopted at Christiania (Norway) for building during severe frost, down to 14 degrees F, consists in the use of unslaked lime. The mortar is made in small quantities only, from unslaked lime, and used at once, and the greater the cold, the larger the proportion of lime in the mortar. The bricks used must be dry, and the mortar is probably used in a very moist condition, and in thin joints. The new work is always protected as soon as built, especially against rain, snow and cold winds....

CEMENT AND LIME MIXED MORTAR

In building massive works it is sometimes desirable to use a strong and quick-setting mortar for the facework only. Such mortar can be made by adding Portland cement to the lime in general use. In one case, one measure by bulk of Portland cement was added to one of Burham gray chalk lime, and five to six measures of good sand. The cement should be well mixed with the lime in dry powder.
Another instance gives 1 cement to 3 sand and ½ of a good slaked lime…gives a good dense mortar for foundation and above-ground work.

CONCRETE; LIME CONCRETE.

VARIOUS RECIPES. MOST PRETTY LEAN IN BINDER. Very detailed descriptions of mixing, mixers and proportions.

Appendix on the preparation of hydraulic (Kankar) limes in India.

Benton J (1893), Executive Engineer, Bari Doab Canal, India, Manufacture of Kankar Lime, Appendix I in Heath AH (1893) Lime and Cement, a Manual on Their Treatment and Use in Construction. London & New York Spon.

The lime chiefly used in the plains of the North of India for engineering purposes, is made by calcining kankar with charcoal. Kankar is a calcareous concretionary deposit formed in the alluvial soil of the plains of India, from carbonate of lime held in solution. It is composed chiefly of carbonate of lime, silicate of alumina, and silica in grains. The kankar best suited for lime-making contains a high proportion of carbonate of lime and a small proportion of silica in grains....

The kilns in which the kankar is burned…are built of underburnt or of sun-dried bricks; laid in mud mortar, or may be made of mud walling. The outer and inner surfaces of the kiln should be plastered with clay, in order to assist the retention of heat....Three or four such kilns make a convenient group (to ensure continuity of supply), and for large work there may be one or more groups.

(Charcoal and kankar is mixed together before loading into the kilns above a cow-pat and charcoal charge)....Good charcoal leaves very little ash, an important advantage attending its use as a fuel for lime burning; it also burns very evenly, and the out-turn from a well-managed charcoal-fired kiln is uniformly burnt…

On large works the calcined kankar is reduced to fine powder in disintegrators….When (these) are not available, the calcined stone is ground under edge-runners…or is pounded by hand under hard wood mallets, or iron hammers. The finer the reduction the better is the lime for mortar mixing….Kankar should always be used when newly burnt...The limit of keeping after the burning should be about one or two weeks in the wet season, and two or three months in the dry season; sometimes the dry weather term is limited to one month after burning….

Well-burnt brick, when pounded or ground to powder, is known as 'surkhi', and is used in India as a substitute for sand in the preparation of mortar. Sand is but rarely to be procured of suitable quality, and free from clayey matter; it is generally loamy, or is in fine rounded grains having smooth texture of surface…. (Bricks should be made from sticky clay, not sandy, and have a large proportion of soluble silica)….

To a rich, or comparatively pure, block Kankar lime, surkhi may be added in the proportion of ½ to 1 of surkhi to 1 of lime, by bulk. (Bricks must be well-burned to 'incipient vitrification')…Mortar made from lime and underburnt surkhi oftentimes sets fairly well, but is liable to disintegrate subsequently from exposure to the weather….

KANKAR LIME USED UNDERWATER

If kankar lime mortar be submerged in water within 48 hours after mixing, it usually does not set and harden. It must therefore, be exposed to the air for at least 48 hours before being covered with water, and it will then continue to harden satisfactorily. The property of hydraulicity will be enhanced by the admixture of powdered well-burnt clay, containing from 60 to 70% of soluble silica, with the powdered caustic (unslaked) lime…

KANKAR LIME CONCRETE

(aggregate should be) from ¼ inch to 1 ½ inch cubical well mixed together in equal proportions of fine, medium and coarse….

The lime and surkhi (or sand) are spread out in successive thin layers on a clean, hard, impervious mixing floor, and are first mixed in a dry state, then water is added through a finely perforated rose jet, and the mixing of the moist materials continued until there is a homogenous pulpy paste (*hot mixed, therefore*). When the mortar is thoroughly mixed it is to be placed in the required proportion on a 6 inch layer of the broken stones etc and the mass must be thoroughly incorporated by turning over with shovels, and stirring with rakes having long tines. At least two or three turnings over are required.

The mixed concrete is to be deposited in place, and not thrown down from a height, nor slid down an inclined plane (*contrary to British practice at the time*); it is to be spread in layers of about 4 inches uniform thickness, and each layer must be compressed by ramming with heavy wooden rammers till it loses about one-fourth of its deposited thickness. If it be necessary to expose this kankar concrete to running water within 48 hours after deposition, it may be given a surface coating of mutton fat mixed with a little lime, as a temporary protection from the solvent action of water. In many cases of constructive works, an open-textured concrete will be as serviceable as a dense concrete…

Fox T A (1897) The Mason's Department. Boston. The Brickbuilder February 1897. Boston

How to Prepare Mortar.

Mr Edward Wolfe, an American authority on the subject of limes and mortars, makes some very interesting suggestions relative to the proper method of slacking lime and preserving it in good condition thereafter. He says:- —

" The slaking operation should be done in a watertight box made of boards, and so much water should be mixed in that the contents will never get dry, and a sheet of water will remain on top to prevent access of air. If the box will not hold the entire quantity of lime required, the contents may be emptied into a cavity made in the ground close to the pan, and this process may be repeated. This should be done at least two weeks before sand is added, or before the mortar is prepared for use. Slaked lime prepared and kept as stated has been found free of carbonic acid after many years, air and gas not having been able to find access.

Sutcliffe G L (ed) THE PRINCIPLES AND PRACTICE of MODERN HOUSE-CONSTRUCTION. VOL 1 1899 Blackie, London, Glasgow & Dublin
P73
Concrete for foundations was at one time generally made with a matrix of common lime, but nowadays hydraulic lime or Portland cement is almost invariably used. The latter is by far the stronger material, and good cement is more uniform in quality than good lime; hence the use of Portland cement is rapidly extending. There is, however, a great deal of rubbish sold as Portland cement coarsely-ground and of a yellowish hue, and this must be avoided. Plasterers, it may be said, regard it with especial favour; it is cheap, and great strength is not, they think, necessary in their work.

P74

The proportions of cement, sand, and aggregate used in concrete for foundations vary from 1+1+4 to l+2 + 8 or even 10. Good work may be ensured (p75) by a mixture of one part of cement, one and a half parts of sand, and Jive parts of broken stone or gravel.
(Basement Walls)
As most bricks and stones are very far from being impervious, it follows that a wall built of these materials alone however well it may be constructed cannot be absolutely water- proof. Certainly a wall built of good bricks in Portland-cement mortar (one part of cement to two of sand) and well grouted with neat cement, ought to be practically impervious, especially if a cavity (which need not be more than ½ inch or ¾ inch wide) be left in the body of the wall and run with grout; but such is the carelessness of the ordinary bricklayer that it is almost certain it will not be
A coat of Portland-cement mortar (1 cement -I- 1 sand) carefully applied to the exterior of the wall after the joints have been well raked out, is a safer protection than the grouted cavity.

Chapter IV Mortar and Stucco
P116 The importance of good mortar can scarcely be over-estimated. If the mortar is bad, the wall is bad. Bad mortar allows wind and rain to penetrate, favours vegetation, easily cracks, and rapidly crumbles away, exposing the arrises of the bricks and stones to atmospheric action, and thus leading to their decay. When the face of a brick decays, it will usually be found that the mortar has first been eaten from the joints; a good mortar-joint not only makes a wall drier and stronger, but also more durable. In vain are the bricks and stones selected if the mortar also is not carefully prepared, and, be it added, used in sufficient quantity to fill the joint*.
Unfortunately mortar is easily scamped, and so are mortar-joints, and as long these matters are left in the hands of jerry-builders and unscrupulous contractors, such will be the case. It is a good plan for the building owner to provide all lime, cement, and sand; then, and then only, may he hope to have them mixed in proper proportions and used in sufficient quantity to flush the joints, and even then he will be disappointed if constant supervision be not exercised, for the ordinary bricklayer can scarcely be compelled to make a solid vertical joint: he scrapes his trowel on one arris of the brick, and leaves three-fourths of the joint absolutely devoid of mortar. Still, the temptation to do this is less when he knows that his master will not grumble at the number of hodfuls which he uses.

Mortar ought to serve at least three purposes: it ought to form a soft but gradually hardening bed to receive the various building-materials, so that these shall obtain an uniform bearing notwithstanding the irregularity of their surfaces; in the second place, it ought to prevent the passage of wind and rain through the joint of the walling; and, lastly, it ought to have adhesive and cohesive strength enough to bind the component parts of the wall into one solid mass. Jerry-builder's mortar seldom does more than partially serve the first and second purpose*. Only the best Portland-cement mortar will thoroughly fulfil the three.

The by-laws of the London County Council relating to mortar are as follows: All brick and stone work shall be put together with good mortar of good cement. The mortar to be used must be composed of freshly-burned lime and clean sharp sand or grit, without earthy matter, in the proportions of one of lime to three of sand or grit. The cement to be used must be Portland cement, or other cement of equal quality, to be approved by the District Surveyor, mixed with clean sharp sand or grit, in the proportion of one of cement to four of sand or grit. Burnt ballast or broken brick may be substituted for sand or grit, provided such material be properly mixed with lime in a mortar mill.
As far as they go, these regulations are satisfactory; but they do not go far enough, as they do not say what is mean by "lime " and " Portland cement ". The lime best suited for agricultural purposes is the least adapted for mortar, and yet in many districts the same lime is used in both cases. Indeed, lime may mean anything from the fattest of fat limes or the poorest of poor limes to the best ground lias lime, while Portland cement may be anything from very bad to very good. Certainly the by-laws are explicit enough to render penal the substitution of "gas-lime" (i.e. lime which has been used for the purification of coal-gas) for freshly-burned lime, and of filthy street-scrapings and mud for "clean sharp sand or grit", both substitutions not unknown in the building-trade. It will be noticed also that mortar containing ashes or furnace-clinkers in lieu of sand does not comply with the regulations.
Careful experiments have been made by Mr. Charles Colson to ascertain the relative values of mortars containing gray lime, Portland cement, and mixed lime and cement, the briquettes being kept in air. The results are summarized in Table II, and a column is added showing the relative cost per unit of strength. In these experiments, three samples of gray lime were used, and were found to vary greatly in strength. The fractured briquettes of the lime-mortar " showed **that induration . . . had penetrated only to the extent of from one- eighth to three-sixteenths of an inch, but in the majority of instances to only one-eighth of an inch.** The remainder of the area, although dry and moderately hard, had become so mainly from the evaporation of the moisture originally contained in the mass, and in no sense from the absorption of carbonic acid. It was possible, moreover, to crush it in the hand without any great exertion of force."
The loam used in the tests was "yellow, fresh-dug, and rather damp". The quantity of water includes that required for slaking the lime.
The Portland-cement mortars (Nos. 4, 5, and 6) were so raw and harsh " that it would be practically impossible to use them in a satisfactory manner". In order to render them "more plastic and tenacious", lime or loam was added in the remaining tests, to the extent of one-twelfth of the volume of the sand, this being the least quantity that would render the mortars convenient for working. Both these ingredients act injuriously on the mortars, and materially enhance the cost per unit of strength. Loam, however, is much the worse of the two. If we compare tests 5 and 11, we find that the addition of the small quantity of loam lessens the value of the mortar more than 50 per cent. The real

economy, therefore, of using clean sand artificially washed if necessary is evident.

TABLE II.

TENSILE STRENGTH OF GRAY LIME AND PORTLAND CEMENT MORTARS, &c., AT THE AGE OF SIX MONTHS.

No.	Composition by Volume. Portland Cement.	Gray Lime.	Loam.	Sand.	Water.	No. of Tests.	Average strength in lbs. per sq. inch.	Ratios of strength.	Cost per cub. yd. of mortar.	Relative cost per unit of strength.
1	—	1	—	2	1·33	17	27·13		s.	
2	—	1	—	2	1·33	27	47·09 } 36·88	1	11·83	100
3	—	1	—	2	1·33	27	36·44			
4	1	—	—	6	1·25	15	103·79	2·81	11·56	35
5	1	—	—	8	1·66	20	68·8	1·86	9·93	45
6	1	—	—	10	2	35	50·16	1·36	8·88	55
7	1	·5	—	6	1·5	70	73·47	2	12·2	52
8	1	·66	—	8	2	74	58·94	1·6	10·72	57
9	1	·83	—	10	2·5	85	42·34	1·14	9·75	72
10	1	—	·5	6	1	21	60·8	1·64	11·44	59
11	1	—	·66	8	1·33	25	38·43	1·04	9·82	80
12	1	—	·83	10	2	19	28·66	0·77	8·76	96

It will be noticed that a mortar composed of *one* part of Portland cement, *one-half* part of gray lime, and *six* parts of sand,—a mortar, be it said, which is sufficiently plastic for the bricklayer's purpose,—is, at the age of six months, exactly twice as strong as a mortar composed of *one* part of gray lime and *two* parts of sand, while the cost per cubic yard is practically identical. As far, therefore, as convenience in working, strength, cost, and, I may add, durability, are concerned, the advantage is on the whole greatly in favour of the cement-mortar, but it must not be forgotten that a mortar containing such a large proportion of sand is far from impervious. In any volume of sand, the inter-

p119 The wisdom of allowing no more than four volumes of sand to be used with cement is manifest, and it is certainly better that even a smaller proportion of sand should be used, or that a certain amount of thoroughly slaked lime should be added in order that the mortar may be more dense. The writer usually specifies cement-mortar to be a 1 to 2 mixture, and never goes beyond 1 to 3. Excellent mortar can be made from hydraulic lime, such as the well-known Lias limes, mixed with sand in the proportion of 1 to 2. The lump or shell lime may be used, but the ground lime is much to be preferred, especially where a mortar-mill is not available. The ground lime can be distinguished from Portland cement by its yellow colour.

As sand (or some substitute for sand) forms the greater part of nearly all mortars, its importance cannot be denied. Certainly pure sand is inert, but much " sand " used in buildings is mixed with clay, iron and other salts, and organic impurities, and is detrimental to the lime or cement with which it is used. In one case about a thousand concrete blocks, in which sand containing iron-pyrites had been used, were quite worthless, as the pyrites destroyed the setting

properties of the cement. The salt in sea-sand, when this is made into mortar or plaster, attracts moisture, causing dampness and often leading to efflorescence. The clay in loamy pit-sand may lessen the strength of cement- mortar as much as 50 per cent. Soot in mortar or plaster will cause stains in paint and wall-paper. Organic matter, such as dung in road-scrapings, may lead to the colonization of the house-walls with innumerable micro-organisms, which may be quite harmless or quite otherwise.
Sand from quarries, quickly-flowing streams, and little-frequented roads macadamized with coarse-grained stone, is usually suitable for mortar. Pit-sand is good, if reasonably free from clay and other impurities.
" Sand " from sluggish streams and ditches, from roads macadamized with hard, fine-grained limestone and "granite", and from foundries, had better be rejected; so also must street-sweepings.**The principal substitutes for sand are ashes or "breeze", brick-dust, and burnt clay-ballast.** Ashes yield mortars of a somewhat weak and porous character, and may interfere with the proper setting of cement if they contain coal-dust or other impurities. Brick-dust and clay-ballast make good mortar, if they are properly burnt, hard and clean.
P120 When a mortar-mill is not used, all grit and lumps should be carefully screened from the sand and lime before these are mixed, as they would tend to crack the bricks and stones if used in the mortar.
In making mortar, a little sand more or less does not matter very much when ordinary lime is the matrix, but even in this case the measurement of the lime and sand should be carried out with some approximation to accuracy. When, however, hydraulic lime and cement are used, the careful measurement of these and the sand, in suitable boxes or frames, must be insisted on.
Water used in mortar should be fresh and clean.
The proper use of mortar now calls for notice. It is in vain to have good mortar if it is not properly used. The one flagrant defect in brickwork is usually that the vertical joints are not flushed with mortar. The bed-joints are almost invariably entirely filled, but the ends of the bricks receive the merest scraping on the front edge, while in thick walls the sides of the filling- in bricks may receive none at all. Only the closest supervision of a resolute clerk-of-works can prevent the "brickies" from scamping their work in this way. **Mortar made from cement or hydraulic lime must be mixed in small quantities and used fresh. Mortar which has once 'set' to any appreciable extent cannot be remixed without loss in ultimate strength.**
The thickness of mortar-joints in brickwork depends on the regularity of the bricks, the fineness of the mortar, and the care of the workman. In good work the joints are usually about ¼ of an inch thick, certainly not more than 3/8. In stone walls there is more variation than in brick, from the thick joints of rubble and flint work to the ashlar joints scarcely thicker than a penny.
As water is absolutely essential not only for the initiation but also for the continuation and completion of the chemical processes involved in the setting and hardening of hydraulic limes and cements, it is imperative that the moisture should not be abstracted from the mortar too soon. Hence the necessity of protecting stucco from brilliant sunshine, or of repeatedly spraying it with water; hence also the necessity of dipping bricks in water immediately

before using them, and of sprinkling a dry course of bricks with water before the bed of mortar is spread above it to receive the next course. **With lime mortar, a moderate use of water in the same way is advantageous, although the lack of it has not so marked an effect as with cement and hydraulic lime.**
The method of finishing: the joints externally, although apparently a small matter, is by no means unimportant. The joints may be finished as the walling proceeds, or may be left rough to be raked out and finished at some subsequent P121 period. To distinguish the two operations, the former is sometimes spoken of as "jointing", while the latter is always known as "pointing". "Jointing" ought always to be adopted unless the mortar is of wretched quality or likely to be damaged by frost…
The joints of internal walls are left rough in order to afford a better key for the plaster.
In consequence of the difficulty experienced in getting the vertical joints of a wall thoroughly flushed with mortar, it is a wise precaution to have the walls run with grout every two or three courses. This is a very thin mixture of lime or cement, fine sand, and water. Ordinary lime is of little or no use, and with hydraulic lime and cement the less sand that is used the better, as the sand tends to settle at the bottom of the pail, and the first part of each pouring may contain most of the lime or cement, and the latter part be nearly all sand. Certainly not more than its own bulk of sand should be mixed with the lime or cement. Besides consolidating and strengthening the wall, the grout has the merit of exposing defects in the jointing by escaping at the defective places, which are at once made good by the workman in order to stop the leakage.
Walls of concrete, rubble, and common brickwork are frequently covered exter(122)nally with stucco. This practice is now more prevalent abroad than in our own country, but the practice is not by any means unknown among us. Formerly the matrix of the stucco was some kind of hydraulic lime, but nowadays Portland cement is almost invariably used, as it hardens better, and is more weatherproof and durable. The cement is made into mortar with two or three times its bulk of clean sharp sand, and applied to the wall as in ordinary plastering. The joints of the wall should be raked out to the depth of an inch to afford a kev for the stucco, and the wall should be well wetted before the mortar is applied, lest it should abstract the moisture from the mortar and prevent it hardening.
The first coat is scored while wet, and afterwards finished with a second and somewhat richer coat. The whole may be coloured with Duresco, or ordinary oil paint.
Rough cast is a covering now seldom used for buildings as a whole, except in the case of cottages and farm buildings, but it is still occasionally adopted for the gables and some other portions of the upper parts of country houses and cottages. **It is executed by throwing a very thin paste of hot lime, coarse sand, and grit or fine gravel, upon a wet plastered surface.** The whole requires an annual coat of limewash, which may be tinted with ochre or other colouring matter.
P140 (Pitched Roofs)

The space between the top of the wall and the upper side of the common rafters must be thoroughly filled with bricks and mortar, before the roof-boarding is laid or the slating begun; this is known **as beam-filling**, and is often left by the bricklayer to be done after the completion of the roof, which means that it will be only half-done.

Maginnis O B (1900) Bricklaying. New York City. Owen B Maginnis.

(Lime) mortar is made by bricklayers' labourers, who, first, on a platform of planks form a shallow basin of screened sand taken from and close to the sand pile. Into this basin they dump one barrel of lump lime, and on this dumped lime they pour water until the lime is thoroughly slaked…In the sand basin it steams and boils, when being slaked, and it will require to absorb one quarter of its own weight of water before it is thoroughly slaked, and will expand to two or three times its lump size. When lime is properly slaked it is reduced to a slimy consistency by the laborers, who use the 'hoe', until the lime is entirely free from lumps. While in this state they add from two to five barrels of clean, sharp sand, screened…, and continue mixing the lime and sand together with the hoe, until each grain of sand is covered with the lime and the whole mass is pasty and workable, under the shovel and trowel. This thorough working and mixing is indispensable to good mortar. When ready, it is shovelled…into the hod…and then conveyed by the hod carriers to the bricklayers's scaffold and there dumped into the mortar box.

Richards H W (1901) - Bricklaying and Brickcutting, Longmans, Green and Co. London, New York, Bombay.

LIMES AND CEMENTS

…Quick, living or caustic lime is the resulting lime left immediately after burning.

Slaking, or 'slacking' as practical men term it, is the process of chemical combination of quicklime and water. Slaked lime, the resultant **powder** after slaking.
Setting, the hardening of lime which has been mixed into a paste with water.

Limestone, such as chalk and marble, consist almost entirely of pure carbonate of lime, while in all limes and cements, before calcination, the latter is the principal constituent.

The analysis of limes and cements is given as follows: a small percentage of clay unacted upon, soluble silica, oxide of iron, soluble alumina, sulphuric acid, lime, magnesia, alkalies, etc.

Of these, in the best setting limes and cements, lime is present in the proportion of from 50 to 65 %, and soluble silica 20 to 25%. The latter is a most important constituent, as the setting of limes and cements is partly due to the peculiar chemical action between the soluble silica, the lime, and the alumina.

Limes may be placed in two classes, viz natural and artificial.

Natural Limes. These are rich, fat, or pure limes; poor limes; three classes of hydraulic limes; Roman and Medina cement. Plaster of Paris, although not a lime or cement, may also be classed as natural.

Rich, fat, or pure lime is produced from limestone composed almost entirely of carbonate of lime; it is known in the building trade as chalk lime. This lime absorbs a larger quantity of water, slakes more readily, and increases more in bulk, than any other lime. The increase is from 2 to 3 ½ times the original bulk of the lime.

Poor lime, which is also known as chalk lime, is similar to the above, but contains about 15 to 20% of useless matter. Both of these are fit only for plasterers' work and sanitary purposes; they do not set.

Limes are said to be more or less hydraulic, according to their power of setting underwater or in places from which air is excluded. Limestones likely to yield hydraulic lime occur amongst the marly or argillaceous beds.

In all hydraulic limes, clay plays the most important part…it lessens the slaking action and, when a large proportion is present, the slaking action does not take place at all….

Fairly hydraulic limes are produced from limestones containing from 8 to 12% of clay. They set under water after from 15 to 20 days, and ultimately become as hard as a block of dry soap.

Hydraulic limes – from limestones (with clay at) 15 to 18%. The slaking action does not begin until an hour after the water has been added. These limes set after from 6 to 8 days under water, and continue to harden, and ultimately become as hard as the **softer…building stones.**

EMINENTLY HYDRAULIC LIMES.

These are similar to the above in composition, the clay, however, being in the proportion of from 20 to 30%. Although this lime would probably slake after a long period, it would be impossible to wait for it to do so. It is therefore sold in the form of an extremely fine powder, in which state, after exposure, it becomes air-slaked. It sets within the third or fourth day *[as will most available modern NHLs],* and at the end of six months is similar in hardness to the harder kinds of limestones.

ROMAN CEMENT

…consists of septaria nodules…which contain from 30 to 45% of clay. These nodules are burnt in conical kilns at a low temperature, and then ground to powder…the cement…sets in about 15 minutes, but has no great ultimate strength, and is being rapidly superceded by Portland cement.

(description of Portland cement manufacture)

CONCRETE, MORTAR ETC

Concrete. …the matrix should consist of either Portland Cement or Blue Lias lime and sand. The proportions for the concrete must depend upon the situation in which it is to be used; but for ordinary purposes the following may be accepted: 5 parts clean broken stone, brick etc: 2 parts sand: 1 Portland cement or Blue Lias lime. Or 7 parts Thames ballast (already containing sand): one part Portland cement, or Blue Lias lime *[note the equivalence of Portland cement or lias lim. Compare this to a modern 1:3 or 1:2 ½ NHL 5: sand lime concrete]*.

In mixing, care should be taken that the materials are kept clean: a wooden platform or paved surface is therefore advantageous. The materials must be accurately measured, carefully incorporated, being turned from two to three times while dry, and several times while just sufficient water to bind them together is being sprinkled through a rose over the mass. It is very clear that if too much water be added, the mortar will be so soft as to escape, or when lowered into the trenches, the aggregate will sink to the bottom, leaving a bed of mortar only at the top….

Mortar

…two classes: mortar for building purposes and mortar for pointing…

Building mortar may again be divided into two classes: cement mortar and lime mortar…The decision as to the quality of the mortar will depend upon where it is to be used. Thus, for work underwater, footings, piers receiving heavy weights etc Portland cement or Blue Lias would be used; for ordinary purposes, fairly *[feebly]* hydraulic, such as grey stone lime. Fat or poor limes should never be used for building brickwork.

(Recommended proportions:)

Above ground: fairly hydraulic lime, one part to three sand *[unslaked lime];* eminently hydraulic lime: 1 part to 2 sand *[little or no expansion upon slaking];* Portland cement: 1 part to 5 sand.

For footings: eminently hydraulic lime, 1 part to 1 sand; Portland cement: 1 part to 2 sand.

For work washed by water, such as river walls, etc: Portland cement and sand in equal proportions.

Mode of Mixing

A clean site or platform having been chosen, the lime and sand should be measured out in a yard measure. In the case of **fairly hydraulic lime which is supplied in lump, the screened sand is formed into a ring, the lime shot into the middle, and sprinkled with just sufficient water to slake it. Some of the sand is then turned over the lime, and it is left in this state till the lime has become thoroughly slaked. Water is then added, the remaining sand gradually pulled in, and the whole mass carefully incorporated with a larry and shovel.**

For **hydraulic limes and cements**, which are supplied in a powdered state [*but unslaked],* **the lime and sand are again measured and shot upon a platform, the sand first and the lime on top of it. These are mixed together, first in a dry state, and then with just sufficient water to form a fairly stiff paste…**with the latter mortar small quantities only should be mixed at a time.

…**Mortar for Pointing.**

(recipes for coloured mortars for use on London brickwork – yellow and red)

…Putty for pointing is made of **silver sand and stone lime, 2:1.**

The lime, **being dry-slaked, is mixed with the sand, passed through a very fine sieve, mixed with sufficient water to form a very hard paste,** oil sometimes being added to make it work better, and then **well-beaten with a club hammer** or other heavy instrument. For black putty, vegetable black is added to the above.
LEANING J (1904), F.S.I. The Conduct of Building Work
And the Duties of the Clerk of Works London Batsford.

P13

The ideal Clerk of Works-
Is honest.
Is temperate.
Knows one building trade practically and
thoroughly.
Can make working drawings for any trade.
Knows the general practice of measuring
artificer's work.
Can make a simple land survey.
Can use a dumpy level.
Can set out a building.

Knows the value of the leading items of
each trade.

The Clerk of Works should be at the building from 9 a.m. until the men cease work, and if he has reason to suspect trickery should occasionally go to the works in the morning at the same time as the men. Omissions of concrete, filling up large piers with rubbish, building in bats, and other vagaries often occur in the early morning, "the sweet hour of prime."

Mortar.—See that the lime is fresh and thoroughly slaked; that the prescribed proportion is used in the mortar, and if not described, a reasonable proportion to make mortar, the test being its proper hardening by exposure. Less than one part of lime to three parts of sand should never be accepted, and it should be mixed in quantities sufficient only for daily use.
See that lime is kept under cover.

P76 Cement for Setting.—The use of cement for setting stonework, especially where exposed to view, should be avoided.

P83 Tiler.
Bedding.—If tiles are bedded in lime and hair, as little as possible should be used. It should not reach as far as the tail of the tile, as if it does water will be drawn in.

P93 Plasterer.
Proportions of Material.—The Clerk of Works should see that the proper proportion of lime and hair is used in all cases.
Hair.—Where there are moulded ribs on ceilings an extra proportion of hair must be used, or their weight will bring the ceiling down. Hair should be well beaten; although this is generally specified the stipulation is systematically disregarded.
See that it is free from grease.

Putty.—The putty should be run a month or six weeks at the least before it is required for use.

Thickness of Laths.—The Clerk of Works should see that the laths are of the proper thickness, that they butt at joints and do not lap, that the joints are frequently broken, and that the early coats of plastering dry thoroughly before succeeding ones are put on.

P95 Gauged Work.—If plasterers' work is gauged the Clerk of Works should make notes of the proportion of cement or plaster used, and where it is used, the superficial quantity involved may be measured at the adjustment of accounts. Claims are frequently made for the gauging of plastering which are most unreasonable, and after the time which usually elapses before the valuation is made they are very difficult to criticise or to estimate with certainty.

Henry Adams H (1906), Cassell's Building Construction. Cassell & Co London, Paris, New York and Melbourne.

P69

Bricklaying in Frosty Weather

There is no recognised time or period of the year in which bricklaying should be suspended on account of frost; this is a matter that is determined by the weather and by local custom. Generally speaking, in England work continues throughout the winter, the only protection being a scaffold board, laid on the top course; but sometimes sacking is laid over the upper courses when the work is left for the night. If a hard frost sets in, the work may be suspended until the frost breaks; but in Sweden and Norway building operations are not so readily interrupted, as **sugar** is added to the mortar in order to lessen the liability to freezing. In the United States and Canada brickwork in cement mortar is continued in frosty weather by using **hot water** for mixing the mortar.

…p161

Poor lime contains 60 to 90% of carbonate of lime, together with useless inert impurities, slakes sluggishly and imperfectly, with little increase in bulk; it sets rather firmer than rich limes, owing to the presence of a small quantity of clay, but has no strength…

Stone lime, or grey chalk lime, slakes very freely; after being wetted, it pauses a few minutes, then slakes with decrepitation, development of heat, cracking and ebullition of vapour. It will set in still water owing to its containing 5 to 12% clay, is firm in fifteen to twenty days, and in twelve months is hard as soap. Stone lime is suitable for building ordinary walls of brick or stone; it is feebly hydraulic, of a light buff colour, and when made into a mortar with two parts of sand will sensibly resist the finger nail at a month old.

P162 Mortar

Lime mortar in London is usually composed of 1 part of best grey stone lime (Merstham, Halling, or Dorking), and two parts of clean sharp sand. Blue lias lime is a hydraulic lime having the power to set under water, and may therefore be used in wet ground; those named above being suitable only for dry situations. Chalk lime is unsuitable for use in brickwork owing to its solubility and want of setting power.

…The common proportion for London mixture is 3 to 1, instead of 2:1 as given above, but most architects specify the 2 to 1 proportion.

P166

Plasterers’ Materials

The basis of ordinary plaster is calcium carbonate, and of the hard coats calcium sulphate.

Coarse stuff is a rough mortar containing 1 to 1 ½ parts sand to 1 of slaked lime by measure, and 1 lb of ox-hair to every 2 cubic feet to 3 cubic feet of stuff. The sand….is first heaped round in a circular dish formed on hard level ground. The lime, previously slaked (*but still hot)* and mixed with water in a large wooden tub to a creamy consistency, is then poured into the middle. The hair – long, sound ox-hair from the tanner’s yard, free from grease or dirt, and previously well switched with a lath or immersed in water to separate the hairs – is then added, and well worked in throughout the mass with a three-pronged rake. The mixture is then left for several weeks **to cool,** that is, to become thoroughly slaked to prevent blowing after being laid.

Fine Stuff is pure lime slaked to paste and **afterwards** diluted to the consistence of cream. It is then allowed to settle, the water rising to the top is run off, and the stuff is left till it is thick enough for use. A little white hair is added for some purposes.

Plasterer’s Putty is pure lime slaked with water, brought to a creamy consistence, strained through a hair sieve, and allowed to evaporate until stiff enough for use. It is the (p167) last coat applied to internal walls that are to be coloured, and always is used without hair.

Gauged Stuff is plasterers’ putty with a portion of plaster of Paris mixed with it, the proportions being 3 parts putty to 1 part plaster of Paris, when required to set quickly, and gauged in small quantities.

Radford’s Cyclopedia of Construction, Carpentry, Building and Architecture 1909 Chicago.

p43. Common Lime Mortar.

The first step in the preparation of common lime mortar is the slaking of the lime. This should be done by putting the lime into a water-tight box, or at least on a platform which is substantially water-tight and on which a sort of pond is formed by a ring of sand. The amount of water to be used should be from 2 1/2 to 3 times the volume of the unslaked lime….

Although close accuracy is not necessary, the lime paste will be injured if the amount of water is too much or too little. In short, the amount of water should be as close as possible that which is chemically required to hydrate the lime, so that on the one hand it shall be completely hydrated, and on the other hand it shall not be drowned in an excess of water which will injure its action in ultimate hardening. About three volumes of sand should be used to one volume of lime paste.

(p45) The substitution of more than 20 per cent of lime (to a cement mortar) decreases the strength faster than the decrease in cost, and therefore should not be permitted unless strength is a secondary consideration and the combination is considered more as an addition of cement to a lime mortar in order to render it hydraulic.

(p10) PLASTERING

(Discussing habit elsewhere of laying down lime paste for months for plastering)…In this country, such slow-going methods are not to be expected. While lime does gain in strength by standing in this thin putty state before sand or other materials have been mixed with it, yet three or four weeks at the least are necessary before the increase becomes very apparent….At the end of the fourth month its strength will have increased about one-fifth, and most of this gain will have occurred during that month. From then on the gain continues but decreases amount.

It is more economical for the plasterer to use a lime that has been slaked for some weeks, as, when tempered down, it will work freely with the admixture of a much larger proportion of sand than is taken up by lime mixed as soon as it can be readily worked. This extra amount of sand does not add to the strength of the mortar; but, **as it causes the lime to cover a greater surface, it is a considerable economy for the contractor, made, however, at the expense of the quality of his work.**

Lime mortar need be left standing only long enough for all its particles to be thoroughly slaked, and, if properly mixed and wet down in the first case, a great deal of time need not be required to effect that result. This once secured, **the quicker the mortar is mixed and put upon the building, the better and stronger will be the plastering that is obtained….**mortar mixed with clean water (after standing a while) never becomes so hard as that mixed with the water obtained in slaking the lime (lime-water).

The sand and hair are next added, the hair being put in before the mortar becomes too stiff to work readily. After the sand is mixed, the mortar should not be left to stand for any length of time, as it would become considerably set and a loss of strength would result. If the mortar does become set in the bed, reworking would be necessary before it could be put upon the walls. The strength then lost bears a direct relation to the length of time it has stood, and the solidity it has obtained before this final working up.

(p11) …Once certain that the lime is slaked, it would appear better that not more than a week should elapse before the use of this mortar; and a less time than that is, under many circumstances, undoubtedly desirable. It is evident that no more lime and sand mortar should be mixed at one time than can be used within a few days at the most. The length of time that mortar should be allowed to stand is determined more or less by the dryness or moisture of the atmosphere. The dryer the atmosphere, the shorter the time…

Champly, René (1910-1914) Nouvelle encyclopédie pratique du bâtiment et de l'habitation. Volume 2, avec le concours d'architectes et d'ingénieurs spécialistes. Paris. H. Desforges.

Champly, René (1910-1914) New pratical encyclopedia of building and of habitation. Paris, H. Desforges. Translated by Michel E (2018)

<u>Lime slaking</u> - fat lime is placed in a basin formed of planks, masonry or even a simple hole dug in clay soil. We water the lime with a spray, the burnt stones crack, expand and melt into a beautiful white, cohesive and creamy paste ready to make a mortar.
This slaked lime can be conserved from one year to the next by covering it with a good layer of sand and a roof that will keep the rain water away from it, the sand that covers the lime needing to be kept moist….

Cements are divided into *prompt* cements or *roman cements*, the set of which happens a few minutes after being mixed and *slow cements* or Portlands, in which the set takes several hours and the hardness is only complete after a few months.
The prompt cements are used for under water or underground works, they do not harden well in the air. Slow cements for masonry foundations, basins and reservoirs walls, coatings for humid walls, paving […].

Prompt cement mixed with fat lime in the proportion of 1 to 2 cement to 10 of lime (by volume) gives a *mortier bâtard* (mixed mortar to be polite) that has great hydraulic properties.
Half to one percent of sugar added to the cement promotes its hardness but delays its set a little….

We differentiate mortars thus: fat lime, used for raising walls, hydraulic lime for foundations, substructures, basement and works meant to be immersed. Slow or prompt cement for underwater works or in very humid places. Cement mortars with a slow set are greatly used for coatings, pavings and facing….

When we build, underwater masonry which will be submerged in a distant future, the mortar does not have to be very hydraulic. If, on the other hand, they will be subject to immediate inundation, they need to be very energetic.

In the first case, we make it with feebly hydraulic lime and sand or with fat lime mixed with energetic lime and sand (one method of his) or fat lime, lean pozzolans and sand. In the second case, we use energetic lime with sand, or fat lime, or feebly hydraulic lime or energetic pozzolans and lastly we use sometimes a mortar of pure cement….

Special coating (render) for rammed earth wall: Make a clear but binding paste with **one part of slaked lime, four parts of clay and some water.** Add and mix into this paste, as much hair as it needs for the mix to be full of it. Use hair from tanners or from the sheet shavers (the people shaving the sheets made from cotton as short as possible for a smoother finish).
The hair has to be well divided and beaten, so that it does not form clumps in the paste.
Apply the coating in the autumn on a well dried rammed earth wall with a big paint brush or by throwing it and then spreading it with a trowel.
Do not apply it during heavy rains nor during frost, which would prevent the drying out.

Dibdin W J (1911) *Lime, Mortar & Cement: Their Characteristics and Analyses.* London. The Sanitary Publishing Company Ltd.

…The lime most suitable for making mortar is by no means the best for making lime-water in large quantities, or for the purpose of the gas manufacturer in purifying his gas. These differences…are due to certain substances – or impurities…- which affect the quality of the lime.

P8

Table of the approximate composition of various limestones and the percentage of pure lime…in the burnt stone [balance is dolomite]

	Unburnt Stone		*Burnt Stone*
	Carbonate of lime	Clay & moisture	CaO
Pure or Fat Limes –			
White Chalk	98.5	1	98
Oolite	95	3	95.5
Poor Lime			
Siliceous Oolite	70	26.5	73.5
Feebly Hydraulic			
Grey Chalk	92	8	86.5
Hydraulic			
Dolomite	51	9	53.5
Carboniferous	86	14	81
Grey Chalk	83	17	73
Strongly Hydraulic			
Blue Lias	79	21	72
Carboniferous	71.5	27	60
Scotch	68	31	56.5

The various (p9) limestones may be classified under four heads, viz 1) fat or pure limes; 2) poor limes: 3) hydraulic limes; 4) cements, natural and artificial…These classes merge gradually into one another…therefore we have 'good' and 'bad' limes, according to the purpose for which they are intended.

….Thus, if the lime is required for use in a gasworks, etc, where the chemical activity of the lime is of the first importance, it should be as pure as possible, and therefore, 'fat' limes should be obtained. If, on the other hand, **the lime is required for mortar making, good hydraulic lime should be purchased.**

P12 Chapter II

CLAY

The principal ingredient (of clay) is a silicate of alumina, which when perfectly pure is white. In this form it is known as Kaolin, or white china clay, pipe clay, fuller's earth, etc

P 24 Chapter IV

MORTAR AND CEMENT

…The essential feature in the formation of both mortar and cement is the hydration, or combination with water, of the lime, known as 'slaking', and the subsequent 'setting' of this material in contact with silica and clay. In the case of mortar, **we must have a hydraulic lime containing roughly about 3 parts of lime to 1 of clay.** After slaking, this is added to a certain proportion of silica in the shape of sand. Other materials will answer (particularly brick) to a certain extent, but, undoubtedly, good, clean, sharp sand is the best.

P25
The proportion of lime to sand is generally very variable, and the only legal definition of 'mortar' is that contained in the bye-laws of the London County Council, which specifies that the mortar to be used under Section 16 of the Metropolitan Management and Building Acts Amendments Act, 1878, **must be composed of freshly burnt lime and clean, sharp sand or grit, without earthy matter, in the proportion of 1 of lime to 3 of sand and grit.** In the case of 'cement-mortar', the cement to be used must be Portland cement, or other cement of equal quality, to be approved by the surveyor, mixed with clean, sharp sand or grit, in the proportions of 1 of cement to 4 of sand or grit. Also, that burnt ballast (clay) or broken brick may be substituted for sand or grit, provided such material be properly mixed with lime **in a mortar mill.**

In the manufacture of Portland cement, lime and clay are mixed together, burnt and ground into a powder. The quantities are not quite the same as those in hydraulic lime…being roughly 2 parts of lime to 1 part of clay. The difference in the resulting compound is **mainly brought about by the action of heat,** by means of which the lime and silica of the clay are caused to combine, with the result that when moistened and allowed to set, the **particular combinations so feebly present in the mortar are present to a much larger extent in the cement,** with a consequent increase in its strength. (the mixtures of cement are designed to achieve) (p26)… the maximum strength obtainable. (3 parts chalk to 1 part clay give best result)….When properly (burned) the cooled masses have the appearance of a cinder. If the heating is carried to the extent of vitrification the cement is useless. The burnt cement is then ground to a fine powder, the strength of the cement depending very largely upon the degree of fineness. *[These proportions are the same as Eckel (1922) describes for the 'ideal' hydraulic lime. Temperature of firing, therefore, is critical].*

P30 Chapter V

The Setting of Mortars and Cements

…mortar is essentially a mixture of hydrate of lime with 3 or 4 times its weight in sand…(setting by carbonation, absorbing carbon dioxide from the air). This absorption is at first rapid, and then gradually slower. (p31)…The hardening may be in some cases partially due to the formation of silicate of calcium, but the evidence for this is not very strong.

It is generally held that pure silica in the form of sand acts **merely mechanically,** and enters into no chemical combination with the lime. (Dibdin not even convinced that carbonation is what sets up mortars, discussing instead theories of 'crystallisation', by which both air lime and water limes were considered to be set.

P36 …The suggestion that the adhesive powers of mortar and cement are due to **a process of crystallization in contact with a roughened surface** is strongly supported by the results of Mr Grant's experience…

P66 Chapter VIII

Typical analyses of mortar and cement.

(This chapter effectively a paper from 1896, given by Dibdin and Grimwood to the Society of Public Analysts).

P67 THE LEGAL DEFINITION OF MORTAR

(As above initially, for lime and cement mortar…)

In the bye-laws made by the Council under Section 31 of the London County Council (General Powers) Act, 1890
, it is provided that plastering or coarse stuff shall be composed of lime and sand, in the proportions of one of lime to three of sand, mixed with water and hair; but Portland, Keene's, Parian, Selenitic or other cement or plaster of Paris, may also be used for plastering. The lime must be freshly burnt lime, the sand must be clean, sharp sand, free from loam or earthy matter; the hair must be good (p68) and sound, free from grease or dirt, and one pound of hair be used to every three cubic feet of coarse stuff. Fibrous material may be used instead of

hair, and ground brick or furnace slag…may be used instead of sand; and the setting coat must be composed of lime or cement mixed with clean washed sand, or cement only.

USUAL CHARACTER OF MORTARS

Earthy Matter

…Analyses which have been made from time to time by us (Dibdin and Grimwood) have shown distinctly that it is only under exceptional circumstances that mortars which come within these regulations are employed. To take one factor only, the earthy matter. Analyses of samples…show that the earthy matter…varied as follows – 1.5, 2.1, 0.14, 0.81, 0.61, 0.64, 0.85 and 0.70 %. (other tests of mortars from buildings then in construction showed earthy matter (p69) of 3.8% at lowest, to 14.7% at highest proportion.)

…*Carbonic Acid*

…Genuine mortars made with good materials were found to contain, even after the mortar had been made for some three months, only carbonic acid equal to 1.02, 1.36 and 1.06 % of carbonate of lime; and some cement mortars 2.6, 2.86. 1.04. 1.87. 1.45 % of carbonate of lime.

(the remainder of the book is concerned mainly with Portland Cement).

Kemp W (1912) The Practical Plasterer London Crosby, Lockwood and Son.

Most of the lime used in London is prepared from chalk found largely in Kent ; but lias lime, made from rock of the lias formation, is also a good deal employed in the metropolis, although its colour is less white than that of chalk lime.
Dorking lime used to be in considerable demand for stuccoing, when that kind of work was popular; but there is not much lime produced at Dorking now.

Hydraulic Lime

When lime of this character is used by the plasterer, he should bear in mind that there is apt to be in it, even when well ground, little lumps of unslaked lime, which, even if not larger than a pin's head, will materially injure the appearance of his work by ‘blowing’ or slaking, after the finishing coat has been applied. Want of proper attention to this point frequently results in a new ceiling or partition breaking out here and there in blisters, and thus injuring the plasterer's reputation as an able and conscientious craftsman.

"Fat" limes are principally employed for internal plastering, because of their readiness to slake into a fine powder, whilst they still ‘set’ or harden, withsufficient rapidity for general purposes.

Blue Lias Lime. The hydraulic lime formed by calcining rocks of the blue lias formation is extensively employed for building operations at the present day, especially in the Metropolis. Beds of the lias are found over a considerable portion of Great Britain…. Portland cement is manufactured from this stone at Rugby on a large scale. Despite its good properties, this lime is more uncertain in its behaviour than chalk lime…

Coarse Stuff. This is a rough description of mortar, composed of from 1 to l ½ parts of sand to 1 of slaked lime (by measure), with the addition of short animal hair, in the proportions given hereunder.
Coarse stuff varies according to the proportion of sand which it contains, and may be classed, according to its quality, as No. 1, 2, and 3, the last being the finest and best. A bushel of this mixture should weigh from 14 Ibs. to 15 Ibs. The hair may be added in the proportion of 1 Ib. to 2 cubic feet of stuff for superior work, and 1 Ib. to 3 feet for ordinary work.

The hair should be that of the ox, clean, unbroken, and not too short. It should not be dirty or greasy, and if matted together when it comes from the tan-yard (as it usually is), should be well beaten with a lath or stirred up in water, to thoroughly separate the fibres. For some kinds of work white hair is to be preferred, although for first coats the colour of the hair is of no moment.

The sand is generally heaped up in a circular bank on the gauging-box, platform, or other surface where the plaster is to be mixed. The lime is mixed with water so that the liquid is of about the thickness of cream, and is then poured into the centre of the circle of sand. The hair is next added, and the surrounding sand drawn into the central with the "rake" liquid, and the whole mass well worked together until it is intimately amalgamated.

The mixture should then be left for several weeks to 'cool', as it is technically called, until the lime is thoroughly slaked, and its heating entirely killed.

Fine Stuff is composed of pure lime, slaked with a small proportion of water into a smooth paste, and subsequently further diluted with water until it is of the consistence of cream. It is then permitted to remain until the slaked lime has subsided, and the superfluous water has either been run off or allowed to evaporate, so that the resultant mixture is of the proper consistency for use.

Rough Cast. This is composed of sand, grit or gravel, well washed to remove clay or dirt, **mixed with hydraulic lime and water in a condition of slaking**. …

Limewash. Take well-slaked lime; dissolve 2 ½ Ibs. of rock alum in boiling water and add to every pail of the limewash. This compound should be used very thin. As it begins to dry the alum will act as size and bind it to the wall, and the second coat will form a white smooth finish.

Stucco Whitewash. Put half a bushel of un- slaked chalk lime into a cask and slake it with boiling water, and cover it over. Strain when cold through a fine hair sieve. Then dissolve 1 Ib. of table salt in warm water and add to the lime solution. Then take 3 Ibs. ground rice, 1 Ib. glue, and ½ Ib. Spanish brown; dissolve these
in boiling water, put to former solution, add 5 gallons boiling water, stirring well, and let the mixture stand (with the cask covered) until cold.
Make this wash quite hot before you apply it. This is for external work.

An excellent Whitewash. The following method of preparing whitewash has been strongly recommended. Take a clean, water-tight barrel, or other suitable vessel, and put into it ½ bushel of chalk lime, slake it by pouring boiling water over it in sufficient quantity to cover the lime five inches deep, and stir briskly until thoroughly slaked. When the slaking has been effected add 2 Ibs. sulphate of zinc dissolved in water, and 1 Ib. of common salt. This will cause the wash to harden and prevent unseemly cracking on the wall.

Mitchell C F (1912) – Building Construction. Seventh edition, thoroughly revised and much enlarged. London. Batsford.

P1. Chapter 1 Limes and Cements

Limes are classified under the following heads:
1. Pure or rich limes
2. Poor limes
3. Hydraulic – feebly hydraulic, moderately hydraulic, eminently hydraulic.

Limestones are never found absolutely pure in Nature (p2) but are either mixed with impurities or in combination with them, which impurities, if soluble in acids, are useful in accelerating the setting action, but if insoluble in acids are valueless for that purpose.

Rich Limes Limes are said to be rich or pure when the impurities insoluble in acids do not exceed 6% of the whole mass.
For plastering, rich, pure or fat limes only should be used, because of their readiness to slake, and their consequent non-liability to blister as compared with hydraulic limes.

Poor Limes are those containing from 15 to 30 % of impurities insoluble in acids. They possess the general properties of rich limes, but in less degree. They take longer to slake, and do not increase in bulk to such an extent as the rich limes. They do not take such a large ratio of sand, owing to the foreign matter they already contain.

Hydraulic Limes contain a quantity of combinable substances other than lime, such as silica and alumina, which on being burnt form calcium aluminate and calcium silicate, together with a portion of lime, the measure of these bodies up **to a certain point** being the measure of the hydraulicity.

Limes containing between 6 to 16 % of these useful substances are termed feebly hydraulic; those containing 16 to 26 %, moderately hydraulic, and those from 26 to 36 % eminently hydraulic.

Hydraulic limes only should be used as the matrix for lime concrete, and they are most suitable for constructional work

P4 For the burning of pure dense limestones, about ¼ of their weight of coal, and for hydraulic limestones about 1/6 of their weight of coal is necessary in each case.

P5 The object of slaking lime is to form a calcium hydrate, thus rendering it quickly in a fit condition to readily combine with the CO2 to form crystals of calcium carbonate….Slaking is induced by **adding water to quicklime**…The slaked lime thus formed is soluble, and hence **when more water is added,** some of this dissolves and forms a saturated solution.

If quicklime be left exposed in the air, it absorbs CO2, which under these conditions renders it inert, as the resulting carbonate is not crystalline.

Slaking of the lime is an important process in the manufacture of mortar, and it is imperative that every particle of quicklime must be thoroughly slaked, for if any unslaked portions are built in the work it will, by its subsequent expansion, disturb the rest of the work.

To obviate this failing, **the mortar after mixing should always be left to temper, covered over sometimes with a layer of sand, for at least a week to one month before being used.**

The purer the lime is, the longer it may safely be matured.
Setting of Lime

The setting of lime depends on the absorption of of CO2 from the atmosphere by the slaked lime in solution in this mortar, the carbon dioxide being soluble in water. The Ca(OH)2, with the excess of CO2, combine to form Ca(HCO2), which decomposes on evaporation into crystals of CaCO2, the H2O helping to dissolve the next particle, forming it into a saturated solution, and putting it into a condition to take up a molecule of CO2; this in its turn repeats the action already described and crystals of CaCO2 are formed. The crystals always have a tendency to adhere to something rough and hard, such as sandy particles or the surfaces of bricks; for this reason the addition of sand up to a certain ratio increases the strength of the mixture, **the best ratio being one part eminently**

hydraulic lime to one of sand, the maximum being one of pure lime to three parts of sand. (*Measured in quicklime*).

A long time elapses before pure limes harden, owing to their depending upon external aid to attain this state. If lime alone was used, the surface would set and form an impervious layer, and so check the CO2 from acting on those particles below the surface, the moisture in which evaporates and leaves it in the state of a powder; and even when a large proportion of sand is used and the mass made porous, the supply of CO2 must necessarily small; and a long time elapses before the material hardens. …pure limes should be avoided for constructional work, and a lime or cement which does not depend on external aid to set, be used.

Hydraulic Lime Mortar The strong hydraulic limes are usually ground into powder to facilitate the slaking. **Slake the lime by sprinkling it lightly with water, then turn it up together in a heap, and cover it with sand. After 24 hours it may be made into mortar by adding the proportions of sand and water.**

One part of lime and 2 parts of sand make excellent mortar.

Selenitic Cement or Selenitic Lime is an invention of General Scott, and is made by adding to the limes of the lias formation (the best)…or to the magnesian limestones or any lime possessing hydraulic properties, a small proportion of calcium sulphate in the form of plaster of Paris, mechanically mixed and ground with lime.
P13 An artificial puzzolana is made and largely used by grinding old well-burnt bricks and tiles, and adding to lime in lieu of sand to make mortar.

Roman Cement is a natural cement prepared by burning **at a low temperature** nodules found in the London clay, and the shale beds of the lias formation.

It contains about 40% clay, is of a rich brown colour…It is kept in barrels, as on exposure to the atmosphere it absorbs CO2, and moisture, and becomes inert. It should, therefore, be used fresh.

It is about one third the strength of Portland cement (in 1912) and is much weakened by the admixture of sand, which should never be used in greater ration than 1 to 1.

…It is chiefly used for tidal and constructional work and where rapidity of setting is a necessity. **It is now almost entirely supplanted by Portland cement for all works.**

P14. *Portland Cement* a good Portland cement should contain approximately 60% of lime, 20% of silica and 5 to 10% of alumina, and small quantities of alkalies, oxides etc.

….p20 The 'initial' set of Portland cement is due to the relatively rapid hydration and crystallisation of the aluminates; whilst the 'final' set or hardening is primarily due to the slower chemical activity of the silicates. (gypsum addition will inhibit this early hydration).

Mitchel C F (1947 edition).

P25

The cementing material used in brickwork or masonry may be either Portland cement or lime or a mixture of the two…

P26 …the use of a strong mortar is not always necessary, and may be detrimental.

Lime Mortar A suitable ratio of lime to sand for lime mortars is 1:3 (*quicklime:sand).* The lime should be semi-hydraulic; **high calcium lime is unsuitable for mortar unless gauged with cement. Lime mortars should not be used for external work and in general it is preferable that, whether for external or internal work, lime mortars (other than hydraulic) should always be gauged with a proportion of cement.** Mortar prepared with hydraulic lime **may be unreliable and cannot be recommended for general use.**

Cement-Lime Mortars Suitable proportions for cement-lime mortars vary according to conditions and requirements from 1:1:6 to 1:3:12, cement: lime: aggregate. A 1:1:6 mix should be suitable for use under most conditions of **severe exposure**; Mixes containing a larger proportion of lime become progressively more liable to suffer damage from frost and exposure, although the workability and plasticity of the mortar increases with the increase of lime content. **A 1:2:9 mix should be suitable for all normal work except under conditions of severe exposure; but a 1:3:12 mix should be used for internal work only.**

P27 *Wetting of Bricks.* The presence of water in mortar is necessary for the setting action to take place; precautions should therefore be taken to prevent the work drying too quickly; as a means to this end, especially in hot weather, all the bricks should be saturated before bedding, to prevent them absorbing the moisture from the mortar, and also to remove all loose dust from the surfaces that are to be in contact with the mortar.

J A Van der Kloes J A (1914) A Manual for Masons, Bricklayers, Concrete Workers and Plasterers, revised and adapted to the requirements of British and American Readers by Alfred B Searle. London J & A Churchill.

This represents a summary of craft practice and understanding of materials consequent upon the ever hardening of the latter across Western Europe. Van der Kloes dismisses the value or usefulness of fat lime mortars; whilst at the same time demonstrating that the stone decay at Cologne is apparent only to those parts of the fabric either built with, or repaired using Portland Cement mortars. Van de Kloes' described methods of slaking are not those advocated only decades earlier and involve slaking the lime separately from the sand. This illustrates the changing narrative of craft practice during the early 20th C, and although the methods may have had longer precedent in Central European craft practice, this seems unlikely – they are more likely responses to routine gauging with either Portland cement or the routine use of trass mortars. He later describes a mixing method that would be 'hot mixing' if the lime concerned was quicklime

(Following a description of serious stone decay to both ancient and relatively recent parts of Cologne Cathedral, to sandstones known to be generally very durable, and describing patterns of decay which would now be directly ascribed to the use of dense and incompatible cementitious mortars, and attributed by many to salts consequent upon atmospheric pollution:)

p14
These defects may be seen as much on the carved or profiled stones as on smooth blocks. The scaling is independent of the natural stratification of the stone…There is no evident difference due to the position of the structure relative to the positions of the compass.

P16 In comparison with the long series of building stones which have not proved durable at Cologne, there are very few in which no deterioration could be detected. *(only a lava stone and a 'fairly compact French limestone from Saint Meme fell into this latter category…)*
The contradiction between the alleged deterioration of all these stones by sulphurous acid and the fact that in the same atmosphere a limestone remains for a long time without being appreciably attacked…

In the opinion of the author, the deterioration at Cologne of stones which are elsewhere found to be of excellent quality is largely due to the mortar employed. This is the more probable, as most of the buildings (p17) where such stones have proved satisfactory were **built before the use of Portland cement became common.**

(But, some confusion)
Glazed bricks and tiles. The effect on glazed bricks and tiles of cement and **mortars which are rich in lime** is often serious. The glaze, after a time, becomes covered with a very fine network of hair-like cracks on which, and on the joints, a similar efflourescence to that described on P 8 is produced. The same salts crystallise in the porous material behind the glaze and eventually cause the latter to peel or scale.

…P20 It will be shown later that osmosis and wall cancer are often caused by the constituents of the mortar used in a building…

p73

Lime. When…quicklime is brought into contact with water it 'slakes'. If lime is well-burned and the proper quantity of water is employed for slaking (with fat lime the amount of water required is about half the weight of the lime), the (p74) lump lime falls into an impalpable, perfectly dry powder (*hydrated lime or slaked lime)*.

In dry-slaking, the lime is spread out on the ground in a layer 4 to 6 inches thick, and is sprinkled with water by means of a rose on a watercan. It is mixed with the aid of a shovel, and is then heaped up and left to itself for a day, so that it may be fulled slaked. It is advisable to cover the heap with sacks so as to retain the heat in it…
The dry, slaked lime is sifted...so that all coarse particles are separated and a really fine, soft powder is obtained.

As the proper slaking of lime is a process requiring considerable skill, some lime manufacturers now supply properly slaked and sifted lime ready for use under the term *hydrated lime*. This method of slaking is termed 'dry-slaking' in contradistinction to 'wet slaking', in which the lime is **mixed with three or four times its weight in water in a flat wooden trough, a liquid slurry being produced, which…is made to flow into a pit dug out of the neighbouring ground.** *(this method only for fat or rich limes)*.

With both methods of slaking a considerable amount of heat is developed…**(p75) To produce a building lime of good quality it is necessary to develop as much heat as possible,** avoiding the addition of too much cold water to any part of the lump lime and screening the material from the wind and draughts….Both methods of slaking will produce an equally useful lime for masonry and plastering.

(always a risk of premature carbonation with dry slaked lime, which) is bound to happen to some extent in ordinary dry-slaking with a suitable quantity of water, and is probably the reason (p76) why the use of lime putty has given better results than dry-slaked lime in tests with pozzalans….Wet-slaking is also the easier method and produces lime of better quality, as well as a durable lime paste. The use of rather more water than is strictly necessary does not do any damage in wet-slaking, providing that care is taken not to add too much *cold* water at a time and to regulate the supply of water *(in Van der Kloes' method, water is still added to the lump lime, not vice-versa),* **so that the temperature in the slaking trough remains sufficiently high to retain the whole mass at a boiling heat for some time.** (must be properly mixed and stirred throughout process)…

The provision of a grate at the outlet of the trough is superfluous and even harmful, because it easily leads to the use of an excessive quantity of water and to the resultant cooling or 'drowning' of the lime.

….During slaking….one bushel of lump lime…will produce three to three and a half bushels of **dry powder…**such limes are named *fat, rich or aerial lime.*

P77 The term 'aerial lime' originates in the fact that such a lime cannot harden otherwise than by exposure to the air, from which it absorbs carbonic acid. For this reason lime putty which is stored in a pit never hardens…A thin skin of carbonate of lime is formed at the surface, and this also **assists in excluding the air. The thickness of this skin increases extremely slowly.** The lime putty in the pit is usually prevented from drying out and superficially hardening by covering it with a layer of sand.

Hydraulic Lime. A lime of entirely different properties is made by burning limestone containing clay.

P78 It goes without saying that wet-slaking cannot be employed for hydraulic limes and that dry-slaking is the only permissible method. The manufacture of hydraulic limes is easier than that of fat limes, as less heat is needed to burn them, and they are usually supplied in a more completely burned state than are quicklimes. Hydraulic limes not infrequently contain lumps of 'dead-burned' material...(viz) portions which have begun to melt; these are worthless, as they will not slake *but will, which Kloes does not say, promote flash setting when ground)…*

Hydraulic limeis less easily spoiled when it is allowed to slake by simple exposure to the atmosphere without any addition of water.

It is advisable to purchase hydraulic lime from the dealers **in a ready-slaked condition,** as this not only saves the trouble of slaking, but it is probable that the slaking has been carried out in a better manner and by specially-skilled labour.

Cement Lime. There are several kinds of lime which, after being burned, either slake with difficulty or not at all, but yet form a powerfully hydraulic material when they have been ground to a powder….(79) other terms applied to these materials are *ground lime, bag lime, natural cement and Roman cement.*

….Most hydraulic limes seem to consist of irregular mixtures of feebly and vigorously hydraulic particles.

P86
The action of hydraulic agents, such as trass or pozzolana, being of a chemical nature, they will serve their purpose better **the finer they are ground and the more thoroughly they are mixed with the lime;** in a coarse, granular hydraulic agent the greater part of its usefulness is lost, though it may form an excellent

builder's sand. The greatest hardness is obtained by grinding the pozzolana and dry-slaked lime together, instead of merely mixing them.

P92 Chapter V The composition, preparation and use of materials.

Kinds of Mortar.

Lime mortar – mixtures of lime and sand
Trass mortar – mixtures of lime, sand and trass or other pozzolana
Cement mortar – mixtures of Portland cement and sand.

Mixtures of lime, Portland cement and sand are termed *lime-cement mortar,* and mixtures of Portland cement, trass and sand are termed *cement-trass mortar*.

Footnote: (Trass and lime mortars commonly used in Belgium and Holland in the past – for damp-proof courses, eg) The reason why our ancestors did not experience the disadvantages of such mixtures as much as the builders of the present day is that they used **an imperfectly burned lime and a coarsely ground trass, both of which introduced a certain amount of coarse stone powder (which acts like sand) into the mortar.** At the present time, the demand is for very finely powdered trass and for lime which is purer and has been burned much better…The use of such strong trass mortars for structures which are intended to remain **continuously under water** merely results in a great waste of money, but **if the structure is exposed to the air, the mortar shrinks and becomes loose and partially separated from the stones…**

P94 **Proportions.** …expressed in parts by measure, or volumes, all the materials, even the lime, being measured in a dry state.

In the case of lime paste or lime putty, one measure of paste taken direct from the pit may be considered equal to two parts of dry-slaked lime…

P95 Lime Mortar. In lime mortar the proportion of lime to sand may vary between 1:2 and 1:4 according to the nature and the properties of the lime and the purpose of the masonry.
It is not advisable to use fat lime in a lime mortar. For this purpose hydraulic lime is far preferable. The reason is that the hardening of fat lime is almost entirely dependent on the carbonic acid in the air…(p97) even under the most favourable conditions, the hardening can only take place very slowly…In dense lime mortars the fat lime may not become any harder than lime putty stored in a putty pit…

Hence, fat or aerial lime usually remains in the interior of heavy walls in an almost completely unpetrified state and, if water gains access to it, such lime is liable to be washed out. Even the use of hydraulic lime does not entirely (p98) prevent some lime entering into solution and being washed out…

P99 For roads and waterworks which are difficult to protect from the action of water the use of a mortar (p100) made of fat lime is never advisable. For building houses and other town buildings, on the contrary, the use of mortar made of hydraulic lime will produce dry masonry of excellent quality. **Ordinary fat lime should…never be used without the addition to it of trass or some other hydraulic agent.**

Notwithstanding…there are many instances in different countries where not only is hydraulic lime used on a large scale for viaducts, retaining walls, etc, but such buildings are even constructed with mixtures of fat lime **and hydraulic lime. This is foolish, as neither ….should be used for such structures.**

(Lean lime and trass mixes should be typically 1 slaked lean lime: 1 ¼ trass OR 1 slaked fat lime powder: 1 ½ trass). …There is no advantage in using hydraulic lime in trass mortar; indeed, the hardening of the mortar is somewhat delayed by this kind of lime.

P107 Any excess of lime in trass and cement mortars is liable to be dissolved or washed out in a manner similar to the non-hydraulic portions of lime mortar.

(Generally, Van der Kloes attributes dissolution of lime from lime/trass mortars to be caused by the fat lime, rather than by the hydraulic component preventing the carbonation of the fat lime, at the same time as dismissing the ability of straight fat lime mortars to carbonate much at all beyond their face).

P145 It is now increasingly recognised that pozzolana mixed with a suitable proportion of lime and sand makes an excellent mortar, and it is also known that the defects observed in masonry where trass mortar was used are not due to the trass itself, but to the unsuitable composition of the mortar.

P146 **Cement Mortar.** In order to make absolutely water-proof joints with Portland cement it is necessary to use no more than two measures of sand for each measure of Portland cement. If the masonry is to be exposed to the atmosphere…, in order (p147) to avoid shrinkage…add seldom less than three and in no case less than two and a half measures of sand to each measure of cement. These limits are very seldom observed in practice and the 1:2 cement mortar, often used for many abutments of bridges is both unnecessarily expensive and gives bad results.

P148 Portland cement in mortar….always contains free lime. This lime, like that in lime mortar and in trass mortar rich in lime, is liable to be washed out and to form crusts.

Lime-Cement Mortar. As Portland cement alone is subject to a washing out of lime, as just described, it is clear that the addition of lime to cement mortar **can only increase the trouble.** Indeed, such an addition…(p149) is about the worst thing that can be done.

….(p150) The addition of lime to cement mortar has a two-fold purpose – a) to make the mortar cheaper and b) for the convenience of the workmen.

…the more the lime exceeds the cement, the more does it hinder the hardening of the latter and the damper will the walls remain…(p151) when the proportion of lime in a mortar is very large, such a mortar will never harden properly.

(Portland cement at this time was more like an eminently hydraulic lime than today, with much less compressive strength).

(Says that the addition of trass to cement-lime mortars will prevent run out of free lime)…In marine works no cement mortar should be employed without adding a hydraulic agent.

P155 **Choice of Mortar.** Recapitulating…on choice of mortar:

1) Lime mortar made of fat lime must be entirely discarded
2) Lime mortar made of hydraulic lime is a very useful material for ordinary buildings, but it must *not* be used for roadways, bridges, or masonry exposed to water such as marine work or reservoirs
3) Lime must *not* be added to cement mortar
4) Trass (or other pozzzolana) is in most cases, an excellent substance to add to cement mortar
5) When the choice lies between lime-trass mortar and Portland cement mortar, the trass mortar is preferable in most cases because
   a) it is easier to work;
   b) it is less liable to be spoiled if it is not used immediately after mixing. (trass mortar will not be spoiled if it remains a whole day after mixing before being used)
   c) it is usually cheaper
   d) it adheres to the stones almost, if not quite, as tenaciously as cement mortar.
6) For kiln, furnace and boiler work, clay mortar should be exclusively employed.

The value of a mortar depends on:

a) its hydraulicity and the rate at which it combines with water during hardening
b) no more than the necessary amount of lime being used
c) the presence of trass or other agent to fix any free lime present or which may be found during the hardening of the cement or mortar; and
d) the presence of a sufficiency of sand to keep the shrinkage within suitable limits.

Preparation of Mortar

P157 A thoroughly well-mixed mortar may be made either by hand-mixing… or by mechanical means, but since mortar mixers have come into general use, hand-mixing is seldom employed; even where it is still used it is frequently carried out in a most imperfect manner, ie by stirring the materials with too much water in a flat wooden trough by means of a rake.

The most suitable form of beater resembles a spade with a long handle, the blade of which is bent at right angles to its usual position…like a large, toothless rake…it should not be used as a stirrer.

The proper way to mix mortar by hand is as follows:

The sand is first measured and shot out on a wooden floor or mixing board; the other solid constituents of mortar are also measured and added to the sand, the whole being mixed together in a dry state by means of the rake. After having worked through the heap several times, a hollow is made in its centre and a suitable quantity of water is poured on, but on no account must too much water be used. The mass is again turned over several times with the rake, and is then kneaded in such a manner that the workman pushes off a small quantity of the paste with the flat side of rake, rubs it flat over the floor, and fetches it back. He repeats this until the whole mass has been treated in this manner….
The mixing must not be stopped before the rubbed (p158) out surfaces show a uniform colour, quite free from white spots or 'eyes'.

If the mixing has been properly done, it will be found that, while only a small proportion of water has been used, the resultant mortar will be a perfectly tractable paste, just fluid enough to be worked with the trowel.

P201

Table of relative costs of materials:

1 cubic yard of	Portland cement	34s 8d
	fat lime powder	4s 8d
	hydraulic lime powder	10s
	trass	27s
	Lime trass cement	24s
	Plaster of Paris, dry	5s
	mixed	25s
	Builder's sand	8s
	Fine gravel	9s
	Ballast	7s

Lazell E W (1915) Hydrated Lime: History, Manufacture and Uses in Plaster, Mortar, Concrete; a Manual for the Architect, Engineer, Contractor and Builder. Jackson-Remlinger Pittsburgh. Facsimile by Filiquarian Publishing LLC.

The thrust of Lazell's treatise is clear and unambiguously promotes the use of dry hydrated lime for all building purposes, and for plastering. Advances in the industrialised production of reliable, good quality dry hydrate – both of high calcium and magnesian – lime indicated to him that this was the most convenient, most economic and most reliable form of slaked lime, obviating the need to either slake to stiff putty or to dry powder by traditional methods, which he considered more time consuming; more vulnerable to the inexperience or inattention of the masons or plasterers who carried out the operation and with more variable and less reliably burned lump lime. At no point does he entertain the notion that this may be an inferior product, whether used as the only binder, or in combination with Portland cement. He includes images of a number of high-rise and high status buildings the masonry of which was built using dry hydrated lime and Portland cement, as well as having been plastered within with dry hydrated lime mortars. He quotes historic Italian sources, including Vitruvius, to argue that slaking lime to a dry hydrate, to be laid down for later use, was the best way to achieve mortar of the highest quality but then bemoans the unreliability of traditional methods of dry-slaking and disapproving of "the modern method of slaking the lime in the middle of a ring of sand and almost immediately hoeing in the sand. In the present practice, more often than not, the plaster is placed on the wall or the mortar laid between the bricks within a few hours." (pp39-40), a rare confirmation of Millar's earlier assertion that this was, indeed, general craft practice, although Millar suggests that hot mixed plasters be subsequently laid down for up to 3 months. For Lazell, industrially produced dry hydrate solved all of the inconveniences of traditional forms of lime, slaked by traditional means and is flagging up a definite shift in lime use not only in the USA but in Europe also; a shift that ran in parallel with the rise in the use of Portland cement and saw increasing combination of dry hydrates of lime and Portland cement for all uses in the Construction industry.

Chapter III Classification of Lime.

….

TYPES OF LIME. Classification of lime based upon chemical composition:

a) *High Calcium Lime* – containing at least 90% of calcium oxide
b) *Calcium Lime* – containing from 85% to 90% of calcium oxide
c) *Magnesian Lime* – containing from 85% to 90% of calcium and magnesian oxides, 10% to 25% being magnesian oxide
d) *High Magnesian Lime* – containing not less than 85% of calcium and magnesian oxides, not less than 25% being magnesian oxide
e) *Hydraulic Lime* – which contains as large a percentage of lime silicate, aluminate or ferrate as to give the material the property of hardening

under water, but which at the same time contains so much free lime that the burned mass will slake upon the addition of water.

BUILDING TRADES CLASSIFICATION OF LIME.

Classification of lime and lime products based upon the form in which they are supplied the trade:

a) *Run of Kiln Lime* – the product as it comes from the kiln, without any sorting or further preparation
b) *Selected Lump Lime* – a well burned lime which has been freed from core, ashes and cinder by sorting
c) *Ground or Pulverised Lime* – lime which has been reduced in size to pass a ¼ inch screen
d) *Hydrated Lime* – a dry flocculent powder resulting from the treatment of quicklime with sufficient water to satisfy chemically all the calcium oxide present.

The various kinds of lime mentioned under the chemical classification may be brought into the market in any of the above four forms….

Chapter V

SLAKING LIME

QUICK OR SLOW SLAKING LIMES

…in order to render lime as it comes from the kiln suitable for use in mortar, it is necessary to slake it. This is **generally accomplished by adding sufficient water to the lime to produce a thick paste….**The high calcium limes are quick slaking and give off the greater amount of heat because these limes consist principally of calcium oxide, this being the material which, by combining with water, generates the heat. As the amount of impurities (silica, alumina and iron oxide), increases, the lime contains less calcium oxide and is therefore slower slaking. Such slow slaking limes are generally called 'lean' limes.

The dolomitic quick limes are slower slaking and generate less heat because they contain less calcium oxide (a part of this being replaced by magnesian oxide), which does not combine with water under the ordinary conditions of slaking….(Impurities make the process slower again).

METHOD OF SLAKING

The ordinary method of slaking quicklime is to add sufficient water to produce a thick paste after the reaction of slaking is completed….Sufficient water should be used in order that it may come into contact with all parts of the lime. If insufficient water is used some parts of the mass of lime become dry and are 'burned' in slaking. 'Burned' lime works tough and non-plastic in the mortar. If an excess of water is used, the slaking proceeds slowly and the resulting paste is thin and watery. Such lime paste is spoken of as 'drowned'.

Since various kinds of lime differ greatly in their behavior in slaking, some requiring more water and some a longer time to become reduced to a proper paste, it is necessary to exercise great care in slaking. **A quick slaking lime will require a large amount of water and this must be added quickly, also the lime must be turned over rapidly, so that the water has access to all parts and no 'burning' takes place during slaking.** On the contray, the slower slaking limes…require less water, and care is necessary to see that these limes are not 'drowned'….Too often the slaking is left to inefficient and ignorant labor, with the result that the mass of lime is not thoroughly slaked, being either 'burned' or 'drowned'….

AGING LIME PASTE.

(Lazell supports the view that lime paste should be well-aged before use to allow full slaking to occur),

The necessity of aging lime paste before using was recognized by the Romans *[but contradicted by the experiments of French and US military engineers some decades before Lazell's work].* Vitruvius gives the following directions for the preparation of lime paste to be used in plastering. "This will be all right if the best lime, taken in lumps, is slaked a good while before it is to be used, so that, if any lump has not been burned long enough in the kiln, it will be forced to throw off its heat during the long course of slaking in the water, and will his be thoroughly burned to the same consistency. When it is taken not thoroughly slaked but fresh, it has little crude bits concealed in it, and so, when applied, it blisters. When such bits complete their slaking after they are on the building, they break up and spoil the smooth polish of the **stucco.** *{Vitruvius is here describing the preparation of lime for fine stucco-work, not for building].*
"But when the proper attention has been paid to the slaking, and greater pains have thus been employed in the preparation for the work, take a hoe, and apply it to the slaked lime in the mortar bed just as you hew wood. If it sticks to the hoe in bits, the lime is not yet tempered; and when the iron is drawn out dry and clean, it will show that the lime is weak and thirsty; but when the lime is rich and properly slaked, it will stick to the tool like glue, proving that it is completely tempered."
"Vitruvius, translated by Morris Hicky Morgan, Cambridge, Mass., 1914, page 204. 38

The art of preparing lime mortar of the finest quality has survived in Italy *[again, for fine stucco finishes, and particularly, for repair and conservation of the same, and some 60 years before Lazell was writing]:*

"So late as 1851 an English architect, when sketching in the Campo Santo at Pisa, found a plasterer busy in lovingly repairing portions of its old plaster work, which time and neglect had treated badly, and to whom he applied himself to learn the nature of the lime he used. So soft and free from caustic qualities was it that the painter could work on it in true fresco painting a few days or hours after it was repaired, and the modeler used it like clay. But until the very day the architect was leaving no definite information could he extract. At last, at a farewell dinner, when a bottle of wine had softened the way to the old man's heart, the plasterer exclaimed, 'And now, signor will show you my secret! And immediately rising from the table, the two went off into the back streets of the town, when, taking a key from his pocket, the old man unlocked a door, and the two descended into a large vaulted basement, the remnant of an old palace. There amongst the planks and barrows, the architect dimly saw a row of large vats or barrels. Going to one of them, the old man tapped it with his key; it gave a hollow sound until the key nearly reached the bottom. There, signor! There is my grandfather! He is nearly done for.' Proceeding to the next, he repeated the action, saying, 'There, signor, there is my father! There is half of him left.' The next barrel was nearly full. 'That's me!' exclaimed he; and at the last barrel he chuckled at finding it more than half full; 'That's for the little ones, signor!' Astonished at this barely understood explanation, the architect learned that it was the custom of the old plasterers, whose trade descended from father to son from many successive generations, to **carefully preserve any fine white lime produced by burning fragments of pure statuary**, and to each fill a barrel for his successors. This they turned over from time to time, and let it air- slake in the moist air of the vault, and so provide pure old lime for the future by which to **preserve and repair the old works they venerated.** After inquiries showed that this was a common practice in many an old town, and thus the value of old air-slaked lime, such as had been written about eighteen hundred years before, was preserved as a secret of the trade in Italy, whilst the rest of Europe was advocating the exclusive use of newly burnt and hot slaked lime." (quoted in Hodgson, Concrete, Cement, Mortar, Plaster and Stucco, pages 22 to 25).

NECESSITY FOR HYDRATED LIME

If a good, sound, smooth working lime paste is to be HYDRATED LIME made from lump lime, it is absolutely necessary that the lime be slaked some considerable time before using. Compare the method of slaking recommended by Vitruvius and that of the skilled Italian plasterer with the <u>**modern method of slaking the lime in the middle of a ring of sand and almost immediately hoeing in the sand. In the present practice more often than not, the plaster is placed on the wall or the mortar laid between the bricks within a few hours.**</u> Such mortar must contain free lime that has not had time or opportunity to slake. This lime later takes up water causing the mortar to be crumbly or the plaster to crack and pop.

In spite of improvements in the method of producing lime with better and more economical kilns, the material is brought into the market in the same manner as

it was centuries ago. Further, the method of slaking lime has changed only for the worse, in that our rapid modern practice does not admit of the slow action of slaking lime thoroughly on the operation.
The only improvement in the form of the **merchantable** lime, known to the author, is that of hydrated lime.

CHAPTER VI

MANUFACTURE OF HYDRATED LIME

Within recent years, a method has been introduced of treating lime with water in a suitable apparatus in which the lime combines with sufficient water to satisfy the chemical requirements of the calcium oxide, forming a dry, finely divided flour, the so-called Hydrated Lime. *Hydrated Lime can be defined as the dry, flocculent powder resulting from the treatment of quicklime with sufficient water to satisfy the calcium oxide.* This material comes into the market in bags…and is ready for use, requiring only **guaging with water and mixing with sand** in much the same way as cement is used. The fact that lime could be slaked to the form of a dry powder has long been known, and three methods have been used in the past to produce this powder.

METHODS OF SLAKING (to a dry powder):

1. Lime, in comparatively small pieces about the size of an egg, is placed in a basket and immersed in water for a minute or two, until hydration has commenced, when it is withdrawn. The wet lime is generally put in heaps or silos in order to conserve the heat and prevent the escape of vapour. The material swells, cracks and becomes reduced to a dry powder.
2. Lumps of lime are placed in a heap and wetted at intervals so that the mass is equally moistened throughout. The slaking proceeds as in the first instance.
3. Small pieces of lime are exposed to the air for a number of months. The material absorbs both water and carbon dioxide from the atmosphere, falling to a dry powder. The powdered form consists of a **hydrated sub-carbonate of lime** containing about 10% to 11% of water.

The methods of dry-slaking lime are crude, and unless the greatest care is exercised, the resulting dry product will contain particles of unslaked lime. Further, the hydrates produced by these methods **generally work short and possess poor sand carrying capacities.** In fact, hydrated lime produced by any of the above methods is **only suitable for use on the soil,** and such hydrate should not be confounded with hydrated lime manufactured by modern methods, (which are much more controlled and exact. Lazell details a number of modern, industrial processes)….

CHAPTER VIII

USE OF HYDRATED LIME IN SAND MORTARS.

It may be stated that hydrated lime is suitable for any use in the building trade to which lump lime can be put…

A mortar made with hydrated lime often does not trowel quite so easily as a mortar made from lime putty. The smooth working qualities of the hydrate can be greatly improved by proper method of manufacturing and by **allowing the mortar or paste to soak overnight so that the gauging water becomes thoroughly incorporated.** The great ease of handling hydrate and the thoroughness with which it has been slaked make up to a great extent for any lack of plasticity.

The use of hydrated lime does away with the necessity of slaking lime to a paste, thus saving the cost of slaking…Hydrated lime comes into the market in convenient packages of a definite weight. This makes it possible to proportion the mortar (exactly)…which is always appreciated both by architects and engineers. It is much more difficult to obtain accurate proportions of lime and sand when lump lime is used, especially as it is a **general custom to add as much sand as possible, with the result that the mortar is often over-sanded and possesses little strength.**

ADVANTAGES OF HYDRATED LIME

(LAZELL PRESENTED RESULTS OF TESTS ON BOTH HYDRATED AND LUMP LIME MORTARS TO AMRICAN SOCIETY FOR TESTING MATERIALS IN 1910…) One of the most important conclusions …**was that mortar produced from hydrated lime was stronger than that produced by lump lime slaked to a paste** (- expected because hydrate fully and properly slaked)…The user in dealing with hydrated lime is handling a product **which can be definitely proportioned and will produce known results. ….**With lump lime the user is dependent upon the thoroughness of slaking and it is well known that unless paste is run off and stored for some considerable time, there is **no assurance of complete and thorough slaking.**

Practically all those who investigated the strength of lime mortars have recommended the use of hydrated lime rather than lump lime.

In Circular No.30, 1911, of the Bureau of Standards:

"The proportion of impurities in hydrated lime is generally less than that in the lime from which it is made. **In building operations, hydrated lime may be used for any purpose in place of lump lime, with precisely similar results** The consumer must pay the freight on a large amount of water, but the **time and labour required for the slaking is eliminated** and there is no danger of spoiling it either by burning or incomplete slaking…**For all building purposes hydrated**

lime is to be preferred to lump lime. By its use the time and labor involved in slaking may be saved **and the experience of the labourer is eliminated as a factor in the problem.**

In plastering (the need to lay down lime or coarse stuff is removed, causing potential delay). Moreover, plaster made from lime does not set quite so rapidly or in the same manner as gypsum plaster…(leading people to think that hydrated lime will also cause delay)…By the use of hydrated lime the delay due to slaking and seasoning is done away with, and by a proper method of planning and rotating the work, the job can be completed without delay *[does hydrated lime carbonate faster than other forms?]….*

…Sand for use in lime mortars should be clean, free from dirt and loam, and as coarse as is **consistent with the character of surface required.** Investigations of sands have shown that coarse sand yields a stronger mortar than fine sand *[Treussart and Totten showed the opposite]. …*

…(asserts that sand-carrying capacity of hydrated lime is very good)….It would require 264 pounds of hydrate to carry the same amount of sand as 200 pounds of lump lime….

Hydrated lime is especially adapted for use in the mortar mixer because the material comes on the work in a convenient form and in packages of known weight.
On a recent job with which the author is familiar, all the mortar used in the brick work was mixed in this manner. The mixer machine was operated only during the last few hours in the afternoon, enough mortar being prepared for next day's requirements. The mortar mixed in the machine was dumped into the basement in a pile and was **allowed to age overnight.** When used, the mortar was entirely satisfactory and worked free and smooth.

PREPARATIONS FOR HYDRATED LIME PLASTER.

WOOD LATH - THREE COAT WORK

Scratch Coat 1:3.5 + hair (by weight)

Brown Coat: 1: 4 + hair (by weight)

Finish Coat, White: lime putty properly gauged with Plaster of Paris.

Sand Float Coat 1:2.75 (by weight)

WOOD LATH – TWO COAT WORK

First Coat: 1: 3.5 + hair (by weight)

Finish Coat, white: as above

Sand Float finish: as above.

BRICK OR TILE, THREE COAT WORK (all by weight)

Scratch Coat: 1:4 + hair

Brown Coat: 1:4

Finish or sand float finish, as above.

TWO COAT WORK – as above, without brown coat.

ON CONCRETE:

8 LIME: 2.5 CALCINED PLASTER (GYPSUM): 1 SAND.

HAND-MIXED MORTARS.

(Best by mortar mixer but two methods if perforce by hand):

FIRST: soak the hydrate with water so as to produce a thick paste, and allow to stand over night, then add the desired amount of sand and sufficient water to give the required consistency to the mortar. It is generally conceded that **this method produces the more plastic mortar.**

SECOND: Mix the hydrate and sand dry, the same as with cement mortar, then add the water to produce the required consistency.

When hair is used, it should always be well soaked and beaten before mixing with the mortar. Thorough hoeing and mixing always improves the plasticity and working qualities of a mortar.

LIME-CEMENT MORTARS

In many cases where a mortar having a greater strength is required, or it is advisable to have considerable strength produced quickly, it is advantageous to use Portland cement in the mixture.

Investigations by various authorities have proven that hydrated lime and Portland cement can be mixed in any proportion, from an addition of 10% of hydrate to the Portland cement for making a cement mortar, to an addition of 10% Portland cement to the hydrate for making a hydrated lime mortar. The addition of hydrated lime to a cement mortar improves the **plasticity and water**

tightness, and the addition of Portland cement to a hydrated lime mortar increases the early time strength.

ADVANTAGES OF HYDRATED LIME OVER OTHER FORMS OF LIME

- Hydrated lime is generally purer than the quicklime from which it is made
- Hydrated lime is easily subjected to inspection and tests, and the same material is used as is tested
- The use of hydrated lime does away with the slaking of lump lime, hence saves the cost and the space required for this operation
- Hydrated lime is thoroughly slaked and this fact can be determined by tests
- By the use of hydrated lime mortar definite proportions can be maintained. This is a difficult matter with lump lime
- The putty or mortar made with hydrated lime requires no aging to be assured of thorough slaking…In the south of Europe at the present time, it is the custom to slake lime the season before it is used.
- Hydrated lime can be economically mixed by means of a mortar mixer.
- Mortars made from hydrated lime are stronger than mortars made from lump lime slaked to a paste.
- Hydrated lime can be mixed with cement mortar or concrete in any desired proportions. It is a very difficult matter to mix lime paste with cement thoroughly.
- Hydrated lime can be stored without danger of fire. No heat is generated when water comes into contact with hydrate.
- Hydrated lime is not apt to be spoiled by air slaking, as is the case with lump lime. Often large amounts of lime are lost in this manner.
- Hydrated lime comes to the market in packages of definite weight and convenient size.
- The paper sacks generally used cost less than half as much as the barrels required to hold an equal weight of lump lime
- The paste made from hydrated lime requires no screening.
- There is no loss in the form of 'core' when hydrated lime is used.

Against all these advantages only two objections are obvious. One, the mortar made from hydrated lime often works harder and is less plastic than that made from lump lime. This difficulty is generally greatly exaggerated. Second, hydrated lime will not carry so much sand as a corresponding weight of lump lime….

The second objection is dependable on the first, because the larger sand carrying capacity of lump lime paste is due to its plasticity, or buttery, easy-working quality. This quality of lump lime *[and especially of hot-mixed quicklime]* usually results in the addition of too much sand *[as during the 20th C as putty lime was more used, and during the Lime Revival].* The over-sanding of lime mortar is very generally practiced, since it is the custom to add as much sand as possible, in order to cheapen the cost of the mortar. **This results in a lean, over-sanded mortar possessing little strength.** The manufacturers of lime are not blameless in this respect, since they have educated the public to believe that the greater the yield of paste from a barrel of lime, the more sand it will carry, overlooking the fact that that a leaner lime, or one which does not yield as great a volume of paste, produces a stronger mortar [*though here Lazell is comparing meagre, feebly hydraulic limes]*.

The increase in bulk when lime is slaked is mostly due to the water mechanically absorbed. When the lime mortar hardens, this water evaporates, causing it to shrink and the excess water is therefore a source of weakness and not strength. The greater the amount of water held mechanically, the greater the volume of the paste, and therefore, the less the amount of binding ingredient or lime contained in a volume of paste.

It has been proven by many experiments that the poorer limes make the stronger mortars. These poor, or lean limes contain clay, which unites with the lime during the process of burning, and the presence of this clay imparts some hydraulic or hardening properties to the mortar. These hydraulic limes are largely used in Europe, but, unfortunately, little of this material has been manufactured in this country. Practically the same results can be obtained by the use of a mixture of hydrated lime and Portland cement.

From all the advantages possessed by hydrated lime it would appear to be the **best form** of lime to be used. It is perfectly logical that the process of slaking **should be taken away from the haphazard manner used on the work and done at the point of manufacturer of the lime, where skilful supervision is possible. (80)**

Williams Ellis C (1916) *Building in Cob, Pise and Stabilized Earth. Shaftesbury. Donhead.*

Clough Williams Ellis allows little for quicklime addition to earths, except in reference to the occasional addition of lime to Norfolk lump construction (adobe, but of large 18″ x 12″ x 6″ blocks), a method probably imported into Norfolk from Spain by returning Peninsular War soldiers (pers comm Joe Orsi). More recent research in Spain would indicate that rammed earth had between 10% and 20% lime content, depending upon purpose (domestic or military respectively) and probably some adobe blocks did, too. He does give a succinct summary of the potential benefits of soil stabilisation, though Portland cement is his preferred addition:

"Broadly, 'Stabilization' can be thought of as any process by which earth is made less liable to volume change, more resistant to water, and of greater strength and hardness."

Protective Coverings for Earth Walls.

A TRADITIONAL METHOD

A common traditional external protection was a rendering of lime roughcast. The following extracts by Dr Abraham Rees from the *Cyclopedia or universal dictionary of Arts, Sciences and Literature*…gives a clear picture of one of the common ways in which this was done:

"to prepare the walls for plastering, indent them with the point of a hammer, or hatchet…all those dents must be made as close as possible to each other, and cut in from the top to bottom…The wall surface having been duly hammer-chipped, the work must be scoured with a stiff brush to remove all loose earth and dust, and finally to prepare it for rough-casting. **Roughcast consistes of a small quantity of mortar, diluted with water in a tub, to which a trowel of pure lime is added, so as to make it about the thickness of cream** *[it is likely that by 'mortar' Rees meant earth mortar].* One workman and his labourers are sufficient; the workman on the scaffold **sprinkles with a brush the wall he has indented, swept and prepared; after that he dips another brush, made of bits of reed, box etc into the tub which contains the roughcast, and with the brush, throws the roughcast against the wall…."**

LIMEWASHES

The basis of most lime wash recipes is the mixing of a quantity of tallow, which may be from 2 to 10 lb, into a bushel of quicklime to form an insoluble calcium soap. The tallow should be placed in the centre of the quicklime and the whole should be slaked together. If the quicklime is slow in slaking it should be covered with sacking, and hot water should be used. The addition of pigment may necessitate an increase in tallow, but a useful mean to remember is 5lb tallow to a bushel of quicklime.

When tallow is not available, calcium stearate in powder form may be substituted, or linseed oil may be added….The pigments should be lime fast **and should be added during slaking.** If this is not possible the pigment should be mixed with alcohol and added to the strained whitewash….
There are several traditional formulae consisting of lime (not whiting) thoroughly slaked and thinned to a cream to which various additions are made, such as salt, alum, powdered glue, casein (skimmed milk), etc. The effect of salt is probably to hold the moisture and facilitate the carbonation of the lime, while the addition of a small quantity of alum improves the working qualities and is thought to increase the hardness of the surface. Caseins and glues give greater binding properties to the mix.

The following recipes are taken from *White Paints and Painting* (Scott), and are reliable:

13. *'Factory' Whitewash (interiors), for Walls, Ceilings, Posts, etc:*
9. 62 lb (1 bushel) quicklime, slake with 15 gallons water. Keep barrel covered till steam ceases to arise. Stir occasionally to prevent scorching.
10. 2 1/2 lb rye-flour, beat up in 1/2 gallon of cold water, then add two gallons boiling water.
11. 2 1/2 lb of common rock-salt, dissolve in 2 1/2 gallons of hot water

mix (b) and (c) then pour into (a), and stir until all is well mixed. This is the whitewash used in large implement factories and recommended by the insurance companies. The above formula gives a product of perfect brush consistency.

(2) '*Weatherproof' Whitewash (exteriors), for Buildings, Fences, etc*
4. 62 lb (1 bushel) quicklime, slake with 12 gallons of hot water
5. 2 lb common table salt, 1 lb sulphate of zinc, dissolved in a gallon of boiling water.
6. 2 gallons of skimmed milk.

Pour (b) into (a), then add the milk (c), and mix thoroughly.

(3) *'Light House' Whitewash:*
8. 62 lb (1 bushel) quicklime, slake with 12 gallons of hot water
9. 12 gallons rock-salt, dissolve in 6 gallons of boiling water
10. 6 lb of Portland cement

Pour (b) into (a) and then add (c).

Note - Alum added to a whitewash prevents it rubbing off. An ounce to the gallon is sufficient.

Kidder F.E. (1920) Building Construction and Superintendence. Revised and enlarged by Thomas Nolan. Part 1 Masons' Work.

Limes, Cements and Mortars Chapter by Thomas Nolan. William T Comstock Company New York.

145. Importance of the subject.- There is hardly any material used by the architect or builder upon which so much depends as upon mortar in its different forms, and it is important that the architect should be sufficiently familiar with the different kinds of limes and cements to know their properties, and to understand their adaption to and suitability for different kinds of work. He should also be able to judge of the qualities of the materials with sufficient accuracy to prevent any which are actually worthless from being used, and he should have some knowledge of mortar mixing. …

There is considerable difference…in the limes of different localities, and before using a new lime the architect should make careful enquiries regarding its quality, and if it has not been much used it would be better to procure a lime of known quality, at least for plastering purposes; for common mortar it is not necessary to be so particular.

(Classifications)

Group A High calcium limes, limes containing less than 5% of magnesia…

Group B Magnesian Limes – limes containing over 5% (usually 30% or over) of magnesia. These limes are all slower slaking and cooler than the high calcium limes…and they appear to make a stronger mortar. **They are, however, less plastic or 'smooth', and in consequence are disliked by workmen.**

In the Eastern cities lime is sold by the barrel, weighing for Rockland Me. lime 220lbs net; but in many parts of the country it is sold in bulk, either by the bushel or by weight. When shipped in bulk it is generally sold by the bushel of 80 lbs, 2 ½ bushels or 200 lbs of lime being considered equivalent to a barrel….

Good lime should possess the following characteristics: 1. Freedom from cinders and clinkers, with not more than 10% of other impurities; 2. It should be in hard lumps, with but little dust; 3 It should slake readily in water, forming a very fine, smooth paste without any residue 4. It should dissolve in soft water.

There are some limes which leave a residue consisting of small stones and silica and alumina in the mortar box, after the lime is drained off. Such limes may answer for making mortar for building masonry, but should not be used for plastering if a better quality of lime can be procured.

148. SLAKING AND MAKING INTO MORTAR.

…When quicklime is slaked at the building operation, the ordinary practice is to do the slaking either by putting the lime in a water-tight box and adding water through a hose, or by pails, or by forming on a plank floor or on a bed of sand, a circular wall of sand, shovelling into the ring thus formed, the lime, and turning on the water from a hose. When the process of slaking is complete, the slaked lime is covered with a layer of sand until wanted.

…finally the lime is reduced to a powder…In this condition the lime…is ready for making into a mortar. The best limes slake without leaving a residue. The mortar is made by mixing clean, sharp sand with the slaked lime in the proportion of 1 part of lime to from 2 to 5 of sand by volume. The New York Building Code requires that not more than 4 parts of sand to 1 part of (*quick?)*lime shall be used. **Practically the proportion of sand is seldom, if ever, measured, but the sand is added till the person mixing the mortar thinks it is of the proper proportion.** For brickwork over a certain proportion of sand cannot well be added, for if there is too much sand in the mortar it will stick to the trowel and will not work easily. With stonework the temptation is always to add too much sand, as sand is generally cheaper than lime….

Some limes when slaked leave a residue of stones, lumps and gravel, so that instead of mixing the mortar in the same box in which the lime is slaked, a larger proportion of water is added, and the slaked lime and water (about as thick as cream) is run off through a fine sieve into another box, in which the mortar is mixed. Such lime does not make as good mortar as that which leaves no impurities, but it is sometimes used in ordinary brickwork and stonework.

The general custom in making mortar has been to mix the sand with the lime as soon as the latter is slaked and to let it stand until required for use. Much stronger and better mortar will be obtained, however, if the sand is not mixed with the slaked lime until the mortar is needed (*most would disagree…)*

148a HYDRATED LIME When quicklime is slaked on the work, it is usually done by careless laborers in a very indifferent manner, and the slaked lime seldom reaches a condition of theoretical efficiency. …ready-slaked lime, carefully prepared at the lime-plants, has been introduced during recent years. This is placed on the market under the names of 'new-process lime', 'hydrated lime' 'limoid' etc. Its manufacture involves grinding the lump quicklime to a fairly uniform, small size; the thorough mixing of the resulting grains of powder with the proper proportion of water; and the reduction of the slaked lime to a uniform fine powder by passing it through a sieve…

The product is generally sold in either heavy, closely woven burlap or duck bags containing 100 pounds, 20 bags to the ton or in paper bags containing 40 pounds, 50 bags to the ton.

148b HYDRATED LIME AND PORTLAND CEMENT MIXED. Very interesting tests have been made on the strength of a mixture of hydrated lime and Portland cement… Up to certain limits the addition of hydrated lime to Portland cement mortar makes the latter easier to work and more plastic…(and leads to) an actual increase in tensile strength when the addition does not exceed 10 or 20 %.

149 SAND. The reason sand is used in mortar is because it prevents excessive shrinkage and reduces the cost of the lime or the cement; and while its addition to cement mortar always weakens it, its addition to lime mortar in the proportion of 1 to 2 for example, adds to the latter's strength…

the usual specifications for sand used in making mortar require that it shall be angular in form, of various sizes, and absolutely free from all dust, loam, clay, earthy or vegetable matter, and also from large stones.
Recent tests and experiments, however, seem to lead engineers to the following conclusions:

1. it is not necessary to have the grains sharp;
2. the coarseness of the grains governs largely the quality. In mortars loam or clay is sometimes injurious, and sometimes beneficial, at least in cement mortars
3. **the pouring of water into sand does not accurately determine the voids**, which can be found by weighing the sand and finding its moisture
4. because of the effect of varying degrees of moisture, a study of voids does not result in a method of comparing sands
5. dry sand measured loose is heavier than moist sand
6. when mixed with cement coarse sand makes a denser mortar and requires less water than fine sand
7. fine sand with grains of uniform size and screened coarse sand when dry have nearly the same weigh, but with ordinary moisture fine sand is lighter and more porous than coarse sand
8. the weight of mixed sand is usually greater and the volume of voids smaller that that of coarse or fine sand…

For rough stonework a combination of coarse and fine sand makes the strongest mortar. For pressed brickwork it is necessary to use a very fine sand. …

Some masons attempt the use of fine sandy loam in their mortar, as it takes the place of lime in making their mortar work easily; but it generally tends to weaken the mortar, and it is better not to permit its use.

150 WHITE AND COLOURED MORTARS. To be used in laying face bricks should be made from *lime paste or putty* and finely screened sand. After the slaked lime has stood for several days the water evaporates and the lime thickens into a heavy paste, much like putty, from which it takes its name of 'lime putty'. By the time the putty is formed the lime should be well slaked and have no tendency to swell or 'pop'. Coloured mortar should *never* be made with *freshly slaked lime,* but only with lime putty at least three days old….

Clear lime putty may be kept for a long time in casks, for use in making coloured mortar, only a little mortar being made up at a time. Common lime when slaked and evaporated to a paste may be kept for an indefinite time in that condition without deterioration, if protected from contact with the air so that it will not dry up. It is customary to keep the lime paste in casks or in the boxes in which it was slaked, covered over with sand, to be subsequently mixed with it in making the mortar.

THE SETTING OF LIME (quotes Professor Clifford Richardson:

" The setting of lime mortar is the result of three distinct processes which, however, may all go on more or less simultaneously. First, it dries out and becomes firm, Second, during this operation, the calcic hydrate, which is in solution in the water of which the mortar is made, crystallizes and binds the

mass together….Third, as the per cent of water in the mortar is reduced and reaches 5%, carbonic acid begins to be absorbed from the atmosphere. If the mortar contains more than five per cent this absorption does not go on. While the mortar contains as much as 0.7 % the absorption continues. The resulting carbonate probably unites with the hydrate of lime to form a sub-carbonate, which causes the mortar to attain a harder set, and this may finally be converted to a carbonate. The mere drying out of mortar, our tests have shown, is sufficient to enable it to resist the pressure of masonry, while the further hardening furnishes the necessary bond"

….Lime mortar…attains its strength slowly, and where high buildings are built rapidly the mortar in the lower story does not have time to get sufficiently hard to sustain the weight of the upper stories, and for such work cement should be added to the lime mortar….

For the brickwork of ordinary buildings, and for light rubble foundations, lime and natural cement mortar forms a suitable and frequently used mixture; and when a still superior quality and strength are wanted, lime and Portland cement mortar is used.

2. HYDRAULIC LIMES

154 General Description. Hydraulic limes are those containing, after burning, enough lime to develop, more or less, the slaking action, together with sufficient of such foreign constituents as combine chemically with lime and water, to confer an appreciable power of *setting* under water, and without access of air. …Hydraulic lime or cement should not be used after it has commenced to set, as the setting will not take place a second time and the strength of the mortar will be lost.

Mr Edwin Eckel states that "theoretically, the proper composition for a hydraulic limestone should be calcium carbonate 86.8% and silica 13.2%. The hydraulic limes in actual use, however, usually carry a much higher silica percentage, reaching at times 25%, while alumina and iron are commonly present in quantities which may be as high as 6%....The hydraulic limes include all those cementing materials (made by burning siliceous or argillaceous limestones whose clinker after calcination contains so large a percentage of lime silicate… as to give hydraulic properties to the product, but which at the same time contains normally so much free lime that the mass of clinker will slake on the addition of water". …

Artificial hydraulic lime can be manufactured by mixing together, in proper proportions, soft chalk or thoroughly slaked common lime and unburnt clay, then burning and grinding in much the same manner as the manufacture of Portland cement…

158 DEFINITION OF NATURAL CEMENT. Natural cement is the product resulting from the burning and subsequent pulverisation of a natural clayey limestone containing from 15 to 40% of silica, alumina and iron oxide. There is no preliminary mixing and grinding. The temperature of the burning is about that of the ordinary lime kiln, and **not sufficient to cause vitrification.** Almost all of the carbon dioxide is driven off, there is a combination of the lime with the silica, alumina and iron oxide, and the formation of a mass containing silicates, aluminates and ferrites of lime; or in case the original rock contains magnesium carbonate, the formation of magnesia and magnesian compounds. As this resulting mass, as it comes from the kiln, will not slake if water be poured on it, it is ground into a fine powder, which, when mixed with water, hardens or sets rapidly either in air or water. The property of hydraulicity, as in the case of all silicate cements, is due principally to the formation of tricacic silicate. …

164. THE USES OF NATURAL CEMENTS. As the use of lime mortar is confined to dry places where it is exposed to the air, being usually employed only in construction of thin walls above ground and in the foundation coats of plaster; and as it loses its binding properties when exposed to dampness, as in basement walls, and when excluded from contact with air, as in thick walls; and as it sets too slowly to bear any immediate heavy weight; cements have to be added or cement mortars substituted to meet these conditions.

In mortar, natural cement is adapted to ordinary brickwork not subjected to high water pressure or to contact with water until about one month after laying; and for ordinary stone masonry where the chief requisites are weight and mass. Natural cement mortar or concrete should never be allowed to freeze, should never be laid under water, nor in very exposed situations, nor in marine construction.
Natural cement may be substituted for Portland in concrete, if economy demands it, for dry unexposed foundations…and will not be exposed until three months after placing; for backing or filling in massive concrete or stone masonry where weight and mass are the essential elements; for subpavements of streets and for sewer foundations…..

CEMENT MORTARS

200. USE Cement mortar should be used for all mason work which is below grade, or situated in damp places, and also for heavily loaded piers and arches of large span. It should be used for setting coping stones, and wherever the mason work is especially exposed to the weather.

For construction under water, and in heavy stone piers or arches, and, for concrete, Portland cement should be used; elsewhere natural cement mortar will answer….

202. KEEPING CEMENT MORTARS MOIST. Hydraulic cements set better and attain greater strength under water than in the open air; in the latter, owing to the evaporation of the water, the mortar has a tendency to dry rather than to set. This difference is very marked in hot, dry weather. If cement mortar is to be exposed to the air it should be shielded from the direct rays of the sun and kept moist.

...205 CEMENT-LIME MORTARS. Some constructions require quick-setting mortars, but do not need the strength nor warrant the expense of a 1 to 2, 3 or 4 mixture of cement and sand. A 1 to 5 or more mixture would give ample strength, but would work 'short'; that is, it would not work easily, rapidly and smoothly on the trowel. It would not adhere perfectly to the stone or brick and could not be safely used. *(This is the commonly used mix for new build in the UK in 2017)*. The addition of a limited quantity of slaked or hydraulic lime corrects these faults, results in a cheaper mortar and gives a mixture suited to a great variety of uses. It permits the use of Portland cement mortar for very many purposes.

The following are the principal advantages of Portland cement-lime mortar:

1. Cheapness in comparison with other hydraulic materials
2. Rapidity of setting and hardening
3. Marked hydraulic properties
4. Great strength on exposure to air
5. Remarkable resistance to the weather.

In making cement-lime mortar the sand and cement are thoroughly mixed dry, the lime putty is mixed with water and screened into a mortar box, and the whole is then thoroughly mixed and worked together until a proper consistency is obtained.

The following mixtures by measure that have been used with excellent results:

Cement 1 part, sand 5 parts, lime paste ½ part.
Cement 1 partm sand 6 to 7 parts, lime paste 1 part.
Cement 1 part, sand 8 parts, lime paste 1 ½ parts
Cement 1 part, sand 10 parts, lime paste 2 parts.

In regard to strength, a mixture of Portland cement 1, lime paste 1, sand 6, is as good as a mixture of Portland cement 1, sand 3, in this case one half the cement being replaced without loss of strength….

212 SUGAR IN MORTAR. Sugar has been employed for centuries in India as an ingredient of common lime mortar, and adds greatly to the strength of the mortar.

An addition of sugar or syrup equal to one-tenth of the weight of the unslaked lime, to lime mortar, adds 50% to the strength of the mortar and will cause the mortar to set more quickly. The addition of sugar to lime mortar is especially beneficial when used in very thick walls, as the lime mortar thus placed is never fully acted upon by the carbonic acid of the atmosphere.

Blake E G (1920) Building Repairs, Batsford, London.

Mason.

…Mortar for facework (in replacing failed stones individually) should be of good blue lias lime, and sharp washed sand (not too fine) and the back of the stone and the cavity should be thoroughly wetted, the mortar flushed all round and the stone pressed into the cavity so that the whole becomes a solid mass.

In the opinion of many, this method of repair should be carried out in some other material, such as brick or plain red tiles, or flints, so that the repair does not in any way spoil the ancient appearance of the structure but is at once apparent as a repair. This is only possible in the case of isolated stones in plain ashlar work…

Plasterer

Hair Mortar. The mortar for plastering should be made exclusively with chalk lime. It should be **made up roughly, at least a fortnight being being required for use, and should be allowed to lay in a heap, in order that the lime may become thoroughly slaked.** If the lime is used too fresh, it is probable that many small particles of lime will remain unslaked after it is spread, and these in the course of time would absorb moisture and expand…commonly called 'blowing'.

The mortar should be gauged **1 of lime to 2 of sand,** and the lime should be run before using in the following manner:

A bay, or ring of sand is formed, and a barrowful of lime is placed in a tub and well-covered with water, which will generate sufficient heat to cause the water to boil. When this has subsided, it should be run through a fine sieve…into the bay, to separate cores, stones, etc from the liquid lime, the sieve being supported on pieces of slate batten laid across the ring of sand from side to side. After standing overnight, any water which has risen to the surface can be run off if necessary, leaving the lime in a paste beneath. The hair should then be added, having been previously well beaten with sticks in order to free it from dirt and dust, and to bring it to a loose separated condition. This should be worked into the lime with a hair hook…after which **the sand is distributed over the lime, and the whole mixed up with a larry or with shovels.**

…**Putty**

The setting or finishing coat is composed of chalk lime which has been run into a tub or bay as before, and allowed to stand until the excess of water can be run off and the resulting 'putty' is of the required consistency. An equal quantity of sharp washed sand may be added to the setting coat if desired…the addition of sand, however, is not essential, but if pure lime putty is used alone, a rather shorter interval should be allowed between the floating and setting coats than when sand is added.

Pulver H E (1922) Materials of Construction. Engineering Education Series. McGraw-Hill New York.

Natural Cement

….Natural cement pastes and mortars are about half as strong as corresponding Portland cement pastes and mortars in tension, and only about a third as strong in compression….(After a month) neat natural cement cubes should average 800 psi (5.5 Mpa) or more; and 1:2 sand mortar cubes should average more than 500 psi (3.4 Mpa).

ASTMS standard specification, tensile strength:

1:3 natural cement: sand, 24 hours in moist air, 27 days in water: 125 psi (0.86 Mpa).

Uses of Natural Cement

Natural cement is used sometimes in structural works where mass and weight, rather than strength are required, as in sewers, conduits, massive foundations, pavement foundations, sidewalks, and rarely in large masonry dams, abutments etc. Natural cement when mixed with sand or with lime and sand, makes a suitable mortar for brick and stonemasonry that is not subjected to heavy loads. Natural cement should not be used in exposed places or under water or where it will be exposed to the action of frost before the concrete has set and dried….

Natural Puzzolana Cement

…Good puzzolan cement mortar of a 1:3 mix is about as strong in compression as alike mortar made with Portland cement, but is only about 70% as strong in tension. (Made with hydrated air lime).

LIMES AND LIME MORTARS

…*Quicklime* may be divided into two general grades as follows:

a) Selected lime – a well-burned lime containing no ashes, clinker, or other foreign material. It contains 90% or more of calcium and magnesian oxides and less than 3% of carbon dioxide. Sometimes called 'white' lime.

b) Run-of-kiln lime – a well-burned lime containing 85% or more of calcium and magnesium oxides and less than 5% of carbon dioxide.

Hydrated Lime – a quicklime to which just enough water has been added to produce a complete slaking.

Hydraulic Lime – obtained from the calcination of an ordinary limestone containing from 10 to 20% clay….

Manufacture of Hydraulic Lime

…The limestone rock used should be such that, after the silica has combined with the lime during calcination, enough free lime remains to disintegrate the kiln product by its own expansion when it is slaked. Such a limestone usually contains from 40 to 50% of lime; about 1% magnesia; from 7 to 17% of silica and about 1% of alumina and iron oxide….

After the burning, the lumps of lime are…slaked in the same way as quicklime, great care being taken to use just the right amount of water and no more, as an excess of water would cause the lime to harden. The expansion of the quicklime in slaking breaks up the lumps into a fine powder which consists principally of lime silicate with about 25 to 33% of hydrated lime, The lime is then screened through a 50-mesh sieve and placed in bags.
The underburned limestone and overburned materials (known as grappiers), which are left after the hydraulic lime is slaked and screened, , are ground to a fine powder and sold as 'grappier' cement….

Properties of Hydraulic Lime. Hydraulic lime pastes and mortars are about as strong as those of natural cement. …the strength of hydraulic lime pastes and mortars is about 1/3 as strong in tension and about ¼ as strong in compression (as Portland cement)….The rate of gain in strength is very slow and the maximum strength is not reached in less than a year. Hydraulic limes are about 5 times as strong in compression as they are in tension….

Uses of Limes. About half the lime made is used for various structural purposes…Most of the lime used for structural purposes is mixed with sand to form mortars for laying brick and stone masonry. A large amount of lime is used in plastering the walls and ceilings of buildings….Some lime is used for whitewashing. A little lime is sometimes used in cement mortars to make them more plastic and permeable.

Hydrated lime is used for the same…purposes as quicklime, and it is more easily handled, stored, and shipped as there is no danger of air slaking….

Hydraulic limes and grappier cements are sometimes used for the purposes of interior decoration. At one time they were much used in construction work, but they were replaced some time ago by the natural cements, and later by Portland cement. Hydraulic limes are not suitable for use in underwater work and they are too slow setting for practical construction work.

LIME MORTARS

Lime mortar is a mixture of slaked lime usually in the form of a thick paste, sand or other fine aggregate, and water.
The lime used is usually a quicklime which must be properly slaked or hydrated before the sand or other fine aggregate is added. **In general, a high-calcium lime makes the strongest and best-working mortar for ordinary uses.** Sometimes a hydrated lime (a lime which has been slaked by the manufacturer) in the form of a fine powder is used….

The sand used for lime mortar should be clean and sharp and be composed of rather small grains in preference to large ones…

Slaking the Quicklime. When quicklime is used, it must first be properly slaked before being mixed with the fine aggregate. It is important to secure a complete slaking of the lime and no more, because, if too much water is added, some of the binding power of the lime will be destroyed, and if too little water is used or proper care is not exercised by the workman, some of the lime may not be slaked…If the quicklime is properly slaked, the lime paste formed should have about three times the volume of the original quicklime. There are three general methods of slaking quicklime, namely, drowning, sprinkling and air-slaking.

Slaking by the drowning method is the most common way. The lumps of quicklime are placed in a layer 6 or 8 inches deep in a water-tight box and then water is poured on the lumps. The water should be equal to about two and a half or three times the volume of the quicklime. If the proper amount of water is added, the lime will form a thick paste. With a high calcium (quick-slaking) lime, it is better to add the water all at once, but with a magnesian lime, the water should be added gradually. As lime slakes best when hot, care should be taken not to chill the lime and retard the slaking. 'Burning' occurs when only a little water is present and this water is changed into steam by the heat produced. 'Burning' tends to prevent a complete slaking of the lime.

Another method of slaking by drowning is to fill a water-tight box with about 8 inches of water and then add lumps of lime in sufficient quantity to form a thick paste. The mass must be stirred to assist in breaking up the lumps of lime.

Slaking by sprinkling consists of sprinkling a heap of quicklime with water equal to about 1/3 or ¼ of the volume of the lime and then covering the mass with sand and allowing it to stand for a day or so. If the slaking is properly done, the hydrated lime will be in the form of a powder. This method requires extra care and expert labor and is, consequently, expensive.

Air-slaking consists of spreading the quicklime in a thin layer and allowing it to slake by absorbing moisture from the air. Frequent stirring is required. The method produces a good quality of slaked lime, but is rarely used due to the large storage area, labor and time required.

PROPORTIONING AND MIXING OF LIME MORTAR

Sand should be added to the lime paste for four reasons:
1. to prevent excessive cracking and shrinking of the lime mortar when the water evaporates
2. to give greater strength to the mortar
3. to divide the lime paste into thin films and to make the mortar more porous, thus aiding tin the absorption of carbon dioxide…which causes the lime to set or harden
4. to reduce the cost.

The usual proportions vary from 2 to 4 parts of sand to 1 part of lime paste. With most sands and limes, the correct proportion will be from 2 ½ to 3 parts of sand to 1 part of lime paste by volume. …The volume of the lime paste should be just a little more than enough to coat completely all of the sand grains and fill the voids.

In mixing the mortar, the lime paste is first spread out in a thin layer a few inches thick and the sand spread uniformly over the top. The lime paste and sand are then mixed by hoe or shovel until the mass is of uniform color. A little water should be added, if necessary, to make the mortar of the proper consistency. Thorough mixing is required to make a good mortar….

If too much sand has been used the mortar will be 'short' and 'stiff' and will not work properly; while if too much lime paste is used, the mortar will be too sticky to work properly. A mason can tell very quickly whether the mortar is correctly proportioned or not when he starts to use the mortar in his work. The proportions which give the best working mortar are also the best proportions in regard to strength, hardening and other properties (except when clay or loam is used instead of sand).

Properties of Lime Mortar.

Lime mortar has the important property of 'setting' or 'hardening' when the water evaporates and the lime absorbs carbon dioxide from the air thus forming calcium carbonate. This setting takes place very slowly…

In a lime mortar, an excess of lime paste delays the hardening, increases the shrinkage, decreases the compressive strength, and makes the mortar sticky….

The freezing of lime mortar delays the evaporation of the water and thus delays the absorption of carbon dioxide from the air. The expansion of the water due to the freezing may damage the mortar. Alternate freezing and thawing decrease the adhesive and cohesive strength.

A fine, sharp, clean sand gives the best results in a lime mortar….

Oils, acids, strong alkali, vegetable matter, etc decrease the strength and hardening qualities of a lime mortar.

The tensile strength of a good 1:3 lime mortar, 1 month old, varies from 30 to 60 psi. When it is six months old, the strength will probably be from 10 to 15 psi more.

The compressive strength (of same)…at the age a 1 month will probably be between 150 and 400 psi, while at the age of 6 months the strength may vary from 170 to 750 psi.

Common Lime or Wall Plaster. Is a lime sand mortar in which hair, fiber or dome similar material has been thoroughly mixed….to keep the plaster from shrinking and cracking when it sets and hardens on the wall.
Wall plaster is usually applied in two coats, The first…is about half and inch…the finish coat consists of a rich mortar (a 1:1 or 1:2 mix) made of a very white lime paste and a fine, sharp, clean, light-coloured sand.

It is important that the quicklime used in a wall plaster shall be thoroughly slaked before it is placed on the wall. **This is usually made sure of by allowing the plaster to remain in a water-tight box for several days before it is applied to the wall….**

Uses of Lime Mortar. Lime mortar is used as a mortar for stone and brick masonry, where the mortar can be placed in comparatively thin layers and the walls are not very thick, and where great strength is not required. Lime mortar should not be used in massive masonry, under water, or in a wet soil, as the lime will not harden unless it can absorb carbon dioxide from the air….Lime mortar is sometimes mixed with Portland cement mortar to make the Portland cement easier to work and also where a mortar stronger than lime mortar is required.
Eckel Edwin C. 1922 Cements Limes and Plasters, Their Materials, Manufacture and Properties. John Wiley and sons, New York; Chapman & Hall, London. Second Edition. Reprinted by Forgotten Books.

Eckel was a civil, formerly military, engineer. He looks very carefully at the chemistry of materials, whilst at the same time approaching them and their use *from the perspective a quantity surveyor. Much of the book is concerned with gypsum plasters, as well as with common and hydraulic limes and cements. His observations regarding hydraulic limes and their manufacture are of particular pertinence to current discussion and debate.*

CHAPTER XIII

THE THEORY OF HYDRAULIC LIMES

P172 The materials heretofore discussed in this volume – the (gypsum) plasters, common lime, magnesia, etc – have been simple both in composition and action. With the hydraulic limes, however, we take up the first member of a great class of **very complex products.** All these products possess hydraulic properties. In composition, they further agree in that they all consist essentially of **silica, alumina, and lime, with or without magnesia and iron oxide.** This group of complex cementing materials includes the hydraulic limes, the natural cements, the Portland cements, and the puzzolan cements. These four classes are quite distinct **commercially,** but it is at times difficult to draw the dividing line between the classes in words.

(Explains that he will use the Cementation Index to distinguish between them, as being more accurate and useful tool than is made available by the existing 'Hydraulic Index' – the latter based upon their readiness to set under water, but which makes no distinction between silica and alumina as the agent of this, giving them apparent equal power.)…

p173 The 'hydraulic index,' as usually defined, is the ratio between the percentage of **silica plus alumina** to the percentage of lime.

(eg hydraulic lime from Metz is 18.47% silica; 5.73% alumina; 68.19% lime. The silica and alumina are added together and divided by the percentage of lime to give a hydraulic index of 0.355. In this system the relative hydraulic indices given by Spalding are quoted:)

Hydraulic Index	Product
Less than 0.1	common lime, quicklime
0.1 – 0.2	feebly hydraulic limes
0.2 – 0.4	eminently hydraulic limes
0.4 – 0.6	Portland cement (if burned at high temperature)
0.6 – 1.5	natural cements
1.5 – 3.00	weak natural cements
3.0	puzzolanas etc

[note that Portland cement at this time less strong than natural cements].

(Whilst 'better than nothing', it is flawed because☺

1) no allowance is made for the action of either magnesia or iron oxide, and
2) the assumption is made that silica and alumina are quantitively interchangeable – ie that 10% of silica will have exactly the same effect as 10% of alumina.

(Cementation Index evolved from a system devised by Newberry for proportioning Portland cement mixtures. It assigns relative values to the impurities that reflect their relative hydraulic potential, so that in the previous example of Metz lime:

2.8 X % of silica is added to 1.1 X % of alumina plus 0.7 X % of iron oxide divided by percentage of lime plus 1.4 X % of magnesia, so that the final sum becomes 60.322 divided by 71.914, giving a Cementation Index for the Metz lime of .839, this figure being typical CI for a 'good hydraulic lime'.

P175 The use of the Cementation Index…involves certain assumptions as to the constitution of hydraulic cementing materials. These are, in order of importance:

1) that in hydraulic limes and cements, the hydraulic activity is due to the formation during manufacture of certain compounds of lime and magnesia with silica, alumina and iron.
2) That the silica combines normally with the lime in such molecular proportions as to form the **tricalcic silicate, 3CaO-SiO2**
3) That the alumina combines with the lime as the **dicalcic aluminate 2CaO – Al2O3.**
4) That magnesia is, molecule for molecule, equivalent to lime in its action
5) That iron oxide is, molecule for molecule, equivalent to lime in its action.

(Of these, first three are general consensus of American chemists; the last two more open to debate at this time. Cementation Index will be used by Eckel to classify the various hydraulic products)….

But it cannot be the sole basis for classification, because **the properties of a hydraulic cementing material** will be later seen to **depend not only on its composition, but on the <u>conditions of its manufacture.</u>**

A material having a CI of 1.05, might be, eg, a hydraulic lime, a natural cement, or a cement of the Portland type, depending upon the temperature at which the raw material was burned…a material with a CI of 0.40…could, under no possible temperature conditions, yield anything but a somewhat weak hydraulic lime.

[St Astier disputes the reliability of CI due to its assumption that all available silica/alumina/iron combines with lime, which it says, whilst true of Portland

cement, is not true of NHL. Maximum combination relies upon very high temperatures. However, Eckel posits the generation of tri-calcium silicates as defining factors in the creation of hydraulic potential. NHLs are generally supposed not to contain (fast-setting) tri-calcium silicates. St Astier also argue that almost ALL historic mortars were made with limes of some hydraulic potential and equates these historic feebly hydraulic limes with their own product, disputing the ability of historic mortar analysis to identify many of these feebly hydraulic mortars. www.stastier.co.uk/nhl/info/hydraul.htm]

P176 Definition of hydraulic limes – the *hydraulic limes* will include all those cementing materials (made by burning siliceous or argillaceous limestones) whose **clinker** after calcination contains so large a percentage of lime silicate (with or without lime aluminates and ferrites) as to give hydraulic properties to the product, but which at the same time contains normally so much free lime **that the mass of clinker will slake on the addition of water.**

The commercial advantage of manufacturing a material of this kind is that while the product has hydraulic properties, yet **its clinker will slake and pulverise itself on the simple addition of water,** thus avoiding **the expensive mechanical grinding required by the clinker of natural and Portland cements.**

The definition requires, therefore, that a material to be called a hydraulic lime must satisfy two conditions:

1) its clinker must contain enough free lime to slake with water and
2) the resulting powder must be capable of setting or hardening under water….

The *minimum* amount of lime (must be…) enough free lime (after burning) in addition to that combined with the silica, alumina and iron,…to reduce the entire mass to powder by the force of its own slaking. The *maximum* amount of lime…is determined by the **commercial condition** that no more free lime should be present than is absolutely necessary to accomplish this pulverisation, for the free lime…is by the same slaking, made into an inert, or, at least, non-hydraulic material.

The desired result – the formation of clinker consisting largely of lime silicates etc, but also containing sufficient free lime to slake readily – can be attained in two different ways, which **yield products very different in quality.** These two methods are: (p177)

1) By the calcination, at a **medium temperature,** of a siliceous or argillaceous limestone having a Cementation Index lying between 0.30 and 1.10. Such a limestone will carry so high a percentage of calcium carbonate (relative to its content of silica, alumina and iron oxide) as to leave, after *most* of its silica etc, have combined with lime, sufficient free lime to slake the clinker. Hydraulic limes produced in this fashion are the *typical* hydraulic limes (on which all subsequent chapters will focus)…

2) (the second and 'much less satisfactory method:) By the calcination, at **temperatures too low to permit the perfect combination of the silica, alumina, and iron oxide with the lime,** of a siliceous or argillaceous limestone (less rich in lime than those employed in the first method) having a CI of 1.10 to 1.6 or over. In other words, **a rock is used which would, under proper conditions of burning, give a good natural cement**. If it is burned at too low a temperature to effect this, however, the result will be a hydraulic lime, for the clinker will consist partly of free lime, free silica and free alumina *(see St Astier web-page above…)*. Hydraulic limes produced in this way necessarily carry a very large proportion of absolutely inert material. They are, in fact, **simple imperfectly burned natural cements** and will not be discussed further…

There is…considerable reason for dividing the true hydraulic limes into two groups, the first or *eminently hydraulic limes* containing those products whose index lies between 0.7 and 1.10; while the second group, or *feebly hydraulic limes*…ranges from 0.7 down as low as 0.3. Commercial as well as theoretical differences serve to separate the two groups….

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CHAPTER XIV.

EMINENTLY HYDRAULIC LIMES: GRAPPIER CEMENTS

The hydraulic limes are usually compared to Portland or good natural cements, only feebly hydraulic. (No hydraulic lime manufacture in USA, where an 'abundance of materials suitable for the manufacture of natural cements has prevented (its…introduction', though a 'considerable amount' is imported, their market in architectural, rather than engineering, contexts)…
(the discussion of their manufacture and properties)…will be practically confined to practice followed at Le Teil, France, where the largest and best known plants are located (Lafarge).

Composition of an ideal hydraulic lime – the clinker of an ideal hydraulic lime should…satisfy two limiting conditions…it must contain sufficient free lime to disintegrate the entire mass of clinker by the force of its own slaking…(and) no more free lime should be present than is absolutely necessary to effect this disintegration.

(It is possible to calculate this:

p179

Table 74, Composition of an ideal hydraulic limestone and hydraulic lime.

Hydraulic	hydraulic lime

	Limestone Before burning	before Slaking	after Slaking
Si02	13.20	21.20	19.08
CaO + CO2	86.8	78.80	70.92
H2O			10.00
Index	0.753	0.753	0.753

In actual practice, however, it is found that…if a limestone of the above composition is burned under the ordinary conditions of hydraulic lime manufacture…all of the silica does not combine with three-fourths of the lime, as required by the theory. What actually happens is that part of the silica will combine with part of the lime to form tri-calcic silicate, thus leaving a certain amount of uncombined silica and **entirely too much un-combined lime.** Any increase in the un-combined lime beyond the amount necessary to cause the clinker to disintegrate by its slaking **lessens the hydraulic value of the product.**

(So, modification required:)

a) *Lower lime content.* The limestones in actual use…differ from the ideal hydraulic limestone in carrying from 70-80 of lime carbonate…This decreases the amount of un-combined lime.
b) *Presence of alumina and iron.* Even the best hydraulic limestones in actual use carry notable amounts of (p180) alumina and iron oxide. These…act as fluxes, facilitating the combination of the silica and lime. They also combine themselves with lime to form aluminates and ferrites of lime.

…In hydraulic limes of the best types, such as are used at Le Teil, France, the silica will vary between 13 and 17 %, while the alumina and iron together will rarely exceed 3%. *(St Astier is 75% lime; 13% silica: 1.43% alumina and iron).*

P181 Burning – (in same kilns and manner as common lime). The temperature attained is, however, higher in hydraulic lime kilns…(greater fuel requirement, therefore). The higher the CI, the more care required to keep temperature down to preserve sufficient free lime….

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Slaking- Hydraulic lime, after burning, is a mixture of **two distinct compounds.** Part of the mass is composed of **lime silicate,** which would not slake if water were poured upon it, but would form a hydraulic cement if finely ground. The remainder…consists simply of quicklime, which will slake with water.
The result of the mixture of the two ingredients is that if water be poured on a lump of hydraulic lime, the portion consisting of quicklime will rapidly take up

water and slake…its expansion will break up the entire mass into a fine powder. If this operation is done carefully, with just the proper amount of water, the result will be a fine, dry, white powder, consisting **mostly of lime silicate,** with about 1/3 to ¼ as much of slaked lime.

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In the earlier days of hydraulic lime manufacture in France (**and even at the present day in England)** it was the practice to put the hydraulic lime on the market **in lumps**, just as it is drawn from the kiln**, leaving the work of slaking it to the purchaser.** At present, however, the slaking at the French works is done at the lime-plant. The advantages of this method…are that 1) the slaking is done more uniformly and carefully, so that the value and reputation of the lime is improved, and 2) the lime gains considerably in weight and bulk during slaking, so that the cost of slaking is made up.

Slaking should be done with as little water as is compatible with thorough slaking. The lime as drawn from the kiln is therefore spread out in thin layers and lightly sprinkled with water. It is then shovelled up into heaps or into bins, where it is allowed to remain for 10 days or so. The slaking is completed, while the lime is heaped up, by the aid of the steam which is generated.

After slaking is completed, the lime remains as a fine powder **interspersed with lumps (grappiers) of harder material.** These lumps consist in part of lime silicate and in part of unburned or underburned limestone…The lumps of lime silicate…will, if finely ground, make a good natural cement.

(In US at this time, grappiers separated and finely ground to make a natural cement)…a certain percentage of ground grappiers is usually added to the lime, in order to increase its hydraulicity. *[what happens to these in modern production?].*

Recommended mixes:

Mortar for use in salt water: one scant measure of lime to two full measures of sand

Mortar for use in fresh water: 1.75 lime: 3 sand

Mortar for use in air: 1 lime: 3 sand

For concretes:

In salt water: 2 mortar: 3 broken stone

In fresh water: 1 mortar: 2 broken stone.

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CHAPTER XV

FEEBLY HYDRAULIC LIMES: SELENITIC LIMES

The feebly hydraulic limes have been defined (above) as including those products whose Cementation Index ranges between 0.30 and 0.70.

This means that…no matter how high the burning temperature, not over 70% of its total lime *can* be in combination with the silica, etc, while if the CI, as shown by analysis, falls as low as 0.30, only 30% of the total lime can be so combined, even under the most favourable circumstances. As combination can never be theoretically complete, it is safe to say that **in the feebly hydraulic limes only from 20 to 60 % of their total lime is combined, the remainder being left free and capable of slaking. A product containing so much free lime and so little in the combined form (lime silicate) can obviously possess little hydraulicity or strength.**

Limes of this class **would hardly merit description, were it not for the fact that they are the usual type of *English* hydraulic limes,** and that they often serve as a basis for making…selenitic lime…

Table 88 ANALYSES OF FEEBLY HYDRAULIC LIME ROCKS

	Holywell England	Palhagen Germany	Horb Wurtemberg
Silica	5.00	4.64	7.40
Alumina and Iron oxide	4.23	7.08	2.40
Lime	48.65	48.27	40.82
Magnesia	1.86		4.52
Carbon Dioxide	40.26	37.92	37.00
Cementation Index	0.356	0.443	0.581

P195 (Table 89 has further analyses of Falhagen, Horb and Holywell hydraulic limes, as well as of Aberthaw, Blue Lias:

Silica	16.05
Alumina	1.92
Iron oxide	3.22
Lime	77.29 (includes carbon dioxide)
Magnesia	1.52

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Selenitic Lime: Scott's Cement

The cementing material known as Scott's cement, selenitic cement, or selenitic lime consists essentially of lime plus a small percentage of sulphur trioxide. The lime used…is always a more or less hydraulic variety, while the sulphur trioxide may be added to it in the form of **either plaster of Paris or sulphuric acid.** The resulting selenitic lime…shows a markedly higher strength, both in compression and tension, than the lime from which it is made.

CHAPTER VI

LIMESTONES

P94 If a number of limestone analyses be examined, it will be found that the principal impurities present are silica, alumina, iron, sulphur and alkalies.

Silica when present in a marble or crystalline limestone is usually combined with alumina, iron, lime or magnesia, and occurs therefore in the form of a silicate mineral. In an ordinary limestone, it is very often present as masses or nodules of chert or flint, or else combined with alumina as clayey matter. In the softer limestones, such as the chalks or marls, the silica may be present as grains of sand.

Alumina is commonly present combined with this silica, either as grains of a silicate mineral or as clayey matter.

Iron may be present as carbonate, as oxide, or in the sulphuric form as the mineral pyrite.

Sulphur is commonly present in small percentages in one of two forms: as pyrite or iron disulphate ($FeS2$) or as gypsum or lime sulphate ($CaSO2 + 2H2O$).

The alkalis soda and potash are frequently present in small quantity, probably in the form of complex silicates.

(Mollusc shells as source of lime):

…analyses show that in ordinary practice, commercial lots of oyster shell…carry around 5% of silica, iron oxide and alumina; with entirely unimportant percentages of sulphur, potash, phosphorous, etc

p96 (in parts of US where oyster-canning industries thrive…) oyster shells are burned into lime. An important lime-burning industry is, eg, based upon the use of waste oyster-shells at Baltimore, Md.

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CHAPTER VII

LIME-BURNING.

(A pure limestone when properly burned will lose 44% of its weight, and from between 12-20% in bulk.)

100lbs of limestone + heat = 56lbs quicklime + 44lbs carbon dioxide.

The dissociation of limestone on heating begins at a temperature of 750 degrees C, but is usually not complete until 900 degrees C, or thereabouts, is reached.

(Examination of types of lime kiln and their relative efficiency)

P117 CHAPTER VIII

COMPOSITION AND PROPERTIES OF LIME

…When made from a limestone rock, the lime should be in lumps, the occurrence of powder or dust proving that the lime has been exposed to the air so much since burning that air-slaking has begun. When the lime has been made from shells, marl, highly crystalline marbles, soft chalk, or shelly limestones, however, it will often come from the kiln in small fragments, which in this case is no sign of deterioration.

If the raw material is impure, containing much clayey matter or iron oxide, the resulting lime will not be white, but will vary from yellowish to gray or brown in colour, according to the amount and kind of impurities present. It will also, in general, slake much slower than would a purer product.

High-calcium vs magnesian limes:

High calcium limes slake rapidly on the addition of water, and evolve much heat during slaking. They also expand greatly, giving a large bulk of slaked lime. Magnesian limes slake very slowly, and evolve very little heat during the process. Their expansion is also less; so that, taking equal weights, they give less bulk of slaked lime.

Owing to the slowness and coolness with which the magnesian limes slake, there is some danger that the average (human) mortar-mixer will not give them sufficient time to slake thoroughly. Owing to the fact that they make less bulk of slaked product than do the high calcium limes, the average contractor or builder thinks that they are too expensive.

But…they are much stronger in long-time tests than the high calcium limes, and will therefore carry much more sand.

Composition of commercial high calcium limes – the non-magnesian or high calcium limes as marketed will rarely carry less than 90 % of lime oxide, while they commonly carry over 95%. The remaining 5 or 10% is made up of magnesia, silica, alumina, iron oxide, and a little carbon dioxide and water.

Lean and poor limes- a lime containing over 5% of such impurities as silica, alumina and iron oxide will usually be dark in colour, comparatively slow-slaking, and **difficult to trowel in working…In a few cases,** the impurities are so evenly and finely distributed throughout the original limestone that, on burning, **a certain amount of combination takes place between the lime and the impurities.** This gives **slightly hydraulic** properties to the product. Ordinarily, however, no such chemical combination takes place on burning, and the impurities simply serve to depreciate the quality of the lime produced.

Lime-slaking –

P122 CaO + H2O = CaO2H2 (lime hydrate).

With absolutely pure lime, the amount of water that must be added in order **to change all of the quicklime into lime hydrate will equal 32.1%, by weight, of the quicklime.** The resulting lime hydrate will therefore consist of 75.7% lime oxide and 24.3% water.

…Actually we know that this theoretical purity is never attainable on a commercial scale. The original limestone always contains silica, alumina, iron oxide, etc in quantities more or less large. The limestone is never perfectly burned, so that some portions of unburned lime carbonate will always be present in the product.

(these will reduce amount of water required to effect the slake and will somewhat reduce the expansion in volume)

p123

Methods of slaking lime in ordinary practice – When lime is used for making ordinary building mortar, the common practice is to add much more than the amount of water theoretically required. The result is not only to slake the lime, but to convert the slaked lime into a thin or thick paste, according to the amount of water used.

When ordinary laborers are slaking lime, it is evident that this method possesses the great advantage of being **on the safe side.** It is possible that the addition of surplus water weakens the mortar somewhat, but on the other hand, it ensures thorough slaking, or would insure it, if even reasonably good care were taken during the operation. **The trouble, however, is that lime-slaking is not regarded as an art, but as a disagreeable necessity, and it is usually carried on by laborers who are not even supposed to know anything about the subject.**

The result of these conditions is that the slaked lime used in mortar rarely even approaches its theoretical efficiency. Either so much water has been added that the strength of the product is impaired, or else the water supply or mixing has been insufficient and the product is not thoroughly slaked. *[conviction about this point led quickly into an embrace of hydrated lime in the US around this time, as avoiding these variables].*

A realisation of these facts has **caused the introduction of ready-slaked lime, prepared carefully at the lime-plants....Hydrated lime…**In its preparation, particular care is given to insuring that the product shall be thoroughly slaked, and that this slaking shall be done with as little water as possible…

In ordinary practice, where quicklime is slaked on the work, only one general method is followed, though books on construction invariably list and describe several other methods. The process as actually carried out is to form, on a plank floor or on a bed of sand, a circular wall of sand. The lime is shovelled into the ring thus formed and water is turned on from a hose until the labourer considers the amount sufficient. The lime commences to slake more or less quickly, according to its composition, and when the process is completed it is covered over with a thin layer of sand until required for mortar. *[or is mixed with the sand for immediate use].*

Use of lime mortars – Lime is never used alone as a binding material, for it shrinks greatly on drying and hardening…In practice, sand is always added to lime mortars, the proportions for ordinary use being **from two to four parts sand to one part lime paste.**

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The hardening of lime mortars is a simple process, though occasionally statements of opposite tenor may be found in print. It may be accepted as proven that lime mortars harden by simple recarbonation, the lime gradually absorbing carbon dioxide from the atmosphere and becoming, in fact, artificial limestones. As this absorption can take place only on the surface of the masonry, the lime mortar in the interior of the wall never becomes properly hardened *[or, at least, it will take a long time].* In this process the sand of the mortar takes no active part *[unless it is reactive, or porous, Eckel should say].*

Strength of lime mortars – few recent determinations have been made…as **lime is steadily decreasing in importance as an engineering material.**

P126 CHAPTER IX

HYDRATED LIME: ITS PREPARATION AND PROPERTIES

(A response to 'inefficiently accomplished' slaking on building sites…) it has only been within the past few years that any extensive effort has been made to provide a more satisfactory article for the contractor or builder.

Under the name of 'new process lime', ;hydrated lime', 'limoid' etc, a large number of lime-plants have within recent years placed a ready-slaked lime on the market. When this product is carefully prepared, **it does away with all the trouble, waste and unsatisfactory results entailed by the old method of slaking lump lime on the work.**

(Production is likely to greatly increase).

Preparation of hydrated lime –

1) the lump quicklime must be ground to a fairly uniform small size
2) the powder or grains resulting must be thoroughly mixed with sufficient water
3) the slaked lime must finally be sieved or otherwise brought to a uniform fine powder.

P131 Mixture of hydrated lime and Portland cement –

…This mixture has been tested by several experimenters…(Sabin and Thompson)…The addition of hydrated lime to a Portland cement mortar renders it more plastic and easier to work. When this addition does not exceed 10 or 20%, an actual increase in tensile strength seems to be shown.

(Table to show increase in consumption of hydrated lime in US from 120,357 short tons in 1906 to 853,116 short tones, 1920).

CHAPTER X

MANUFACTURE AND PROPERTIES OF LIME-SAND BRICKS

(refers to their manufacture as early as 1828. Then quotes from 1855 account of the process in New Jersey-)

"*Gravel bricks* – a new building material…which promises to be both cheap and durable. The common clean gravel and coarse sand of the country is mixed with 1/12 of its measure of stone lime *[feebly hydraulic, almost certainly]* and made into bricks. These bricks are sun-dried and then laid up into walls. They are cheap, durable and but little affected by the changes of the season.

"In making, the gravel is laid on a common mortar bed, and the lime, which is slaked and made into a thin putty in a lime-trough, is then run on the gravel and the whole worked up into the mortar….(p133) (the moulds) are set on smooth ground and filled with mortar. This is worked in a little with the shovel and struck off at the top. In **ten or fifteen minutes** the mortar will have set, so that the moulds can be taken off. The bricks are soon dry enough to handle, when they can be piled up and allowed to dry thoroughly. They are laid in mortar similar to that from which the bricks are made, and the outside of the buildings are roughcast with the same." (Cook GW 2nd annual report of the Geological Survey of the State of N J for the year 1855, pp107-108 1856).

(Typical size – 12″x9″x6″.)

…"When fist laid up they are not quite as strong as other bricks…Care must be taken to make them so early in the season as to be entirely dry before the winter's frost." (Ibid).

…Lime-sand brick manufacturers today claim that their product derives its hardness, not from simple re-carbonation of the lime, but **from a more or less thorough combination of the lime with the silica of the sand or gravel…**

p134…The action of lime upon silica, forming a silicate of lime and thus binding together particles of sand, as in mortar, has been known from the remotest ages, and concrete walls of great antiquity are now standing, vying with the natural rock in hardness and durability.

Some years since, a concrete block, compacted by pressure, was brought out in this country and used to some extent as a building material, but the slowness of the induration and uncertainty in the product hindered its general introduction.

The improvements (now) **consist in the use of heat in connection with quicklime and sand, by which the formation of the silicate of lime is hastened,** and the same effect, which formerly took years to be consummated, **is now produced in a few days.**

Ground quicklime is thoroughly mixed with clean, sharp sand, and is then subjected to the action of either super-heated or high-pressure steam, which slakes the lime and causes it to attack the silica. This process continues for from 20 minutes to 10 days, according to the degree of heat employed, when the material is moulded and compressed by a heavy steam-hammer into blocks of any desired form.

The ordinary building block made by this process is 10″ wide and 4″ deep, having a hollow space in the centre 6″ long by 1″ broad…(so that in building) a continuous sequence of air-chambers will be formed within the wall…Thirty days exposure of the block, after it is first formed, to the air, produces an induration **quite sufficient for all ordinary building purposes, but the block**

continues to harden for an indefinite period. A church built entirely of this material was recently dedicated at Morrisania (Bronx, NYC) (as well as YMCA in Chicago, though recently burned down. Built 1892-93)….The endurance of this stone when submitted to repeated freezing and thawing is quite remarkable, and experiment proves it to be equal in this respect, to granite.

The theory of lime-sand brick –

When ordinary quicklime is slaked, mixed with sand, and used as a mortar, the mixture hardens very slowly and never attains much strength. (Setting by gradual carbonation). *[NB, the quicklime is first slaked and then mixed with the sand when cooled].* So far as is known, there is no chemical action between the lime and the sand of the mortar…

(p135)…In making lime-and-sand brick by modern processes, it is claimed by its advocates that the lime and sand of the brick *do* combine to form lime silicates, the combination being in this case brought about through the action of steam under high pressure. It is also claimed, though rather by suggestion than by direct statement, that these lime silicates make up a considerable proportion of the entire brick.

To (Eckel) the first claim does not seem to be justified. No proofs have been presented that, in the course of lime-sand brick manufacture, any chemical combination takes place between the lime and the sand. It is undoubtedly true that the treatment with steam under pressure increases **in some unexplained**

way the chemical activity of the slaked lime; but further than that we cannot go at present.

The second point…can be readily settled…(p136) The amount of slaked lime used in making lime-sand brick will amount to 5-10% of the whole mass, averaging about 8%. If *all* of this 8% of the lime be combined with silica in the richest possible silicate (CaO- SiO2), it will take up only 7% of the sand. So that, on the most hopeful possible basis, only 15% of the brick would have any binding properties, the remainder being merely un-combined and inert sand.

[All of this said, clearly SOMETHING happens because the quicklime and sand are engaged in combination with high temperatures – this is of immediate relevance to hot-mixing of mortars, even though Eckel cannot arrive at a solution of as to why].

(p137)…Tests show that the bricks decrease in compressive strength and increase in tensile strength as the amount of fine sand in the mixture increases…(which confounds the combination theory, since fine silica sand would combine more readily).

…Necessary properties of the lime –

The lime should be carefully and thoroughly slaked, and should be as free from impurities as possible. The presence of more than a few percent of clayey matter or iron oxide (p138) is undesirable (not because it affects strength, but changes the colour).
Test results for a mixture of 2 coarse sand: 1 fine sand: 10% lime. Blocks moulded under 15,000 lbs psi pressure and hardened by exposure to a steam pressure of 150psi for 4 to 14 hours at a temperature of 185 degrees C. Using a high calcium lime, compressive strength of 7745 psi after hardening was achieved as an average of 12 tests.

Methods of slaking the lime –

The lime may be either slaked to a paste…or to a dry powder. Generally as performed in dry hydrate industry.

(p140). A mix of 6:4:4 coarse sand: fine sand: high calcium lime gave best compressive and tensile strength figures. The usual mix employed was 100lbs of sand to 5-10 lbs of lime.

(p141) (In the industry, hardening by steam under pressure in a sealed cylinder is most common. Ordinary air-hardening works, but much more slowly).

US Department of Agriculture Farmers Bulletin 1279 – Plain Concrete for Farm Use 1922

(p6) The mixtures given below have been found to meet the requirements indicated, and having been adopted as arbitrary standards, are recommended for use in farm concrete work. The amount of water required is discussed under "Consistency."

ARBITRARY MIXTURES. Rich mixture. — Used for concrete subject to high stresses or where exceptional water-tightness and resistance to abrasion are desired: 1 : 1 ½ : 3 : i. e., 1 part cement, 1 ½ parts sand, and 3 parts gravel. Standard mixture. — Used generally for reinforced concrete and water-tight work: 1:2:4; i. e., 1 part cement, 2 parts sand, and 4 parts gravel.

(p7) Medium mixture. — Used for plain concrete of moderate strength: 1:3:5; i.e., 1 part cement. 3 parts sand, and 5 parts gravel. Leaner mixtures are sometimes used after a test has proved them to be suitable for the work at hand.

Department of Commerce. Recommended minimum Standards for Small Dwelling Construction. Report of the Building Code Committee. 1923. Government Printing Office, Washington.

P14 Mortar for foundation or exterior walls, chimneys, or piers shall have a strength not less than that of a cement-lime mortar of the following proportions by volume : One part Portland cement, one part lime, six parts sand.
All cements and limes shall conform to the requirements of the standard specifications for such materials issued by the American Society for Testing Materials. (See Appendix, par. 10.

Appendix. Pp 38-39

Par. 9. Quality of Mortar.In proportioning cement and lime for mortar it is convenient to remember that a bag of Portland cement equals about 1 cubic foot, and a bag of hydrated lime equals about 1J cubic feet; also that 1 cubic foot of stiff lime putty is approximately equal to a bag of dry hydrated lime. The proportions of sand and cement specified in section 7 are based on the assumption that damp sand will ordinarily be used. If sand is thoroughly dry, a slightly smaller relative volume is advisable.

It is also quite important when a mortar as lean in cement as 1-1-6, as specified in section 7, is used, that the mixing be very thoroughly done in order to get uniform strength and quality.

The committee does not feel justified in approving use of straight lime mortar for construction of walls of the minimum thickness herein permitted (8″), for the reason that its weakness in compression and slowness of set as compared with cement-lime mortar, coupled with its tendency to disintegrate under high temperatures, combine to unsuit it for this purpose.

Where walls of greater thickness are used or where 8-inch walls are used for a one-story building and where reasonable care is taken to prevent undue loads, the use of straight lime mortar should be made optional.

Natural cement.—The committee would not prohibit the use of natural cement conforming to the test specifications of the American Society for Testing Materials, wherever such cement is available, and experience has proven that it gives satisfactory results.

P44

Par. ii. Laying of Brick.During warm and dry weather all brick should be thoroughly wet just previous to being laid, in order that a good bond may be obtained between brick and mortar, and so that sufficient water will be left in the mortar to permit its acquiring full set.

It is common practice in our northern cities to build upon frozen brickwork for dwellings and other small structures, but if long- continued low temperatures ensue, precautions against injury and overloading must be observed and special care should be taken if brickwork is subjected to alternate freezing and thawing. **Brick should be thoroughly dry when laid in cold weather, and for best results both bricks and mortar should be warm, so that the latter may obtain at least a partial set before it is frozen.**

P78

Par. 46. Mixing and Application of Plaster.1. Proportions of sand and lime or gypsum will vary with each

Grade or make of materials. Common practice requires the scratch coat to be one part of hydrated lime, or well-slacked lime putty, to three and one-half parts of sand, or one part by weight of gypsum to two parts sand. Corresponding figures for the brown coat are one to four for lime and one to three for gypsum. For best results these proportions must often be intelligently varied, and the old custom of adding sand by guess until it “ feels right to the plasterer ” can not be too strongly condemned.

2. The finish coat may be of straight gypsum or of lime. If lime is used, a very plastic lime prepared as putty is required, and in the case of slacked lime putty, aged for about two weeks, after which it is mixed with about half its volume of gypsum or tempered with plaster of Paris, applied to the wall and troweled to a smooth, hard finish. Much skill and care is needed for success. For best method of making lime putty see A. S. T. M. Standard C-5-21-T.

Hodgson F T (1920) Cyclopedia of Bricklaying, Stone Masonry, Concretes, Stuccos and Plasters. Sears, Roebuck & Company. Chicago.

Specifications, General Clauses

…If the lime mortar is mixed in a mortar mill, the architect, at his discretion, may allow the contractor to substitute a certain proportion of clean, hard brick, hard burnt ballast, or other approved material in lieu of sand….shall clearly state the exact proportion of the substitute material….

The limes for mortar shall be the best of their respective kinds…and shall be fresh burnt (and ground) when brought on the works. ….the contractor must satisfy the architect, by analysis or otherwise, that the lime is not adulterated or air-slaked…

The lime shall be thoroughly slaked at the scene of operations by the addition of sufficient water. During the process it shall be effectively covered over with sand to keep in the heat and moisture. All lime must be used within ten days of slaking.

The contractor shall, at his own expense, provide a proper mortar mill, worked by steam or other approved power, for the due incorporation of the materials…

If a mortar mill is not provided for the making of the mortar, the contractor will be required to thoroughly screen the materials before mixing to get rid of any dangerous and refractory lumps.

A proper stage is to be provided to receive the lime mortar when made. The mortar in no case to be deposited on the ground.

The materials for all lime mortars are to be measured in the proper stated proportions, in quantities sufficient only for each day's requirements.

Fat lime mortar must not in any circumstances be used for the purposes of the specification.

The stone lime mortar for brickwork above ground level shall be composed of one part of gray lime…and two (three) parts of sand, mixed with a sufficiency of water and thoroughly incorporated together (in a mortar mill). (The lime and sand shall be mixed together in their dry state before being put into the mortar mill.)

The lias lime mortar shall be composed of one part of blue lias lime…and one part of sand…(The lias lime mortar for brickwork above ground level shall be made in the same manner, but in the proportions of one part of lime to two parts of sand.)

The blue mortar shall be composed of three parts of fine foundry ashes, two parts of ground stone lime and two parts of sand.

Graham F D & Emery T J (1924) Audels Masons and Builders Guide #1. Theo. Audel & Co. New York.

MORTAR

The principal mortars are:

1. Lime mortar
2. Lime-cement mortar
3. Cement mortar
   a) Portland
   b) Natural

Lime mortar is recommended for ordinary house construction. It may be used except where very heavy loads have to be carried, as on brick piers, or walls much cut up by window or door openings, or in very exposed situations.

It should not be used for exterior basement walls subject to a great deal of dampness…

Cement-lime mortar has come in favour within the last few years. Tests show it to be stronger in compression and better than Portland cement mortar, when properly proportioned.

Lime Mortar. …is composed of sand and either slaked lump lime or hydrated lime….Lump lime is slaked by pouring water on it….When water is added, it should slake into a fine smooth paste without leaving any residue…

Hydrated lime. It sometimes happens that lime slaked on the job may, owing to carelessness or lack of skill, be burned or otherwise spoiled. (but more now being slaked at the plant in controlled conditions)….**It should be used where experienced labor cannot be had.**

Apparatus for Mixing and Handling Mortar:

1. Screen
2. Mortar box
3. Mortar platform
4. Hoe
5. Shovel
6. Hod

…**Mortar Box.** In suburban districts the mortar box is usually built on the ground or in the street at the most convenient place for water and use….

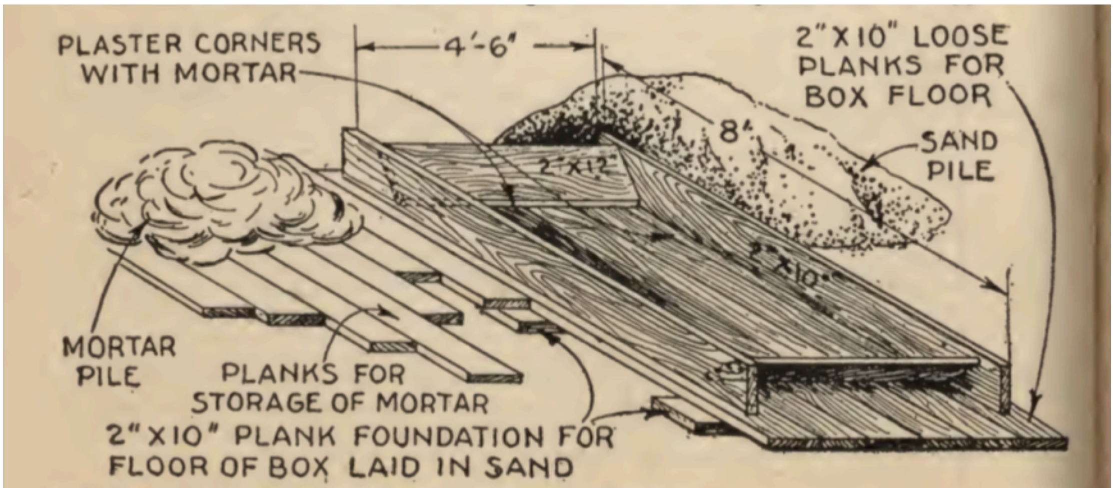

FIG. 3,866.—Mortar box and platform erected on sand bed.

Mortar Platform. In the preparation of mortar…a platform is usually provided for stacking a supply of the mortar for the hods, while additional mortar is being mixed in the mortar box…

Preparing Lime Mortar

The various operations in preparing the mortar for use are:

1. screening the sand
2. slaking the lime
3. proportioning
4. tempering

The sand should always be screened, or much time will be lost by the bricklayers in having to dig out the larger stones while they are spreading the mortar….

Slaking the Lime. …Lump lime must be prepared or slaked at least one week before it is used for mortar. …*(laid, not mixed to mortar after one week)*.

In slaking the lime, form a shallow basin of screened sand in the mortar box. Place the lime in this basin and pour water over the lime until thoroughly slaked…In the sand basin it steams and boils…when the lime is properly slaked it is reduced to a slimey consistency by the labourer, using a hoe.

Proportioning the Sand. As soon as the slaking process is complete, mix the sand with the paste and shovel it out onto the wood platform, to remain until tempered for use.

Tempering Mortar. Working the mortar and adding water to bring it to a proper consistency for actual use is called tempering. Mortar should be tempered until *it slides easily off the trowel*…and should be worked until all white spots of lime disappear, otherwise they will swell and pop after the mortar is laid.

FIG. 3,875.—***Preparing lime mortar.*** *Proportioning the sand.*

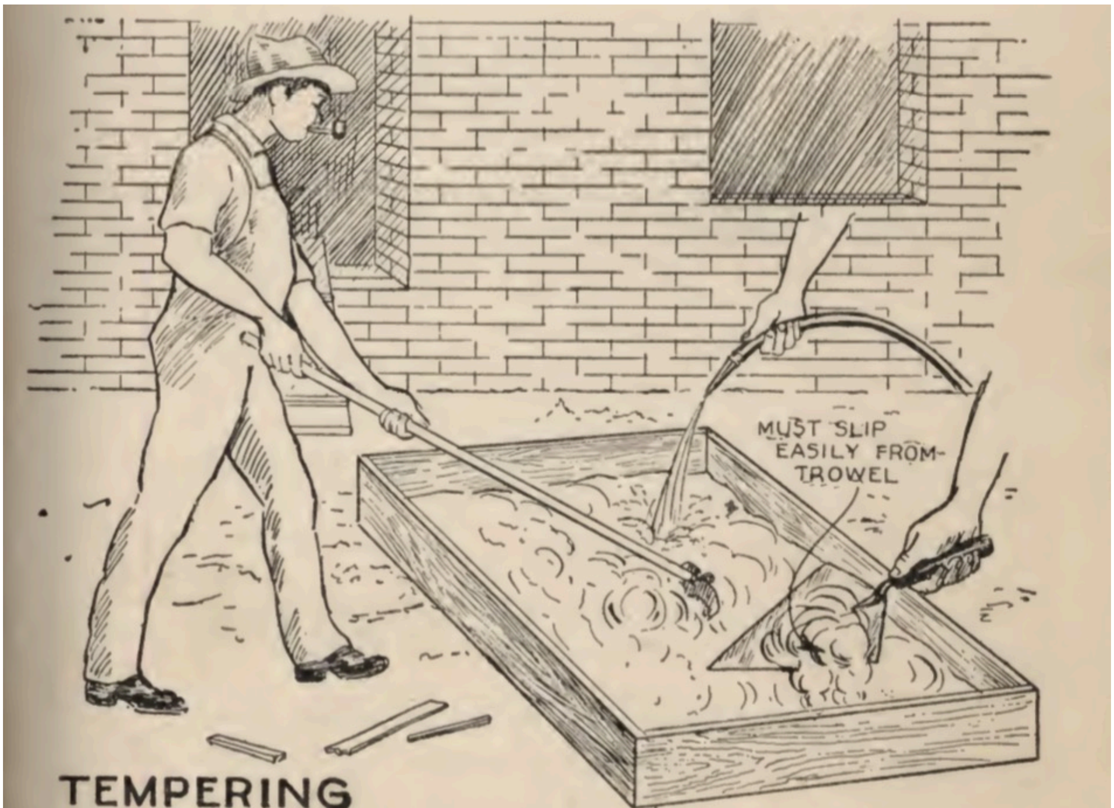

FIG. 3,876.—***Preparing lime mortar.*** *Tempering.*

Frost W (1925) The Modern Bricklayer, a Practical Work on Bricklaying in all its Branches Volume I. London. Caxton Publishing Company.

Mortar is as important to the bricklayer as are bricks. It serves the purpose of a soft bed, equalising all irregularities in the bricks and filling voids, thus preventing water penetrating the wall, and at the same time provides an adhesive material which cements the whole walling together, giving it solidity, resistance, and a certain measure of impermeability. It therefore follows that care is required in the selection of materials, their mixing, and in the use of the mixed mortars.

Types of Mortar.—There are various types of mortar: lime mortars, cement mortars, gauged mortars, grout (or liquid mortar), mastics and putties (containing lime and mortar). Mortars are composed of a matrix and an aggregate. The matrix consists mainly either of lime, gypsum, natural cement or an artificial cement, such as Portland cement. The aggregate is usually sand, but may also consist of crushed brick, etc.

Limes—Limes are divided into three main classes: non-hydraulic, hydraulic (which have the power of setting under water, and **are largely water repelling**), and selenitic, usually termed selenetic cement.

Lime is obtained from burning limestone, chalk, etc. Burning is important, because imperfectly burned lime will not slake properly and is liable subsequently to " blow " in the mortar, that is to say, absorb moisture by which it expands and disintegrates the mortar
.
Limes are divided into three classes:
(1) Pure, Fat, or Rich Lime (known as Chalk Lime in the London district), which should not contain more than 5 per cent, of impurities.
(2) Poor or Lean Limes, which often contain from 0 to 20 per cent, of impurities.
(3) Hydraulic Limes which are produced in three degrees of strength, Feebly, Moderately, and Eminently Hydraulic.
Pure, fat, or rich limes are generally used for internal walls, plastering and repair work. They have little strength.

Poor or lean limes, owing to their impurities, are feeble and only used for cheap work.
Dolomite limes contain magnesia and make stronger mortars than either fat or lean limes.
Selenitic limes are prepared by mixing lime with sulphuric acid, or adding about 5 per cent, of calcium sulphate to lime. It is most frequently used in its forms of Patent Selenitic Cement. They are moderately hydraulic.

Hydraulic lime, such as Dorking grey lime, is a moderate hydraulic lime and is used extensively in London and the provinces for the making of mortar. It is very suitable for the purpose and attains a considerable degree of hardness in course of time. Strong hydraulic limes which are sold in bags and ground into a fine powder, when mixed with sand in the proportion of 1 part of lime to 2 or 3 parts of sand, make a very fine mortar. Blue lias lime is an hydraulic lime and one of the best of the natural hydraulic limes. **It is especially suitable for work under water or for foundations in damp situations**.

Gypsum is seldom used except for plastering and as a component of special cement, etc. For instance, plaster-of-Paris is produced by the heating of gypsum in closed vessels to a very high temperature. Gypsum is a soft stone varying in colour from white to brown and is found in Westmorland and Derbyshire and in very large quantities near Paris. The finest powdered grained variety of gypsum is termed alabaster. Plaster-of-Paris is used in connection with the fixing of stoves, mantles, and various plug holes. It is very useful in this connection owing to the rapidity of setting and its expanding powers at the time of setting, but should not be used in exposed parts of a building. It is sometimes mixed with lime and also with cement. Plaster-of-paris is mixed with lime to increase the rapidity of setting. Gypsum is also mixed with Portland cement, a small proportion being used in the manufacture to produce a slower setting action in the cement.

Medina Cement is of a light brown colour, and has similar qualities to the Roman cement; it has a greater strength than Roman cement after setting.

Keene's Cement.—This cement is made by recalcining plaster-of-paris (which means reducing the plaster-of-paris to a powder by means of heat), this is then soaked in a solution of alum. This is used for tiling, internal wall decorations, where a slower setting action is required.
Hydrated Lime.—This is a powdered lime which is slaked by the means of steam.
Sirapite is a variety of plaster-of-paris which is made from gypsum found in Derbyshire and impregnated with petroleum.
It sets quickly, but should on no account be used on damp walls. It is used extensively tor interior wall surfaces; it makes, when finished, a hard, durable, and smooth surface. It is generally used as a finish coat about 1/8 inch in thickness; sometimes a small proportion of lime putty is mixed with it.

Pudlo is a very useful cement waterproofing powder, but its composition remains a secret. It can be used in the waterproofing of cement mortars, concrete, etc. I have used it on various occasions and found it to be satisfactory in resisting dampness. It is generally used in the proportion of 5 lb. of the Pudlo to every 100 lb. of Portland cement with a proportion of sand with it. For instance, the cement and sand proportions might be 1 part of cement to 3 or 4 parts of sand. The materials should be thoroughly mixed together 3 or 4 times in a dry state and then twice in the wet state to the consistency of a stiff mortar. It is also used for waterproofing drainpipe joints, vertical damp-proof courses, and various other work where dampness occurs, or is likely to occur.

Puzzolana is a volcanic substance found at Puzzula in Italy. It consists of alumina, silica, and small quantities of potash, lime, magnesia, and metal oxides and other mattes. Puzzolana mortar is weaker than cement mortar.
It is not used much in England, though sometimes it is used mixed with an hydraulic lime. This produces a much better mortar, and is considerably stronger than the former mortar.

Roman Cement is a natural cement which consists of nodules found in the London clay and shale beds of the Lias formation. These nodules are burnt at a low temperature in the preparation of the cement.
It contains about 40 per cent, of clay and weighs about 75 lb. per bushel. the colour is of a rich brown. It is weaker than Portland cement, being only equal to a. third of the strength. It sets very quickly, the usual time being about fifteen minutes after it has been mixed. Only a very small portion of sand should be used with it, as this weakens it considerably. It is sometimes used for works under water where a rapid set is required. It is also used for various repair work, etc.

Portland Cement (description and then numerous simple tests to establish its goodness)…

Aggregates.—Aggregates for mortars usually consist of sand, although crushed bricks and other materials are sometimes used. They should be clean, free from dust, soil, and organic matters, and must not contain salt. Salt causes effervescence and dampness in the mortar, and prevents the cement and lime used in the mortars from adhering to the particles of sand.
Sand should always be clean. Loam can be detected sometimes by the naked eye and also by taking a handful of sand and rubbing it together; the loam will be detected by the touch, the sand being sharp and the loam rather of a soft sticky nature. Sand is sometimes examined under a microscope to see whether the grains are of a sharp angular shape or rounded.shape Sand is sometimes washed through a sieve to eliminate the loam and other matters found in it.
In sea sand and river sand the grains are of a round shape on accounts of the continual movement of one grain against another while a good pit sand possesses grains which are of a sharp, angular shape. Being very often found mixed with stones or gravel, it is sifted or screened. The wires in the sieves or screens are spaced according to the fineness of the sand required. The frame is usually fixed at an inclined angle with a prop placed at the back of it to keep it in a firm position. The mortar man has a large pile of sand deposited to be sifted, in front of this he places his screen, and fixes it in position, he then shovels up the unsifted sand and throws it against the screen. This being in an inclined position, the surplus stones from the sand roll down the face of it slowly and form a heap, the fine sand passes through the screen and forms another heap and is removed from time to time when ready for use.

Quicksand is sand which is easily distinguished by the particles, which are very small and round, in some cases the sand is as fine as a powder. These small particles are worn round by the action of water. **This sand should not be used for mortar**. The quicksand, if made into mortar in combination with another material, has the tendency to settle to the bottom, leaving the matrix in the topmost position. The mortar man has to be continually mixing it, in order to combine the two together.

Crushed bricks form an excellent aggregate. Mr. L. E. Walker cites the case of a speculative builder who put up a large block of flats on a plot partly occupied by small houses, which he pulled down. The bricks were crushed on the job, and were mixed with the lime (no sand being used) in the mortar mill. The proportion of lime was below the average, yet the mortar proved quite satisfactory.

Indeed, when part of the brickwork had to be cut away, it was found that the mortar had developed amazing strength within a month or two.A useful mixture is 1 part lime, 2 parts crushed brick, 1 part fine sand; next dry and gauge as in usual way.
Water.—Water used in mixing mortar must be clean, free from clay, soil, salt, or organic matter.

Mortars
Mortars vary according to the purpose for which they are required. In all cases accuracy must be observed in proportioning the various component parts, and great care taken in the mixing. **As a rule not more mortar should be made than can be quickly used**. This is of particular importance where cement mortars are concerned, as in these initial set begins fairly soon, and knocking up, unless the cement is slow setting and contains a certain admixture of hydrated lime, weakens the adhesive powers and the strength.

When lime mortars are used in large quantities it is always advisable to slake the lime on or near the job. For this purpose a pit is dug and boarded, into which quick, or lump lime, broken into convenient size, is tipped, and clean water run in. A ton of lime will require 75 gallons of water *(340 litres or one third of a ton)*. It is stirred vigorously to ensure the breaking up of the lumps and thorough slaking. Great heat and volumes of steam will be evolved during the process. **The lime is only fit for use when all the heat has been given off.** Good lime (lime putty as it is termed in this state) should be smooth and "fatty." If lumps are allowed to be unbroken, or the slaking otherwise imperfectly carried out, the mortar will be more or less hygroscopic and liable to " blow.' When once slaked it should be kept protected from dust and rain.

Mortars can be mixed by hand or in a mill. By hand a suitable position should first be selected to place the materials upon. For this purpose a banker is usually laid upon the ground. This consists of a number of scaffold boards, about twelve in number and about 12 feet in length. Four stakes are driven in the ground.

This keeps the boards in position and also keeps them close at the joints of the boards, which stop as much water as possible from oozing through the joints. **Sand is placed on the banker and a large ring made. The lump lime should then be placed into the middle of the ring of sand, and the pieces of lime broken as small as possible. Sufficient water should then be put on the lime, using a watering-can or a hose with rose attached. The lime should then be covered with sand and the whole allowed to stand from twenty to twenty-four hours. It can then be mixed together with the shovel or larry into a paste form ready for use. All the unslaked lumps should be taken from the bed of material and should not be used.**

The mortar mill, or mortar pan, is a revolving iron pan with mixing paddles or arms into which the lime or cement, sand or crushed brick, are placed for mixing. **The mill is first revolved with the materials in a dry state, water being added gradually.mixing and is more economical than hand labour when large quantities are involved**. A mill ensures thorough mixing and is more economical than hand labour when large quantities are involved. Large mills are driven by power, small ones by hand but even with the latter there is a saving of time and labour.

When mixing large quantities of either cement or lime mortar it is best to have various gauges or boxes for the purpose as to enable two men to lift them; these are made in different sizes, such as the cubic yard box, which would measure 4 feet 6 inches in length 3 feet in width, and 2 feet in depth.The half cubic yard box which would measure 3 feet in length, 3 feet in width, and 1 foot 6 inches in depth and also the quarter cubic yard box, which would measure 2 feet 6 inches in length, 2 feet 6 inches in width and 1 foot 1 inch in depth.

Lime Mortars.—The lime or matrix in lime mortar depends upon the purpose for which the mortar is required for **ordinary building purposes. A greystone lime from Maidstone or Dorking would be suitable. A pure or fat lime should only be used for work that is of a temporary nature. The blue lias lime can be used for good-class building work and in damp situations, such as footings and underground cellars, etc. The Dorking and Maidstone limes are feebly hydraulic limes, and limes like the Halkin Mountain lime are eminently hydraulic.** Ground lime is now frequently used in various parts of the country; it is very useful and can be used almost immediately. The proportions which would be required for ordinary building purposes are 1 part of stone lime to 3 parts of sand. In good-class building work the proportions should be 1 part of selenitic lime to 4 parts of sand.

Piers and walls required to carry weight, 1 part of lias lime to 2 to 3 parts of sand.

When using lump lime about one and a half to two gallons to every bushel of lump lime. The amount of water required varies considerably in relation to the nature of the ingredients used.

Ground lime should be used in the proportion of **1 part of lime to 3 parts of sand.** This should be made by hand. The sand should be placed on the banker, the ground lime should then be placed upon this. These two materials should then be thoroughly mixed by turning over with the shovel, the whole of it at least twice; it should then be passed in the dry state through a sieve, or a riddle as it is sometimes called. The materials should be left for a few days, when they can be taken and mixed with water as required for use. This fine material is sometimes used for internal pointing, etc.

Lumpy lime and sand is also passed through a sieve in the dry state when required for good work.

When lime mortar is mixed in the mortar mill, where large quantities are regularly required for general purposes, the proportions are generally **1 part of lime to 3 or 4 parts of sand.** Good clean old bricks, as already mentioned, are also used for the aggregate. They should be well crushed. All materials should be clean.

When lump lime is used it should **be slaked first and poured into the mortar mill in a semi-liquid state in the proper proportions to be mixed with the aggregate,** the water being added as the materials progress towards their proper consistency.

Liquid mortar, which is generally known as grout, is used for grouting in the interior of walls, and for joints in floor tiles, etc.with various materials: neat Portland cement, also neat Portland cement with a small proportion of sand, and also grout lime mortar.

Lime mortar should never be used in very frosty weather; if the lime mortar after having been placed in position on the wall either as a bed or cross joint is frozen and then thaws it will lose its strength.Sugar is added in the making of lime mortar in India, and greatly adds to its strength. It is said to retard the setting action of the cement mortar, which enables the chemical changes to take place more perfectly; if used in excess it renders the cement useless.It should never be used in damp situations or construction under water, because the sugar is soluble in water. About 1 ½ to 2 percent of sugar is sufficient to add, and should be used in a dry climate.

Gauged Lime Mortar.—This consists of 1 part of lime, 3 parts of sand, and small addition of neat Portland cement to give the mortar quicker setting power. Another method is to add 1 part of Portland cement to 6 parts of good lime mortar; or if to be used in very cold weather,1 part of Portland cement to 4 parts of good lime cement. This will not be damaged by slight frost. With these mixtures will be no efflorescence. Composite mortars of the above description are also coming more into favour, as besides being stronger than lime mortars they are said not to be so much affected by vibrations from modem traffic.

Concrete.

… All cement concretes should be used directly after they have been mixed. Lime concrete should stand for a period after being mixed; this enables the particles of lime to be all thoroughly slaked before using.

Cement and lime concretes used for foundations of any kind should not be built upon for at least a week after being placed in the trenches or foundations.

… In a lime concrete which has been made for a period of twelve to fifteen months, and mixed in the proportion of I part of matrix to 6 parts of aggregate, the matrix made of grey lime or blue lias lime will have a higher crushing strength if the aggregate is brick instead of ballast. Again in the case of the broken brick aggregate used in conjunction with the lime, it has a stronger crushing weight than the lime which is mixed with the ballast, and varies from 10 tons to 30 tons per foot super, varying also with the class of lime used for the purpose, blue lias lime being stronger than the grey lime.

Johnson H V (1926) Cement-Lime Mortars Technologic Papers of the Bureau of Standards No. 306. Washington Government Printing Office.

Abstract

Tests were made upon cement-lime mortars in which the percentages of cement, lime and sand were varied considerably. It was found that the addition of lime to cement mortars increased the water requirement for the ame consistency, very nearly in proportion to the percentage of lime added, that shrinkage is increased by the addition of extra water; therefore, where low shrinkage is of prime importance, lime should be limited in cement mortars. The addition of lime cannot be expected to increase the strength of cement mortars richer than 1:2 by weight; with leaner cement mortars the maximum increase in strength which may result from the proper addition of lime is greater the leaner the mortar. The addition of lime in small amounts increased the density of lean cement mortars. **The principal advantages resulting from the use of lime in cement mortars are an increase in workability and a reduction in cost.** While a cement-gauged lime plaster retains much of the workability of a straight lime plaster, the presence of the cement gives it greater strength and a shorter time of set.

When one is about to prepare a mortar, it is well to consider what are its requirements for the work in question. It may be found that a desirable change in one property results in disadvantages in others. That choice of proportions then must be made which will result in the **best possible compromise.**

Mixing Water

In practice, when a cement mortar works too poorly, it has been found that this difficulty can be met by adding lime or other finely divided material to the mortar; this will necessitate adding more water, but not to the extent of greatly reducing the strength of the mortar….

Landis has shown that when the mortar is fresh, there is too much water present for it to absorb carbon dioxide, and that if the mortar is dried completely it does not absorb carbon dioxide. **Richardson went further and set 5 to 0.7 per cent moisture as the limits within which carbonation of lime mortar can occur.**

…The time of set of mortars containing lime is influenced by the amount of water which must dry out, and the amount of water retained in the mortar influences the rate of carbonation of the lime.

Plasticity

The improvement in workability is one of the principle arguments advanced in support of the practice of adding lime to Portland cement mortars...plasticity was taken to be an index of the workability of each mortar…

…a greater amount of lime is required in the leaner cement mortars than in the richer mortars to produce the same plasticity. About 16% of the total dry weight in the 1:1 cement mortar gave a plasticity figure of 70, while the amount of lime necessary to produce this result in the 1:4 cement mortar increased to about 30% of the total dry weight….

The experimental evidence leads to the conclusions that, for a given plasticity, where more lime is added, more sand can also be added, but at the expense of strength…

Relation of cement to voids and density.

The voids occupied 35% of the volume of the dry Potomac River sand, and yet greatest density of mortar was obtained with cement and sand mixed in equal proportions by weight (approximately equal by volume also). **It is impossible to fill the voids in sand with just the amount of cement theoretically required, for in the mixing some fine particles of cement lodge between the sand grains and hold them apart...**

the volume of cement must exceed the volume of voids in the sand in order to obtain the greatest density of mortar, and that while there is a limit to the amount of cement which can be added to produce greatest density, the strength continues to increase with further additions of cement.

Conclusions

In order to obtain a workable consistency, more water must be added to a mortar than the amount which results in greatest density; additions of lime in small amounts can increase the density of lean cement mortars – the leaner they are the more effective is the lime in this respect; and the volume of cement must exceed the volume of voids in the sand in order to obtain maximum density. In evaluating density of a mortar with reference to its various uses, it is found that where the density is low the thermal conductivity of a plaster is less, the total weight of plaster on the walls and ceilings is reduced, and the fire resistance of a mortar is only slightly affected, but the permeability is greater and the strength is less than where the density of the mortar is high.

Volume Shrinkage

Conclusions

1) The tendency of mortars to shrink when drying is increased by the use of extra mixing water; 2) The addition of lime to cement mortars increases the shrinkage in proportion to the amount of lime added; this is largely due to the extra mixing water which the mortar requires when lime is added; 3) the general effect of increasing the richness of a mortar by adding cement is an increase in shrinkage but to a much less extent than would be noted by the addition of an equal weight of lime. 4) Shrinkage varies with different limes, even when they contain the same percentage of mixing water; this is true for cements also. 5) Sand acts as a stabilizer in mortars, for the decrease in their tendency to shrink is nearly proportional to their leanness.

Tensile Strength

…In straight lime mortars, the greatest tensile strength resulting in 28 days was obtained when the lime was 20% of the combined weights.

…The general effect of increasing the cement content of cement-lime mortars was an increase in strength. However, in the lime mortar of the proportions 15:85 by weight, **no appreciable increase in strength was noted until the added cement was over 25% of the lime by weight…**

The leaner lime-sand mortars are more porous, and, air having better access, they carbonate at a more rapid rate, and invariably the mortar which gives greatest strength a seven days is leaner than the one which gives greatest strength for a longer aging period…

In leaner cement mortars, increases in strength result from the addition of lime, and more lime can be added. In a lime mortar of any proportions, additions of cement will increase the tensile strength, but the cement added must be 25% or more of the weight of the lime if any noticeable effect is to be attained….

When 33% of lime had been added, the strength was still equal to that of the cement mortar without lime.

…All of those (cement-lime) mortars aged for one year…in which the cement constituted 5% of the total weight were **uniformly weaker than the corresponding lime mortars without any addition of cement. There was no increase in the strength of any lime mortar where the cement was added in quantities less than 22% of the lime by weight….**It appears to be necessary to add 25% of cement, by weight of lime, before there is any noticeable increase in the strength of a lime mortar…

Recommended Practice

…A mortar having a high content of cement is characterised by high strength and by a short time of set; it is also fairly workable and shrinks some on drying. One having a high content of lime will have less strength, will be slower in setting, will be more workable, but will show more shrinkage. The chief characteristic which a high sand content f=gives to mortar is low shrinkage, but it also results in low strength and poor workability…An excessive amount of water may permit of easier application of a mortar, but at the expense of strength. The evaporation of this water may be accompanied by excessive shrinkage, or the mortar may be left porous. This high porosity is to be desired if light-weight and low thermal conductivity are important; it is not desirable from the standpoint of strength or of permeability.

(recommends 1:3 cement: sand for exterior stucco).

Lime Plaster

Scratch coat on lath. For plaster, where strength is of somewhat less importance than it is for stucco, and where the succeeding coats are to be of straight lime mortar, a reduction in cost can be made by the use of a 1:5 lime mortar **by weight** for the scratch coat on wood lath. The mortar can be improved in respect to strength and time of set by adding cement, but the cement must be at least 40% of the weight of the lime to be effective…

Masonry Mortar

A mortar for masonry should be fairly plastic, for this permits the mason to spread out a longer bed and to 'butter' the bricks more easily. Shrinkage is of some importance, for when the mortar shrinks it pulls away from the ends of the bricks, leaving vertical cracks through the wall. A rather lean mortar of either cement or lime seems to meet the above requirements, and a mixture of equal parts of 1:3 cement and lime mortars by volume possesses advantages not found in either one alone. The lime gives it plasticity and the cement gives it the ability to set quickly. This is the mortar usually known as 1:1:6.

…The role of the mixer of cement-lime mortars should be that of an intelligent workman who secures the desired changes in the properties of his mortars by varying the proportions of his four materials – cement, lime, sand and water. The properties are variables which cannot all be changed favourably for a given purpose at the same time. The problem, then, consists in altering the proportions of a mortar until one obtains the most suitable combination of these variables for the purpose in view.

Cowper A D (1927) Lime and Lime Mortars. Shaftesbury, Donhead

A literature review, primarily.

Historical

Mortars

Until John Smeaton made his painstaking investigations in 1756 in connexion with the building of the Eddystone Lighthouse, and as a consequence **revived the almost forgotten technique of the preparation of a true *hydraulic* mortar…little progress had been made in the art of mortar-making** [*had any been especially necessary?];* the presence of gypsum and of soft mortar still containing up to 20 per cent of free (uncarbonated and uncombined) [*does he mean lime lumps? Might the gypsum be as a result of atmospheric pollution interacting with the lime and limestone?]* lime in the piers of St Paul's Cathedral illustrates this. However, traditional Indian building methods show an appreciation of pozzalanic additions, in the form of 'surkhi' or burnt clay; and a hydraulic mortar has long been in use in India, made from argillaceous limestone 'kankar'. Hydraulic mortars made with the Italian pozzolana and the German trass of similar properties, have also had a limited use for centuries….

A curious aspect of the history of the use of lime is afforded by the array of materials which have been added…to lime plaster and mortar, **generally with a view to slowing down the setting** and making possible a more extended manipulation of the material in artistic work. Thus fig and other fruit juice; elm bark (presumably in the form of an infusion), barley water, bullock's blood, cow dung, hot wax, white of egg, wort and beer, pitch, milk, gluten, butter-milk, cheese, saponifies beeswax, etc have been recommended….sugar is apparently a common addition to lime mortar in India; and the modern use of glue or size-water in the gauging of plaster is familiar….

Perhaps the most important recent development has been the marketing of mechanically hydrated or slaked lime, of uniform quality and in extremely fine powder, for preparing lime putty or mortar directly by the addition of the necessary water, This movement has made great headway in the United States. Class A or Fat Limes slake rapidly and energetically and have their volume doubled, or more, in the process; their consistence remains sensibly the same after many years of immersion in water [in lab]; and they dissolve practically completely in pure water frequently changed.

Class B or Lean limes slake slowly, with little or no increase in volume, and behave in water in similar manner to the Fat Limes, except that they leave a residue…

Class C2 Moderately Hydraulic Limes, set in 15 or 20 days after immersion and continue to harden…after one year their consistence is equal to that of hard soap. They dissolve in water with great difficulty (leaving an appreciable residue); the expansion on slaking is small.

Class C1, Feebly Hydraulic Limes will be intermediate between Class C2 and Class B.

Class C3, Eminently Hydraulic Limes, set at some time between the second and the fourth day of immersion. After one month they are already very hard and altogether insoluble. At six months they appear like the absorbent calcareous stones, splintering under a blow and presenting a slates structure. The expansion on slaking is small. [*currently available NHLs are all generally Class 3]*.

The uses of Lime in Building

The slaking of lime

Burnt lime or quicklime is seldom used as such in building operations, but is practically always slaked before use, and then mixed with sand, hair, etc *[this is a bald and clearly erroneous assertion within the context of a literature review]*.

…the method of carrying out this slaking process should vary according to the type of lime and the purpose to which it is to be put. **For the present, the previous slaking of the lime or the use of a mechanically-slaked hydrate is assumed.**

LIMEWASHES

Plain Lime and Lime-salt washes

The simplest 'whitewash' consists merely in milk of slaked lime in water; this, however, easily rubs off, and disappears almost entirely if exposed freely to the weather for some months [*this is entirely untrue and/or mistaken]*.

A plain lime wash can be greatly improved by the addition of common salt, in the proportion of 15lb of common salt to 50l of hydrated lime or the putty obtained by careful slaking of half a bushel of lump quicklime, with 7 1/2 gallons of water. [*3:5 salt to quicklime]*.

[regular testing - 10 days; 30 days; 6 weeks; 2 months; 3 months - of samples exposed to the 'full effect of the weather'] little improvement was observed from the addition of a number of materials which appear in current formulae, such as plain glue, whiting, or flour paste, etc **to the simple lime-salt formula….**

LIME PLASTERS

Tempering of Slaked Lime for Plasters

Lime used in plaster-work is generally slaked with an excess of water to form a putty, and this putty is then stored in a covered pit or trough until used *[Millar says otherwise, with hot mixed coarse stuff laid down being common].* Practically all the authorities, both ancient and modern, are unanimous in demanding an adequate length of storage time for *tempering* this slaked lime before it is actually used…. Mitchell quotes Specification Clauses at the London County Council requiring that lime for plaster should be run to putty at least one month before using, and then screened to remove unslaked particles….

…There is a danger of burning a fat lime in slaking, as a result of an insufficient supply of water or inadequate stirring…the use of too large a quantity of water - 'drowning' in the slaking process is usually considered to have an unfavourable effect, besides giving more trouble by requiring the excess of water to be run off or evaporated subsequently before use.

The method recommended for slaking the hot, high-calcium plastering limes is accordingly that of immersion, in sufficient water to yield ultimately a putty, and with close attention and constant stirring…and after the violent action and steaming have subsided the whole should be thoroughly worked in order to ensure that all lumps have been broken down.

MORTARS AND CONCRETE

Vitruvius upholds the practice of adding lime mortar pozzolanic materials such as ground potsherds or Vesuvius ash. Vicat says of fat limes: 'Their use ought forever to be prohibited, at least in works of any importance'. Sir Charles Pasley states of fat lime mortar: 'when set it is a pulp or paste and when dry it is a little better than dust'. Allen says, 'pure lime in itself has neither power of setting nor ultimate strength, and it is only when combined with clay and burnt that it is of value…it is only fit for plastering and other sanitary purposes'. Rivington speaks of the 'superficial carbonation, less than 1/2 inch thick, the interior being a soft pulp or friable powder'. Mitchell states, 'pure lime mortar built in thick walls never hardens or sets, but crumbles into a friable powder'. *[what would they have said about earth mortar???].*

Sand in Mortar.

The hydraulic and lean limes…can tolerate without serious loss of ultimate strength, very much less sand than the Class A, fat, high calcium limes, particularly when the sand itself contains a large proportion of the finer sizes. A moderately coarse sand (well-graded) appears best; if this is also of a pozzolanic character, such as ground brick or some types of clinker of granulated slag, **an excellent mortar results** [*the harder the better for Cowper, clearly].* The actual proportions sand for maximum strength approach 2 to 1 of lime for hydraulic mortars.

Storage and 'knocking-up of hydraulic mortars.

…A (fat) lime for plaster cannot be tempered too long. However, it is otherwise with hydraulic limes ; **an ample period for completing the somewhat sluggish slaking process here is desirable, but long storage of mixed hydraulic mortar, with subsequent working up of a material which may already be partly set, is evidently accompanied by serious danger of reducing its full strength when completely set, and should be avoided. The time-limit for storage of hydraulic lime mortars is given in the textbooks as some nine days;** the actual maximum period permissible will obviously depend on the degree of hydraulicity of the particular mortar, and its speed of setting, and for good work should be previously determined.

Slaking of lime for mortars

The proper slaking of Class A limes has been discussed already in connexion with plasters. When used for mortars, the same care should be taken to avoid over-heating the lime during the slaking process, and to remove unslaked lumps of overborne or under burnt lime after slaking, as well as to allow a reasonable time for the process to complete itself; but the long period of tempering advisable in connexion with lime putty to be used in plaster is not called for in connexion with mortar….

With lean Class B limes, it is best to conserve the heat produced in the slaking process; therefore, after the water is added to the lime, the latter should be covered up with a layer of sand and left for some time for the process to come to an end. Any large unslaked particles of overburnt or under burnt lime should then be removed…**As with plaster, the use of finely divided ready hydrated lime greatly simplifies the process of mortar mixing.**

Eminently hydraulic limes may show so little activity in the slaking process that it is better to have them in a finely ground condition before commencing the slaking; and to allow plenty of time for this operation.

SPECIFICATIONS

SLAKED LIME IS TO BE PREPARED FROM HYDRAULIC LIME BY SPRINKLING THE REQUISITE QUANTITY OF WATER ON THE LIME, COVERING UP LIGHTLY SO AS TO RETAIN THE HEAT AND MOISTURE FOR 24 HOURS; AND THEN THOROUGHLY STIRRING AND INCORPORATING THE SAND, TOGETHER WITH MORE WATER AS REQUIRED..

ALL MORTAR SHALL BE THOROUGHLY MIXED TO A UNIFORM CONSISTENCE WITH ONLY SUFFICIENT WATER TO ATTAIN A PLASTIC CONDITION SUITABLE FOR TROWELLING; AND **HYDRAULIC MORTAR SHALL BE USED <u>WITHIN 10 DAYS</u> OF SLAKING THE LIME.**

Schaffer R J (1932) The Weathering of Natural Building Stones. Building Research Station.

Schaffer's primary concern is stone decay, but he does note the potential for Portland cement mortars to promote decay and the potential for efflorescence when either Portland cement or hydraulic limes (both natural and artificial) are employed. Schaffer's work is still considered the most authoritative on the subject. Portland cement in 1932 had a similar compressive strength to currently available NHL 5.

The Effect of Dense Pointing. When a brick wall is pointed with a dense cement mortar, little movement of water can occur through the pointing, and practically no drying takes place from the mortar joints. If the wall becomes wet, most of the drying takes place by evaporation from the surface of the bricks and any soluble salts in the wall, whether originating in the mortar or in the bricks, will tend to be concentrated in the bricks, and considerable decay may result. As a rule, however, damage of this kind is frequently found to be limited to the softer kinds of bricks, or to those which possess a surface skin, but even Tudor bricks which have remained sound for hundreds of years have been observed to suffer decay after repointing with dense mortar….

Similarly, it has been observed that the use of a dense mortar for repointing the walls of medieval and other buildings is liable to accentuate the rate of decay of the masonry. Originally, the practice of the Ancient Monuments Section of HM Office of Works was to remove all decayed old mortar and loose dirt, wash out the joints with clean water and repoint with lime mortar. Where raking out exceeded 3 in. in depth, the joints were tamped with a 1 to 5 Portland cement mortar kept back at least 2 in. from the face of the wall, the pointing then completed with lime mortar. But the result of consolidating walls even in this manner had, in some cases, the effect of causing a more rapid rate of surface decay in the stone itself.

The crystallisation of soluble salts within the pores of building materials is an important cause of their decay. Soluble salts may also crystallise on the surface forming unsightly deposits, commonly known as efflorescence….The damage caused by florescence depends very largely on whether the salts crystallise within the pores, as cryptoflourescence, or on the surface, as florescence….

Salts derived from External Sources.

From Jointing Materials. - Decay may arise from the absorption of soluble salts from the jointing materials…Efflorescences derived from Portland cement **or**

hydraulic lime mortars usually consist of salts of the alkali metals, carbonates or sulphates of soda and potash…It is commonly stated that bricks laid in cement mortar effloresce badly, whereas similar bricks laid in lime mortar do not do so…Anderegg states that the use of Portland cement for setting Indiana limestone has often resulted in bad staining and in the formation of efflorescence, whereas the same stone was used with uniformly good results when it was customary to use lime mortar… trass mortars are equally affected (Hasak). In the experience of the Building Research Station, cement mortars are found to be somewhat more liable to cause efflorescence than lime mortars, **although hydraulic lime mortars are not entirely immune.**

The South Western Stone Co Ltd (1933) Portland Stone. London & Portland

{The context here is stone ashlar cladding, although of some depth. The Portland cement addition will – in 1933 – have possessed a similar hydraulic power to a modern NHL 5.0).

MORTARS used in masonry vary according to the kind of stone and structural requirements. The ultimate success of a stone-faced building largely depends upon the discrimination displayed in the choice of mortars…

Stonework does not depend to any great extent upon the strength of the bedding material for its stability, the mortar bed acting as a cushion between the planes, thereby allowing each stone to take its full bearing and load. The arrangements of the bonding and the large true surface areas obviate the necessity for a hard-setting mortar, especially in work of an ordinary character. The mortar used should not set harder than the texture of the stone.

For setting Portland stone facings, a mixture called 'masons' putty' should be used as a bedding material. This is usually composed of seven parts Portland stone dust, five parts lime putty and two parts Portland cement, a daily supply only to be made. Great care should be taken to ensure that no unslaked lime is used. Hydrated lime conforming to the standard test of the Building Research Station is preferable…

The successful pointing of Portland stone facings is always a difficult problem. It is not advisable to rake out the bedding and jointing material and point during cleaning-down processes. It is preferable and conducive to the best finish of the pointing of the beds and joints if it be done immediately after the fixing of the stone, and with the same admixture as used for the bedding material. The finish of the pointing can be left 'struck' or 'slightly weathered'. The most appropriate width for beds and joints for Portland stone facings is from one-eigth to one-quarter of an inch.

Thomas P E Editor (unknown date…1940s?) Modern Building Practice in 40 volumes, George Newnes London.

Limes, Cements and Mortars, in Volume 3.

Lime was once one of the most important of building materials, but its use is tending to become restricted on account of the employment of cement and the different makes of gypsum plasters that are today on the market. These substitutes are justly popular, on account of their more scientific manufacture and resulting standardised composition, which renders them easier to employ on modern constructional work where large quantities of material are mixed by mechanical means. **Nevertheless, many builders of experience** still hold that **lime possesses a number of valuable qualities which up to the present have not been reproduced in other materials.**

…When water is added to quicklime it immediately becomes hot, swells to nearly twice its original bulk, and finally falls apart into a powder. If more water is **added** until the mass becomes a pulp, it is known as putty.
If slaking begins in less than 5 minutes, the lime is known as *quick-slaking or fat* lime; if between 5 and 30 minutes, it is called *medium-slaking,* but if no action takes place for half an hour, it is called *slow-slaking or lean* lime. Quick-slaking lime should be just covered with water to begin with, and the mass carefully watched. At the slightest appearance of steam, more water should at once be added, and the heap hoed over with the special hoe.

Medium slaking should have water added so as half to cover the mass, and a little more poured on from time to time to prevent steam escaping and the mass becoming dry and crumbly.

Slow slaking lime should be thoroughly wetted at the outset, and then be allowed to stand until the slaking action begins. Water should be added sparingly from time to time, but not in sufficient quantities to overcool the mass, and in cold weather, hot water should be used. The lime should not be hoed until nearly slaked, as it is **necessary to retain the heat as much as possible.**

…Air-slaking, due to the lime absorbing moisture from the air, tends to weaken the setting properties of the material, as the lime has absorbed carbon dioxide from the air as well as moisture, and has therefore begun to carbonate.

Hydrated Lime

Many modern manufacturers now supply hydrated lime in bags in a similar manner to cements…By using this lime, the risk of incorporating unslaked quicklime particles is removed, and with it the chance of work ‘blowing’ or ‘popping’ after completion…

…While (air) lime plastering will set in reasonable time as it has a large surface area exposed to the air in comparison with its thickness, **several years will elapse** before the lime mortar in a wall has been able entirely to carbonise.

Hydraulic Lime.

For ordinary builder's mortar it is best to use a hydraulic lime, which is one containing silica and alumina in addition to calcium oxide. These limes slake very slowly, but do not require exposure to the air to harden, depending for this largely on the hydration of the silicate. They are sometimes called *Lias,* and when very hydraulic are used in positions where the setting has to take place in water.

The limestones which produce hydraulic limes contain in themselves the silica, alumina and iron oxide required, and have not, as has Portland cement, to be specially mixed before burning, and thus when ground are **really of the nature of a natural Portland cement.**
This may be seen by comparing an analysis of the two materials:

Hydraulic lime		*Typical Portland cement*	
Calcium oxide	67%	calcium oxide	63.3%
Magnesian oxide	0.1%	mag oxide	1.3%
Silica	17.5 %	silica	22.7%
Iron oxide	2.4%	iron oxide	3.3%
Alumina	7.2%	alumina	5.5%
Water etc	4.9%	sulphur anhydride	1.9%
		Other	2.0%

The setting quality (of Portland cement mortar) may be tested by mixing up a pat, using the minimum amount of water, on a sheet of glass until it is about 3 inches square and 1 inch thick. In 24 hours this pat should be hard enough to resist the impression of a thumb nail, and in 48 hours it should be difficult to break in half. Should be stored in a moderately warm place under cover.

MORTARS

…For ordinary brickwork, mortar may be composed of 1 part grey stone lime *[feebly hydraulic]* to 3 parts of sand; and for quick-setting, and very heavy loads, 1 part Portland cement to 4 parts sand.

The mortar should be prepared on a properly constructed deal platform or 'bank' and measured in boxes or moulds. If mixing is done by hand, **this measured quantity of sand is piled over the slaking lime and left for sufficient time to complete the process before it is mixed.** With lime already hydrated, all that is required is to mix the sand and lime dry, and then add enough water to render the mass plastic. **A few days should elapse before using the mortar so prepared.**

A mortar mill should be employed whenever possible…as it minimises the danger of unburnt or unslaked lumps in the mortar.

PLASTER AND ITS APPLICATION (IN VOL 3).

Lime Plaster.

For centuries, in this country, lime has been the principal material used in plasterwork…The condition of this old plasterwork at the present time speaks well for the durability of the materials used, and for the workmanship exercised in their application.
…After calcination, the quicklime…is **slaked in a large tub or cistern** to prepare it for use in making mortar.

Where the work is of sufficient magnitude, a large square pit is prepared, either by digging in the ground, or by building four sides with planks to form a reservoir.

The cistern or lime box is mounted at one end of the pit and has a sluice covered with a sieve or fine grating at one of its ends; the box is so placed as to have a slope towards the pit.

Water is run into the box until it is about half full, **then the quicklime is placed in the water** until the whole box is covered, care being taken to keep the lime under water *[this contradicts all previous slaking procedure, 'drowning' the lime].*

….violent boiling takes place.

When boiling has ceased, the lime has changed from a stone-like form to a **thick paste**; this is stirred with a paddle to ensure thorough mixing with the water; the sluice of the box is opened, and the liquid falls into the large pit, where it remains to cool off, and stiffen into what is known as **lime putty.**

This should stand in the pit **for at least a month** to ensure that all the lime is thoroughly slaked…After slaking, the lime has increased to 3 or 4 times its original bulk.

When matured, the lime putty is taken from the pit, and mixed with sand in various proportions according to the purpose for which the mortar is intended. *[this is quite a change in method since 1920 (above), with the method then for slaking to a putty for fine finish coat is applied to all coats].*

Lime for lath ceilings

…1 part lime to 2 parts of sand, and ox or goats hair added

Lime for brick walls. 3 or 4 parts sand to 1 part lime, with a smaller quantity of hair than for lath work.

These mortars are usually mixed in large quantities and allowed to stand for some time before use: this has the effect of improving their working qualities *[they are lime lean]*.

Hydraulic Limes

Lime is rarely found in a pure state…These hydraulic limes, as they are called, are not favoured by the plasterer, because although they **attain great strength, their working qualities are inferior to the rich or fat limes,** which also have a greater capacity for carrying sand.

The ideal lime, therefore, for plastering purposes is one having the highest percentage of calcium carbonate, (such as is) found in Derbyshire, where the limestone is the purest in the country.

…**importance of time in plastering**

The most important thing in lime plastering, apart from good materials, **is abundance of time.**

Time is necessary to allow each coat of plaster to dry out, before another is applied.
Lime hardens very slowly, by a two-fold process – evaporation and carbonation….

There are no means of hastening this process **without adversely affecting the quality of the finished work,** and in all lime plastering, the more the natural processes are allowed to operate, the better the result.

Methods employed to hasten the hardening process.

For many years it was the custom, **when work had to be hurried,** to mix plaster of paris with the coarse undercoating in order to speed up the hardening process and allow work to proceed without waiting for natural drying to take place.

This was not always successful and much of this kind of work suffered from cracking and other weakness after the work became dry.

It has to be realised that when plaster of paris or any other setting agent is added to lime, **it is only that agent which actually sets**, not the mass of lime with which it is mixed, and that the moisture contained in the mass has still to be evaporated; also, until evaporation takes place, the lime cannot carbonate.

The hardening of a mixture such as this is due to the power of the setting agent to hold or support – by a network of crystals interlacing the mass – the bulk of material with which it is mixed, but the hardening is not the same as that which comes from natural drying out.

National Lime Association (USA) (1934) Masonry Mortar, Bulletin 321. Washington DC.

DRY WALLS WITH LIME MORTAR.

A water-tight masonry wall has a neglible number of unfilled joints or open spaces where brick and mortar apparently meet but are not attached. The formation of such openings is influenced by the properties of the materials used and the class of workmanship employed. The presence of openings between units and mortar is the primary cause of *excessive water penetration* into the wall.…This condition must be prevented if the masonry is to remain durable.…The most effective method of preventing the condition….is to lay up the masonry in a mortar having properties which will permit the mason to completely fill all joints. The mortar should also possess properties which permit the formation of maximum extent of bond plus ability to maintain such bond.

The fact that openings exist is proved by the many instances of leaky walls wherein both units and mortars are comparatively impervious. Mortars of very low porosity are often associated with bad leaks….

Water that enters pores and voids of bricks, stones, mortars etc readily evaporates from the exterior surface. This is a normal condition offering no cause for concern.

To prevent excessive water penetration into a wall, one must use an adaptable mortar. This is a mortar that can be expected to adhere satisfactorily to all types of building units.
Lime promotes mortar adaptability and a mortar rich in lime is suitable for all types of units. An adaptable mortar is first of all *workable*. It has *bonding power*. It is characterised by low volume changes subsequent to hardening. It has good extensibility, produces good strength and has a rate of hardening compatible with modern methods of construction.

PROPERTIES OF A MORTAR THAT MAKE IT ADAPTABLE AND SUITABLE.

1. *WORKABILITY*

Warren E Emley in Bureau of Standards Technologic Paper No. 169 states: "The *ability to retain water,* while the *most important,* is not the only factor governing plasticity." …this property has been found to be always associated with plasticity, (therefore) it may be said that a measure of the water retaining capacity of a mortar provides a good index to its plasticity or workability….

The three known factors that control workability are:

1. water retaining capacity
2. bulk density
3. good troweling properties

…Water is the sole lubricating medium in mortar and the more retentive it is of water, the more workable is the mortar under practical working conditions. If the mortar loses water to the brick too rapidly, it stiffens so quickly that intimate contact is not made and as the mortar adheres to the brick only in spots….the extent of the bond is poor. If the mortar has high water retaining capacity the extent of bond is good.

Water-retaining capacity of mortars as related to the water-tightness of test walls

mortar composition Lime: OPC: sand Proportions by volume	water retaining capacity (flow % after suction for 1 minute on a standard	maximum rate of leakage of 8-inch test walls made with dry-press bricks set dry (cubic centimetres of water transmitted thru walls per min
0.15:1:3	54	402
1:1:6	75	386
2:1:9	93	98
3:1:12	91	128

NB these tests were ‘extremely severe, far more so than the conditions to which a wall may be exposed in the most severe rain storm. The extent of bond obtained with 2:1:9 and 3:1:12 was *complete’*

…It is difficult to get a satisfactory bond with a mortar deficient in water retaining capacity, no matter what the absorption of the brick may be.

…Bonding power involves general adaptability. Bonding power is that property of a mortar which gives it a tendency to adhere uniformly and completely at all points of contact where bricks and mortar meet, under widely different conditions and with various types of units, the intensity of its adhesion being such that the tensile strength of bond is either equal to or greater than that of the mortar. (a 1:1:6 has much better bond that a 1:3 cement mortar)….

More recent data, published in Bureau of Standards Research Paper no 683, ‘The Properties of Bricks and Mortars and Their Relation to Bond’ show conclusively that mortars richer in lime than 1:1:6 have better bonding power than that mortar. As lime, either putty or dry hydrate, was substituted more and more for Portland cement, the bonding power was improved.

….Volume changes

Lime and rich in lime mortars have a high water retaining capacity and therefore tend to undergo a minimum of compacting when in contact with porous building units.

Shrinkage During Early Hardening

a. This type of volume change is omnidirectional
b. It attends hardening through cementing action
c. **It occurs but once during the lifetime of a mortar**
d. **Its magnitude is diminished when the mortar is in contact with an absorbent unit and is greatest when in contact with solids of zero porosity**
e. **A mortar which hardens slowly is more or less plastic when most of this type of shrinkage is completed**
f. **Any possible damaging effect of this type of volume change is dependent as much (and probably more) on the *rate of hardening* as on the magnitude of shrinkage**
g. **Data obtained during an extensive study at the Bureau of Standards show conclusively that this type of volume change is not damaging either to the mortar or to the bond between the mortar and bricks. This was found to be true regardless of the magnitude of the shrinkage of mortar during early hardening…**

Volume Changes Subsequent to Hardening

a. This type of volume change is characterised by expansion on wetting and shrinkage on drying
b. It is cyclic and frequently is rapid if the conditions for wetting and drying are favourable
c. It takes place in rigid mortar that has an elastic limit
d. **High volume changes subsequent to hardening are characteristic of dense mortars of outstanding hydraulic properties. They are lowest for straight lime mortars. This type of volume change is reduced as lime is substituted more and more for Portland cement (Bureau of Standards Research Paper no.321, 'Volume Changes in Brick Masonry Materials'.**

…When the extent of bond is poor (less than 90% of the flatside area of a brick) there is a tendency for it to be destroyed entirely if the mortar is one that has high volume changes subsequent to hardening.
If the extent of bond is complete or nearly so, high volume changes in the hardened mortar tend to produce cracks in a direction more or less perpendicular to the plane of contact of brick and mortar. These cracks may heal slowly when the mortar is wet, but they occur again and again and tend to admit an excessive amount of water into the wall and, as a consequence, further occurrence of volume changes is accelerated.
Usually, a mortar having low water retaining capacity is one that also undergoes relatively high volume changes subsequent to hardening….

STRENGTH

A strong wall is one having integrity, ie, adhesion of mortar to units throughout. 'Mortar pancakes' that keep bricks apart and not together do not provide a strong wall, be the strength of the mortar what it may. A chain is only as strong as its weakest link….This weakest link is at the plane of contact of bricks and mortar when the latter has poor bonding power. All other things being the same, a water-tight wall is always stronger than a leaky one.

(Quotes National Bureau of Standards circular no.30 as per Boynton and Gutschick.)…

…These two undesirable properties, low water retaining capacity and high volume changes subsequent to hardening are *usually associated.* The same holds for the desirable combinations, high water retaining capacity and low volume changes subsequent to hardening, and *this desirable combination does more to promote strength in a wall of masonry than mortar strength per se.* This fact should be appreciated and thoroughly borne in mind by all who are interested in improving unit masonry from the standpoint of both strength and water-tightness.

WEATHER RESISTANCE

Two factors control the resistance to frost in unit masonry. These are:

1. The extent to which the wall becomes saturated during its life history and,
2. The frost resistance of the building materials (units and mortar).

The first of these two factors is much more important than the second. A comparatively dry wall is not exposed to weathering from severe climatic action. Water is the universal solvent and chief weathering agent. When water which saturates a wall is repeatedly frozen and thawed the masonry is disrupted regardless of the fact that the materials composing it may, in themselves, be frost resistance in the usual laboratory tests. The extent of bond between units and mortar in such a wall is poor to begin with, else the masonry would not be excessively saturated. A poorly distributed bond…soon fails entirely from frost action.

The freezing and thawing of moisture which, under the most severe conditions, only dampens or partially saturates the wall, does relatively little damage. In such a wall, the extent of adhesion between mortar and units is good. The bond is therefore relatively durable both because it is uniform and complete and because it is exposed to a minimum of exposure.

It so happens that those mortars which have the best freezing and thawing records in laboratory tests are usually associated with leaky masonry. The properties that enable them to endure severe freezing and thawing in the laboratory are not properties which cause them to bond completely and firmly to various types of building units. It also happens that those mortars of relatively less resistance to (these tests)…are usually associated with dry walls. They have properties which insure good adhesion at all points throughout the wall. It is more important to avoid excessive exposure of a wall than it is to have materials that are the most resistant when severely exposed….Excessive dampness in itself is damaging both to health and property.

Lime mortar has an enviable record for resistance to weathering in the oldest brick buildings in the history of this country. The walls in these fine old buildings seldom if ever became completely saturated. Therefore the lime mortar did not decay and fall out.

Lime and rich in lime mortars attain their full strength at a rate less rapid than that of Portland cement mortars. Many of the natural cements and hydraulic limes also attain their strength at rates comparable to that of lime mortars. To subject specimens of mortars having a relatively slow rate of attaining strength to severe laboratory freezing and thawing tests at an early age is a procedure that can only add to an accumulation of '*mis*information' which is of no practical value. The number of cycles of freezing and thawing provided for in the usual laboratory procedure before specimens have aged a year is more than would be attained, even in a leaky wall, in half a century of normal exposure. The proof of this statement is found in the many examples of old masonry in both the United States and Europe made of materials which of themselves give negative results under prescribed laboratory tests, yet these buildings stand today in mute testimony of their endurance after centuries of exposure.

RATE OF HARDENING

Some have expressed scepticism about the use of lime or rich in lime mortars for the reason that they believe that such mortars harden too slowly to meet the needs of modern construction. Let the facts dispel such an illusion.

Table 8
Rates of Hardening of Mortars on an Impervious Base as Indicated by Vicat Tests
(National Bureau of Standards Research Paper No.683)

Mortar composition Lime: Portland cement: sand (By volume)	Rates of hardening. Average of 3 tests. Modified Vicat test after the mortar had been on an impervious (steel) base for 2 hours. Millimetres penetration in 30 seconds.
0:1:3 (opc no.1 - grey)	5.2
0:1:3 (opc no.2 – white)	0.8

1:1:6 (opc no.1)	1.8
2:1:9 (opc No.1; quicklime)	3.8
3:1:12 (opc no.1; quicklime)	4.0
1:1:6 (opc no.2; hydrated lime)	1.0
2:1:9 (opc no.2; hydrated lime)	2.5
3:1:12 (0pc no.2; hydrated lime)	3.5
0.15:1:3 (opc no.1: quicklime)	1.8
1:0:3 (quicklime)	30
1:0:3 (hydrated lime)	22.7

Table 9
Mortar Mixes for Various Types of Masonry

Masonry Type	Construction Type	Loading	Proportions
Common and face Shale or sand-lime Brick	Dwellings, garages and similar	Any for such types	1:0:3
Clay or shale Brick	Walls and piers below grade continuously exposed to wet or damp conditions	Ordinary distributed Heavy concentrated Eathquake tremors	1:1:6 1:1:6 1:1:6
Granite, limestone, Marble, sandstone, Terracotta facing and trim	exterior walls and piers above grade	Ordinary distributed Heavy concentrated Earthquake tremors	2:1:9 2:1:9 2:1:9
Common and face clay, shale or sand-lime brick, concrete brick	Interior walls and piers above and below grade	Ordinary distributed Heavy concentrated Earthquake tremors	2:1:9 2:1:9 2:1:9
Hollow clay tile, Concrete block, Concrete tile, Cinder block Gypsum block	Exterior walls above grade and interior partition walls	Non-bearing partitions, exterior and bearing walls and partitions	2:1:9

(NB Portland cement circa 1934 very much less strength than after WWII and since - around 500 psi/3.4 Mpa. A modern 2:1:9 would be stronger (3.8 after 28 days; 4 Mpa after 90 days) but still less strong after 2 years than most currently available NHLs.(HE/BLF/Figuieredo 2018) and with a higher free lime content). Similar – and beneficially lesser – strengths, but with earlier initial set may be achieved with a hot mixed lime mortar and up to 10% pozzolanic

addition, without any sacrifice of workability and, if 10%, with 80% free lime content, offering excellent effective porosity)

Lime mortar containing no cement does harden slowly on an impervious building unit. With more porous units such as dry-press bricks, there should be no difficulty whatsoever. Lime mortar is particularly suitable with very porous units set dry in winter construction. The bulk of the water is out of the mortar and in the brick before it can be frozen. At the same time the lime mortar is sufficiently retentive of water to make the necessary intimate contact with the highly porous units without necessitating wetting such units to any extent whatsoever. Bricks should never be wetted when laid in freezing weather….

MORTAR RECOMMENDATIONS

From the foregoing study of essential mortar properties it is apparent that lime mortar meets all of the requirements, including strength of masonry, for most purposes.
However, in order to avoid delay, where rapid methods of modern construction are employed, the addition of Portland cement to lime mortar is recommended, even though this practice adds to the cost of construction and often results in considerable sacrifice in quality of the finished masonry. When cement is so added it replaces an equivalent volume of lime in the mortar mixture.

It must be remembered that *as Portland cement is substituted more and more for lime, there is a greater and greater sacrifice of the essential properties – water retaining capacity, workability, adaptability, bonding power, and low volume changes subsequent to hardening.*

Laboratory and service tests have both shown that a mortar consisting of 2 volumes of lime, 1 volume of Portland cement and 9 volumes of sand is well adapted for use with a wide variety of units and under a wide variety of conditions, it is therefore recommended for general use **where a mortar having a rapid rate of hardening is required.** If it is desired that the mortar strength is increased, it is recommended that the sand content be reduced to 7 or 8 volumes but that the ratio, 2 volumes of lime to 1 volume of cement, be maintained. This procedure will increase mortar strength with no sacrifice of the more essential properties….

Searle A B (1935) *Limestone and its Products, Their Nature, Production and Uses.* London. Ernest Benn Ltd.

Hydraulic limes are prepared by calcining an argillaceous limestone, the clay present entering into combination with a portion of the lime and forming what may be regarded as a mixture of Portland cement and quicklime.

The chief raw material in this country for hydraulic limes is the blue Liassic limestone of Warwickshire, South Wales, etc., but other argillaceous limestones may be used. As will be understood from the previous section on the raw materials used for Portland cement, a much superior cement is obtained when the composition of the material is adjusted so as to give a product of approximately the same composition as Portland cement.
The composition of the limestones used for making hydraulic limes must lie between (1) pure limes with 3 per cent, of clay, and (2) marls or mixtures of clay and chalk which contain no excess of lime. It has been found that argillaceous limestones with 70-80 per cent, of calcium carbonate, 10-17 per cent, of silica, and not more than 3 per cent, of iron and alumina are best, as, in the hydraulic limes made from these, most of the clay is combined with lime, yet there is sufficient free lime present to cause the material to slake satisfactorily. Hydraulic limes may also be produced by under-burning a rock which would, at a higher temperature, produce an excellent natural cement, but these are very inferior and unsatisfactory.

Hand Slaked Lime. Until a few years ago, all slaked lime was prepared by hand. The essential feature of the slaking is the addition of water to the lime in such proportions and at such a rate as to produce either a dry powder or a plastic paste, according to what is required, if a dry powder is desired the process is often known as *dry slaking,* but if a paste or putty is to be produced the term *wet slaking* is used. If a large excess of water is added rapidly the slaking tends to be incomplete or so seriously retarded that the lime is said to be " drowned "; what really occurs is that the wet surface of the lime becomes impervious to water so that the latter does not reach the interior of the lumps. If " drowned lime " is used for plastering, the pieces of quicklime, which have been protected in the " slaking " and are, therefore, unaltered, gradually absorb moisture from the air, swell, and cause objectionable "blebs " or " blisters " on the surface of the plaster.

In slaking a fat lime by hand, the water should be sprinkled over the surface of the lime, the weight of water required being about half that of the lime, or about five gallons to each 1 cwt. of lime. If the lime were perfectly pure, the quantity of water which would combine with it would be exactly 32.1%, but so much heat is generated during the slaking that a considerable quantity of water is driven off as steam, so that more than the theoretical quantity of water must be added.

When slaking a fat lime it is preferable to add the water slowly, but all at once, as when it is added in two or more successive portions, water is lost by evaporation and too little may remain in combination with the lime. The workman should place a convenient quantity (say 100 lb.) of lime on a concrete or stone surface and sprinkle water on it—preferably through the rose of a watering can—and then turn the material over repeatedly with a spade until the slaking is sufficiently advanced for it to be completed without further attention.

If insufficient water is used some parts of the lime will remain unslaked and this may cause serious trouble when the slaked lime is used. Incompletely slaked lime is said to be "burned." Precisely what causes "burning" during hydration is not known, but it appears to be due to the addition of too much water at first and too little at a later stage of the hydration, or to the use of too little water through the slaking. The excessive heat developed appears to cause the colloidal hydroxide to become hard and, therefore, non-plastic so that the "workability" of the lime under a trowel is diminished or even destroyed.

If too much water is used, however, the lime is said to be "drowned" and the resultant produced is a thin watery paste of little or no value.

When the slaking is properly conducted the product is either a light, dry and fine powder or a moderately soft paste according to whether hydrated lime or lime putty is required.

The men engaged in slaking lime by hand should have their mouths and noses carefully protected by means of respirators.

Unless the source of lime is changed too frequently, a man will usually be able to judge fairly accurately the amount of water required and the best rate at which to add it. Unless exceptional care is used, however, lime slaked by hand tends to be too moist and, therefore, "sticky," hence, the custom of making it into a putty or paste.

The slaked lime should be carefully examined and any unslakable materials such as unburned limestone, pebbles, or flints, removed. If, later, they are mixed and ground with the slaked material they will detract from its quality.

For some purposes the slaked lime is passed through a sieve with 24 holes per running inch, and, occasionally, a much finer sieve is used. Hand slaked lime, is, however, regarded as a crude product, and, consequently, few attempts are made to convert it into an attractive one. This is the more unfortunate as hydrated lime of first-class quality can be obtained by careful hand slaking followed by suitable screening or air separation.

Some men, when slaking lime by hand, add most of the required water to the lump lime and after a suitable time, place the product on a sieve with ½ - ¾ in. holes; the finer material which falls through the sieve is used as slaked lime, whilst the coarser pieces are treated separately with more water to see whether they then fall to powder. This method separates the larger pieces of impurity and "core," but unless the fully slaked lime is passed through a fine sieve most of the other impurities will become mixed with the hydrated product.

If the process is carried out properly and suitable lime is used, the lumps will evolve much steam and will gradually fall to a moderately fine powder free from lumps. If an impure lime is used, or the process has been badly controlled, an unsatisfactory mixture of lumps and powder will be produced.

Notwithstanding the apparent crudity of the method of slaking by hand, some of the best commercial hydrated lime on the market is obtained by this method.

In *dry slaking* by hand the lime is spread on the ground in a layer, 4-6 in. thick, and is sprinkled with water by means of a rose on a watercan. It is mixed with the aid of a shovel, and is then heaped up and left to itself for a day, so that it may be fully slaked. It is advisable to cover the heap with sacks so as to retain the heat in it. It is also wise to watch the heap during the first few hours, as the temperature reached in slaking lime is often sufficient to set cloth or wood on fire.

In an alternative method, the lumps of lime, in a basket, are immersed in water for a short time and are then withdrawn and placed in heaps or silos to prevent the escape of water. The lime slakes and falls to powder but is very liable to contain some unslaked lime.The dry, slaked lime is sifted, usually through sieves with 4-8 holes per running inch. Such coarse sieves are unsatisfactory, as they allow many particles, which have not been sufficiently burned, and also small clots of paste to pass through them. It is much better to employ sieves with 36 or more meshes per linear inch, so that all coarse particles are separated and a really fine, soft powder is obtained. Indeed, the present tendency is to require all dry-slaked lime to leave less than 6 per cent, of residue on a 200-mesh sieve.

If the lime is properly slaked it will quickly fall to an apparently dry powder, but if a slight excess of water is added the product may be adhesive and plastic. Unless the excess of water added is large, the apparently pasty lime may evolve so much water that by the time it is cold it may be a dry powder.

During the slaking of lime a considerable amount of expansion takes place. One bushel of lump lime (made from stone) which contains little or no non-volatile impurities will produce 3-3 ½ bushels of dry powder. This is the case with the best limes made from blue or grey limestone. The colour of these stones before burning is due to combustible bituminous matter; this burns away, leaving a pure white lime.

The amount of swelling depends partly on the purity and porosity of the lime and partly on the manner in which the water is added, the swelling being less if the water is added very slowly. This is particularly noticeable with magnesian limestone.

Dry slaking is *not* suitable for hydraulic limes.

In-wet slaking by hand the lime is mixed with three or four times its weight of water {*i.e.* 33-45 gallons for each 1 cwt. of lime) in a shallow tub or trough, the mixture being well stirred with a wooden rake so as to produce a *milk* or *slurry;* this is run off into another vessel or into a pit, as desired. This process ensures the complete hydration of the lime, which is uncertain with dry slaking, and produces a stronger mortar when such lime is mixed with sand or trass.

Care should be taken not to "drown" the lime in an excess of water, and it is desirable not to add too much water at a time. When the slaking is skillfully done the mixture remains at a boiling heat for some time. Wet slaked lime should not be run through a grate or sieve, as this creates too great a temptation to use a large excess of water. Any pieces which cannot be slaked soon settle and remain behind when the slurry is run off. If a paste or putty is required it is sometimes better to dry slake the lime first and obtain a dry powder to which can afterwards be added the water necessary to produce a paste. If all the water needed is added at once, some parts of the lime may be "drowned."

The use of mechanically hydrated lime is increasing so rapidly that the production of hand slaked lime is quickly diminishing. This is unfortunate, because a skilled lime slaker can adjust the quantity of water added to suit each batch of lime, whereas a machine must be adjusted in order to produce slaked lime of " average " quality.

Hand slaking is very slow and, therefore, costly, but hand slaked lime is, for some special purposes, superior to mechanically slaked lime.

Greystone lime is slaked in a similar manner to fat lime, but a longer time is required, as the silica present is combined with some of the lime similarly to that in hydraulic limes.

Hydraulic lime is slaked in a different manner because such lime is really a mixture of two materials: *[a)* quicklime, and *[b)* a hydraulic cement. The slaking relates only to the first constituent, the resulting product being a powder containing unslakeable lumps *{grappiers)* which must be separated by screening unless the original lime has been ground to powder, prior to slaking. Unless a hydraulic lime is to be used at once it is important not to add any more water than is needed to slake the quicklime present. Any excess of water will cause some of the " cement " to harden and will render it useless.

Unlike quicklime, hydraulic limes do not swell appreciably when slaking, and they develop far less heat. A hydraulic lime may, therefore, be mixed with a limited amount of water with little or no risk of spoiling it. According to Le Chatelier, the vapour tension of calcium hydrate, when cold, is practically nil, but that of calcium silicate is several millimetres of mercury. At 100° C it is not more than 1 mm for the first, but several centimetres for the second. Consequently, in a mixture of lime and silicate the lime will hydrate progressively without the silicate being hydrated and the silicate will, if necessary, part with its combined water until all the lime is fully hydrated. If only sufficient water is added to a lump of hydraulic lime, only the calcium oxide and magnesia will be hydrated, but the expansion due to this slaking should cause the whole lump to crumble to a fine powder, consisting essentially of calcium hydroxide, tricalcium silicate, tricalcium aluminate, and a complex mixture of more or less inert matter, the whole forming a cementitious material resembling a weak Portland cement.

About 10-15 per cent, of water is usually required for slaking a hydraulic lime, but the optimum proportion should always be found by trial as imperfectly slaked lime can cause serious trouble when in use. The water should be supplied in the form of a very fine spray so that no part of the lime receives an excessive quantity of water. If the water is added through coarse jets, part of the lime becomes too wet and then loses its cementitious properties unless it is used immediately.

The best qualities of hydraulic lime are not used for some time after being slaked, so as to ensure complete slaking.

A good hydraulic lime should fall to powder when immersed in water for 24 hours, or when sprinkled with a suitable quantity of water, and at the end of this time should not leave more than 5 per cent of residue on a No. 24 sieve. A properly hydrated hydraulic lime will usually require only 7-8 per cent, of its weight of water, but 10-11 per cent, is usually added to allow for loss by evaporation.

A dry slaked hydraulic lime usually contains a considerable proportion of lumps (grappiers) of harder material; these should be removed by passing the product over a 50-mesh screen or sieve. As these grappiers can be ground and made into cement, it is an advantage if hydraulic cements are slaked by the manufacturer who can make use of the grappiers.

It may seem strange that hydraulic lime requires so long to slake completely because all movement ceases within 48 hours of adding the water and no vapour appears to be set free! The true test is that mortars made with hydraulic lime which has only been slaked for 48 hours, crack and show other signs of incomplete slaking, whilst mortar made of the same lime which has been slaked for a fortnight will be excellent. A hydraulic lime purchased in a ground state should pass completely through a 24-mesh sieve and not leave more than 10 per cent of residue when washed through a 200-mesh.

Ample time must be allowed for slaking hydraulic cements, both when neat and when mixed with sand, but care must be taken to avoid re-working a material which has been slaked with too much water and has begun to set. If the lime is slaked whilst warm, as it comes out of the kiln, or if *hot* water is used, the time of slaking may sometimes be reduced to three hours.

Hydraulic limes should always be sifted after slaking, in order to remove any imperfectly slaked lumps (grappiers) and it is preferable to grind the lime to powder before slaking so as to avoid inconvenience caused by the formation of these lumps.

When large quantities of hydraulic lime are to be slaked, as in France where the slaking is done at the lime works, the lime is spread out in layers on large floors, sprinkled with just sufficient water to slake the free lime, and then shoveled into heaps or placed in bins where it is kept for about ten days, during which the slaking is completed. The product—which should chiefly consist of a fine powder—is then sieved or screened—usually through 50-mesh gauze—or passed through an air separator to remove the lumps (grappiers) and is then ready for sale or use. A portion of the grappiers is usually ground to powder and added to the sieved product so as to increase the hydraulicity of the latter. The process used is described under " Ground Lime." In slaking prior to sale, an excess of water should be avoided, or some of the cementitious part of the lime will be spoiled.

GRAPPIERS

The coarse material separated when hydraulic lime is slaked is known as *grappiers*. It is a highly cementitious and hydraulic material, though inferior to Portland cement. It is obtained as a by-product when hydraulic cement is hydrated at the works, as is usual on the Continent, and requires to be ground so as to leave not more than 10 per cent residue on a 180-mesh sieve in order to be of the same fineness as Portland cement, for which it is used as a substitute. To be useful, the grappiers must be free from more than about 15 per cent of unburned limestone and the more nearly their composition resembles that of Portland cement, the more valuable will be the grappiers.

Crude grappiers is an irregular mixture of white, grey, and black particles. It is first exposed to the air for a month or more, so as to hydrate the free lime completely. Sometimes steam is admitted to the aerating rooms in order to hasten the hydration. The product is screened and the fine "heavy lime" added to ordinary hydraulic lime. The residue is ground and forms the *white cement* largely used for mosaic work. The harder portions, which occur as tailings from the " white cement " screens, form a grey sand which, when finely ground, produces *grey grappier* cement….

In France, where the grappiers industry is more extensive, there is an increasing tendency to simplify the procedure by grinding the lumps of grappiers as finely as possible and adding them to the hydrated lime, thereby increasing the hydraulicity and cementing power of the latter….

3. THE USE OF LIME IN BUILDING CONSTRUCTION

For most building purposes, a somewhat impure lime is often preferable, because the argillaceous material present, or the siliceous material introduced by burning the stone in contact with the fuel, produces feeble hydraulic properties which make a stronger joint or surfacing material.

A rough distinction exists in the building trade between " fat " or " rich," and " poor " or " lean" limes. The former slake rapidly with high rise in temperature; the latter slake slowly and without much rise in temperature. Fat limes set only by absorption of carbon dioxide, but lean limes are hydraulic and set like diluted cements.

LIME FOR USE IN MORTAR

Mortar is a mixture of sand and water with some binding material, such as lime or cement or both. A fibrous material, such as hair, is often added to increase the strength. In lime mortar the lime forms a colloidal gel with some of the water and this gel coats the sand grains. As the mortar dries, the colloidal gel dries and shrinks and so holds the particles together. A small proportion of crystalline calcium carbonate is also formed and the interlacing of the crystals increases the strength of the mass. The mixing of the various ingredients must be thorough; all fat lime mortars are improved by prolonged mixing, but in those containing hydraulic lime cement the mixing must not be continued after the cementitious portion has begun to set. The mixing may be by hand or machinery; the use of the latter is generally known as *grinding,* but no actual grinding should occur with properly prepared materials. Mortar made with fat lime should not be used for 24 hours or more as storage greatly improves its workability.

For the production of ordinary mortar for general use by builders, either a fat lime, a lean lime, or a hydraulic lime (Lias lime) may be used. Fat limes are preferred, but lean limes can be employed if they do not slake too slowly; they are regarded less favourably by some builders, because they have a much smaller sand carrying capacity, and-the resulting mortar does not "work" very smoothly. Hydraulic limes are stronger in cementing power, and behave like a mixture of fat lime and Portland cement.

Magnesian limes are generally suitable for mortar and sometimes exceed calcium limes in smoothness, working, sand carrying power, and resistance to weather. There is also evidence that magnesian limes give mortars that eventually give greater strength than those made of high calcium limes. They slake more slowly than calcium limes, and, unless care is taken, the mortar may prove to be unsound by a steam pat test. The slow slaking is often due to partial over-burning of the lime.

Greystone limes are highly appreciated for the strength of the mortar which they produce as a result of being feebly hydraulic, though this reason is seldom realized. Ground greystone lime requires about one month after being mixed with water before it develops appreciable hydraulic strength. It loses this property if the lime is stored in the form of putty or if it is soaked and kept for a long time before use.

Mortar made with *fat lime* or a *lean lime* with a low silica-content does not "set" in the same manner as hydraulic lime or concrete. Such lime merely dries, and by gradual absorption of carbon dioxide on its surface it becomes moderately hard externally, but the interior of the mass may remain soft for several hundred years *(really?)*. The purer the lime and sand used in the preparation of the mortar, the softer will be the mortar, no matter how long it has been in use. The carbon dioxide absorbed from the air combines with the lime at the surface of the joints, and, by closing the pores, prevents a further penetration, so that most joints in old masonry are only hard for a very short distance below the surface *(this is prejudice, certainly not observation)*.

Hydraulic lime, on the contrary, undergoes a complex chemical change when in contact with water and " sets " to a hard mass. It does this equally well in air or under water, **provided the mortar is supplied with sufficient water to ensure its adequate setting and subsequent hardening. If the supply of water is insufficient, the hardening will be incomplete.**

Fat limes can be caused to harden like hydraulic lime and cement, by adding a suitable proportion of a material which will combine with the lime, forming a compound somewhat resembling those in hardened cement concrete. Such material is known as *pozzuolana;* the commonest variety is *trass,* which is extensively used on the Continent, but an equally good substitute is made by grinding underburned bricks or tiles to a fine powder, provided they are sufficiently rich in clay.

Pure limes to which no pozzuolana has been added should not be used for work in contact with water, but only for structures above ground level.

High calcium limes are generally regarded as preferable, because they slake readily and completely in a short time whereas magnesian limes slake more slowly and uncertainly and may, therefore, cause trouble …

In limes used for building construction, the physical characteristics, such as plasticity, time of set, colour, hardness, and strength, are of great importance, whereas chemical composition is immaterial except indirectly, inasmuch that limes made from limestone of different purity and composition usually have different physical characteristics. Thus, magnesian limes in general are more plastic than high calcium limes and are preferred for " finishing " purposes …The lime which can carry the largest quantity of sand should be the best for mortar.

A useful indication of the quality of a lime is to measure its volume before and after slaking. All good limes will increase in volume, but a fat one should increase to three times its original size. Limes which produce less than twice their volume of slaked lime are described as *lean* or *poor.*

Before mixing it with sand or any other solid material, a quicklime should be slaked and made into *lime putty*;- the hydrated lime merely requires to be mixed with water, and the hydraulic lime should be slaked by sprinkling it with water, avoiding an excess, and finally passing it through a No. 5 or finer sieve.

The chief disadvantages of lump lime for use in mortar are:

(i) It requires slaking, which is troublesome and tedious.
(ii) It frequently contains much *core* and useless material.
(iii) The quality varies greatly and cannot easily be checked by the builder; consequently, the quality of the mortar also varies.
(iv) It soon spoils if kept before being used.
(v) It is inconvenient to keep on account of its caustic properties.

In short, it has all the disadvantages of a crude material. In the United States, it has been replaced almost completely by hydrated lime, which is free from all these objections.

In some localities, the quality of lime, as compared with that made fifty years ago, has deteriorated seriously. This is due to the skilled burners having left or died and other men with less care and skill having taken their places. To a smaller extent, the change is also due to the use of inferior coal, which does not burn the stone so effectively, and introduces a larger percentage of ash into the lime. It is, therefore, more than ever necessary that builders should ascertain the quality of the lime they are buying…..

The advantages of hydrated lime in making mortar are:

(i) It can be stored indefinitely and easily.
(ii) It requires no slaking.
(iii) It is more uniform in quality.
(iv) It contains less "core" or useless material and so can be used without waste.

(v) It avoids the production of bad putty through carelessness or ignorance of the man in charge of the mortar.
(vi) It avoids the loss otherwise caused through having to make more putty than is needed to allow for useless material in the lime.
(vii) It is particularly easy to measure and use.
(viii) E. W. Lazell has shown that mortar made with hydrated lime is stronger than that made with hand slaked lime and used immediately. The reason is that mechanical slaking under proper control ensures complete hydration, whereas, with hand slaking, the paste must be left for some weeks before the hydration is complete. Moreover, in hydrated lime, the coarser, unaltered particles are separated, so that the risk of caustic lime in hydrated lime from a good firm is negligible. Much of the hydrated lime on the market is not as good as a hand slaked lime putty about a year old, because the plasticity of lime can only be developed in the presence of more water than is permissible in hydrated lime. For most building purposes, however, hydrated lime is as good as need be desired.

…. The *advantages* of fat lime—either lump or hydrated—are:

(i) It enables bricks to be laid more rapidly and more easily than when cement is used, as lime is more plastic than cement. A greater strength can be used by replacing some or all of the lime by Portland cement, but where such additional strength is wholly unnecessary there is no object in securing it, and lime mortar has ample strength for all ordinary buildings.

(ii) Fat lime produces the only mortar that can be prepared in large quantities in advance, *i.e.* that made from either quicklime or hydrated lime. All the lime mortar needed for a structure can be mixed before the walls are started. It may be stored, either in a stack or pit, until required, and, in fact, is actually better and more easily worked because of the ageing. This feature of lime mortar affords a good chance for economy, as machine mixing is particularly suitable and satisfactory. As the mortar is required, it may be re-tempered to the desired consistency and used with full confidence.

(iii) Fat lime makes the most economical mortar. The cost of the materials is low, because of the high sand carrying capacity of the lime. The strength of the mortar is ample, thus permitting jt to be used under practically all conditions. The natural plasticity of the lime decreases the cost of mixing the mortar, of spreading the mortar bed, and of placing the bricks. No mortar is wasted. If the mortar is mixed as needed, any left over at the end of a day, or not used, because of a sudden shut down on the job, can be stacked and used when work begins again. If cement mortar works short, the droppings are excessive, 10 per cent, being sometimes wasted. This is not the case with lime mortar, for the only droppings are due to trimming the joints, and these are negligible.

(iv) Fat lime mortar avoids delaying the bricklayers, who, when cement mortar is used, have to wait for mortar to be mixed. Lime mortar is always ready for use and so increases the efficiency of the entire force and makes maintenance of construction schedules easy.

Some builders add a small proportion (15 per cent.) of Portland cement to lime mortar in order that it may set quickly enough for the bricklayers to work rapidly, as in many modern steel skeleton structures with brickwork panels.

In order to secure the best results, the lime must be properly treated. The best method is to prepare a lime putty by slaking the lump lime or by mixing the hydrated lime with water. The modern desire for speed makes most builders unable to keep the putty for a long time, and, consequently, the full plasticity of the lime is seldom developed in modern mortar. This is wasteful of lime as old lime putty will carry more sand, than newly made putty…

Hydraulic limes can be purchased-in the lump or ground form, the latter being far more convenient. They are characterized by their power of setting and hardening in water and behave in many respects like a mixture of Portland cement and lime. **They differ greatly in composition and properties,** and are conveniently divided into three classes: (i) feebly hydraulic; (ii) moderately- hydraulic; and (iii) eminently hydraulic….

Hydraulic limes are chiefly used where a mortar is required to have a greater strength than can be produced with a fat lime. At one time they were widely used, but since the use of Portland cement has become so popular the latter is usually preferred, as it is stronger and **more regular in composition and properties.**

Hydraulic limes are also used in foundations and in locations where the brickwork or masonry may be in occasional or constant contact with water.

When slaking hydraulic lime, the use of too much water must be avoided; too little will do no harm. It is usually better to buy the hydraulic lime ready- slaked.

LIME FOR WINTER MORTAR

When brick laying must be carried out in very cold weather, the most satisfactory mixture consists of one measure of Portland cement, two of fat lime, and nine of sand. This is much cheaper than a cement-sand mortar**, is less sensitive to frost,** and is easier to work. Mortar must not be used during actual frost, and bricks laid just prior to a frost must be covered, or otherwise protected until the mortar has hardened.

LIME IN CEMENT MORTAR

The addition of a little lime putty or hydrated lime to cement mortar makes the latter spread more easily and work more smoothly. It also increases the adhesive properties of the mortar.

The lime putty, or a paste made by mixing hydrated lime with water, should be added to the dry mixture of cement and sand, any additional water required being then added and the whole mixed thoroughly.

On work frequently exposed to water, the addition of lime is undesirable as it tends to be washed out and leaves a porous mortar.

The best lime is a fat, high calcium lime, such as is used for *fine stuff* in plastering. Hydrated lime is more convenient than lump lime.

LIME CEMENT

Lime cement is a term applied to lime when mixed with sand so as to form a mortar or plaster which is used as a cementing agent. Before the invention of Portland cement, lime was extensively used as a cement, and today when speed of hardening is not important, it is still useful for many purposes. **Unfortunately, the tendency to require rapid hardening materials for all purposes, even under conditions where time is of minor importance, has led to an increasing failure to recognize the advantages of lime as a cement.**

For this purpose, two kinds of lime are available : (a) a fat lime, and (b) a hydraulic lime.

The fat lime should be high in calcium oxide and very low in magnesia. In course of time, magnesian limes form products which are as hard and strong as those in which pure calcium oxide is used, but magnesian limes slake very slowly and somewhat uncertainly, so that **they are generally less suitable than calcium limes.**

The lime should contain at least 95 per cent, of lime and magnesia (on the ignited sample) and not more than 5 per cent, of carbon dioxide. It should, when slaked and washed through a sieve with water, pass completely through a No. 20 sieve and not leave more than 20 per cent on a No. 100 sieve.

Hydrated lime, equal in quality to the lump lime just mentioned, may be used, instead of lump lime and is usually more convenient as it does not require to be slaked.

Lime cement of the kind described is merely a good quality of lime, but lime cements composed of lime and casein or similar materials are quite different; they are described later.

Lime cements composed solely of hydraulic limes resemble a mixture of fat lime and Portland cement, **but are somewhat uncertain in their behaviour**. For structures requiring a material stronger than ordinary mortar, but not so strong as a cement sand mortar they are excellent and cheap.

LIME CONCRETE

Long before the invention of Portland cement, lime concrete was extensively used, especially in the East. The lime is mixed with twice its volume of coarse aggregate. If half the sand is replaced by trass, or, still better, by an artificial pozzuolana made by lightly calcining clay and grinding the mass to powder, a better concrete will be produced. The concrete is excellent in quality, but requires longer to harden sufficiently than do cement mortars.

The lime used should be a fat lime, such as is employed for mortar, but hydraulic lime is also used for the same purpose.

When rapid hardening is not essential, lime concrete will serve many purposes for which cement concrete is generally used, and will be much cheaper. It is not, however, suitable for reinforced concrete.

… Fat lime is particularly suitable for interior plaster, because:

(i) It is more plastic than any other, can be spread with less effort, and covers a large surface.

(ii) It is cheaper than cement or plaster of Paris, both in first cost and in sand carrying power.

(iii) It does not spoil (like cement) if used slowly.

(iv) The plaster can be prepared some time before and used when required.

(v) There is less waste than with other materials.

(vi) It is an ideal base for colours and decoration.

Lime for use in plastering must not crack when in use. The shrinkage of fat lime is overcome by the use of a suitable proportion of sand. It is a common mistake for plasterers to use too little sand; the result is that the plaster shrinks, cracks, and may fall away. For ceilings, the addition of a little plaster of Paris is an advantage which is well worth the extra cost.

For *Exterior Plaster,* including *rough-cast* and *stucco,* lime is the most suitable binding agent. It has a greater covering power than Portland cement. It is a mistake to use too little sand with the lime, as both "rough cast" and "stucco" should be as lean as possible.

The most suitable lime is a fat lime, such as that specified for interior plaster ("fine stuff") and, whilst an inferior lime may be used, it is not recommended.

The advantages of lime for exterior work are:

(i) It is cheaper and "goes further" than Portland cement.
(ii) It is equally durable.
(iii) It has a greater sand carrying power.
(iv) It is more plastic and so is easier to use.
(v) The slow hardening enables the material to adjust itself to the background better than cement plaster can do.
(vi) The waste is much less.

… LIME PUTTY

Lime putty or *Plasterer's putty* is made by slaking a fat lime with as much water as will produce a soft plastic paste. All lump lime must be converted into this form before it can be used satisfactorily for plastering. The putty must be kept for at least a week and preferably for several months before it is used, so as to ensure every particle of lime being fully slaked. Any unslaked pieces of lime will slake whilst the plaster is in place on walls or elsewhere, and will cause pimples, popping, or other unsightly defects. Lime putty does not spoil appreciably on storage.

Lime putty is made by placing the lime in a tub of water in which it is stirred and slaked. The slaked lime is then carefully sifted through a fine sieve into a wooden bin; the residium which does not pass is rejected for plasterer's work.

A considerable excess of water is added and the surplus is allowed to drain away from the bottom or through the sides of the vessel in which the putty is stored.

The finely sifted calcium hydrate with excess of water may be left with safety for a year or so to mellow, the water which rises to the top drains away through the joints of the wood-bin, or it evaporates, leaving the pure slaked lime putty as a creamy mass; only the thin outer crust exposed to the air will set. For the setting coat of plaster work, putty should not be used until it has mellowed for at least three months…. The long time required for ageing the best lime putty has caused hydrated lime to be used wherever possible, but even hydrated lime should be mixed with water to form a putty and kept for at least 24 hours before it is used.

LIME IN WALL COATINGS

Under the term *limewash, whitewash, distemper, etc.* is included a milky suspension of slaked quicklime or hydraulic lime or hydrated lime in water. No definite proportions of lime and water are used, the user judging by the appearance of the wash when applied to a surface. **Equal weights of lime and water** usually produce an excellent lime wash, but much depends on the nature of the lime.

The addition of 30 lb. of common salt or 10 lb. of dry calcium chloride to 100 lb. of the slaked lime or hydrated lime produces a superior lime wash. The addition of a little glue is also advantageous and prevents earlier work from being rubbed oft. A mixture of 6 lb. of glue, 4 gallons of water, and a cream containing 100 lb. of slaked or hydrated lime is generally quite satisfactory. Instead of common salt, a mixture of 4 lb. of zinc sulphate and 2 lb. of common salt per bushel of lime is preferred by some architects. The zinc sulphate combines with the lime, forming a substance similar to plaster of Paris and rendering the whitewash more durable.

Some users find that the addition of linseed oil or melted tallow lessens the tendency of the material to be "rubbed off," and one well-known builder uses milk instead of water for the same reason.

A more elaborate whitewash is made as follows:

Add enough water to 12 lb. of hydrated lime to make a thick cream. Dissolve 1 lb. of washing soda in 1 gallon of boiling water, and add this to the lime. Dissolve 1 lb. of glue and 1 lb. rice flour in 3 quarts of water. Add this to the above mixture and apply. The above quantities will make enough whitewash to cover about 600 square feet.

Hydraulic lime must be carefully selected or the wall or other surface will not be sufficiently white. It will, however, be more durable than when quick-lime or hydrated lime is used.

The mixture of lime and water (with or without other ingredients) should be made fairly thick, passed through a No. 50 or finer sieve, and then diluted with water as required. If the screening is omitted, the wash may not have a sufficiently smooth surface.

Whitewash is the cheapest of protective paints, but it requires frequent renewal. Its slight disinfectant power adds greatly to its value.

McGarvey G A (1941) Bricklaying, An Analysis of the Trade of Bricklaying Together with Suggestive Courses of Training for Apprentices and Journeymen Workers. Vocational Division Bulletin No. 208; Trade and Industry Series No. 60. Washington United States Government Printing Office.

All types of mortars are composed of three essential elements: 1) the cementing medium – lime and cement; 2) the aggregate or filler, usually sand, and, 3) water, which is added to the mixture to give plasticity. Mortar of the proper mixture and first quality masonry units are important factors in masonry construction. Workmanship, however, is much more important. A skilled craftsman who uses proper construction methods may lay up a good wall, even with ordinary brick and mortar of no great crushing strength, while an unskilled workman who uses the best brick and high strength mortar may lay up a poor wall.

Properties

The binding or cementing material in any mortar mixture is cement or lime or a combination of these two materials….

Lime is prepared for the market in lump, pulverised, and hydrated form. Hydrated lime is preslaked lime containing just enough water to break down the chemical structure of the lime and produce a dry powder, readily soluble in water. This method of preparation makes the lime easier to handle and more adaptable for certain forms of mortar. Regardless of the type of lime used it should be made into a paste or putty and allowed to age for a time before using.

Kinds of Lime

The mortars generally used in masonry work are classified as 1) cement mortar; 2) cement-lime mortar, and 3) lime mortar.
Cement mortar is one which contains not less than 75% of cement as the cementing medium. Cement-lime mortars are mortars in which the proportions of cement and lime are nearly equal. Lime mortars are mortars which contain not less than 75% of lime as the cementing material. The percentage of lime or cement used in a mortar mixture depends largely upon the purpose for which the mortar is to be used. Cement mortars are rarely used in masonry construction except for reinforced brickwork or for work that requires a high crushing strength or for masonry work below grade.
Cement-lime mortar is used for most types of masonry above grade. Lime mortars may be used satisfactorily for non load-bearing walls, for load-bearing walls upon which the load is comparatively light, or for walls constructed in sections where weather conditions are not too severe.

The proportions of lime, cement, and sand recommended for mortar are as follows:

Cement mortar: 1 part cement: not over ¼ part lime putty: 2 ½ to 3 ½ parts of sand.

Cement-lime mortar: 1 part cement: 1 part lime putty: 5 or 6 parts sand.

Cement-lime mortars made with a higher percentage of lime are known as cement mortars and lime mortars. They are mixed as follows:

Cement mortars: 1 part cement: 2 parts lime putty: 7 to 9 parts sand.

Lime mortars: 1/5 to 1/3 parts cement: 2 parts lime putty: 6 to 7 parts sand.

Qualities of mortar

The quality of mortar depends on its crushing and bonding strength as well as its workability under the trowel….The working condition of the mortar under the trowel and its adhesion to masonry units determine its suitability for use in laying up brick.

RIBA Committee – The Architectural Use of Building Materials - Post-War Building Studies No.18 1946 London HMSO for the Ministry of Works.

Focus is upon new building and the aesthetics of the same.

P4.
3. In judging the various materials it has been assumed that they will be used by trained designers and skilled craftsmen, **for even the best materials in the hands**

of poor designers and skilled craftsmen merely produce poor results. There is danger also in the injudicious mixture of materials. …

4. The question of the training of the designer and craftsman is one that requires special consideration; moreover, it is not only a question of training designer and craftsman but also of general education, for if there is not a widespread demand for good design and workmanship the supply will inevitably be lacking….It is therefore to be hoped that every opportunity will be taken to educate the taste of the people.

5. To earn the title of 'well-designed' and to have value and significance, a building must truly have grown out of its own conditions and must truly fulfil its own requirements; then it will have not only an aesthetic but also a practical value…

p5

7. …Buildings…must be so designed that age, rather than making them less attractive, should add to their beauty…

13. The technical evidence does not point to short cuts in the achievement of good building; it points consistently to the discovery by scientific means of the (p6) rationale of established building traditions, which should be altered only with the full knowledge of the consequences

14. Three examples are important, and throw light on the situation in which modern building finds itself, namely:
a) Limestones and good clay bricks are superior to concretes and cast stones in an important particular; their very small or negligible moisture movements cause less risk of cracking.
b) Dense cement mortars have disadvantages when used in association with common bricks for ordinary building purposes, and **it is now emphasized that lime, although not yet in all forms the subject of exact specification, has valuable uses in joints and rendering.**
c) The chemical reaction to moisture of many manufactured building materials makes more necessary than formerly the thorough defence against rain penetration by means of drips, copings, cornices, or their equivalents, and also by avoidance of capillary cracks. These points influence the appearance of a building in the matter of choice of material, in elimination of cracks and crazing, in tidiness of joints, and in surface quality….

16. Good workmanship requires adequate time for the various building processes to mature. A small house, in which some 16,000 bricks are used, will on completion contain some four to six tons of water….Also the bad standards set by false economies arising out of ill-considered competitive costing, which make qualitative specification difficult, ought to be recognized and guarded against in post-war building….

P7 NOTE ON REPAIR OF ANCIENT BUILDINGS

20. Though this Report is primarily intended as a guide for future building practice from an aesthetic point of view, it must be borne in mind that there will always be a considerable amount of repair required to our rich heritage of ancient buildings. In addition to the normal wear and tear of time, so many of our finest buildings have been damaged in air raids that their repair will be an important branch of building practice for many years after the war. This will offer scope to a large number of architects and craftsmen, who should set themselves to specialize in this responsible and difficult work. **Knowledge, enthusiasm, and a reverence for historical continuity will be necessary in the care of our surviving monuments,** which, owing to irreparable losses in the war, have become increasingly important as national assets.

(Section of Stone)

p20 Decay, preservation and repair of stone

…135. The best precaution against the decay of stone and its degradation by dirt is smoke abatement Quite apart from improvement to public health, and costs of cleansing, washing and decorating, the whole question of amenities, the (p21) regeneration of city life and the beauty of buildings is largely dependent on a successful policy of smoke abatement. We have become so used to polluted air in our industrial cities that grime and blackness are almost taken for granted…

Action of Soluble Salts
142. Decay in stone is often caused by soluble salts in the soil, also in Portland cement backings or in brick backings; some of the modern bricks have a high percentage of soluble salts…

p23
Summary.
149. Decay in masonry is due to the selection of the wrong stone, unsuitable mortar, defects in design, and atmospheric pollution. The remedies, therefore, to choose a stone suited to the exposure, to take reasonable precautions in design, especially by the provision of cornices and drips, and to choose the most resistant and durable beds. Smoke abatement is essential where the air is polluted.

BRICKWORK

…152.
It is sometimes thought that a dense brick is more waterproof than a porous one. But a dense brick used with the wrong mortar may enable moisture to penetrate to a greater extent than a more porous brick…the almost shiny surface of some

dense bricks looks unpleasant, and in effect delivers the full charge of rainwater immediately upon the mortar joints….

175. The fully flush joint is the most straightforward and natural way of finishing brickwork, It knits the wall into a unit, in which bricks and joints seem to contribute equally to sound construction. If the bricks are irregular, the bricklayer must see that the edges of the joints are not left too ragged. Ruling lines with the point of the trowel is to be avoided. Tuck-pointing is laborious and artificial, and should be avoided.

176. In general, the colour of lime mortar is satisfactory with any kind of brickwork, and variations of colour are better obtained by the use of different sands than by the addition of colouring matter. **A dense cement mortar is usually cold and dismal, and tends to produce capillary cracks in the joints.** Pointing with black mortar should always be avoided and, as a rule, any brickwork where the joints are darker than the bricks will look heavy and dull. **Non-hydraulic, or semi-hydraulic lime (conforming to B.S. 890-1940) gauged with cement and sand usually adheres to the bricks better than cement mortar and is less liable to shrinkage cracks.** The composition of the mortar should be selected to suit the particular characteristics of the brick. **The type of lime known as 'hydraulic' often makes excellent mortar, but this lime is not produced in large quantities, and as it is not the subject of any specification, it varies from one works to another.** Some definition and specification of hydraulic lime would be helpful to architects.

P44 Roofing Materials

TORCHING
221. In unboarded and unfelted roofs, 'torching' in lime and hair mortar fillets is frequently applied to the battens and to the underside of the tiles. This precaution excludes air from the timbers and tends to hasten laminations in certain types of tiles. It is essential, therefore, to reduce the torching material to a minimum and to provide ventilation from other sources. The practice of torching is rightly falling into disuse, being superseded by other methods of weather-proofing.

P56 Section IX External Finishes

Renderings

346. It has been an ordinary practice in this country to use renderings on walls:
a) To give a weather-proof coating
b) as a means of giving to rough and unsightly material a more finished appearance.

347. Rendering is the application of a plaster which may be formed of various mixtures of sand, lime or cement. The colour, texture and finish are very varied.

Cement and Sand Rendering
348. The colour of such a rendering is **drab and unattractive. It cannot be recommended, as it has proved to be uncertain as a means of waterproofing a building…**cement rendering trowelled smooth with a steel trowel is liable to shrinkage cracking…

Lime and Sand Rendering
349. A plaster of **lime and sand** was commonly used until recent times, particularly in East Anglia. This was applied to laths or reeds as an external finish on buildings of timber studding or was applied directly to the brickwork in other cases. The finish was often patterned. This gave decorative interest.

Stucco
350. Stucco is a term vaguely applied to many mixtures made of common and hydraulic limes and also to some cements. In Regency days it was finished smooth and at a later date was painted.

Lime-Cement Renderings
351. **It is now common practice to use lime and cement in conjunction.** It is generally accepted that a mixture of sand and lime and proportion of cement gives the most satisfactory results. An increase of cement in the mix makes for greater frost resistance.

Finishes to Renderings
352. The most usual finishes to renderings are:
a) Smooth from a steel trowel
b) A textured finish from a wood or felted float.
The textured finish is the better of the two. It is pleasant to the eye and the density of surface produced by the steel trowel is avoided. A dense surface is apt to give trouble by crazing, but this can be minimised by removing the laitance with a scraper.

P57
Roughcast finish or harling
353. Roughcast finish is used in the country very generally. The method is 'throwing' a mix of sand, grit or gravel mixed with cement or a gauged lime in a semi-fluid state on to an undercoat of coarse stuff usually mixed with cement.

Technical Points
356. Points which should be noted in connexion with renderings are:
a) **The final coat should be open textured rather than smooth and dense. Exaggeration or over emphasis of texture is to be avoided.**
b) The 'throwing on' method is perhaps a better protection against crazing than the 'laying on' method.
c) Texture should be chosen with relation to atmospheric conditions, a less rough finish being preferable in contaminated atmospheres.

d) Care should be taken to avoid working up a rich skin to the surface.
e) Horizontal surfaces must be protected.

P58
Lime washing
367. This is a traditional method of covering plaster, stone, brick, or concrete. It is specially suitable in the form of whitewashing or colour-washing for small buildings, farm buildings, domestic buildings, etc. When mixed with Russian tallow it is not only cheerful but also is a protection against wet….

P65
Wall and ceiling finishes
412. *Cracking of Plasters.* The unsightly cracking of plasters together with buckling, shelling off, curling, etc is often due to imperfectly understood techniques. **In all lime mixes and cement mixes, some shrinkage cracks must occur, and one object of good plastering has always been to distribute and reduce them to the least noticeable.** The traditional lime plastering in several coats allowed each succeeding coat to dry thoroughly and **crack less noticeably,** until the scarcely observable 'fire cracks' on the setting coat were reached. Today greater strength is required to resist conditions of vibration. If a lime mix is gauged with Portland cement, **the effect of shrinkage is increased;** but on the other hand Plaster of Paris expands on setting and can therefore be used to give a mix which will not shrink. A gauging of between 1:3 and 1:6 of Plaster of Paris will serve this purpose but will of course increase the rapidity of the set….Note that Plaster of Paris and retarded hemi-hydrate plaster must not be introduced into a mix containing Portland cement.

P87 Appendix on brickwork
13. The efficiency and, in some cases, the durability of brickwork is influenced by the type of mortar used; the choice of mortar depends upon the characteristics of the brick and the function of the brickwork. Although it is not possible to detail mortar compositions for individual bricks, certain broad principles may be mentioned. With engineering bricks it is appropriate to use a strong and dense cement mortar, while with open-textured, absorptive bricks it is often preferable not to use a mortar consisting essentially of cement and sand….In these cases **a mortar which combines good workability with adequate strength and good adhesion is most suitable.** This may be obtained by using a mixture of Portland cement and non-hydraulic lime with sand or by using an eminently hydraulic lime with sand. Very strong mortars are sometimes used with a hope of increasing the strength of brickwork as a whole, **but with a brick of average strength the full strength of the brickwork will be obtained with a mortar of relatively low compressive strength. On the other hand, a plain non-hydraulic lime mortar is not suitable under conditions where a moderately rapid development of strength is required.**

H B Newbold & Edgar Lucas Modern Practical Building Volume 1 Third edition 1950 Hazell, Watson and Viney Aylesbury and London

P329 Chapter 13 Mortars.

The mortars used for jointing brickwork and stonework consist of a mixture of lime, or cement, sand and water. There are three kinds of mortars in general use: 1) lime mortar, 2) lime-cement mortar, 3) cement mortar. …Generally it is advisable to use a mortar of similar strength and porosity to the brick or stone. Thus, a strong cement mortar should not be used with a porous brick or stone of only moderate strength.

Materials

Limes

…There are various kinds of lime, each requiring different treatment. The manufacturer's instructions should be carefully followed in slaking and mixing. Limes may be divided into three types: 1) non-hydraulic, 2) moderately hydraulic, 3) strongly hydraulic.

Lime Mortars – Lime mortars are usually prepared in the following proportions: one part lime to three parts sand, by volume.

For hand-mixing, the sand is placed in the shape of a ring on a clean, water-tight platform. The lime is placed in the centre, water is added, and the heap left to slake for about twelve hours….After mixing, the heap should be smoothed over the exterior with the (p330) spade, so that air cannot readily penetrate the interior. Non-hydraulic lime mortar so treated will keep in good condition for a period of up to seven days. It should be knocked up as necessary to bring it to a suitable condition. Non-hydraulic lime mortar is not recommended for permanent walls, as it has little strength.

Moderately hydraulic lime mortar should be used if possible on the day of mixing, or within 24 hours at the outside. If allowed to stand longer, the setting and hardening action will take place in the heap, and much of it will be lost when the mortar is used.

Strongly hydraulic lime mortar, such as mortar made with blue lias lime, has a strong setting and hardening property. It makes a durable mortar if properly prepared, but must be used within a few hours of mixing. If allowed to stand for long, the setting action takes place before the mortar is used…Ground hydraulic limes should be slaked by mixing with damp sand to make a stiff mix. The finished mix is then prepared by adding further sand and water. The mortar should then be used within about 4 hours.

Mill Mixing- On large jobs mill mixing is usual. It is efficient, especially in breaking up the small lumps to a fine powder. Furnace ashes, clinker, and crushed bricks are often used as aggregate, instead of sand. Ashes and clinker make a black mortar of good strength, provided that the aggregate is free from partially burnt material and chemical impurities. If crushed brick is used, the old bricks must be clean and old mortar or plaster cleaned off.

The Mixing Operation is carried out either in a pit or on a close-boarded platform of wood. The sand and lime are measured into the correct amounts to give the required proportion, and the sand is formed into a circular bank on the platform. The lime is then placed within this bank, or ring, and water is sprinkled on with a hose-pipe, which is best suited to the purpose when fitted with a rose or some form of sprinkler. Steam will be generated during this sprinkling operation, and when this has ceased, the lime is stirred with a 'larry'…The sand is then shovelled, starting from the outside of the ring first, on to the lime, the larrying operation being continued the while. When thoroughly mixed, the mortar is left to stand for a week or so before being used, when it should be 'buffered', or beaten up again with the larry and shovel. For use, it is customary to add more water, as the wetter it is, up to a point, the easier it is to handle, but this should not be over-done.

It should be remembered that the setting action of mortar consists in the action which takes place in the lime….(the absorption of CO_2)…This calcium carbonate forms an impervious skin on the surface. This prevents the further entrance of CO_2, which, it may be noted, is the function of the sand to facilitate…thus allowing the CO_2 to penetrate further and for a longer time….(1:3 the optimum quicklime: sand ratio)

P332
Hydralime is made from quicklime and water in the requisite proportions. It is supplied grey for mortar and white for plaster, and where rapid setting is required, Portland cement is mixed with it in the proportion of hydralime 2 parts, Portland cement 1 part and sand 8 parts. For ordinary plasterwork it is mixed…1 part hydralime to 4 parts sand.

P333 *Lime Putty* is run into a box, or a pit lined with plaster, and then left to stand for at least 3 months. In preparing this, the lime is slaked in a similar manner to that employed in preparing coarse stuff for plaster, and then the paste is run through a sieve. The water should be drained (p334) off after it is run into the tub or pit, and the putty should be covered up from the air or it will lose its setting properties.

P336
Lime-cement mortar. This is sometimes called 'compo' or 'gauged' mortar. It combines the advantages of lime and cement mortars, and for all ordinary work, it is preferable to either. Setting and hardening of compo is superior to lime mortar, and, though the strength is not so great as cement mortar, it is adequate

for walls and piers bearing normal loads. A great merit of lime-cement mortar is that it is not likely to develop shrinkage cracks. It works easily off the trowel, and sound work can be done at a higher speed than with cement mortar. …The Building Research Establishment recommends that at least 20% of the total volume of lime-cement should be cement.
The following proportions make a fairly strong mortar: 1 part Portland cement, 1 part non-hydraulic lime, 4 parts sand….

Sand. Any clean sand is suitable for making mortar. It is desirable to use 'graded' sand…a mixture of sand particles from small to large. If most of the particles are large, the mortar will be harsh and will not work easily off the trowel. If very fine sand is used, more water is necessary, resulting in excessive shrinkage and some loss of strength.

Vol III

Chapter II Plastering: Surfaces and Materials

P254 When brickwork or stone masonry is to be rendered with coarse stuffthe joints are often left unstruck, so that the protruding mortar may afford a key for the plaster. But as such protruding mortar will have dried before the rendering can be undertaken, it is far better to rake out the joints, so that the rendering may work into the joints and thus form its own key. Unless the bricks or stones have a rough-textured face, the work will require hacking or roughing, otherwise there would be imperfect adhesion….

p256 MATERIALS

Modern developments in building construction, though multiplying methods of wall and ceiling finish have not, on the whole, lessened the importance of the plasterer's trade. There is, indeed, a call for greater attention than ever in this difficult branch of the industry, partly owing to the lessening of time allotted to the various operations and partly because of the increasing diversity of materials used both as a base and for rendering.

P257 Lime.

(Lump lime) must be slaked in pure water, about 32% by weight of the lime being required for this purpose. This is usually done in a mortar box, or for large quantities in a pit, the sides and bottom protected by planks, on a platform within a ring of sand or on a base of sand with a ring of sand round it. The lime and water has to be well-stirred to break up the lumps. It swells, becomes hot and throws off steam. Stirring must be continued until little steam arises. It may then be left alone, when it gradually dries. For plastering purposes, the slaking must be very thorough, all lumps being broken up during the process. If this is not done some caustic lime will remain…causing blowing.

To ensure perfect slaking after the first process the lime is broken down and once more mixed with more water to form a thick cream, which is allowed to stand for from two to four weeks to 'cool'. This long running produces what is known as 'plasterers' putty'.

Fat or rich lime…works smoothly and easily, improves for being mixed some time before being used, but lacks strength. It is essentially for interior and fine work.

Poor lime, containing between 60 and 90% of carbonate of lime, part of the inert matter being clay, slakes slowly, does not greatly increase in bulk, hardens well, but lacks strength. It is suitable for exterior work of a rough kind.

Hydraulic limes…the lias or blue lias limes belong to this class. They are feebly hydraulic if containing no more than 10% of silicate of alumina, ordinarily or medium hydraulic if over 10 and under 20% and strongly hydraulic if up to 30%. Such limes are only suitable for exterior rendering in positions exposed to water. ….

P259 Portland cement is often used on brick and stone as an undercoat for finer plaster finishes. Mixed with sand it is also largely used for the outside rendering of walls, roughcasting, pebble dash and so on.

P259 Ox or cow hair, fresh, clean and particularly free from grease, is used to give strength to plaster….usually 1 pound of hair to 3 cubic feet of coarse stuff (for undercoats) is used and rather less for upper coats….extensive or heavy ceilings should have at least 1 pound of hair to 2 cubic feet of plaster.

Chapter 12

P267 Exterior rendering.

Rendering mixes – the old stucco mixes consisted of 1 part hydraulic lime to 3 parts sand, with 1lb cow hair to the cubic foot of stuff. It was necessary to protect this stucco with oil paint. Modern rendering consists of a Portland cement and sand, or a Portland cement-lime-sand mix.

A Portland cement mix is strong and dense but tends to crack or craze through creep and shrinkage. A cement-lime mix is not so liable to give trouble. The Building Research Station recommend the following:

Under coat (parts by volume)
3 parts white hydrated lime or stiff lime putty
1 part Portland cement
10 parts clean sand or crushed stone aggregate
Finishing coat:
3 parts lime, as above

1 part Portland cement
12 parts sand or crushed stone, according to colour and texture required.

The materials can be mixed mechanically or by hand. If lime putty is used, this may be knocked up into lime-sand coarse stuff, and the cement added before use.

P270 Interior Plastering

Coarse stuff. This is composed of 1 part of slaked lime, 2 to 3 parts of sand, crushed slag or brick and from ½ to ¾ pound of ox hair to the cubic foot. It is used for the rendering or base coat.
Gauged stuff is a compound of 3 to 4 parts of lime paste to 1 part of plaster of Paris, or of coarse or setting stuff with plaster of Paris in the ratios of 3:1, 2:1 or 1:1. It is used in second coat work…it should contain hair.
Fine stuff is made up of 3 parts of lime paste and 1 part of fine sand, without hair. It is used for the floating coat in three coat work and as the finish in two coat work.
Setting stuff or Plasterers' putty is also made with lime lime paste and a very little fine sand, both passed through a hair sieve before mixing. This is usually the finishing coat.
Cement plaster is made up of 1 part of powdered quicklime, 1 part of powdered baked gypsum, and 4 parts of powdered baked clay. The quicklime and gypsum are mixed separately with half each of the clay, and the two mixed together and well stirred to ensure slaking of the quicklime. The stuff is gauged with glue water just before use. It is useful for rendering on rough walls and positions likely to suffer from dampness.
Fancy setting stuff. Setting stuff may have sifted marble dust added to it, which makes it finer, much harder, and enables it to take a high polish. The addition of ground glass or carborundum powder gives it a sparkling finish.
Stucco Duro …is made up of equal parts of fat slaked lime and finely powdered white marble, gauged with lime water. Stucco for fresco and fine oil painting is usually made up with 2 to 4 parts of washed silver sand, 1 part of lime putty gauged with lime water. A mixture of 2 parts marble dust and 1 part lime putty is also excellent for the purpose.

Ministry of Works Advisory Leaflet No.6 (1950) Limes for Mortar. London HMSO.

How to Use Lime When Mixing Mortar.

The Kinds of Lime.

All limes start as lump lime, or quicklime, which is obtained by burning chalk or limestone in a kiln.

Blue Lias, and similar limes, which come from limestone containing clay, have the property of setting under water soon after slaking; they are therefore known as hydraulic limes, and are used mainly for mortar.

Greystone Limes come from chalk containing only a little scattered clay minerals – not enough to make them fully hydraulic – but they will harden under water or when moist in two to three weeks after slaking. These limes are classed as semi-hydraulic; they can be used for both mortar and plastering.

White Limes (mountain limes, chalk lime etc) come from rocks which are practically pure limestone or chalk. They do not set hard under water, and are therefore classed as non-hydraulic limes. They are used for plastering and making cement-lime mortar.

Magnesian Limes are made from dolomitic limestone. They are in a class by themselves and are used mainly for mortar, but they must not be used with bricks containing sulphates. They are mostly non-hydraulic.

Lime Putty.

Quicklime must be slaked before it can be used. In the old days all builders used to slake their own lime, running it to a paste known as lime putty *(this is true only of the 20th C, for the most part].*

Lime putty run from quicklime is still used in some parts of the country and for special jobs, since one of its chief characteristics is good workability.

Slaked non-hydraulic limes improve with keeping, so they should stand for **at least two weeks** to fatten up before use. They should be kept moist and undisturbed until they are needed. **Semi-hydraulic quicklimes are usually slaked as non-hydraulic limes, but the wet putty must not be stored.**

Slaked hydraulic limes do not keep – the quicklime is usually slaked on the building site by spraying it with water on a clean wooden platform until thoroughly moist: it is then heaped together, covered with sandand left for about 36 hours. The material is then put through a sieve before use, to remove any unslaked particles which might slake later in the hardened mortar and cause unsoundness or even cracking. **Magnesian limes are also slaked in a heap.**

Dry Hydrated Lime

Nowadays most lime used in building is dry hydrated lime – a ready-made form of slaked lime, which is a white or greyish powder supplied in paper bags like cement. It is usually manufactured from white lime **or from greystone lime,** and is therefore non-hydraulic or semi-hydraulic. Hydraulic limes are also available in dry hydrated form – they set in the same way as cement, but not quite so quickly.

Lime Putty from Dry Hydrated Lime.

Dry hydrated lime is often mixed and used at once as a mortar or plaster. If it is not of the quick hardening or hydraulic type, it is better to soak it in water for 24 hours before adding the sand. **This will give a much more workable mix**. Stir the hydrated lime into the water until a putty-like mixture is obtained. **Don't add the water to the lime or you will get a lumpy putty.**

Lime Mortars.

Lime mortars are usually of a 1:3 lime: sand composition. **For external brickwork it is usually best to use hydraulic lime mortars because other lime mortars do not stand up well to frost. Semi-hydraulic and non-hydraulic lime mortars, however, are used for bedding limestone and sandstone.**

Mixing Lime Mortars.

To make mortar from non-hydraulic lime putty or soaked hydrated lime, mix the sand and lime putty on a clean platform until an even consistency is reached. Round off this 'coarse stuff' into a heap, smooth the sides and leave undisturbed until required for use, but don't let it dry out if you keep it for any length of time. The coarse stuff will stiffen up on standing, but with vigorous beating and stirring it can be knocked up to its original plastic state. **If possible, don't add any water when knocking up – working the mortar vigorously will give a better material than the addition of water.**

Semi-hydraulic putties are mixed in the same way – but when using them, don't make up any more mortar than is sufficient for one day.

To make mortar from hydraulic quicklime which has been slaked on site, mix the sand and the lime thoroughly, adding more sand and/or water if necessary to get the right proportions and consistency. Magnesian lime mortar is also prepared in this way. Hydrated hydraulic lime must not be soaked overnight. Mix it dry with the sand, then add water, and use within four hours.

Cement-Lime Mortars

Lime gives a mortar good working properties. **The more lime in the mix, the better the workability. A fat lime slaked to a putty gives the best working properties, and an unsoaked hydrated lime the poorest.**

Cement gives a mortar strength and durability. Not only is the hardened mortar strong, but it hardens quite quickly. **Without lime, a high proportion of cement to sand is needed to make a workable mix**, but this is wasteful and may easily cause cracking due to too much shrinkage. Unlike a lime mortar, a cement mortar will readily lose water to a thirsty brick and thus give loss of adhesion.

A mortar containing both lime and cement will normally possess a desirable combination of both properties. It will be workable, will set reasonably quickly, and is adequately strong for all purposes in small housebuilding. Hydraulic limes should be used with sand alone and not with cement…

For normal types of brickwork under normal conditions use a 1:2: 8-9 cement: lime: sand mortar. If, however, brickwork has to withstand severe weather, or for bricklaying during winter where earlier strength may be demanded, use a 1:1: 5-6 mix; a 1:3:10-12 mix is only suitable for internal work when there is no danger of frost affecting it.

Cement-lime-sand mixes are also very good for external renderings; a 1:2:8-9 mix is suitable for normal use, but where a wall has to stand up to severe weather conditions, a 1:1:5-6 mix is better.

Mixing Cement-Lime Mortar

These are usually prepared by first making up a wet mix of lime and sand usually known as a coarse stuff. If the lime is added as putty the coarse stuff may be used immediately, but if you use dry hydrated lime, mix up enough coarse stuff for the day's work and let it stand overnight to improve its properties. Immediately before use, mix the cement thoroughly into the coarse stuff, adding more water if necessary. Don't mix up all the mortar at once. Do it in batches so that each batch can be used up within tow hours of adding the cement; throw away any left after this.

Cement-lime mortar may also be prepared by mixing dry hydrated lime, cement, sand, then adding the water, and using straight away. **This often speedy and convenient, but remember that such a mortar does not have good working properties.**

Mortar Mixes.

Mortar	**Proportions by volume** cement	lime	aggregate	**Uses**
Cement Mortar	1	0- ¼	3	for brickwork where strength is needed. Normal brickwork below damp proof course. Granite masonry.

Cement-lime Mortar	1	1	5-6	Normal brickwork in winter Rubble masonry in winter Dense sandstone masonry
Cement-lime Mortar	1	2	8-9	Normal brickwork in spring and summer; rubble masonry in spring and summer; tall chimneys
Cement-lime Mortar	1	3	10-12	Internal brickwork only in Summer.
				Limestone or porous masonry where rapid hardening is necessary.
Hydraulic Lime mortar	0	1	2-3	Normal brickwork; tall chimneys
Semi-hydraulic or non-Hydraulic lime mortar	0	1	2-3	**Limestone or porous Masonry**

The Different Kinds of Lime

[a table].

Type of lime; other names; source; type of slaking; expansion of slaking; method of slaking; maturing time; mixing mortar; when to use mortar; knocking up: use of hydrated lime.

Non-hydraulic limes; (fat lime, high calcium lime, Mountain lime, chalk lime; limestone lime; white lime; white chalk-lime); chalk, mountain limestone; and other almost pure limestones. Slake rapidly with much heat; considerable expansion; gradually stir quicklime into excess of water; mature for at least 2 weeks, but as long as possible; mix putty thoroughly with sand; must be kept moist if not used at once; can be knocked up if it stiffens; as hydrate, stir into water and leave for 24 hours, then use as lime putty.

Magnesian limes; dolomitic lime; dolomitic limestone; slakes very slowly; variable expansion; slake as hydraulic lime or add (hot) water to the lime, sieve; mature 36 hours; mix putty thoroughly with sand; use within 24 hours; can be knocked up if it stiffens.

Semi-hydraulic limes; grey lime, greystone lime; source: grey chalk; slow slaking; moderate expansion; to slake for putty, stir into excess water; for mortar, soak with water and cover with sand; mature 36 hours. Mix putty thoroughly with sand; use within 24 hours; can be knocked up within 24 hours; as hydrated lime, stir into water and leave for 24 hours, then use as lime putty.

Hydraulic limes; Blue Lias lime; blue lias limestone; slakes very slowly, requires fine grinding; small expansion; spray with water and cover with sand, sieve; mature 36 hours; mix covering sand with the slaked lime, adding more if required; use within 4 hours; should not be knocked up after it stiffens; If hydrated: mix dry with sand, add water and continue mixing, use within 4 hours.

British Standard Code of Practice 121.201 (1951)

Cement. Cement should be stored on a wooden floor, well above ground level, in a perfectly dry structure. Consignments should be placed in a manner that permits inspection and use in rotation of delivery. Cement affected by dampness should not be used. Cement delivered hot need not be aerated to cool before use.

Quicklime. Quicklime should be delivered to the site as soon after manufacture as possible.
Semi-hydraulic (calcium) quicklime and non-hydraulic (calcium) quicklime deteriorate rapidly on exposure to the atmosphere and are liable to cause fire if stored in an unslaked condition adjacent to combustible materials. Quicklime should, therefore, be slaked immediately.

Hydrated lime. Hydrated lime, hydrated or pre-treated hydraulic lime and quick-hardening lime (Roman cement) should be stored in the same manner as cement.

Lime Putty. Lime putty may be prepared from the quicklime or dry hydrate of either non-hydraulic or semi-hydraulic lime.

A) Preparation from quicklime. The slaking vessel or pit should first be partly filled with water to a depth of about 1 foot and enough quicklime should then be added to cover the bottom and come about half-way to the surface of the

water. Stirring and hoeing should begin immediately, and the quicklime should not be allowed to become exposed above the surface of the water.
Should the escape of steam become too violent or the quicklime become exposed, more water should be added immediately. The mix should boil gently and, as it thickens, more water should be added. Water and then quicklime should be added alternately until the requisite quantity of milk of lime is obtained.
The stirring and hoeing should continue for at least five minutes after all reaction has ceased. The resulting milk of lime should then be run through a sieve of 1/8-inch mesh into a maturing-bin. It should be protected from drying out and remain undisturbed for a period of at least two weeks to permit it to fatten up to lime-putty.

B) *Preparation from dry hydrate.* The hydrated lime should be mixed thoroughly with water until a mixture of the consistence of thick cream is obtained; this should then remain undisturbed for not less than 16 hours.

505 Mortar Mixing (a) General. Mortar may be mixed on the site, either mechanically or by hand. Mechanical mixing may be carried out by any suitable mixing machine. Hand mixing should be done on a clean watertight wooden platform or other clean surface. If coarse-stuff is to be used, the lime-aggregate mix (coarse stuff) may be delivered ready-mixed….

c) Portland cement/lime mortars

i) CEMENT/DRY HYDRATED LIME/FINE-AGGREGATE MORTAR. Cement, hydrated lime and fine-aggregate should be thoroughly mixed, in the required proportions, first dry and then with the addition of water until the required consistence is obtained. The mortar should be used within two hours of the addition of the water, and mortar not then used should be discarded. Under no circumstances should retempering of dried or partly set mortar be carried out.
ii) COARSE STUFF GAUGED WITH CEMENT. Cement should be thoroughly mixed with the coarse-stuff in the correct proportions immediately before the mortar is required. Water should then be added to bring the mix to a workable consistence. The mortar should be used within two hours of the addition of water and mortar not then used should be discarded and not retempered.

d) ***Lime mortar***

i) HYDRAULIC LIME MORTAR
1) *preparation from quicklime*

A) *Slaking.* Hydraulic quicklime should be fresh and should be slaked as soon as possible after delivery. The quicklime should be slaked upon a clean platform or in a suitable container.

Lump quicklime should be piled into a heap, any lumps larger than 6 inches being broken down. Water should be thrown on or sprayed on as the heap is formed.

Ground quicklime should be piled into a heap. Water should be sprayed on, and the heap turned over three times to mix the lime and water thoroughly.

P34.

Care should be taken not to use too much water; approxiamately 70 gallons is required per ton of quicklime.

The heap of lump quicklime or ground quicklime should be covered with fine-aggregate, banked down to retain the heat and left undisturbed for at least 36 hours or longer, until required. The heap at all times should be protected from the rain.

B) *Mixing.* The requisite quantities of slaked lime and fine-aggregate should be mixed with sufficient water to give a mortar of workable consistence. When prepared from lump lime, the slaked lime should be passed through a sieve of ¼ inch mesh before use, in order to remove any unslaked lumps. The mortar should be used within four hours of mixing….

3) *Preparation from hydrated or pre-treated hydraulic lime.* Hydrated or pre-treated hydraulic lime and fine-aggregate in the required proportions should be thoroughly mixed, first dry and then with water until the necessary consistence is obtained. The mortar should be used within four hours.

ii) MAGNESIAN LIME MORTAR

1) *Slaking.* Magnesian quicklime should be slaked in a manner similar to…hydraulic quicklime in lump form, but the heap should remain undisturbed for at least two days. Approximately 90 gallons of water is required per tin of quicklime….

iii) NON-HYDRAULIC (CALCIUM) LIME MORTAR AND SEMI-HYDRAULIC (CALCIUM) LIME MORTAR.

1) *Lime putty.* Lime putty may be prepared from the quicklime or dry hydrate of either non-hydraulic lime or semi-hydraulic lime.

a) *preparation from quicklime.* The slaking vessel or pit should first be partly filled with water to a depth of about 1 foot and enough quicklime should *then* be added to cover the bottom and come about half way to the surface of the water. Stirring and hoeing should begin immediately, and the quicklime should not be allowed to become exposed above the surface of the water. *(This indicates twice the volume of water as the volume of the quicklime in the first instance – the proportion approximately necessary to slake the quicklime to a powder – subsequently added to with more water and more quicklime. This would pre-empt the drowning of the quicklime and other prescriptions would avoid burning of the quicklime).*

P35

Should the escape of steam become too violent or the quicklime become exposed, more water should be added immediately. The mix should boil gently and, as it thickens, more water should be added. Water and quicklime should be added alternately until the requisite quantity of milk of lime is obtained. The stirring and hoeing should continue for at least five minutes after all reaction has ceased. The resulting milk of lime should then be run through a sieve of 1/8 inch mesh into a maturing-bin. It should be protected from drying out and remain undisturbed for a period of at least two weeks to permit it to fatten up to a lime putty.

C) *Preparation from dry hydrate.* The hydrated lime should be mixed thoroughly with water until a mixture of the consistence of thick cream is obtained; this should then remain undisturbed for not less than 16 hours. If left longer, it should be protected from drying out.

2) *Coarse-stuff.* Coarse stuff may be prepared in two ways:

A) *Preparation from lime putty.* The lime putty should be mixed thoroughly with the required proportion of fine-aggregate.
B) *Preparation from dry hydrate.* The dry hydrated lime should be mixed thoroughly with the fine-aggregate, first in the dry state and then with water. The coarse-stuff should be kept for at least 16 hours before use.

If the coarse stuff is to be kept for any length of time, it should be protected against drying out….

507. Jointing and pointing. It is recommended that mortar in the joints be allowed to protrude slightly and be left for cleaning-off flush at completion…

Sawyer J T (1951) Plastering. Edward Arnold, London. Also 2007 Donhead, Shaftesbury.

Plant and Equipment.

P17 Sieves. Sieves of various sizes are necessary for running lime, washing sand, and for mixing and sifting purposes in general.

Screen. This is a coarse rectangular meshed sieve used by labourers principally for separating stones and shingle from sand. The screen is gradually disappearing from building sites, as sand and ballast merchants are increasingly grading their products at the pits.

P18 **The Stirring Stick** is simply a piece of 2″ x 2″ wood, four or five feet long, for stirring lime when it is being slaked preparatory to running through the sieve.

Slaking Tubs. These are often large barrels cut into halves crosswise, and are used for slaking lump lime. Similar tubs are used for washing sand, and as water butts for gauging purposes.

P19. **Putty Bin.** This is quite often a large galvanised iron tank, used for the storage during maturing of the lime putty or **setting stuff**. The older method was to erect the putty bin from scaffold boards. The inside was rendered over with a strong gauged stuff to make it water-tight. In some parts of the country the putty bin consists of a pit in the ground, with or without a lining of boards.

P20. **Materials.**

Lime.

Quicklime has to be slaked **by the addition of water** before it can be used for any building purpose…

Rich and Fat Limes. These contain a high percentage of calcium carbonate, but a small proportion of impurities is invariably present in even the richest of limes….Lime of this nature is best used for making into putty, an excellent material for **interior cornices and mouldings, and setting stuff for ceiling and wall surface finishes.** For setting stuff a proportion of fine washed sand is added.

Poor and Lean Limes. These contain a higher proportion of impurities, consequently they take considerably longer to slake. Their yield and expansion are very much smaller than those of fat limes. Poor and lean limes are excellent for making up into coarse stuff, and can also be used for setting stuff, although they are inclined to be somewhat harsh for this purpose.

Hydraulic limes are made by calcining rock from the lias shale formations. Some of the finest types…are to be found in districts of South Wales. **Limes from this source are extremely poor and lean,** (p23) …and they have a correspondingly lower proportion of calcium. The presence of…impurities, however, imparts setting and hardening powers far superior to those of rich limes, but makes the material **harsh to use.** The main characteristics of hydraulic limes are: **a) slow and indefinite slaking; b) expansion small to nil; c)**

during slaking, very little change in temperature; d) properties of setting and hardening in damp and moist conditions similar to those of Portland cement.

Blue Lias Lime is a well known eminently hydraulic lime that has so little slaking power that it has to be machine ground to fine powder. **Lime of this nature possesses setting and hardening properties closely associated with those of Portland cement.**

Hydrated Limes. These are thoroughly slaked and tested by the manufacturers, and are marketed in the form of fine powder packed in strong paper bags. Lime in this form is convenient to transport and store, and as it requires no slaking, is easy to prepare for use on a building site, especially where space is limited. Hydrated limes are available in various grades corresponding to the type of chalk or limestone from which they are made.

'Hydralime White', 'Calime' and 'Limbux' are rich and fat limes; they all make up into **excellent lime putty and setting stuff,** while 'Hydralime Grey' is **suitable for coarse stuff for backing coats.** Hydraulic limes are also obtainable in hydrated form. These give good results when used for exterior work where a lime of a cement-lime mix is required.

The increasing use of hydrated lime for plastering is due to the fact that it is easily and quickly prepared; it takes up less space than lump lime, and it is reliable. The erection of putty bins or the digging and lining of pits in the ground, the slaking and 'running' of the lump lime, the 'popping' or 'blowing' on finished surfaces due to particles of unslaked lime in the plastering material, are all largely or wholly eliminated by the use of hydrated lime.

P31 **Mixed Materials**

Lime Coarse Stuff known also as *Lime and Hair* and *Haired Mortar,* is a basic material, as it is not only the backing for a lime finish, but is a general rendering or scratch coat material (p32) for wood and metal lathwork. Its composition varies in different localities, but a typical mixture consists of 3 parts sand, 1 part of lime (quicklime?) with 9lb of well-beaten ox or goat hair per 1 cubic yard of material.

Lime Finish. The traditional finish was carried out with raw (ungauged) coarse stuff for the rendering and floating coats and raw lime setting stuff for the finishing coat. **This is seldom used today on account of the long waiting time necessary between the application of the various coats.** Where a lime finish is specified, **coarse stuff is usually gauged with Portland cement to the extent of 15 or 20 to 1** respectively on backgrounds of brick or slab.

Lime Setting Stuff…consists of 2 to 3 parts of lime putty to 1 part of fine washed sand. The mixture is usually gauged just before use with plaster; 4 parts of setting stuff to 1 part of plaster is an average strength.

Lime Putty. This consists of slaked, sieve-run lime **matured for at least two weeks, or hydrated lime and water mixed to the consistency of milk, left overnight to fatten for use.** Lime putty with added plaster is used mostly for running interior mouldings *in situ,* the usual strength being 2 parts of lime putty to 1 part of plaster.

Compo. This is the term commonly used when referring to Portland cement and sand as a mixture. The proportions of the two materials vary according to the nature of the work. For example, floating coats on brick or concrete walls, etc, to receive either Keene's or Parian cement or glazed wall tiles, usually consist of **8 parts of sand to 1 of Portland cement.** For a Sirapite or Pioneer finish, 4 or 5 parts of sand to 1 part of Portland cement would be quite satisfactory. **Floors** to receive wood blocks, rubber or linoleum have **8 parts of sand to 1 of Portland cement,** while floors to receive terrazzo or marble slabs, or to be left trowelled finish, 2 parts of sand to 1 of Portland cement.

Cement-Lime-Sand. This is frequently used in various proportions for backing coats to receive chiefly hemihydrates or anhydrous plasters such as Sirapite. A cement-lime-sand mixture is also used for the immediate backing coat onto which is dashed pebbles, shingle or spar; the lime in this case should be either hydraulic lime or a lean lime. The floating coat for this class of work consists of 3 to 4 parts sand to 1 part of Portland cement.

Salzman LF *Building in England Down to 1540, a Documentary History (1952)*

Wattle and Daub

'Torching' is one of the terms applied to this plastering with mud; as for instance at the Tower in 1278 - '*in arcillo empto ad torchiandum'* and in 1337. 'for torching the penthouse beside the smithy, with mud, laths and nails of the King's finding, 10s' *[this may be roof-work, of course].* Sometimes other terms are used, as at Cambridge in 1486 - '*pro (4) bigatis de clay, 16s, item pro claying murorum 19s',* or at a lodge the New Forest in 1368, where two men were employed digging red earth *pro parietibus plastrandis',* though 'plastering' is usually applied to the finishing of a wall with plaster. The expression used at Bath in the 15th C was 'rudying' - as, for instance, 'for riding the old walls of the chancel' and '*pro casting de terra et rudyng'* of a house for which wattling had been made *[ruding is more likely to refer to the painting of the walls with raddle, it should be said, red pigment].* At Penshurst in 1470 there is a reference to radelyng and daubing the walls of the barn; and carriage of clay called '*lombe'* for the said work'. More often the word used is, in Latin, '*terrand',* which simply means earthing. For walls in Cambridge Castle, in 1267, we find 'splenteware' and ;batthes' bought, and wyttthes for binding them, and a payment 'to daubers for making the said walls and tearing the kitchen'. And in 1454, when a gable was made to a stable in Stamford, there were payments 'to a man 2 days teryng ye same gavel xd; for 2 lodes of earth to ye same warke 6d'. The comments term, however is 'daubing'. As this is latinised indiscriminately as *dauband and dealband* and the workmen *as daubatores or dealbatores,* it is often impossible to be certain whether the process alluded to is daubing or whitewashing…At York in 1423 we find 200 stoures (stakes) provided for daubing over the kiln house, and also rods, templis, which are also rods, and withies, and similarly in 1531 at Durham rods and 'dalbyngstours' were bought for daubing above four fireplaces in St Giles Street. At Clarendon in 1480 payments are made for collecting rods and shredding them to make the walls in the new chamber, and for bredyng and dawbyng the same walls…'bredyng' is the braiding or wattling between these. Often in later times, laths rather than wattles were employed, as at Sutton in 1402, when Henry Dauber was paid 113s 4d for the lathing and daubing of the walls of certain houses re-erected there, or at Clare in 1347, when money was paid for the daubing of the countrelatthynge of a room, possibly implying laths on each side of the wall. …In 1341, there is a charge for daubing the king's room at Clare, on the outside and plastering it and for stopping cracks round the queen's room.

To make the earth, or mortar, adhere properly it was customary to mix with it some fibrous material such as hair, straw or hay. Palsgrave, writing in 1
530, says that 'daubing may be with clay only, with lime plaster, or lome that is tempered with heare or strawe'; and two years later we find lxx stone of heare provided for the plasterers' at Westminster, and also 'cowheare to make mortar for dallbyng of walls,. In 1286 'white straw' was bought for plastering the walls of the hall in Cambridge Castled in 1375 at Leeds Castle, 8 cartloads of straw were bought for daubing the floors and walls of various buildings. In Ripon in 1454 we have 3 wagon-loads of mud for a room, 2d spent on litter and water for the same mud, and 20d paid for two men for the daubing of the same room and the making of its floor. The churchwardens of St Michaels, Bath, used hay and straw for daubing in 1477, and those of St Mary-at-Hill, London, provided 'strawe to make mortere with to the dawbere' in 1491.

Closely allied to daubing was pargetting or rough-casting, the chief difference…being that in
pargetting, mortar or a coarse form of plaster was used instead of clay or loam. The surface of the parget might be finished either smooth, with a coat of lime wash, or as rough-cast with sand or small stones. For work at Launceston in 1469 'six dozen seams of sand called roughcastyngsonde and helynsonde (= covering sand) were supplied, and Thomas Lucas in the accounts for building his house at Little Saxham in 1507 distinguishes between the two types of finish: 'for lathing, row and white casting of part of my kechen range': 'for lathing, pargetting, tiring and white casting of all my roves, walls, partitions and staires': 'for lathing and laying with here (=hair) and mortar of 4 chambers, with pargetting and white casting thereof.' As early as 1237 we read of the pargetting of the wall behind the leaded chamber' at Marlborough; and at Corfe in 1285 there is reference to Stephen the Dauber who pargetted the long chamber… daubers and pargetters are identified at Wallingford in 1390: 'for 8 casters of

walls and party-walls…otherwise called daubers…lathing and daubing a great gable at the west of the hall and newly lathing, daubing and pargetting a party wall of the Almerhouse - and completely casting with rowe mortar a great portion of the castle wall'…. A variant form of the word occurs in the north, as at Finchale in 1488, 'for the pargenyng and weschyng of the church', for which chalk and lime were bought; and at Durham in 1531: '*in le pargenyng et emendation foraminum'*.

Earth Mortar *[extrapolated from chapter below, p152]*

In Collyweston accounts for 1504: 'for sifting or mortar earth owt of the old walls'. The expression mortar earth occurs again in 1367 in the account of some repairs to the lodge of Beaumont in the Forest of Rutland: 'for digging earth for *mortarherthe'* for the said lodge'. **Apparently when lime was not available ordinary soil was sometimes used instead** *[!!!]*. So at Clarendon in 1363 we find mention of 'digging and carriage of 2 cartloads of white earth for making mortar' and at Oxford in 1453, 'a cartload of red earth for making mortar'.

Mortar: Cement

…It was customary from the earliest times (of masonry building) to use mortar composed of lime and sand, the common proportion being one part of lime with two or three parts sand….

Naturally, purchases of lime and sand are among the commonest entries in building accounts. Lime…might be bought ready burnt, or it could be burnt in kilns specially constructed in the neighbourhood of the building operations. In a Westminster Palace account for 1258 we find 3s paid 'for mortar of lime and sand bought of Sir Hugh of St Albans, monk', and also purchases of 98 cartloads of sand and 300 of lime. For the most part lime was bought by the cartload, quarter, or, in smaller quantities, bushel, but a variety of other measures occur. *most purchases are of lime in form of quicklime, but]* …At Wallingford in 1390 we have 10s paid *'pro v dolis de slekkydlym'* - for 5 casks of slaked lime; at York lime was bought by the 'mele' or tub, which was defined in 1327 as containing 2 quarters and costing 10d, which was still the price 40 years later…

An early instance of the construction of a kiln for the special purposes of building operations occurs at Winchester in 1222, when 50s was paid to Adam de Calce 'for making a kiln.' Seven years later the Abbot of Abingdon allowed the king to clear the timber from 26 acres of Saghe Wood for fuel for two kilns required for work on the city walls and one for the castle at Oxford….In 1242 Master Elias de Derham was granted wood for a kiln for building the chancel of Harrow Church. A kiln was built at large cost of £14 8s in 1236, and another for £20, in 1240, for work at Windsor, and the Hundred Rolls of 1275 complain that the king's two lime-kilns had between them devoured 500 oaks in the forest of Wellington. Such destruction of timber…was lessened by the use of coal, which was common where the presence of coal pits or access to the sea rendered such fuel available. The use of 'sea coal' for burning lime was unavailingly denounced as a nuisance in London at least as early as 1285, and as much as 1,166 quarters of sea coal was bought in 1278 for the kilns in connexion with work at the Tower….

For (a kiln) built in 1400 at York 3,300 bricks and **33 loads of clay** were required….

The actual mixing of the mortar was also unskilled - and, too frequently, unskilful - labour, so that 'mortarmen' usually received the wages of ordinary labourers, and the work was even sometimes done by women, as at Woodstock in 1271, when 2 women servants were employed in making mortar; more often the women simply carried water for the mortar makers. There is a reference in 1399, at Westminster to '**a sieve in which to sift burnt lime for the making of free mortar'.** Probably this means mortar to be used for plastering exposed surfaces of walls *[clearly to be hot mixed].* Another term for it appears in a 14th C account for Leeds Castle, where the daubers had men 'serving them in the tempering of chefmortar'. The Westminster accounts of 1532 mention **'two seevys for the sifting of lyme and making of fine mortar',** and also 'see cole…**for making of black mortar necessary for the laying of Flynte, and 16 bushels of 'Smythys Duste provided for black mortar to be made of, requisite for the laying of Flynte'** *[pozzalans to speed initial set].*

Where masonry was particularly exposed to the influence of wet, it was a common practice to use instead of mortar a cement composed of **wax and pitch and resin**, applied in a molten condition.

Account for a buttress at Westminster Palace, extending into the Thames in 1340:

'for 60 lbs of pitch for making cement for the buttress - 3s. For 100 Flemish tiles for making dust for the same cement - 12d. For 3 earthen pans in which to make cement - 6d. For straw bought for the same buttress, to burn upon it and warm it after the Thames floods, because the stone could not otherwise have held the cement - 7d. For an iron for directing and pouring cement between the stones - 4d.'

Knight B H & Knight R G Building Materials (1955) Third Edition. Edward Arnold London.

Chapter II Sands, Limes, Cements and Plasters

(p25) Sands should be free from impurities; dirty sands with excess fines produce a workable mix but should be avoided because they retard setting and hardening of the binder and may cause cracking and flaking of the work of which they form part….

Coal of any kind is to be avoided; soft lignites and some bituminous coals can cause popping, pitting and blowing of plaster….calcium carbonate in the form of crushed limestone or shell fragments is generally harmless, although it may retard the set of gypsum plasters containing accelerators….

Sea sand is not normally used for plaster or mortar sands since its saline content may give rise to dampness, efflorescence or corrosion of metal; it should never be used for external work and only for internal work if previously tried out.

(p27) Building Limes.
These consist essentially of quicklime prepared by heating chalk or limestone at about 1,100 – 1,200 Degrees C….

Slaking and hydration of quicklime. These are the names given to the process whereby **water is added to lime,** producing calcium hydroxide.

(p28) Classification of Building Limes, as per 1950 Ministry of Works Advice Note 6 (see above)

…(p29) **Ordinary Portland Cement** …this product is controlled during manufacture **to a far greater extent than has ever been possible with hydraulic limes.** (p30) Limestone or chalk and suitable argillaceous ie clayey materials are intimately mixed in the proportions of about 3 parts of chalk to 1 of clay, both by weight, burnt at such a temperature that clinker is formed, and the clinker is then ground to a grey-greenish coloured powder.

(p33) The four most important compounds which cause the setting and hardening of Portland cement are:

a) Tricalcium silicate – 3 molecules of lime to 1 of silica
b) Dicalcium silicate – 2 of lime to 1 of silica
c) (p34) Tricalcium Aluminate – 3:1
d) Tetracalcium alumina-ferrite 4 molecules of lime to 1 of alumina and 1 of iron oxide.

Tricalcium silicate generates considerable heat during its formation and the quantity present has a great effect on the development of early strength. Dicalcium silicate gives out less heat and sets slowly; it causes the increase in strength from 14 to 28 days after mixing. Tricalcium silicate hydrates very rapidly and produces a considerable amount of heat; of all the constituents it contributes least to the ultimate strength of the set cement, and it causes cracking due to volume changes and is attacked by acids and by soluble sulphates. Tricalcium alumina-ferrite has little effect on strength.

(p44) Gypsum and Lime Plasters compared.

Gypsum plasters have largely displaced lime plasters in recent years, for the following reasons:

a) they are obtainable as scientifically controlled products with known properties
b) they require no bulky and slow site mixing
c) they adhere readily to plaster-board
d) fewer and thinner coats are required
e) they do not cause alkali attack of any paints which may be applied to them
f) they are easily worked
g) they set hard in a few hours
h) they expand very slightly on setting and so are free from the shrinkage cracking associated with lime plasters.

…(p45) Gypsum plasters can be mixed with either non-hydraulic or semi-hydraulic lime complying with BS890; quicklime used should be run to putty and matured for at least 2 weeks before use in this way. The addition of lime, especially of fat lime, increases the workability of gypsum plasters very considerably, and hydrated lime is usually used as this obviates the nuisance of slaking on site; it is necessary to soak the hydrated lime overnight before use. Magnesian limes are not suitable for use with gypsum plasters since **delayed expansion** may take place and give rise to blistering or disintegration.

(p49) The setting and hardening of limes, cements and plasters…

Lime. The setting of a fat lime is due to simple hydration and very slow subsequent carbonation, the original unslaked calcium oxide passing into a calcium hydroxide on the addition of water, followed by the taking up of atmospheric carbon dioxide to produce a thin layer of calcium carbonate on the outside skin of the wall. The interior of such a plaster remains as softer calcium hydroxide and is protected from carbonation by the outer enclosing skin of calcium carbonate. The process is facilitated by the incorporation in the mix of sand which permits the ingress of air containing carbon dioxide. The slaking process is rapid but carbonation is extremely slow and continues for many months.

Hydraulic limes set and harden in a manner similar to that now to be described for Portland cement.

..The addition of water…is thought to produce a reaction somewhat as follows –

tricalcium silicate + water = calcium hydroxide + calcium silicate gel.

The crystals of calcium hydroxide being surrounded with a gelatinous hydrated calcium silicate. At the same time hydrated tri-calcium aluminate…is formed as hexagonal crystals. The water which is added to the cement powder gives rise to a supersaturated solution surrounding the cement grains; this solution soon coagulates, the surface of the setting cement shows a dull appearance and initial setting takes place.

(p55) Materials for Rendered Rough-cast Finishes.

…the following are used: Portland cement, dry hydrated lime or quicklime run to putty and sand…Lime should conform to BS890, Class B lime (quicklime or hydrated lime for coarse-stuff and building mortar).

Mixes from 1:0:2 to 1:2:9 to 1:1:6 depending upon exposure.

Concrete

(p65) The 1:2:4 (cement:sand:stone) mix by volume has become very general for most purposes and will be seen in many specifications.

Geeson A G (1952) Building Science Materials for Students of Architecture and Building Volume II. English Universities Press London.

P1 Building Limes.

Before the advent of easy transport, lime was essentially a local material, and the technique for a particular product was understood in each district….

P5 Classification of Limes. The broadest classification is according to the form in which the lime reaches the consumer, viz *quicklime* and *hydrated* lime.

QUICKLIME – quicklime is sold in bulk as *lump quicklime,* or more rarely in bags in the form of a powder, *ground quicklime*….Both types of quicklime are slaked on the job or in the yard by the user, and the operation calls for great care and experience. The lime should be fresh and should be screened to remove any unsound particles. If more water is used than the minimum necessary for hydration, a lime putty is obtained. This is left for **about two weeks before use** in order to develop plasticity or 'workability' and also to permit the slaking of any extremely small, slow-slaking particles that may have passed the sieve.

HYDRATED LIME – hydrated lime is quicklime treated at the works with the correct amount of water (steam) for the chemical process of slaking…there is little possibility of incorrect slaking, and the material merely requires the addition of the necessary sand and water to bring it to the correct consistence for use. Alternatively, it may be 'soaked' ie added to water some hours before mixing with the sand. This enables it to develop workability, though at the expense of any hydraulicity it may have possessed.

STORAGE OF LIME – Both in transit and storage, quicklime must be kept dry to avoid premature slaking. If kept merely in a damp atmosphere it becomes 'air-slaked', but the resulting powder must not be confused with ground quicklime or with hydrated lime. It has not merely become hydrated…but is also partially carbonated, since the process is slow and carbon dioxide is taken up along with the moisture…Most lump limes, even if quite fresh, break up in transit, and thus include a certain proportion of powder when delivered. This fear of air-slaking has led in the past to a certain prejudice (p6) against powder and small pieces generally; and a preference for the largest possible lumps, notwithstanding that these are likely to be underburnt inside or overburnt on the outside.

HYDRAULICITY – A more useful classification is according to the setting properties of the lime, whether quicklime or hydrated lime. These properties depend upon the nature and amount of impurities in the burnt lime…(which) may be active or inactive according to whether they are useful in assisting setting or are merely inert in this respect.

So- classification: *non-hydraulic, semi-hydraulic, eminently hydraulic.*

Non-hydraulic limes – these include limes entirely devoid of hydraulic constituents…and those containing only a negligible percentage of such constituents but an appreciable proportion of inert constituents (the 'lean' or 'poor' limes). They set only (p7) by carbonation, and thus are capable of developing little strength unless gauged with other materials such as a cement or a pozzolana.

Rich limes contain no hydraulic constituents; and only a small proportion of inactive impurities (up to 20%, but usually 5%, or less)….white chalk…the oolitic limestones of the Jurassic system…although these are more largely used as building stones…from the Carboniferous system…called 'mountain' limestones when occurring in massive deposits to distinguish them from the thinly bedded deposits common to northern England and southern Scotland.

Poor limes contain a larger proportion of non-useful impurities (up to 30%). They are obtained from chalk marl…and also from grey chalk…although this may on occasion yield a semi-hydraulic lime. A magnesian lime may be a poor lime.

Semi-hydraulic Limes – A semi-hydraulic lime has a smaller proportion of free lime…whilst the proportion of other matter includes some hydraulic constituents derived mainly from the clay content of the limestone.

The chief sources…are certain parts of the grey chalk mentioned earlier, the lias formation generally, and the Silurian system in an area including parts of northern and eastern Wales and Salop.

The composition of a semi-hydraulic lime depends upon the relative proportions of clay to carbonate in the stone from which it is produced. **It also depends upon the degree of burning.** A semi-hydraulic lime consists…of a mixture of calcium oxide and calcium silicate, and on adding water slaking takes place in the usual way by its action on the oxide. Complete slaking is much slower, however, than for non-hydraulic limes, because of the much longer time necessary for hydration of the silicate; it is this which constitutes the process of setting, the hardening of the hydroxide being dependent upon carbon dioxide as in a rich lime.

A semi-hydraulic quicklime run to putty should be used within a week.

P8 **Eminently Hydraulic Limes –** These are rather similar in chemical composition to Portland cement, but contain free lime. They do not harden so quickly, however, and they do not reach such a high strength *[as cement-sand mortars we would now say]*, but **for mortar and concrete in ordinary building work they are quite satisfactory –** in fact, they have certain advantages. They are obtained from a few distinct localities in the blue lias formation…notably Barrow-on-Soar in Leicestershire, Rugby, Aberthaw in South Wales and Lyme Regis in Dorset.

The hydraulic constituent is hydrated silicate of aluminium, a clay compounded of silica, alumina and water. Note that these may be present in a stone yielding a non-hydraulic lime…During burning the carbonate is converted into oxide, and some of this combines with the clay to form silicate and aluminate of calcium, mainly silicate. The temperature at which this combination takes place most readily is in the region of 1000 – 1200 degrees Centigrade, whereas the carbonate decomposes at about 900 degrees C. If underburnt, the larger pieces may retain a core of carbonate which cannot slake – if overburnt, some of the constituents partially fuse into lumps which are equally useless. **The richer limes can withstand excessively high temperatures better than the more hydraulic types can** – the latter can be more easily spoilt by over-burning, when the lime is said to be 'dead-burnt'.

Eminently hydraulic limes thus consist mainly of silicates; in fact, in an extreme case the proportion of oxide may be negligible. Slaking is therefore not so evident, but hydration of the silicates is completed within a few days *[is it?]*.

The degree of burning is more important than with other types of lime, for clinkering and fusion occur more readily and a much higher proportion of clinker may be formed. This clinker is comparatively inert <u>unless the particle size is reduced by grinding; if it is extremely finely ground, a 'natural' cement results.</u>

It is unusual for an eminently hydraulic lime to be supplied in the hydrated form, because of the difficulty in ensuring the complete hydration of the oxide whilst at the same time retaining the efficiency of the hydraulic components.

P17 **Pozzolanas –** At an early date the idea was tried of adding clay in suitable proportion to chalk or other pure limestone and burning the mixture in an attempt to produce an artificial hydraulic lime *[by Vicat in particular]*. The difficulties attending correct burning, however, together with progress in the (p18) manufacture of artificial hydraulic cement led to its abandonment.

Natural Pozzolanas

…the principal one is volcanic ash, rich in silica and alumina, found in extensive deposits around Mount Vesuvius – notably at Pozzuoli…Another…is Trass, a similar volcanic deposit found in the upper Rhine district and used extensively in many parts of Europe, whilst others are found in the Azores, the Canaries etc. Many other natural minerals are pozzolanic in lesser degree, **notably sands derived from the decomposition of igneous rocks.**

Artificial Pozzolanas – (Chiefly)…clay, burnt at a temperature of about 850 degrees C and finely ground. Some clay bricks and tiles are effective, after grinding. Ground clinker is commonly used as a substitute for sand in some districts, and this has pozzolanic properties, a fact not necessarily realised by the user. Ground blast furnace slag is also a good pozzolana…

Properties of pozzolanas.

(they) do not as a rule possess cementitious properties themselves; the hydraulicity of the pozzolanic mortar arises from the fact that certain constituents of the pozzolana combine with slaked lime and water to produce insoluble compounds which are cementitious. These compounds are stable, and the fact that they are formed at ordinary temperatures means that the materials need not be mixed before burning, but that the addition may be made at any time subsequently, even on the job just before use….

An average natural material has an analysis somewhat as follows:

Silica	55%
Alumina	15%
Iron Oxide	10%
Magnesia & lime	12%
Water etc	8%

P19 In some countries pozzolana mortars and concretes are used on a large scale and have been extensively developed. In Britain, however, (their use) …has been precluded by reason of the great popularity of artificial cements such as Portland. **But for much ordinary building work the very great strength of Portland cement is not necessary, and lime-pozzolana mortar, in which the pozzolana replaces some or all of the sand, gives ample strength and durability.** *[and considerably more breathability, probably].* It also possesses certain advantages, amongst which are **superior workability, better adhesion and a far more pleasing colour.**

P150

Lime Mortars

…Nowadays lime mortar is seldom used without additives, eg cement, to give strength, but in districts where hydraulic limes are produced, these may be **used in preference to cements,** except for structural work, where the highest possible strength is needed. **For brickwork mortar for all normal building work it has the advantage of better workability, less shrinkage and therefore better adhesion, and also a more pleasing colour whatever the type of brick used.**

Non-hydraulic lime mortar – the proportions of lime to sand are usually 1:2 to 1:3 by volume of the dry materials, depending chiefly upon the grading of the aggregate. Since carbonation is the only form of setting, this type of mortar is **comparatively useless without the addition of a cement or pozzolana, or the use of an aggregate having pozzolanic properties.** The former will be referred to later as 'compo'. The latter (with pozzolana) is not usual in the case of mortars mixed by hand or in a mixer, **but is common in mill-run mortars,** the reason being that this type of aggregate (clinker, broken brick etc) is not sufficiently fine without grinding. The aggregate and lime are therefore ground together or 'run' in a mortar mill, and this (p151) method has the advantage that any unsound lumps of lime are reduced and well distributed.

Mill-run mortars cannot be kept indefinitely and then knocked up, but should be used up within a day or two of mixing, depending upon the degree of hydraulicity imparted by the aggregate. When a non-hydraulic lime-silica sand mix (or the lime putty) is stored, its workability is improved. It loses some water and stiffens, but slight working or 'knocking up' is sufficient to restore its workability without adding more water.

Non-hydraulic lime mortar – These limes are used in the same ways as non-hydraulic limes, or they may be used with sand as 'straight' lime mortar. In the latter case the mortar stiffens, although not so much as 'straight' non-hydraulic lime mortar, and regains its plasticity by knocking up. Nevertheless, in order to take full advantage of the **slight** hydraulic set, it should be used within a few hours of mixing, although owing to the slowness of slaking it is usual to sacrifice some strength to ensure complete hydration. The proportions are as for non-hydraulic lime mortars.

Eminently Hydraulic Lime Mortar – As has been said, the use of 'straight' lime mixes, for mortars, renderings and even concrete, is usual in certain districts (those producing the right type of limes eg the blue lias). Since such limes are eminently hydraulic and are **used on account of the strength developed,** great care is necessary in their slaking and use. **They are also in the form of quicklime,** which increases in volume on slaking, which increases in volume on slaking, the proportion may be rather lower than when hydrated limes are used.

The lump quicklime is slaked by adding only sufficient water to break it down, and covering with sand for 2 or 3 days, after which it is mixed with the correct

quantity of sand and sufficient water to give the required plasticity, and used immediately.

Ground quicklime is usually mixed with moist sand and left until required, when it is mixed immediately before use with the remainder of the sand and sufficient water. The usual proportions are 1:2 to 1:4.

P153 **Compo** – This is the name usually given by the user to cement-lime mortars. These can be considered as cement mortar, the workability of which has been improved by the addition of lime; or lime mortar, the setting and strength properties of which have been improved by the addition of cement. **The usual proportions are 1:3:12,** but for higher early strength, such as might be advisable in cold weather or for ½ brick walling (eg cavity work), the proportion of cement is often increased to 1:1:6….

The lime may be of any kind, but there is no point in using the hydraulic types merely for the slight hydraulicity additional to that of the cement; in fact, the reliability of the non-hydraulic limes as regards soundness and ease of slaking makes them the most suitable, besides which their fatness gives the maximum increase in workability.

Internal Plastering – Plastering to internal surfaces is carried out with sanded mixes of a) lime, b) plaster or c) lime gauged with either plaster or cement….

Under more leisurely conditions than those prevailing today, lime and sand were used, with a proportion of hair to facilitate application. Applied in several coats, each was permitted to dry and attain a certain strength before applying the next. On completion, too, ample time was given for hardening without disturbance by vibration, etc and the result was highly satisfactory, as can be proved by inspection. **Nowadays, plastering is hurriedly done on walls,** etc that have not properly settled down, subjected during application and afterwards to jarring and other disturbance from other tradesmen working on the completion of the building. These conditions have led to certain modifications in practice, with the idea of facilitating application earlier in the building programme, and in a shorter time; also to give the sufficient early strength to enable the work to withstand vibration etc, without weakening the bond. To ensure this the lime is gauged with material having a more rapid set, hydraulic or otherwise, plaster or cement being commonly used. Alternatively, plaster may be used without lime, sanded for undercoats, and either lightly sanded or alone for finishing coats.

LIME MIXES. Quicklime for plastering is run to putty as follows: the tub or other slaking vessel is half-filled with water, the lime added slowly (p154) and stirring carried out continuously, more water and lime being added alternately so as to keep the boiling action from becoming too violent. After the slaking has finished and the slurry cooled, it is poured through a 1/8 inch sieve into a tank or tub for maturing. This takes from 2 to 3 weeks, and the slurry thickens as it fattens into putty.

If hydrated lime is used, it may be soaked overnight by placing it in water and stirring thoroughly, giving a putty similar to that produced from quicklime. Alternatively, it may be mixed dry with the sand, then mixed wet and used right away….There should be no excess of lime between the sand grains. 1: 2 ½ is the usual proportion for coarse stuff for undercoats, but if the sand is very fine the lime will carry less of it, and if the sand is coarse, the proportions may be 1:3. For finishing coat less sand is used, often equal proportions of sand and lime, but it is usual nowadays to make additions to this coat so as to secure quicker set, greater strength and smoother finish.

The undercoat may be haired (6 to 8 oz per cubic foot of plaster), especially for work to lathing, but the hair should be added only after slaking.

P156
Cement Renderings – (after realising that dense mortars no good – shrinking and cracking, cement-lime the 'best')…The cement, whether ordinary Portland or coloured Portland and sand are usually in the proportions 1:2 to 13.

Cement-lime renderings…the usual proportions are 1:2:9 to 1:1:6 depending upon the degree of exposure. Cement-lime renderings are more workable, so that adhesion is likely to be more satisfactory irrespective of the type of backing. They are more porous and open textured, so that the risk of cracking is less. They admit rain, but do so uniformly instead of locally via cracks, so that the maximum degree of saturation is less…, and drying out is also uniform and rapid.

P162 Concrete.

…The proportions are best from 1:8 to 1:10.

Lucas E (1964) *Modern Practical Building Vol 2.* London, Caxton.

This summarises general thinking in the 1960s, a (slight) confusion of cement, cement-lime and lime mortars all seemingly allowable as suitable for similar purposes and with an emphasis on stronger mortars offering greater durability. The recommended mixes for ashlar, however, were generally weak and lime rich, as well as using limestone aggregates, and the first site of a cement-lime mortar less strong even than 1:3:12 – 1:4:16. This is the orthodoxy in the years before the onset of the 'Lime Revival'.

Brickwork, Materials and Bonds.

Lime Mortars.

Lime mortars are usually prepared in the proportions 1 part lime to 3 parts sand by volume.

For hand-mixing the sand is placed in the shape of a ring on a clean, watertight platform. The lime is placed in the centre, water is added, and the heap left to slake for about twelve hours. Thorough slaking is essential, otherwise the lime will expand and 'blow' in the mortar joints.

After mixing, the heap should be smoothed over the exterior with a spade, so that air cannot readily penetrate the interior. Non-hydraulic lime mortar so treated will keep in good condition for a period of up to seven days. It should be knocked up as necessary to bring it to a suitable plastic condition. Non-hydraulic lime mortar is not recommended for permanent walls, as it has little strength.

Moderately *(feebly)* hydraulic lime mortar should be used if possible on the day of mixing, or within twenty-four hours at the outside. If allowed to stand longer, the setting and hardening action will take place in the heap, and much of it will be lost when the mortar is used.

Strongly hydraulic lime mortar, such as a mortar made with blue lias lime, has a strong setting and hardening property. It makes a durable mortar if properly prepared, but must be used within a few hours of mixing. If allowed to stand for long, the setting action takes place before the mortar is used…Ground hydraulic limes should be slaked by mixing with damp sand to make a stiff mix. The finished mix is then prepared by adding further sand and water. The mortar should then be used within four hours. Any mortar left after standing for half a day should be rejected.

…Cement Mortars.

…The following is of adequate strength for all ordinary purposes: 1 part Portland cement to 3 parts sand by volume….There are disadvantages in a stronger mix….

Lime-cement mortar.

This is sometimes called *compo* or *gauged mortar.* It combines the advantages of lime and cement mortars, and for all ordinary work it is preferable to either. Setting and hardening of compo is superior to lime mortar and, though strength is not so great as cement mortar, it is adequate for walls and piers bearing normal loads. A great merit of lime-cement mortar is that it is not likely to develop shrinkage cracks (1:3 cement mixes will). It works easily off the trowel, and sound work can be done at a higher speed than with cement mortar…

The following proportions make a moderately strong mortar: 1 part Portland cement, 1 part non-hydraulic lime, 6 parts sand. …

Retempering by adding water after the mortar has stood for some hours has a weakening effect, though re-tempering within twelve hours, using the minimum amount of water, is permissible where maximum strength is not important…

Sand.

Any clean sand is suitable for making mortar. It is desirable to use *graded sand,* by which is meant a mixture of sand particles from small to large….if very fine sand is used, more water is necessary, resulting in excessive shrinkage and some loss of strength.

MASONRY.

For *rubble walling* where, as has been said, the mortar supplies the chief bond, a good mortar is required. This should be composed of 1 part Portland cement to 4 parts sand.

Mason's putty is composed of 3 parts stone dust and 1 part lime putty. This is used for setting stones in wrought facing where the joints are required to be fine. The joints themselves are often grouted with neat Portland cement or with 3 parts stone dust mixed with 1 part Portland cement. For polished granite 2 parts sand to 1 part Portland cement is used…

Lime mortar consists of 3 parts clean sharp sand to 1 part slaked lime, which may be blue lias lime, grey chalk, or stone lime, pure or white chalk lime. Slaked lime is lime which has powdered owing to exposure to the air or from the addition of water. Grey chalk lime is used in the proportion of 1 part lime to 3 parts sand. Pure lime is used in the proportion of 1 lime to 3 ½ sand.

Lime putty consists of a mixture of fat lime and 3 parts by weight of water. *Fat lime* is derived from white chalk and forms a paste when mixed with water. It is pure white; rapid-slaking, slow-setting and non-hydraulic.

It is a mistake to use a strong cement mortar, except where an exceptionally strong, dense stone is used. For ordinary load-bearing masonry mix No.3 specified below is quite strong enough and is generally used for Portland stone and stones of similar density. The two weaker mixes are of adequate strength for ashlar and facing work.

The three mason's mortars following have been favourably mentioned by the Building Research Station:

1) 16 parts fine crushed stone (by volume), 4 parts lime putty or hydrated lime, 1 part Portland cement.
2) 12 parts fine crushed stone (by volume), 3 parts lime putty or hydrated lime, 1 part Portland cement.
3) 7 parts fine crushed stone (by volume), 5 parts lime putty, 2 parts Portland cement.

… PLASTERING.

…The materials available are:

1) Portland cement, which has a strong setting action
2) Non-hydraulic or feebly hydraulic limes, which have no setting action or very little
3) Hydraulic limes with a strong setting action, but not so strong or so quickly developed as Portland cement
4) Sand, which provides the aggregate in many mixes
5) Gypsum plasters…which have a strong setting action. Some types can be used with admixtures of lime and/or sand, and some are used neat.

Portland cement. Normal Portland cement is used in lime-cement-sand undercoats for interior plastering and in all coats for exterior rendering. Portland cement gives strength, good adhesion and resistance to damp, but it shrinks on setting and for this reason mixes strong in cement should be avoided except under very damp or exposed conditions…

Limes. Traditional lime plastering is now obsolete owing to the length of time taken to slake the lime and the need to allow undercoats to set before applying the next coat – the setting takes several weeks. Gypsum and anhydrite plasters have largely replaced lime plasters.

Lime is chiefly used in the form of lime putty and hydrated lime powder, complying with BS 890. These limes have little or no strength. Their value is in making the mix easier to work, giving it a 'fatty' property, less liable to develop shrinkage cracks, more porous and so a better thermal and sound insulator, and in reducing the cost of the mix.

Hydrated powder lime, sold in 1 cwt paper sacks, is now widely used in plastering and rendering mixes. There are two methods of using it, as follows:

1) *Soaking to putty:* this is done by partly filling a suitable tank or container with clean water and then adding the lime powder to the water, stirring it to produce a thick, creamy mix. This should be allowed to stand for at least sixteen hours. Excess water will rise to the top and can be poured or siphoned away, leaving a putty which can be used in the same way as putty run from quicklime in a pit.
2) *Preparing coarse stuff:* this is done by mixing the dry hydrate lime powder with dry sand and then adding sufficient clean water to make a stiff mix, which should be left to stand for at least sixteen hours before use. The wet mix is called 'coarse stuff' and can be used with Portland cement or suitable plasters at any time within a few days, but it should be covered to prevent drying.

The two methods just described develop the maximum workability or 'fattiness' in the mix. It is possible, however, to use hydrated lime with other ingredients, first mixing dry and then adding water, and to use the mix at once. But it will not be so easy to work as those made by methods 1 and 2.

Boynton R S & Gutschick K A (1964 & 1989) Strength Considerations in Mortar and Masonry National Lime Association Arlington Virginia

The approach of this paper is very sound – referencing proven practice and critical thinking among material scientists which challenges the appropriateness of modern mortar testing regimes, practices and assumptions when applied to buildings of traditional, as well as of modern, construction. Though Boynton and Gutschick conclude with the recommendation that 1:2:9 meets all necessary requirements, they make clear that this or any addition of ordinary Portland cement is demanded only when high early strength and fast setting mortars are demanded. All of their arguments would apply to the use of hot mixed air lime mortars if these are gauged with a suitable pozzolan, such as calcined china clay, low temperature fired brick or trass. In most situations, they might apply equally well to straight hot mixed lime mortars of traditional lime:aggregate proportion, most certainly when deployed in summer months.

Beyond this, it should be observed that ordinary Portland cement in 2017 offers significantly greater compressive strength than that available in 1964. Today, a 1:3:12 mortar would offer similar strengths to a 1:2:9 from 1964. A modern 1:2:9 is significantly stronger than would be necessary on the authors' terms, although around the same strength as most currently available NHL mortars and with significantly more free lime content than any of these.

Hot mixed air lime mortars will normally attain between 0.8 and 1.3 Mpa after 3 months, depending upon hot mixing method, though they may not be fully carbonated throughout by this time (Fusarde/HE research). Hot mixed air lime mortars become suitably load-bearing very soon after laying, with very good bond, particularly so if laid whilst hot. As the authors demonstrate, 0.5 Mpa in a mortar is dramatically amplified once part of a masonry wall and 0.5 Mpa is quite sufficient to carry a building up to 9 storeys high.

Mortar strength…is often greatly over-emphasised to the detriment of other essential mortar properties, such as workability, water retentivity, and bond-strength…and those builders who strive for high or maximum mortar strengths usually obtain inferior mortar for normal, above-grade masonry construction.

History. Before the advent of Portland cement in the United States…(1886 on), all of the masonry mortar was a straight lime-sand mix that inherently possessed very low compressive strength. True, some of the lime produced was derived from impure limestone that had varying (but usually faint to moderate) hydraulic qualities; other pure limes were mixed with crude, unwashed sand containing clay that acted like a mild pozzolan with lime. While both of the latter types of mortars possessed slightly more strength than the pure ('fat') lime- clean sand mixes, all would be regarded today as extremely weak in compressive strength (ranging between 50 to 300 psi *.34 – 2.0 Mpa)(*in 28 days). Yet these mortars as a whole were still able to support satisfactorily and safely some large masonry structures (for that time); and they endured, in some cases for centuries, without tuck-pointing.

These early lime mortars were never actually deficient in *ultimate* strength – only in *high early* strength, since they gained strength largely by recarbonation, a very slow process. This meant that construction had to progress from floor to floor very slowly (long 'green' strength periods). As the tempo of construction accelerated, the advantage of adding Portland cement to mortar was a logical consequence because of its rapid setting qualities. Thus entered a new era of high speed modern construction early in the 20th century.

Soon, Portland cement became recognised as a desirable or essential ingredient in mortars, and it was mixed with lime and sand in many varying proportions. 28-day and ultimate mortar strengths were, of course, markedly increased. Gradually, a 'high strength complex' developed among many builders, so that the cement increment was steadily increased until some builders in the 1915-1930 period were using straight cement mortars – without lime – espousing the erroneous theory that the stronger 'the stronger the mortar, the better'. Memories are short. The long history and proven durability of the old straight lime mortars were largely forgotten.

Straight cement and high cement mortars, however, soon exhibited serious shortcomings that dwarfed their questionable advantage of high ultimate strength. Without lime (or enough of it) these mortars proved to be stiff and unworkable so that the joints were insufficiently filled; they possessed low water water retentivity so that absorptive masonry units sucked the water from the mortar before it set, causing the mortar to 'pancake' and preventing it from adhering to the mortar unit interface. This, coupled with an inadequate extent of bond, characterised by frequent voids and holes, caused by poor mortar workability, led to an epidemic of leaky masonry. Even in cases where initial bond between mortar and unit was established due to the use of denser units and better workmanship, often eventually widespread separation cracking occurred at the mortar unit interface (broken bond), an easy prey for driving rains to penetrate. This was caused by the inherent tendency of a rich cement mortar to shrink. Although this type of masonry was extremely hard, and high in compressive strength, it was rigid and very brittle…(prompting National Bureau of Standards and MIT research in late 1920s and early 1930s, which led to re-intro of) lower strength mortars that contained much higher proportions of lime (1:1:6 and 1:2:9 respectively) (*Portland cement much weaker then than now).*

(most tests devised based on compressive strength of 2″ x 2″ cubes. Tensile strength can be deduced from compressive strength being typically 12% of the compressive strength).

Emley was the first to recognise how even slight modifications in mortar test procedures could greatly effect strength values. In effect he said, "Unless the test procedure and material used are *minutely* described, mortar values reported are meaningless"…Variables, noted by Emley, that could singly alter strength values as much as 25-200% were:
1, type of lime, whether high calcium or dolomitic; hydrtae or putty from quicklime.
2. Slight changes in atmospheric humidity and temperature in curing
3. size and shape of specimen
4. Skill and experience of laboratory technician
5. Slight changes in sand gradation
6. Consistency of mix- percent of initial flow
7. Slight variation in proportions
8. Modification in curing conditions

Some curing conditions of mortar specimens are definitely unfair to lime-based mortars – particularly the underwater cure. Curing in a damp closet for 28 days is reasonable for 1:1:6 and 1:2:9 mortars. For very high lime mortars, the damp closet cure is rather harsh, and laboratory air is recommended.

There is considerable disagreement…among masonry researchers on the significance of these strength tests….Voss, Staley, Emley and MacGregor regard the assemblage and wall panel type of strength tests as the only ones of any value. They claim that the mortar cubes and bars do not remotely emulate bricklaying (wall) conditions, such as effect of absorption by masonry units, consolidated weight of wall, and particularly the profound influence of the strength of the units. As a result, they conclude that these latter tests are meaningless, except as a system of mortar classification by compressive strength categories. Others, like Palmer, Anderegg and Connor, tended to the same view, but also felt that strength data on cubes or bars was of minor, secondary value since mortar becomes an integral part of the wall, even though it occupies less than 5% of the wall area. Most of these investigators did not worship high mortar strength….
ASA A.41 and ASTM C-270…are based on compressive cube strength. This system of mortar classification is misleading to builders and engineers, because of the possible inferred connotation that the highest strength mortar types and proportions are the best; the lowest strengths are the poorest etc (*the same may be said of freeze-thaw cube tests)*….A straight cement mortar may contribute to a strength factor of 40 to 60+, an amount far in excess of what is needed. Safety factors of 5-10 are completely adequate *(if still over the top, especially in conservation context),* no additional value can be attached to masonry that possesses higher safety factors. Possibly at one time, strength was a more valid consideration than it is today, since a modern 1:1:6 mortar, containing Type S hydrated lime, is stronger in compression than a straight (1:3) cement mortar was in 1915.

(Staley's research on compressive strengths of 8 x 8 inch brick piers with different mortars showed that)…strengths of straight cement mortar average 10 times (1000%) more than the highest lime content mortar, yet the pier strengths with the weakest mortar (highest lime content) are only 30-55% less than with the strongest mortar…and still possess very ample factors of safety. (results paralleled by Davey for BRE in UK)…. Stang, Parsons and McBurney for National Bureau of Standards and Palmer…concluded that lime up to 50-60% of the volume of the total cementitious material (ie lime plus cement) can be used in a 1:3 mix without any reduction in pier strength of consequence.

With respect to brick pier strength tests, Voss contended that 6-month strength tests were far more meaningful than 28-day strengths since rarely is a building occupied before a 6-month construction period, small private homes excepted. He calculated the load imposed on a typical 4-story school building with 26′ classroom spans of 16″ thick, solid, brick walls at grade at only 80 psi *(.55 Mpa)*…. Staley likens factors of safety to 'factors of ignorance', since high mortar and masonry assemblage strengths sacrifice most of the other essential or desirable qualities in mortar. Masonry units of 10000 psi and mortar of 3000 psi will develop approximate safety factors of 50; factors of 5-15 are completely adequate…and far more desirable. As evidence, he reminds the reader of the hundreds of schools, factories, warehouses, and apartment buildings erected before 1900 in which straight lime mortars (1:3) were employed. These endured even though many of these old mortars tested as low as 50 psi in compression.

National Bureau of Standards Circular No.30:

"This question of the strength of a mortar is apt to be given undue weight. Since masonry is assumed to weigh 150 lbs/cu ft, then the compression load at the bottom of a wall will be 150 over 144 times its height in feet. A mortar with a compressive strength of 100 psi should, according to this reasoning, be able to carry a wall 100 x 144 over 150 = 96 feet or about 9 stories. A mortar joint in a wall may possibly be 9″ wide by 30′ long by ½ " thick. In the joint the ratio is 9 divided by ½ = 18. If a mortar has a strength of 100 psi when tested in the form of a cube, it should theoretically have a strength of 1800 psi when laid up in a wall.

(During 1910s Kreueger in Sweden) studied the loads imposed on mortar beds…(in a 6 story building, calculating individual floor and wall loads, cumulative loads and the loads in psi for each floor)…a low strength brick with a weak 1:3 straight lime-sand mortar…developed a masonry assemblage strength of only 410 psi *(2.82 Mpa)*. Yet this low strength assemblage had a safety factor of about 8 or higher for the exemplified building…

Ritchie postulates that the mortar proportion of optimum efficacy is usually necessarily a compromise between two extremes of high cement or high lime content, If a high strength mortar is desired, the increased increment of cement contributes toward poorer workability, lower water retentivity and rapid stiffening, all of which are undesirable in a well-balanced mortar. Conversely, lime contributes little to strength, but it does provide the desirable characteristics of workability, high water retentivity and maximum extent of bond… he concludes that a compromise proportion of 1:1:6 and 1:2:9…is the logical solution to mortar proportioning.

(the nature of the unit will effect the overall assemblage compressive strength – bricks stronger than breeze blocks eg)…Mortar was originally conceived as a means of bedding masonry units and bonding them together. In this vein, mortar serves masonry in the comparable capacity of a gasket or washer so that ideally some resilience is necessary to 'cushion' deflection, Rigidity in mortar is incompatible with this concept….In non-load-bearing walls, like curtain walls, strength is of even less importance. The only strength requisite is for resistance to the force of lateral pressure, caused by strong winds and gales. In hurricane areas, greater strength is necessary – but not compressive strength. High bond strength, developed by an adhesive, plastic mortar that provides maximum extent of bond, should be the prime objective.

High Early Strength. The essential property of high early strength is provided most efficiently by Portland cement. Contrary to the opinion of some engineers, not much cement is necessary to accelerate the set of mortars markedly in warm weather. One part of Portland cement to 2-3 parts of lime by volume will easily suffice, with the cement in effect being used to gauge the lime mortar. In cold weather construction, however, the setting time may be too slow, so that equal parts of Portland cement and lime by volume may be desirable. Thus, cement is primarily needed for mortar to provide fast setting and high early strength – not for ultimate high mortar or masonry assemblage strength – in conventional masonry construction….

Miscellaneous Factors Affecting Mortar Strength.

The consensus of the data from mortar researchers on mortar strength indicates the following:

1. Effect of limes (strength comparisons at 28 days)
   a) Dolomitic hydrates *per se* in 1:3 (straight lime) mortar appear to develop nearly twice as much compressive strength as high calcium hydrates and putties from high calcium quicklime on average.
   b) Type S hydrated limes per se appear to develop in lime-cement mortars two-thirds greater strength than Type N hydrated limes on an average; however, the Type S develop only about 25% more strength than dolomitic Type N hydrates.
   c) A 1:2:9 mortar with Type S lime develops greater strength than the majority of masonry cements.

d) A 1:1:6 mortar with Type S lime develops greater strength than the majority of masonry cements.
e) Type N hydrates develop more strength on average than putty from high calcium quicklime.

2. The tensile strength of all proportions of lime-cement mortars, as well as straight cement and lime mortars, average about 12% of the compressive strength values at 28 days.
3. Regardless of mortar composition, both tensile and compressive strength values increase as the water-cement ratios are decreased.
4. Measured at standard consistencies or flows, the water-cement ratios steadily increase with increasing increments of lime..
5. Strength of mortars decreases steadily with increasing increments of entrained air. The magnitude of loss is about 20% between 0% and 15% air; much higher losses over 15% air.
6. A small amount of cement (25% by volume) greatly accelerates (several hundred per cent) the set of high lime mortars. Further increments of cement will increase setting rate time steadily but at a slower rate as measured by penetrometer test…
7. In comparing all proportions of mortars at 75% and 110% initial flow, greater 28 day strengths are obtained for 0:1:3 and 1:3:12 (very high lime) mortars at 110% initial flow; with all other lower lime content mortars the reverse is true, with drier mortars developing greater strength. In the latter, gain in strength at 75% flow increased as cement proportion increased.
8. Percentage strength gains between 28 days, 6 months or 1 year are much greater with lime-cement (1:1:6 and 1:2:9) mortars than with straight lime mortars by about 40% on the average. This indicates that lime mortars gain strength much more slowly, but over a longer period of time.
9. No unanimity is apparent on effect of consolidation on wall or mortar strengths. Staley feels that there is a gain in strength, and it is proportionately greater with high lime mortars because it beds more easily due to greater workability.
10. Generally, workability in mortar decreases as strength increases, in absence of entrained air, and vice versa.
11. Tensile bond strength, as measured with the ASTM brick couplet test, generally increases as compressive strength increases, in absence of entrained air. Extent of bond, however, which is more significant than bond strength, generally decreases with increased compressive strength.
12. In general, decreases in either water retentivity or sand-carrying capacity parallel increases in strength for all mortars.
13. 28-day strengths of mortars, regardless of lime content, average about 60% higher than 7-day strengths.
14. Curing methods (pf cubes)

a) High cement mortars of 1: ¼ : 3 develop equal strengths whether they are cured in seven days in damp closet and 21 days under water or 28 days in damp closet.

b) Strengths of 1:1:6 and 1:2:9 mortars are much higher when cured 28 days in damp closet than with ASTM test.
c) Curing 7 days in damp closet, 18 days in water and 3 days in laboratory air produce greater strength than in 14 b above, for 1:1:6 and 1:2:9 mortars, showing beneficial effect of wetting and drying on strength.
d) Curing in air for 28 days develops higher strengths than 28 days in damp closet for 1:4:15 mortars or straight lime mortars.

15. With most masonry sands, an increase in the proportion of total cementitious material (C + L) up to about 25% richer than the conventional 1 to 3 ration increases mortar strengths by 10 – 25%.

Conclusion. *Thus, lime-cement mortars, notably the 1:2:9 proportion…provide completely adequate wall strength with an ample safety factor for all standard masonry construction.* But *most* important, the high lime content contributes other essential characteristics to a well-balanced mortar – improved workability and water retentivity that provides maximum adhesion and a high excess of bond between the unit and the mortar; a safeguard against separation cracking at the mortar-unit interface, caused by shrinkage or deflection that commonly occurs with hard, rigid, brittle mortars; and, as a consequence, watertight joints. Actually, cement is mainly a necessary mortar ingredient for only one reason: to provide quick setting or *high early strength* so that construction can proceed at a rapid pace.

Ashurst J & Ashurst N (1988) Mortars, Plasters and Renders English Heritage Technical Handbook Vol 3. Aldershot. Gower Technical Press.

This was one of the more influential texts of the 'lime revival', and yet was remarkably light on detail – very few mortar proportions were offered, except for exterior renders, which gave precedence to a 1:1:6 cement-lime mortar. Ministry of Works Advice Note No 6, published in 1950, had said that 1:1:6 should be used only for brickwork necessarily executed in the depths of winter, or for very exposed situations such as chimney caps, indicating that 1:2:9 was the most appropriate general mortar mix. At the same time, it had covered the whole range of lime mortars in concise detail, including slaking methods and mix proportions. It had recommended fat lime mortars for the bedding of porous sandstone and limestone. Where had all of this knowledge gone? 1:1:6 was quickly perceived as a 'conservation mix' across the English-speaking world. Ashurst also gave an uncritical 'green light' to the use of imported hydraulic limes, failing to distinguish between the character of these and then unavailable hydraulic limes used traditionally in the UK. He failed to indicate that their use, historically, had been mainly confined to water works. His assertion that adding water to quicklime – 'NB the water is not *added to the quicklime – this is extremely dangerous', whilst insisting that quicklime was always added to a surplus of water (contrary to the advice of ALL historic texts,* may be the source *of a now long-standing conviction that hot mixing was simply too dangerous to be contemplated. Ready-made lime putty was little available at the time he wrote, so that lime was necessarily slaked to putty on site, an operation arguably more 'dangerous' than any traditional method of hot mixing. He gave the clear* *impression that this was what had always been done traditionally, when the opposite was, in fact, the case. Whilst the 'need' to give ongoing hydration and protection to putty lime mortars was stressed, there was no similar recommendation for the aftercare of hydraulic lime mortars and no notion of their demand for such aftercare. There is no distinction between feebly and other hydraulic limes and no discussion at all of the feebly hydraulic limes so commonly used throughout the British Isles historically. Natural cement is discussed and rightly identified as an eminently hydraulic lime, as well as as a mortar that promoted wetness, damage and decay to historic fabric, without any comparison being made with imported hydraulic limes, some of which delivered very similar characteristics. There is much sound advice, of course, about working with lime, and a refreshing sense of pragmatism appropriate to conditions within the conservation and building repair industries at the time. In truth, however, this was a deeply flawed piece of work that had unfortunately far-reaching influence. By comparison with a 1:1:6 cement-lime mortar, even an NHL 5.0 might seem benign. Notably, the Ashursts included a description of hot mixing, saying that it had 'a long tradition behind it', whilst dismissing it as 'really only practicable in long programmes of repair or restoration'. Given the earlier detailed recommendation that quicklime be slaked to putty on site and then stored to mature for a minimum of 2 weeks, and ideally for 2 months before use, this was a strange assertion, indeed. Very few people paid attention to this early paragraph, it would seem.*

The Production of Non-Hydraulic (High Calcium) Lime

…The minimum effective temperature for burning limestone for lime is 880 Degrees C, but for this temperature to be reached in the centre of the stone lumps, an overall temperature at the surface of 1000 Degrees C is necessary…

Slaking

Quicklime (unslaked lime) in lump or ground form can be delivered by a number of suppliers while others allow collection of smaller amounts of lump from their works. For site slaking the lime should be delivered as fresh as possible and kept in dry conditions…

If quicklime is left exposed to the air it will absorb water from it and 'air-slake', or 'wind-slake', the calcined lumps gradually reducing to powder with an increase in volume. On site, slaking usually occurs under water.

During the process of slaking, hydroxides of calcium (and magnesium) are formed by the action of water on the oxides. Traditionally, this process was carried out in pits and the slaked lime was left to mature for several months, or even years *[for plaster finish coats in ancient Rome, perhaps]*. Today, slaking on site for repair work is most conveniently carried out in a galvanised steel cold water storage cistern. Clean, potable water is run into the tank to a depth of approximately 300mm and the quicklime is added by shovel (NB: the water is *not* added to the quicklime – this is extremely dangerous); because the violent reaction which can occur between the water and fresh quicklime frequently raises the water temperature to boiling point *[one would hope so, but does it in fact?],* this operation must be carried out slowly and carefully. Eyes must be protected by goggles, and hands by suitable gloves, and anyone unprotected in this way must be kept away from the slaking tank. The initial slaking process may be carried out more quickly by first breaking the lumps of quicklime down to a large aggregate size and by using hot water in the tank.

The slaking lime must be hoed and raked and stirred until the visible reaction has ceased; enough water must be used to avoid the coagulation of particles which significantly reduces the plasticity of the lime. Experience will dictate the correct amount of water required, which can be adjusted as the process demands; it is always better to have an excess of water than not enough. The addition of water and quicklime continues until the desired quantity has been slaked. Using an excess of water without 'drowning' the lime results in the formation of a soft, rather greasy mass of material, described as *lime putty*.

Sieving the putty through a 5mm screen will remove unburnt lumps and the larger coagulations. The screened putty should be left under a few centimetres of slaking water. This 'limewater' may be siphoned off for use in limewater consolidation of friable lime plasters and limestone….

The lime putty, with a shallow covering of water, should be kept for a minimum period of two weeks before use. Two months is a better period if practicable and there is no upper limit of time. The minimum period is to ensure that the entire mass is thoroughly slaked. After this time, plasticity and workability go on increasing. Old lime putty…acquires a rigidity which is rather like that of gelatin. When the rigid mass is worked through and 'knocked up', it becomes workable and plastic again. This property is peculiar to non-hydraulic lime putty. Any material which has a hydraulic set must not be knocked up after it begins to stiffen.

Slaking lime with sand

A variation on the slaking procedure, **which has a long tradition behind it, is to slake the quicklime in a pit, already mixed with the sand which is to be combined as mortar or plaster. The lime needs to be in small lumps so it can be accurately batched by volume against the sand.** The process requires time and space and is really only practicable in long programmes of repair or restoration, where it is intended to lay up quantities of lime putty *[?]* and sand for a long time. **The technique has, however, a distinct advantage over more familiar mixing procedures in that this early marriage between binder material and aggregate encourages the covering of all the aggregate particles with a lime paste in a way and to a degree which can never be matched by conventional modern mixing.**

Storing 'coarse stuff'

A recommended procedure is to mix the slaked lime putty with the sand and other aggregates and to store the constituents together, protected from the air as wet 'coarse stuff' for as long as possible to mature….the coarse stuff is the best possible base for mortar and lime plaster, whether or not it is to be gauged later with any pozzolanic additives….

The mixing of coarse stuff

Initial mixing of the coarse stuff and final mixing, or knocking up, must be thorough. But mixing, in the familiar sense of turning over with a shovel, was not considered sufficient in ancient times, nor is it sufficient now, if the best possible performance is to be obtained from the lime mortar. The old practice of chopping, beating and ramming the mortar has largely been forgotten. However, recent field work has confirmed that **coarse stuff rammed and beaten with a simply made wooden rammer and paddle or a pick handle, interspersed with chopping with a shovel, significantly improves workability and performance.** The value of impact is to increase the overall lime-aggregate contact and to remove surplus water by compaction of the mass.

Alternative sources of lime putty

Some lime suppliers will supply lime putty in plastic sacks by request. If there is no supply available and site slaking is impossible, use hydrated lime and soak it for a minimum period of 24 hours in enough clean water to produce a thick cream. For many ordinary building situations, **especially if the lime mortar is to be gauged with cement,** this practice is quite satisfactory.

Hydraulic Limes and Cements

…additives which can produce a set when added to a non-hydraulic lime:

PFA (pulverised fuel ash)
Finely powdered brick dust
HTI powder, prepared from refractory bricks
Hydraulic lime
White cement
Masonry cement
Ordinary Portland cement

…Modern practice in Britain makes use of crushed brick dust, HTI powder and PFA of low sulphur content as pozzolanic additives mixed with lime. Yellow brick dust, HTI powder and PFA in the form of light coloured cenospheres (minute glassy bubbles) do not significantly affect the colour of lime mortars, but, of course, red brick dust and grey fuel ash have somewhat limited applications. While it is still common practice to gauge lime mortars with cement when an initial set is required, other pozzolanic additives are

particularly useful where a strong set is not required, as is often the case in the fabric of ancient monuments and historic buildings.

Hydraulic Limes and Natural Cements

…As the temperatures reaches 900 Degrees C, pozzolanic compounds are formed as the decomposition of the carbonates and reaction with clay minerals proceeds. Over 1000 Degrees C, calcium aluminates and silicates are formed and sintering will take place, producing a clinker which is **somewhat inactive until finely ground. Changes in the firing temperature, as well as in the constituents, can produce hydraulic limes of very different characteristics….**Hydraulic limes are imported from France and are in use on many sites…they are delivered in sacks as a finely ground powder….coarse stuff must be used within four hours and must not be knocked up after stiffening has taken place…

Natural (Roman) Cements

…John Smeaton found that Aberthaw lime gave better results than others and concluded that the best limes for mortar *[for use underwater]* were those fired from limestones containing a considerable quantity of clayey matter…'Roman cement'…being a strong, durable material…was welcomed as an external rendering…Unfortunately, it was also used extensively for plastic repairs of masonry and for pointing, roles for which it is too impermeable and too strong…

The Use of Hydraulic Limes and Cements in Building Conservation.

The frequent misuse of cements and, less commonly, hydraulic lime should not prejudice against their sensible use in historic building repair and maintenance work. Quite small quantities, which should always be specified accurately, will protect lime mortar and rendering against failure during frost. But they are by no means needed in many of the situations where they are habitually employed and should positively be excluded in the vicinity of old lime plaster, wall painting and stone sculpture.

APPENDIX TEN

REVIEW OF HISTORIC LITERATURE RELEVANT TO EARTH AND EARTH-LIME CONSTRUCTION.

Earth Mortars and Earth Building as Referenced in Old Texts and Assorted Building Accounts

That earth buildings are widespread across the world – whether of rammed earth, cob, mud and stud or adobe construction – is widely acknowledged and understood. Less widely appreciated is the enormous geographical and historic spread of earth built masonry structures. It would seem fair to assert that the majority of masonry buildings constructed across the UK and Ireland before the 19thC were built with earth or earth-lime mortars and generally pointed with lime rich mortars and that they were originally plastered within with a simple system of earth-lime backing coats overlaid with quite thick haired lime finish coats. In the earlier period, similar was probably applied to the exterior walls. This system of masonry construction was likely introduced into the British Isles by the Romans, continued after their departure and was reasserted by Norman builders. The use of earth mortars in masonry construction was almost certainly the pattern in the UK during Neolithic times, however.

This pattern of masonry construction is evident also in Spain, France, the Czech Republic and across Europe and Asia and, if it did not exist there already, was carried to the Americas by European settlers.

Only during the 18thC did it become more common to use lime-sand mortars for masonry construction, although these had been used in some – but by no means all - high status buildings during all periods and were adopted earlier by bricklayers than by stonemasons in the British Isles.

Until very recently, the prevalence of earth and earth-lime mortars in masonry structures has been substantially ignored by the conservation community, as well as by the 'lime revival', as has their demand for the use of truly compatible and eminently breathable lime mortars for their repair and conservation. Whilst the use of putty lime mortars for this can do no harm to the fabric of such buildings, the use of cementitious or even hydraulic lime mortars may be seen as offering essentially incompatible options. There is increasing evidence that NHL mortars, low in the free lime content necessary to achieve effective porosity (Wiggins 2016) with much greater compressive strength than was possessed by the typically hot mixed lime mortars traditionally used in association with earthen materials, lead to an ongoing accumulation and entrapment of received moisture.

This is to the detriment of appropriate thermal performance, will lead to the unnecessary decay of embedded timbers and may ultimately lead to collapse or other less exaggerated structural failure.

Putty lime mortars, mixed at 1:3 are breathable and workable, but are less durable than hot mixed lime mortars. Before the 20th C, when lime run to putty was expected to be gauged with either Portland cement or gypsum, depending upon location, they were not used as binders, but alone as mortar for fine plaster finishes, high end lime wash or for the very fine joints of gauged brickwork or the most precise stone ashlar. They lack the durability of hot mixed air lime or feebly hydraulic fat lime mortars. Used today, putty lime mortars used in the weather should be enhanced by the small addition of pozzolans. Hot mixed air lime mortars tend to have appropriate durability without such pozzolanic addition; though pozzolans may be necessary in more exposed or especially damp locations.

As the routine modern use of around 3% quicklime addition for soil stabilisation during road construction demonstrates, a small volume of quicklime has a disproportionately efficient effect upon the tenacity, cohesion, water management and load-bearing capacity of clay-bearing subsoils. Whilst carbonation of the lime addition will occur, it is primarily the chemical interaction of the clay and calcium oxide (or calcium carbonate) ions that offers this improvement in performance. Observation would suggest that quicklime was the most common form in which lime was introduced into otherwise earthen mortars, but this may have been 'hot lime' run to putty just prior to addition on occasion and depending upon customary lime slaking procedures locally.

There are real practical advantages in adding quicklime, however, as the earth mortar – improved as necessary by the addition of sands – may be mixed beyond the liquid limit to fully engage the clay content and then brought down below this limit by the addition of a small volume of quicklime. This addition also improves the workability and 'elasticity' of the earth mortar.

Many earth mortars contain a multitude of 'lime lumps'; others far fewer and with streaks or swirls of carbonated hydrated lime.

Analysis of these mortars – particularly where no obvious under- or over-burned, or simply carbonated lime lumps are present – may misleadingly indicate the use of putty lime, as quicklime added to a very wet earth or earth lime mortars will slake to 'putty' during mixing. Even where lime putty may have been used, it will have been slaked traditionally – the water added to the lump lime, not the other way around – and will have been mixed immediately after slaking was complete, whilst still very hot. Alternatively, and particularly when the lime addition was significant, the mortars will have been made by the 'ordinary method': a basin formed of the earth aggregate, the quicklime placed within this and then just sufficient water or a slight excess of water added to the lump lime to effect the slake before earth and slaked lime were mixed together to form the mortar.

Mention or discussion of this universal craft practice in historic texts on lime or construction is rare. More so than with lime, these mortars were hidden in craft practice; guarded by the masons and plasterers themselves, and the many 'experts' on lime writing particularly during the 18th and 19th centuries seemed to see no reason to write about them, let alone explore their properties or potential. They are mentioned in Roman texts; acknowledged by Alberti; identified in several 17th and early 18thC Century texts. Their manipulation is discussed even less – with only Henry Best describing this in 1641. Several authors during the 19thC promote earth construction – as Clough Williams Ellis does again in the early 20th C – as a means of constructing comfortable but easily affordable homes for the rural working classes, but there is little technical detail given. Loudon (1833) is the most encouraging of the use of earth, often presenting it as an equivalent alternative to stone. Very few discuss earthen mortars in masonry construction, and yet earth mortared buildings are everywhere in the British Isles – as commonly in limestone districts as in regions that had little or no easy access to lime.

In North Yorkshire, churches and buildings of very high status from the 16th, 17th and 18th centuries were constructed of earth-lime mortars, finished with lime rich mortars. In Lincolnshire, mud and stud houses were typically plastered inside and out with earth-lime mortars and lime washed rather than lime plastered.
It will be, perhaps, in building account books that the written evidence for earth and earth-lime mortars will be discovered, and several examples are transcribed below, from the 15th and 16th centuries. 18th century contracts between masons and the Fitzwilliam Estate in Malton, North Yorkshire - a town built mainly of limestone upon foundations of limestone bedrock - offer invaluable insights. The mason themselves designed the mortar and specifications called simply for the 'best mortar' in their judgement and according to the materials available. No proportions were ever spelled out, as they were not for lime mortars until the mid-19th C, when architects were becoming more involved in the construction process locally. Lime was supplied from Estate quarries.

On analysis, earth mortars in Malton and elsewhere have a predominance of very fine sands and silts. Larger aggregates tended to be calcareous inclusions, which were most likely present in the subsoil, though some may have been deliberately added. This contradicts the modern specification of earth mortars (for eco-build) to include plentiful sharp sands. It would suggest that silts play as important a role in performance as clays. Clay content is typically 12% by volume, though some plainly successful earth plasters have as little as 5% clay along with a lot of fine sand and silt.

In North Yorkshire, hay was a common addition to counteract shrinkage and to increase flexural strength, although hair is found on occasion and oftentimes no organic addition at all; elsewhere, such as Moffat in Dumfries and Galloway, ox hair was most common. In Spain, organic addition is rare in earth mortars (pers comm Santiago Gonzalez, Asturian stonemason), although common enough in adobe blocks.

Most earth mortar design was accomplished by 'feel' and experience. Testing will have been simple and straightforward, as it remains today where earth building persists. For plasters, trial panels provide the most effective means of assessment – different earths plastered upon a wall with and without hay or hair addition; with increasing volumes of sand addition and/or increasing volumes of quicklime addition. The mortar that shrinks the least and enjoys the necessary workability and tenacity will be selected. This is especially important for plasters; less so for bedding mortars which the evidence suggests could tolerate more clay content and were used in a sloppy consistency.

The qualities and character of a good earth mortar is very similar to those of a 1:3 quicklime: aggregate hot mixed lime mortar. It is not difficult to see why masons in the past assumed that these materials 'liked' one another.

Lime rich pointing mortars – often with hair addition – were laid over the earth bedding mortars almost like a localised render. The bedding mortars were typically struck at the face of the work before pointing with lime, not raked back as would be the norm today. In Yorkshire, in coursed stonework, the stones were tipped slightly forwards, leaving a slight step between courses – the lime pointing was laid over the earth bedding mortars and weather-struck across this step. The lime rich pointing is somewhat deeper-seated in earth-lime mortared brickwork of the 15th and 16th centuries in urban Valencia, the bricks being very thin and with mortar beds often thicker than the bricks themselves. Such brickwork in Spain may be reasonably characterised as forming part of an unbroken Roman tradition of building.

As Niamh Eliot's research into the buildings of Moffat has shown, there was significant pressure from 'enlightened' 18th C landowners, educated in Edinburgh and other cities, to demolish 'inferior' and 'embarrasing' earth built masonry houses on their estates, for them to be rebuilt with lime mortar. Earth mortars survived more easily when unnoticed or ignored and in Malton, once more, are frequently discovered beneath 3 coat lime plaster work from the 19th C.

The use of earth mortars persisted into the 19thC in certain situations – for the parging of chimneys, for the mortars of furnace (and kiln) masonry, both stone and brick and sometimes for plaster base-coats, in the latter case, reducing the delay between plaster coats, the set being less dependant upon complete carbonation of the base coats and allowing sooner application of subsequent lime coats.

Earth and earth-lime mortars have proven to be remarkably durable. Earth-lime mortars abound in the roofless clearance houses of Caithness and elsewhere in the Highlands and survive well in North Yorkshire long after the lime pointing mortars have fallen away.

As the work of Tom Morton and Becky Little in Scotland have demonstrated, earth mortars exposed to the air are surprisingly frost and rain resistant – in the former case, they will freeze but consolidate once more after thawing. That said, good detailing is essential to the longevity of earth as well as air lime mortars, as important as their inherent breathability and as the necessity that all lime mortars applied to them are as eminently breathable as this.

Earth mortars, with or without lime addition – are sustainable and were always locally sourced, as their variation and compositional similarity to immediately local sub-soils indicates. Their use involves a minimum of embodied energy. They are easy and economic to make; they are easy and pleasurable to use, enjoying high workability and good bond strength.

In summary, earth and earth lime mortars – as earth buildings in general - must be taken seriously and afforded the cultural and technological significance merited by so widespread and long-term use. It is essential that lime mortars used (as before) in association with these mortars is as compatible as possible. Historically, the lime mortars thus used were hot mixed air lime or, sometimes, feebly hydraulic limes with a high free lime content. Just as earth and earth-lime and hot mixed air lime mortars worked together in the past and in the buildings we aim to conserve, the hot mix revival should go hand-in-hand with a revival in the appropriate use of earth and earth-lime mortars and the thorough appreciation of their needs.

Cato (c160 BC) De Agricultura

If you are contracting for the building of a new steading from the ground up, the contractor should be responsible for the following: All walls as specified, of quarry-stone set in mortar, pillars of solid masonry, all necessary beams, sills, uprights, lintels, door-framing, supports, winter stables and summer feed racks for cattle, a horse stall, 2 quarters for servants, 3 meat-racks, a round table, 2 copper boilers, 10 coops, a fireplace, 1 main entrance and another at the option of the owner, windows, 10 two-foot lattices for the larger windows, 6 window-shutters, 3 benches, 5 stools, 2 looms, 1 small mortar for crushing wheat, 1 fuller's mortar, trimmings, and 2 presses.
The owner will furnish the timber and necessary material for this and deliver it on the ground, and also 1 saw and 1 plumb-line (but the contractor will fell, hew, square, and finish the timber), **stone, lime, sand, water, straw, and earth for making mortar….**
In a steading of stone and mortar groundwork, carry the foundation one foot above ground, the rest of the walls of brick; add the necessary lintels and trimmings. 5 The

rest of the specifications as for the house of rough stone set in mortar. The cost per tile will be one sesterce. The above prices are for a good owner, in a healthful situation. The cost of workmanship will depend upon the count. In an unwholesome situation, where summer work is impossible, the generous owner will add a fourth to the price.

Vitruvius (30-20 BC) *Ten Books on Architecture*. Translated by Rowland I D; eds Rowland I D & Howe T N (1999) Cambridge University Press.

Book 2 Building Materials

Chapter 3; Mud Brick Masonry

1. First, therefore, I shall discuss mud bricks, and from what type of earth they should be created. For they should not be made from sandy or pebbly clay, nor from loose sand, because if they are made from these types of earth, they will be heavy at first, and then, as rain spatters against the walls, they break down and dissolve, and the straw mixed in them will not hold together because of their unevenness. They should be made from whitish clay or red earth or even coarse sand. For these types of earth, on account of their lightness, have durability without weighing the building down, and they are easily piled together.
2. The bricks should be made in springtime or autumn, so that they dry at a uniform rate. For those prepared in midsummer are defective because when the sun has baked the outermost skin, harshly and prematurely, it makes it so that the brick looks dry when the interior has not yet dried. Then, when it later contracts in drying, it will shatter what has already dried. Thus these bricks are rendered cracked and weak. They would also be most serviceable if they were made two years earlier, as they cannot dry thoroughly before that time. If they are laid new and not entirely dry, then, when the plaster has been laid and remains there solidified, the mud bricks themselves, as they subside (in drying), cannot maintain the same level as the plaster, and as they contract they no longer bond with it, but instead pull apart at the join. Therefore the plaster, split away from the masonry of the building, can no longer stand by itself because of its flimsiness, but shatters, and the walls, having settled haphazardly, are themselves flawed. For this reason, the people of Utica would use a mud brick in the construction of walls only if it were fully dry and made five years earlier, and approved as such by judgment of a magistrate.
3. Now there are three types of mud bricks. One, which is called ‘Lydian’ in Greek, is the one which we use, 1 ½ feet long and 1 foot wide. The Greeks construct their buildings with the other two types. Of these, one is called *pentadoron,* the other, *tetradoron*. For the Greeks, called a palm a *doron*, and that is always done by the palm of the hand. Thus whatever is five palms long in every direction is a *pentadoron*, and what is four palms long is a *tetradoron*, and public works are constructed with *pentadora*, private works with *tetradora*.
4. Along with these bricks, half-bricks are made, which are laid like this: rows of bricks should be laid on one side, and rows of half bricks laid on the other. Therefore, when they are laid on the level on each side, the walls will be tied together with alternating surfaces, and the half-bricks placed over the joints lend a durability and an appearance on each side that is not unattractive.

Book 8 Styles of Concrete Masonry.

Brick Masonry.

16. If, therefore, kings of such immense power did not disdain structures with mud brick walls, kings for whom it was possible, thanks to tribute money and the booty of war, to have buildings in rubble work, or squared stone masonry or even marble, I do not think it necessary myself to look down on buildings made of (mud) brick masonry, **so long as they are roofed correctly**. I shall, however, describe that type of structure which it is not right for the Roman people to have made in the City, and I shall not neglect to mention what the causes and reasoning are for such a phenomenon.

17. The law does not permit greater thicknesses than 1½ feet to be reached in a party wall. All other walls as well, except on the narrowest of sites, have been laid to the same thickness. However, brick walls at (this thickness), unless they are going to consist of two or three layers of brick, cannot carry more than one story, whereas in a city of this grandeur and such endless density of population it is necessary to put up houses beyond number. …the problem itself imposed arriving at the expedient of tall buildings. By the use of stone piers, tile masonry and rubble work walls, heights could be built up and layered (p42) with multiple stories…(restrictions of space therefore lead to an absence of mud brick buildings in the City)…
If the plan is to use them outside the City, this is how to make them flawless even into great age: On the tops of the walls tile masonry should be put under the roof tiles to a height of about a foot and a half, and let it project like a cornice. In this way one can avoid the usual defects that occur in this type of wall, for when roof tiles are broken on the roof, or blown down by the wind, in those places where after can pour down from the tiles, the terracotta armour will not allow the brick to be harmed. 19. Instead the projection of the cornice will cast the dripping water beyond the plane of the walls, thus preserving whole the brick masonry.

Pliny the elder (23-79 AD) The Complete Works of Gaius Plinius Secundus Delphi Classics ebook (2015) Hastings. Delphi Classics Publishing

BOOK XXXV

Chapter 48 (14)

…Have we not in Africa and Spain walls of earth, known as 'formaeoan' walls, from the fact that they are moulded, rather than built, by enclosing earth within a frame of boards, constructed on either side. These walls will last for centuries, are proof against rain, wind and fire, and are superior in solidity to any cement…what person, too, is unacquainted with the fact that partition walls are made of hurdles coated with clay and that walls are constructed of unbaked bricks?

Chapter 49

Walls of Brick, the Method of Making Bricks

Earth for making bricks should never be extracted from a sandy or a gravelly soil, and still less from one that is stony; but from a stratum that is white and cretaceous, or else impregnated with red earth. If a sandy soil must be employed for the purpose, it should at least be male sand, and no other. The spring is the best season for making bricks, as

at midsummer they are apt to crack. For building, bricks that are two years old are the only ones that are approved of; and wrought material of them should be well macerated before they are made.
There are three different kinds of bricks; the Lydian, which is in use with us, a foot-and-a-half in length by a foot in breadth; the tetradon and the pentadoron…These last two kinds…are named respectively from their being four and five palms in length, the breadth being the same. The smaller kind is used in Greece for private buildings, the larger for the construction of public edifices….the Greeks have always preferred walls of brick, except in those cases where they could find silicious stone for…building, for walls of this nature will last forever….At Rome there are no buildings of this description, because a wall only a foot-and-a-half in thickness would not support more than a single-story; and by public ordinance it has been enacted that no partition should exceed that thickness…

Sextus Julius Frontinus (40-103 AD) De aquaeductae Urbis Romae Translation Bill Thayer
http://penelope.uchicago.edu/Thayer/e/roman/texts/frontinus/de_aquis/text*.html
Also **Rogers B (2003) Sextus Iulius Frontinus On the Water-Management of the City of Rome University of Vermont**

123. Repairs that should be executed without cutting off the water consist principally of masonry work (*Rogers says 'concrete work'),* which should be constructed at the right time, and conscientiously. **The suitable time for masonry work is from April 1 to November 1, but with this restriction, that the work would be best interrupted during the hottest part of the summer, because moderate weather is necessary for the masonry properly to absorb the mortar, and to solidify into one compact mass; for excessive heat of the sun is no less destructive than frost to masonry.** Nor is greater care required upon any works than upon such as are to withstand the action of water; for this reason, in accordance with principles which all know but few observe, honesty in all details of the work must be insisted upon.

125. "The consuls, Quintus Aelius Tubero and Paulus Fabius Maximus, having made a report relating to the restoration of the canals, conduits, and arches of Julia, Marcia, Appia, Tepula, and Anio, and having inquired of the Senate what it would please to order upon the subject, it has been RESOLVED: That when those canals, conduits, and arches, which Augustus Caesar promised the Senate to repair at his own cost, shall be repaired, **the earth, clay, stone, potsherds, sand, wood, etc., which are necessary for the work in hand,** shall be granted, removed, taken, and brought from the lands of private parties, their value to be appraised by some honest man, and each of these to be taken from whatever source it may most conveniently and, without injury to them, remain open and their use be permitted, as often as it is necessary for the transportation of all these things for the purposes of repairing these works."

Turton R B (1895) The Honour and Forest of Pickering Vol I London North Riding Record Society

Cost of the New Hall. (within Pickering Castle) Clearing, digging and levelling the place within the castle where the bakehouse was burnt to build there a Hall with a chamber—**building the stone walls of the Hall and chamber, getting and carrying 400 cartloads of stone, digging and carrying soil for mortar, buying 27 quarters of lime**—contract for joiners' work, wages for those employed to saw planks and joists, 152 planks for doors and windows, 80 large spikes, 600 spike nails, 1000 broadheaded nails and 20,000 tacks, 22 hinges for the doors, 28 hinges for the windows and 2600 laths with carriage for the same—lid-roofing the buildings with thin flags by piece-work, collecting moss for the same, **plastering the floors of the upper room and several walls within the chamber, making a chimney piece of Plaster of Paris,** together with the wages of the chaplain who was present at the building —

1313-1314 Duchy of Lancaster Records MINISTERS' ACCOUNTS, Bdle. I. No. 3

Ibid Vol IV

Cost of the Houses within the Castle. A carpenter 4 days mending the wind-battered roof of the old hall with old shingles—1s; 300 nails for that purpose—9d; a man 10 days roofing with tin the small kitchen, the garderobe at the corner of the kitchen, the cellar [?], outside the new hall, within the tower and porter's lodge—2s 6d **; 2 men the same time carrying straw and old hay, and serving him and making mortar to smear over the said houses — 2s 6d** ; hire of cartage to carry 6 cartloads of old hay from the Marsh to Pickering for roofing the said houses with the service of 2 men carrying the hay outside a house in the Marsh and loading the carts —2s 4d.

Malton, North Yorkshire. Medieval Charter. C15thC version.

These rights and privileges persisted until the time of James I.

Thes ar the Customys and Libertes, the qwhyche was concest and graunted to the Burgeses of New Malton; at the fyrst Fundacyon of the said Malton, be the Lord of the same: and in all the tymes hydyrward hath ben usyd.

Fyrst, it was graunted to the forsayd Burgeses, a Wast, of ather side of the Town of New Malton; **that the Burgeses and thare Successors, shall in the sayd Wastys, gett stone, and fro thens, stone and Erd take and cary, to the Edyficacyon and Beyldyng, within the sayd Town; whensoever they Wyll, and als ofte as they wyll, without Impediment of any man.** And thay shall haffe iiii Ports, that is to say, iiii Yatts. And the Walles of the said Burgage, undyr thayr own kepyng, with fre entre, and goyng out, within the said Walles of the Burgage; with All the Proffets of the said Walles, to the mendyng of the said Walls, and also the said Yatts: And the sayd Burgese e'r more hathe usyd for to pastur and to fede the Bests in ye foresayd Wasts.

All Thyse Lyberteis and Customes above wrytyn , with many othyr moo Liberteis, the qwhyche unto the Liberty of the Burgage perteyns; the fore sayd Burgeses claymes for to haffe: the qwhyche thay and thayr Anteassors liberally hafe usyd before tyme; the qwhyche tyme is withowten Mans Membrance or mynde; the qwhyche stonds now in the Clayme of ye sayd Burgeses, And also in tyme coming, for to be Claymed.

Salzman LF (1952) Building in England Down to 1540, a Documentary History Oxford. Oxford University Press.

Wattle and Daub

‘Torching’ is one of the terms applied to this plastering with mud; as for instance at the Tower in 1278 - ‘*in arcillo empto ad torchiandum’* and in 1337. ‘for torching the penthouse beside the smithy, with mud, laths and nails of the King’s finding, 10s’ *[this may be roof-work, of course]*. Sometimes other terms are used, as at Cambridge in 1486 - ‘*pro (4) bigatis de clay, 16s, item pro claying murorum 19s’,* or at a lodge the New Forest in 1368, where two men were employed digging red earth *pro parietibus plastrandis’,* though ‘plastering’ is usually applied to the finishing of a wall with plaster. The expression used at Bath in the 15th C was ‘rudying’ - as, for instance, ‘for riding the old walls of the chancel’ and ‘*pro casting de terra et rudyng’* of a house for which wattling had been made *[ruding is more likely to refer to the painting of the walls with raddle, it should be said, red pigment]*. At Penshurst in 1470 there is a reference to radelyng and daubing the walls of the barn; and carriage of clay called ‘*lombe’* for the said work’. More often the word used is, in Latin, ‘*terrand’,* which simply means earthing. For walls in Cambridge Castle, in 1267, we find ‘splenteware’ and ;batthes’ bought, and wyttthes for binding them, and a payment ‘to daubers for making the said walls and tearing the kitchen’. And in 1454, when a gable was made to a stable in Stamford, there were payments ‘to a man 2 days teryng ye same gavel xd; for 2 lodes of earth to ye same warke 6d’. The common term, however is ‘daubing’. As this is latinised indiscriminately as *dauband and dealband* and the workmen *as daubatores or dealbatores,* it is often impossible to be certain whether the process alluded to is daubing or whitewashing…At York in 1423 we find 200 stoures (stakes) provided for daubing over the kiln house, and also rods, templis, which are also rods, and withies, and similarly in 1531 at Durham rods and ‘dalbyngstours’ were bought for daubing above four fireplaces in St Giles Street. At Clarendon in 1480 payments are made for collecting rods and shredding them to make the walls in the new chamber, and for bredyng and dawbyng the same walls…’bredyng’ is the braiding or wattling between these. Often in later times, laths rather than wattles were employed, as at Sutton in 1402, when Henry Dauber was paid 113s 4d for the lathing and daubing of the walls of certain houses re-erected there, or at Clare in 1347, when money was paid for the daubing of the countrelatthynge of a room, possibly implying laths on each side of the wall. …In 1341, there is a charge for daubing the king’s room at Clare, on the outside and plastering it and for stopping cracks round the queen’s room.

To make the earth, or mortar, adhere properly it was customary to mix with it some fibrous material such as hair, straw or hay. Palsgrave, writing in 1530, says that ‘daubing may be with clay only, with lime plaster, or lome that is tempered with heare or strawe’; and two years later we find lxx stone of heare provided for the plasterers’ at Westminster, and also ‘cowheare to make mortar for dallbyng of walls,. In 1286 ‘white straw’ was bought for plastering the walls of the hall in Cambridge Castle in 1375 at Leeds Castle, 8 cartloads of straw were bought for daubing the floors and walls of various buildings. In Ripon in 1454 we have 3 wagon-loads of mud for a room, 2d spent on litter and water for the same mud, and 20d paid for two men for the daubing of the same room and the making of its floor. The churchwardens of St Michaels, Bath, used hay and straw for daubing in 1477, and those of St Mary-at-Hill, London, provided ‘strawe to make mortere with to the dawbere’ in 1491.

Closely allied to daubing was pargetting or rough-casting, the chief difference…being that in pargetting, mortar or a coarse form of plaster was used instead of clay or loam. The surface of the parget might be finished either smooth, with a coat of lime wash, or as rough-cast with sand or small stones. For work at Launceston in 1469 ‘six dozen seams of sand called roughcasting sonde and helynsonde (= covering sand) were supplied, and Thomas Lucas in the accounts for building his house at Little Saxham in 1507 distinguishes between the two types of finish: 'for lathing, row and white casting of part of my kechen range': 'for lathing, pargetting, tiring and white casting of all my roves, walls, partitions and staires': 'for lathing and laying with here (=hair) and mortar of 4 chambers, with pargetting and white casting thereof.' As early as 1237 we read of the pargetting of the wall behind the leaded chamber' at Marlborough; and at Corfe in 1285 there is reference to Stephen the Dauber who pargetted the long chamber…daubers and pargetters are identified at Wallingford in 1390: 'for 8 casters of walls and party-walls…otherwise called daubers…lathing and daubing a great gable at the west of the hall and newly lathing, daubing and pargetting a party wall of the Almerhouse - and completely casting with rowe mortar a great portion of the castle wall'…. A variant form of the word occurs in the north, as at Finchale in 1488, 'for the pargenyng and weschyng of the church', for which chalk and lime were bought; and at Durham in 1531: *'in le pargenyng et emendation foraminum'*.

Earth Mortar *[extrapolated from chapter below, p152]*

In Collyweston accounts for 1504: 'for sifting of1§ mortar earth owt of the old walls'. The expression mortar earth occurs again in 1367 in the account of some repairs to the lodge of Beaumont in the Forest of Rutland: 'for digging earth for *mortarherthe'* for the said lodge'. **Apparently when lime was not available ordinary soil was sometimes used instead** *[!!!]*. So at Clarendon in 1363 we find mention of 'digging and carriage of 2 cartloads of white earth for making mortar' and at Oxford in 1453, 'a cartload of red earth for making mortar'.

Walker S (2010) Oxford Historical Society. Building Accounts of All Souls College Oxford 1438-1443. Oxford. Boydell Press.

1438

Lime, sand and red earth

224 quarters of (quick)lime, price per quarter, including carriage 20d. £17 13s 4d
And for 42 quarters of (quick)lime at 19d per quarter
And for 23 quarters of quicklime, at 18d per quarter.

And for 312 loads of sand, 2d per load
And for red earth with sand for making mortar

(Similar 1439)

1440

For lime. Bought this year 56 quarters of (quick)lime, price per quarter 16d.

And for 246 quarters 4 bushels of lime bought, price per quarter 17d.

Dawbers

To John Mirthe, dawber for 6 days at 5d a day and his assistant for 6 days at 4d.

(Numerous further entries for daubers).

1441

For lime.

64 quarters 1 bushel at 18d per quarter; 112 quarters and 1 bushel at 17d per bushel; 6 quarters at 16d per bushel.

For sand.

For carriage of 158 loads of sand from Brokenheys (gravel pit in Oxford) at 2d per load.

For clay

For 36 loads of clay bought for the interior walls of the College at 4d per load

1442 More lime purchased.

Still daubing.

Stell P M (2003) York Bridgemasters' Accounts. York. York Archaeological Trust.

1435
…A tiler and his servant on the tenement of Davy Payntour and others…for lime…And for 400 waltyle in the tenement of Roger Joynour for a chimney…And for carriage of sand, lime and plaster…And for one mele and a half of lime…And for 27 bushels and three peckes of plaster for the same chimney…

1440

Conyngstrete. …And paid to John Sharow for three and a half bushels…and in firing a kilne of plaster in Castelgate…And paid to William Plumpton for carriage of twenty loads of lime, tiles and sand…And paid to various men for five tuns and a barrel of plaster at various times…

Castelgate. …William Plumpton for carriage of 25 loads of lime, sand and other things…And Robert Canmsmyth…**for le betyng of one kiln of plaster…And for 2000 turf for firing the plaster kiln in the aforesaid messuage…And to a labourer for betyng plaster in the same messuage…And paid to William Walker for dobyng…And paid for earth, litter, dobyng and water…**And to William Plumpton for carriage of forty loads of lime, sand and other things…**And to William Bouland, limeman, for five mele of lime**…And paid to William None for carriage earth and tiles…And to John Brigg for paving in Nessgate..And to William Plumpton for three loads of cobles.

1444

…And for firewood for burning plaster with carriage of the same…And for pounding of the same…And to Thomas Goodesalve, carrier, for carriage of three tuns of plaster…And to the same Thomas for twenty seams of lime and sand…And to Ralph Somer for two days burning plaster…And for repairing the tubes….

…For carriage of lime, sand and tiles…And to Richard Porter for carriage of lime…And for ashes of a chimney of John Herte and Joanna Guyl…And for lute and straw with working on the chimney of Elizabeth Bellows…

1445

…Paid for pounding of plaster…And paid for ashes of a chimney…Paid for carriage of three tuns of plaster…And paid…for carriage of 40 seams of sand and tiles…And paid,,,for carriage of three meles of lime…

1449

…To a man pounding plaster for one and a half days…And for 500 tiles…to tiler for 3 days…And his servant same time….And to John West for carriage of lime…And to Robert Hynderwell for carriage of thirty seams of sand…And to Thomas Killom for working on a barn in Holgate Lane for five days (and servant the same)…AAnd to Robert Hynderwell for carriage of **twenty two seams of sand and lute**…And to John Usburn for doubyng there for ten days…

1459

Paid to William Ball for piles…and for seven piles from John Forster…And paid for carriage of the aforesaid timber from the staithe and from a close of the monastery…And paid to Robert Fressell for stone flags bought and placed on the top of the aforesaid piles in the earth..And paid for a cart-load of lute bought for claying of the said piles and for repair of various walls of earth…And for wages of a labourer in claying of the same piles for half a day…And for wages of two carpenters for working and making the said post, somers, bandes and piles, and nailing of the floor of the said tenement there by the space of the foot of a man…And for wages given to John Forster, master carpenter, for his labour, advice and help…And paid for fifty sapplattes and **straw bought for mortar**…

1462

…And for wages for labouring and dobyng within the tenement of John Barneby…and paid for nine seams of lute carried to the same tenement…And paid for four bushels of plaster bought for the repair of a wall in the tenement of William Litwyn…And paid for a burdyn of lime there…

And for wages for labouring and dobyng within the tenement of John Barneby for three days…and paid for nine seams of lute carried to the same tenement…

1468

Paid to John Garnet for a cart-load of lime…and for six modii of plaister bought for repairs of a chimney…and for six bushels of plaister…and for 1000 walltiell…

Paid for carriage of seventeen seams of lute for doubyng…including 4d paid for straw bought for mixing with the same…And for wages for working and doubing…And paid to William Gayle for carriage of fifteen seams of sand to various tenements this year….

1472

Paid for three cart-loads of earth for repairs of a floor…And paid for two waggons of earth for repair of the daubed walls…And paid for straw for the same job…and paid for 50 lattes for the same job…And paid for two waggons of earth for repairs on the house in the tenure of John Barneby and the house of Michael Bradford…and paid for eighty laths for the same job…And paid to the same dawber for doubyng in the same house…And paid to two pavers for paving on Fossebrig…And paid for four carts of earth for the same paving…And paid for cobills for the same job.
(to the house of John Taillour and Isabel Santon)…for four bushels of lime…And paid to a tiler there for tiling on a houseof William Colstane..And paid for two seams of sand for the same job. And paid for 200 tiles for the same…And paid for 300 dawbing nailes…

And paid for construction of a chimney…and paid for a glass window…And paid for a modius of plaster for repairs of Isabel Santon…And paid to a plasterer plastering there…And paid for making a wall of earth in the house of William Fraunk…

1486

Stores Bought. And for various payments for two wagon-loads of burnt lime…And for 400 hartlaths price 7d per hundred…and for 700 saplaths at 6d per hundred…Nails, namely 1000 le double spikyng; 1000 mydel spikyng; 1000 skotchym; 1000 stanebrod…twenty four loads of lute…twenty loads of sand; 500 tiles for walling and for le rigge tiles. One quarter le playtre; three loads of stones; one pound of solder….

For various payments for dibyng for twenty-eight days…on various tenements…

1488

…And for purchase of a cart-load of lime bought for the store…And for the purchase of three cart-loads of lute called dobyng earth bought and used…And for the purchase of four quarters of plaister…And paid to James Broun for working and labouring for ten days in le dobyng in various tenements…

1462

Paid to John Spynk for three cart-loads of lime with 4s paid for carriage of the same and 8d for putting in le storehouse 10s 3d. And for five and a half tuns of plaister bought for a price of 2s 9d per tun plus 1d – 15s 6d

And for wages of Thomas Rymour, tiler, for working and repairing walls of plaster and tiles on the tenements of William Guislay.

(Repairs to the Bull)…and for lattes bought for the repair of various walls of earth there with 2s 8d paid to Robert Beltoft, labourer, for working and repairing several earth walls…And paid to Robert Cambyssh, paver, for working and paving the pavement in front of the said tenement…

And paid to John Botterell of Buttercrame for six bushels of plaister bought for the tenement of William Marsshall…And paid to John Savage for 800 hertlattes and 700 sapplattes…

Paid for four cart-loads of old timber….and they have paid …for three posts and new spares of timber for the same house…and paid to John Walus for two sele tre and a panpece *(ceiling beams and wall-plate)*. (Payments to carpenters)….**And paid to Thomas Plumpton for leading *sabulum* (sand) for twenty seams of earth and (daubing)…and paid to a man of Clifton for five cart-loads for daubing of a new house there and paid to John Pereson for daubing and leccyng of the said parclose in the *aula* there…And paid…for daubing the same new house by agreement made in gross. And paid to the same Thomas for working there three days receiving 4d in the day…And paid to William West for carriage of six loads of lyme for pergettyng of the same house…**And paid to Thomas Plumpton for five seams of cobles for the same job (in Gilligate). And for eight seams of wase for the same job there. **And paid for dung bought for daubing there…**

And paid to John Copper, sledman, for carriage of old timber…And paid for 30 (fagottes) with carriage of the same to the same kylns…And paid to Thomas Rymour, tiler, and his servant for working on the said kylns…And paid for 60 (words missing, probably loads of lime) and carriage of the same…and paid…for pounding of the same (lime, probably lump lime)….And paid to the same Thomas Rymour and his servant for making a plaster kiln (alabaster?)…And paid to James Porter for carriage of 60 loads of lyme…

1464

…For seven cartloads of lime bought of John Garnett…for the wages of James Porter for carriage and sledding of the same…For five tuns of plaster bought on le Stathe (of) a stranger at various times….

Paid for 3,300 thaktele…10s the thousand…And for 200 waltele (at 8d the hundred)…for 600 stanlattes…1,400 sapplattes…

Barn in Holgate. And for the wages of Nicholas Thornthwayte, carpenter, for working in the barn at Holgate…And paid to HJohn Copper for daubing for the walls there, 3d for each cart-load…And for wages of Robert Tynly, labourer, for working and repairing the earth walls there…

Skeldergate. …And for wages of William Tynly, labourer, for …daubing walls around the garden adjacent to the postern of the Friars Minor for ten days…for the wages of John Capper for whitewashing…And paid to John Capper for four cart-loads of daubing earth…And paid for straw and hay for daubing of the walls there bought from various men at various times…And paid in expenses made by Ralph Pullen, his servant James Porter for providing and leading a boat full of sand from the sandbed…namely in bread, beer and meats…And for wages of Ralph Pullen, tiler, and his servant for…tiling the house interior and making a wall called plastering for 18 days…

Bouthombarr. …for the wages of William Barley for working and labouring..in making earthen walls for two days….And for the wages of John Pereson and William Tyndale for…daubing in the tenement of Thomas Fournas for four days.

Fossgate with Fossbrygg….

For the wages of William Gaille and Andrew Blyth for carrying 326 seams of tiles, sand, lute ('liquid clay or cement used to seal a joint') and wase (bundle of hay or straw)…And to the same…for 45 seams of coble for le paving at various places this year…And for wages of John Plompton for leading sand…And to James Johnson, porter, for 146 pounds of lyme and plaster at various places this year…

D/BOH/E24
Account of the building of almshouses, Sherborne, Dorset 1440-1444

Translated from the Latin by an unknown hand.

Quarry opened on a site leased from the Bishop of Salisbury.
Easter Week.
Mason 2 ½ days scabbling stone in quarry at 6s a day
2 men carrying stone 4 ½ d each
2 masons 6 days scabbling stone
2 men carrying and digging stone
Week 3
2 masons scabbling stone 6 days each
week 4
2 masons scabbling stone 4 days each
week 5 ditto 4 ½ days
week 6 ditto 3 days
week 7 ditto 6 days
(stone diggers' and carriers' hours mirror those of the masons throughout)
Whitsun week
Mason scabbling stones 2 ½ days
Trinity week 1 mason 5 days
(more weeks of the same)

Iron Goods (all made to order)
Pykes (picks)
Crowbar (crowe)
Iron wedges (wiggis) tempered with steel
Hods (scallops) for carrying stone
Sledgehammers (slegg)
Hand barrows (Berewys) to carry earth.

41 loads of stone carried and victuals (bread, meat, cheese)
payment of women serving three men loading stone and their food

Wood.
35 oaks in gross
carrying 31 loads of same, bread, ale and other victuals.
More oak gifted.

Account No.15 1440-41

31 loads of stone from quarry
2 men and 2 horses clearing a place next to the cemetery to put stone on.

Payments to masons and meat and fish
(cementarii – first use of the term: stonelayers. Latami, otherwise).
Loads of stone carried, masons paid
53 loads of stone bought at Hampden (Ham Hill)
(masons payments vary between 4d and 6d the day: cementarii – 6d a day
latimi 5 ½ d a day (but mostly 6d), labourers 4d a day).
Carting of 13 loads of stone and sand
1 load of sand
cartage of 15 loads of clay and sand
16 sacks of lime at 6d each
3 sacks of same
saw bought for sawing stone
2 sieves bought to sift sand
Osiers for the Lodge, straw for the same
36 hurdles (cladis) for the scaffolding
13 sacks of lime

Wood – oaks felled and lopped, wainscot bought
400 laths.

No.16 1441-42

Masons wages
Carriage of stone from Sherborne
10 loads of clay (argill)
14 sacks lime
Stone deliveries, masons and labourers wages
16 sacks lime
masons
8 sacks lime
14 sacks lime
5 loads of stone and sand
5 sacks of lime
masons
6 sacks lime
labourers wages
5 loads lime, masons and labourers
6 sacks lime
3 loads stone tiles
more stone
2 loads sand
1 load stone tiles
3 loads stones from Ham Hill
9 sacks lime
lots of stone, 3 sacks lime
freestone crests (ridges)
3 sacks lime.
Paid Robt Hulle, mason for making put-log holes for the scaffolding to help the tiler
Wm Symmes for a fireplace
5 sacks lime, masons, labourers
John Hooper for 3 loads of clay
Symmes for freestone crests
13 sacks lime at 7d
1100 stone tillers (total used)
8 loads of clay 2d a load
stone
14 sacks of lime

9 loads of clay
16 loads of stone
3 loads of clay at 3d
stone 3 carts
2 loads of clay
17 sacks of lime at 6d

1 cartload freestone from Hampden (more follows)
stone tiles
John Symmes for windows (eg window at east end of the Chapel)
Wm Helyer for pointing the house 20d
6 sacks of lime
12 loads of stone (much more follows)
1 load paving stones
1 sieve

Wood (excerpts)
200 ft of board sawing
5 boards called wenskottes
In splitting 600 laths at 4d per hundred
Sawing 300 ft of board at 18d the hundred (more later)
Tacknails
Victuals when 4 trusses raised
300 lbs of lead bought
Plumber for casting 4 sheets of lead
Nails
2 lbs wax and rosin
felling 8 elms
200 lbs of lead
plumber making leaden gutter of it
100 laths, hinges, straps etc
850 board nails (many already) 16d per hundred
300 tinned nails 2/4 per 100.

No.17 1442-43

Chapel consecrated
Masons, 6 sacks lime
9 loads clay
6 of stone (and more)
masons and labourers
5 sacks lime
7 sacks lime
1000 stone tiles
more stone, lime, clay and stone tiles
crests and tablement

More wood (similar to above)

2 cartloads straw, one seam of thatching-pins
thatcher 6 ½ days at 5d per day
1 man, 1 woman serving him.

No.18
Masons payments, mainly stone-layers, labourers serving them
53 quarters of lime ‘bought at divers places for the work’
76 loads of clay and sand bought for the same

6 windows of freestone from Symmes (Norton)
2 more
10 loads of freestone
2 doz hurdles for scaffold.

Cost of tiling and stone for same
14 loads stone tiles
600 laths, 3000 lath nails, 200 board nails and hatchenails
2 loads paving stones.

Alberti L B (1460) On the Art of Building in Ten Books. New York. Dover Press.

…There are other kinds of masonry construction – some where **mud, not lime,** is used in the joints, and still others where the stones are fitted together without the support of any mortar….

Any stone to be smeared with a **mortar of clay** should be cut square, but **most importantly it must be dry;** the bricks most suited to this are fired ones, or even better, unfired ones that have been well dried out. **A wall of unfired brick is very healthy for those who live within,** completely impervious to fire and little disturbed by earthquakes; on the other hand, unless it is reasonably thick, it will not be capable of bearing the weight of the flooring. For this reason, Cato recommends that we incorporate masonry pillars in the structure to support the beams.

Some assert that mud, if it is to be used as mortar, should be **like bitumen, and they consider the best mud to be that which dissolves slowly in water, is difficult to wash off the hands, and contracts markedly on drying. Others prefer it to be sandy, being easier to mould. This sort of work ought to be coated on the outside with lime, and on the inside, if you wish, with gypsum, or even silver clay.** In order to make it adhere better, fragments of earthenware should be inserted occasionally into the cracks between the blocks during construction, so that they project like teeth and support the rendering more firmly.

Where the masonry is left uncovered, the blocks must be cut square, and they ought to be larger than usual, as well as being solid and extremely strong. There must be no infill, but the courses should be absolutely even and the joints continuous, and frequent use should be made of cramps and pins. Cramps are devices to fix two blocks together on the same level to form a continuous row. Pins…fix two blocks together one above the other, so as to prevent any rows being pushed out of line. There is little objection to cramps and pins of iron, although if we inspect the works of the ancients, we will notice how iron rusts and does not last, in contrast to brass, which lasts almost forever.

Throughout the buildings of antiquity extremely strong walls are to be found built of nothing but rubble *[concrete]*. These are constructed in the same manner as the mud walls common in Africa and Spain: a temporary form, of panelling or wickerwork, is set up as shuttering to contain the material as it is poured in, until it has hardened. The only difference is this: with the former they pour in an almost liquid dough made of aggregate; with the latter they make the mud pliable by moistening and kneading it, and then pummel it down with beetles and their feet. The ancients would insert a rubble-like layer every three feet as bonding…In Africa, they mix the mud of their earth with Spanish broom or sea rushes; the resulting work has a remarkable resistance to wind and rain.

…Walls consisting of 'shell' – as I prefer to call it…- should be constructed of seasoned wickerwork and reed matting; this is not a work of any distinction, but was often used by the plebians of ancient Rome. The wickerwork is smeared with a mixture of **mud and straw** which has been kneaded for three days. It is then dressed…with either lime or gypsum, and finally adorned with pictures or reliefs. If you mix your gypsum two to one with crushed tiles, it will have less to fear from being splashed. If mixed with lime, its strength will be enhanced. In the damp, frost or cold, **gypsum will be entirely useless.**

Summary of contract for building at Wynyard, Stockton, County Durham. 31st January 1415. Source DCRO D/LO/F 322.

This indenture between Thomas de Langton of Wynyard and Thomas Rose, Vicar of Merrington on the one part and John Todd, wright, Robert Todde of Lanchester and Nicholas Hayforth of Durham on the other, witnesses that John Todde has undertaken to make anew, well and sufficiently, with sawing and all manor of work and things to wright-craft pertaining, except timber and carriage of it, and ironwork, a cross-chamber to the hall of Thomas de Langton at Wynyard with **6 couple of posts, each couple bing from the other 11 feet, with an entry underneath to the kitchen, with an entry closet athwart, in the middle of the said chamber above and two privies to the said chamber…which chamber be sufficiently set in ground-sills ('sole trees'), wattled and daubed ('rabet and dight') in all parts to be plastered…ready for theaking by August 1st next.**
Payment of £6 by instalments.

Nun Stainton 1392.

Lease by monks of Durham to the Prioress of Nun Monkton of the whole of their estates at Nun Stainton for 200 years of one messuage and two bovates of land (24 acres). The Prioress and Convent (shall maintain etc all buildings)…- one house called Le Firehouse, containing five coples of syles and two gavelforkes; one small house…containing three coples of syles and two gavelforkes. (from Surtees Society Vol 58 p167).

Cront 749 Delaps around Northallerton c1450

The hearth-house of John Copsy needs rybbes and walplats for four rowmes, one pair of crippils, 40 tignis (rafters) and 400 lattes with clav (nails) to the value of one carpenter for 6 days found by the Lord.

Cront 753 From ZBA/11/8/1/3

Mich 1426-27. Repair of tenements. Bedale.

8 cart-loads of stone from the Park of Bedale to tenement of John Watson in Ayscogh 4/-
3 cartloads of wattlyng to same 1/6
Stipends of 2 carpenters carrying stone and clay for the same for 1 day 2/4

6 cartloads of timber for repair of house of John Clay 2/6
1 cartload of spars from Frithbylund to the same
1 cartload of stone
600 sclatestane from quarry of Hernby *(Hornby, Bedale)* to manor of Bedale at 9/- per 1000 6/3
4 cartloads of lime from Cracall to the Manor 2/8
2 cartloads of sand for the same 3/-
stipend of the carter carrying 10 quarters of lime of Burton on Yhore to Bedale 2/6
2 cartloads of clay for the Lord's house once of John Caterik in Emgate 6d
3 cartloads of old timber from the tithe grange of Ayscogh to the Manor of Bedale
2 cartloads of old timber from the tenement of Wm Walker to the Manor
2 cartloads of spars and watlyng from the Park for the repair of the tenement of Thomas Rudd in Burrell.
2 cartloads of timber for the Manor Gate from the wood
Stipend of John del Cote tiling (tegen) on the Grange, 9 days at 8d
Bread and ale for raising the house of John Watson in Ayscogh…
2 cartloads of clay for daubing (riggat) a grange.

5 cartloads of clay for repairing a wall within a tenement 1/3
carriage of lime by a hired woman 2d
4 cartloads of straw brought from the Rectory to the tenement 8d
2 cartloads of straw to the tenement of John Watson.

ZBA/11/8/1/4. Michaelmas 1429-30

Repair of the tenement of Thomas Vale
Stipend of John Thirn for cartload of timber for the buildings of one house of Thomas Gale, erected anew 19/-
Stipend of Simon Wade for the carpentry of the same…in gross 100/-

Sawing of 'tubularum' and timber 20/-
Stipend for carrying stones for walling, clay and sand 17/10
1000 laths bought for the same 10/5
4000 lathnayles bought for the same 6s
400 medilspykyngs 20d
iron bought for making chains, crokes, hasps and staples ¾
12 quarters of lime (calceto) 10/8
stones bought for roofing same house 21/6. Carriage 14/10
bread and ale at the raising 2/6
total; £11 – 14 – 5.

ZBA 11/8/1/6

Mich 1431 – 32

Repairs
Symon Ward the carpentry of a tenement lately in the tenure of Thomas Chandelier 21/4
To Thomas Felett and his mate for carriage of timber of the same 2/8
Thomas Harpour for daubing walls 11/9
Stone bought for roofing of the same, of which 9/6 for carriage.
Laths bought for same 5/10
10 quarters of lime bought for same at 9/4 for 7 quarters and 3/- for 3 quarters and for carriage.
4000 brodes 5/2
iron of Laurence Spicer for John Hamsthwayte for crokys, chains and nails 2/5
Bread, ale and cheese at the raising ¼
Roofing.
Total 116/5 ½

(lime for finish coats over earth plasters)

ZBA 11/8/1/7 Mich 1432-33

John Pygot for walling le Yatehouse of the Manor 10d
Thomas Harpur hewing and 'stauryng' the same 4/-
6 cartloads of earth for the same 18d
1 quarter of lime (calcet) 8/-
3 cartloads of sand
Schlatstanes bought at Langthorne for roofing the same manor 6/-
Carriage of the same by two mule-drivers 2/2
To Thomas Schlater for roofing 3 roods of a chamber called Dungron and another called Yatehouse 15/-
Same for mending great chamber on east side 4/-
Paid for carriage of baysestanes for the grange in the tenement of John Chalenor 10d
2 cartloads of wood for the same for wattling and daubing the same 12d.

ZBA 11/8/1/8 Mich 1433-34

Carriage of 19 cartloads of stone for the grange of John Hampthwayte 4/9
Carriage of 11 cartloads of earth and clay to the same 2/9

ZBA 11/8/1/10 Mich 1442-43

Excerpts.

To Wm Godale, carpenter. For making anew a small house in the said messuage
To the same for soleing (soland) lez Stothis et postis within the said house
Collecting several stones called baystonis and carrying
Cutting stoups and carriage from the Lord's wood to said house
Digging and laying in the cart **7 cartloads of clay** with carriage from le stonecannse to said messuage
To Robert Morland hired for 'peyntyng and betyng 7 rood in said capital house
3 quarters of burnt lime at 16d per quarter
2 cartloads of sand.

To Cole and Clapham, labourers, hired for mending walls of (John Burrel) in places
Carrying 2 cartloads of clay from le stonecannse to said house

Carrying 5 cartloads of sand
6 quarters of lime.

John Punderson hired for making anew one wall of a house within the manor called le Carthous
1 quarter burnt lime for same
1 cartload of sand.

To John Hamswayt hired to cut and carry from the wood to (Wm Coltonn) house one cartload of 'dowbynstawris'
To Thomas Clapham constructing and daubing the wall of said house
To John Cartere of Harnby for 2600 slatstonis for roofing said house
…**To Wm Symondeson for 7 quarters of burnt lime for the said walls**
To John Hamswey carrying lime from Ffrtheby to said house
To same for digging, laying and carrying 13 cartloads of calay for said house
To same for 3 cartloads of sand.

To John Hamsweyt for cutting and carting 1 cartload of underwood to said grange (of Robert Medilton) for walling the same
To same for digging 3 cartloads of clay for said grange
To Thomas Clapham for mending and daubing walls and for roofing the same.

Thatching.

2 cartloads of timber from the Lord's wood for the messuage of Wm Smyth.
John Hamsweyt for 4 cartloads of clay for the same

…one sieve for sifting burnt lime
one vessel called a 'bolle'

ZBA 11/8/1/11 Mich 1443-44

To Robert Morton, Parson, for 60 threaves of rye straw for roofing of a capital house in the tenure of Wm Smyth at 2d a thrave
To Margaret Hoddeson for drawing said straw for roofing
To John Hamsweyt for 6 cartloads of stone from the field of Brell to said house
To same for digging 12 cartloads of clay from the stonycawnsey for same
2000 lathnayle
3 cartloads of underwood called wattelyng from the Lord's wood
7 cartloads of clay and carriage from Crynggilgate to the house
To Richard Durrell and Rob Medilton for 60 thraves of barley straw for roofing
To John Webster for 20 thraves of wheat straw.

ZBA 11/8/1/19 1454-55

To Simon Bynkes, carpenter, for one pair of mylletrendles bought for the water mill
To Wm Smyth for a new loop of iron bought for the mill
To John Lofthous for planks bought for part of the millwheel called lez almes mending
To Thomas Herryson for one piece of timber called walplate lying on the wall of the mill, defective, with carriage from the Lord's mill
To Wm Slater of Exylby for roofing the mill house in various places with burnt lime and le slatestones and mending the roofing of the Town Hall
Thomas Cole for mending the wall of the mill in places with clay.

Northamptonshire Archives

Fitzwilliam Misc Vol 432

The Booke of Moneye Laid out about the Building and Repairing of the House.
1579

To the plasterer for a daies worke

For iiij strike of lime at ij d the strike *(a strike was a measure of dry volume – usually half a bushel).*
To a mason for mending the chimney in the great chamber
For iiij strike of heare
ij bundles of lath…
lime iij fooder at ij s ij d…
to Foster the Mason for a daies worke
to hod man
to his labourer…
to the carpenter for ij daies work at xd the day
to the dauber for work at vj d the day…
for the splitting of a tree into boorde…
to the thacker for ij dayes work finding himself…
for a lode of stone…
to the slater for his daies work & his boyes

1581

…for x toone of stone….
To the Slaters charged by the roode…
For lime not the carriage thereof…
For vij bundles of lath…
For riving of lath
The charges of victuals in my absence for the carters that brought me some stone, timber and slate…
For iiij lode of plaister at vi d
For the thacker at x d a day…
For digging of earth & daubing iiij
For a fooder & demi of lime at 1j s ii d the fooder…
Digging of stone…
Forty & five lode of timber

1582
…for brick beside mine….
To the plaisterer for plaistering of xiiij roodes demi & viij yards at vj s the roode…
For digging the foundation of the wall
To the masons….
For sand…
For xiiij fooder of lime…
For ij T & demi of reede for plaistering at iij s T and the charges for bringing it home

Dorset Archives DC-BTB/M/15 Building of the Market House, Bridport 1593.

(*Earth is not mentioned, but lime is, in relatively small quantity. The mortar almost certainly of earth, possibly earth-lime).*

Account of Henry Brohane (?)…collector for the buyldinge of the Market House and Scole House of Bridport…(and of the Gifte of freestone for the building from the right honourable Lady Cromton out of Chideock quarries, as follows

Item paid 3 carpenters for 4 days work
Item paid for drawing of stones
Item paid to Corbyn and Pullam for ?
Item paid Hardy for carriage of iij loads of stones from Chideock(?)
Item to John Hamborne for vij lode of stones carried from Chideock
Item to Corbyn for walling of the ?
Item to Corbyn and Skerry for vj dayes for drawing of stones..
Item to Prince for his horse hair(?)
Item for carriage of tymber
Item for viij hogsetts of lyme…
Item to the stone drawers
Item to Hamborne for vj lode of stones carrying from Chideock
Item to Hardy for vj lode of stones carrying from Chideock…
Item to ij persons for help
Item for help loding stone
Item to the stone drawers
Item for xiiij hogsheads of bere…
Item for mutton
Item for ij quarte of wyne (5 more quarts)
Item for a peck of wheat for cake
Item for a quarter of beef (and more beef)
Item for mutton…
Item for ij capons
Item for butter…
To Hardy for iij calves
To Hardy for half a mutton…
Item for mackerel
Item for butter…
Item for rope and candles
Item for baking of bread…

Welch E (1967) Plymouth Building Accounts of the Sixteenth and Seventeenth Centuries. Devon and Cornwall Record Society.

The early Guildhall was a stone building, of immediately local limestone and of 'moorstone' brought down from Dartmoor. Moorstone was the softer, more weathered and tractable granite that might be won from the surface, rather than deep-quarried; the roof was stone slated. Deliveries of sand and lime, but not of earth suggest lime-sand mortars, lest earth was being won on site. For the new, *later Guildhall, however, lime, sand and earth is carried to site, suggesting earth-lime mortars improved before use by the addition of sand. The evidence of the Shambles and later Guildhall accounts is that the mortars were both earth-lime and lime – the former probably forming the bedding mortar; possibly the base-coat plasters, although when plasterers are being paid, lime, lime-ashes, sand and hair are also listed. It may be that the interior plastering was effected with haired earth-lime and then haired lime-sand finish mortars; with the exterior plastering haired lime and sand mortars throughout. The Orpanage accounts show lime and sand for the moorstone masonry, though earth may have been won in situ. Towards the end of the project, payments are made for 'white hair', as well as the first specific payments for 'quenching' and sifting lime. This would indicate that the finish plasters are being made from dry-slaked and sieved lime to facilitate the removal of lumps. The finish coat almost certainly comprised lime and (white) hair only. By implication, all other mortars, of both earth and lime, were being hot mixed. The lump lime for the Guildhall is being carried and stored in canvas sacks, not by the load or in barrels, at least to the site itself. There was a kiln close to the site, but carriage costs for burned lime to the site are high. Stone, although quarried only a mile away, was loaded onto boats which brought it within ¼ mile of the site; the same seems to have occurred with the lime, hence the need for limesacks. Sand was drawn from the rivers. Lime ashes are as commonly delivered as lime. Lime ashes are a mixture of fuel ash and quicklime, but would make a pozzolanic mortar slaked together on their own or as a gauge for clean lime mortars. Lime ashes likely preferred for the below-ground masonry, laying floors upon; perhaps in the roof works, perhaps as a general pozzalanic addition. Plymouth limestone, as Smeaton demonstrated in 1756, produces a fat lime for all that it is hard and dense and will take a polish.*

At the Guildhall, lime is being burned in the 'town kiln' – associated payments are for burning and carrying the lime, not for the limestone or lime itself. There are entries for sand and for earth. Most payments to day-workers do not identify the work for which they are being paid. Generally, three trades are using lime – masons, plasterers and roofers.

The Shambles and the Guildhall 1606-1607

The Shambles

July 1606

The first weeke

To the Masons:

Thomas Creese 3 dayes 3s
John Werye 3 dayes 3s

To Lawrence Hunne for carieng 1 bote (boat) of Stones 2s
To Thomas Skorye for 2 doss of earthe 3s *['doss' is an unknown measure, the author thinks a small amount, which seems most unlikely, as it costs 3 times the cost of a quarter of sand]*
Paid for 1 quarter of sand 1s
To Alise Jory for bearinge 1 quarter of sande, 1 quarter of Lyme ashes and 1 quarter Lyme 1s 6d

The seconde weeke

To Richard Shepheard for 4 doss of earthe…
To George Palmer for 6 botes of stones at 4s per bote…
To Thomas Nyle for 5 botes of stones…
To Phillip Tookerman…in parte of payment for paving

Item to Alice Joyce for carienge of 12 bushels of Lyme and 4 quarters of Lymes Ashes…
To Lawrence Hunne for carienge 4 botes of stones…
[£2 4s 6d paid to the Masons this week and £2 8s 8d the following week].

August

Item for carienge of 1 doss of earthe 1s 6d…
[15s paid to labourers for 18 man days]…
To Alice Jorye for carienge 3 quarters and 6 bushels of Lyme Ashes and 2 bushels of Lyme 2s.

[Significant payments to carpenters, masons, labourers, sawyers, helliers (roofers) and Pavers]…

To Walter Symons for carieng 20 doss of Ruble…
To Alice Jory for caryeng of 2 quarters of lyme more to her for 14 bushels of sand and the carryage…

The fifth weeke
For 4 bushels of heare (hair) at 8d per bushel
For 2 doss of earthe caryeng away…
For 6 bushels of heare at 9d per bushel…

Item to Alice Jory for carieng 22 bushels of lyme and 8 bushels of sand, and for the sand…

[Payments to the above trades *and* to Plasterers for the first time]:

2 labourers **beating mortar** eache 3 days at 8d per day….

Sixth week

Item to Alice Jory for bearing 1 quarter and ½ of Lyme, 2 bushels of sand and 1 quarter 2 bushels of Lyme Ashes and for the sand…
12 bushels of heare…

[Payments this week to Helliers, Sawyers, Plasterers, Pavers, but *not to masons*]

Seventh week

To Alice Jory for caryeng 1 quarter and ½ of Lyme

[payments to carpenters, sawyers, plasterers, roofers].

Eighth week.

[Payments to plasterers, roofers, carpenters]

To Alice Jory for carieng 1 quarter 7 bushels of Lyme
More for carieng 1 quarter of Lyme Ashes

Best H (1641) Rural Economy in Yorkshire, Being the Farming and Account Books of Henry Best. Published 1857 George Andrews.

When they are to make a new barne floore, they grave it all over, and then rake it all over with hey rakes or iron waine rakes till the mowles be indifferent small; then they bringe water in seas and in greate tubes or hogsheads on sleddes and water it till it bee as soft as morter, or almost as a puddle; then lette it lye a fortnight, till the water bee settled in that it beginner to waxe harde again, and then beate it downe smooth with broad flatte peeces of wood. When a floore is decayed , that there are holes worne, they usually leade as many coupe loades of red clay, or else clottes from the faugh field, as will serve, but they must not leade theire clottes from such places where the clay is not mixed with sands; and then when it commeth, theire manner is for one to stand will a mell and breake the clottes small, another hath a showle and showleth the mowles into the hole, the third and all the rest have rammers for ramming and beating the earth down into the hole….then they water it, and lette it lye three or foure dayes to mawme, for if they shoulde ram it presently it would cleam to the beater: we use to digge and leade clay for our barne from John Bonwickes hill.

P145 In summer-time wee usually fetch clottes out of the field to make morter on, but in winter wee eyther shoole up some dirte togeather, in some such place as is free from gravle and stones, or otherwise wee digge downe some olde clay or mudde-wall that is of noe use, or else grave up some earth, and water it, and tewe it. Morter neaver doeth well unlesse it bee well wrought in, viz.; except it bee well watered and tewed; and it is accounted soe much the better if it bee watered over night, and have nights time to steepe in. In makinge of morter, yow are first to breake the earth very small, and with your spade to throwe out all the stones yow can finde, and then to water it and tewe it well, till it bee soe soft that it will allmost runne; then lette it stande a while till the water sattle somethinge from it, and it will bee very good morter….

They that make the morter have allwayes by them an olde spade to tewe it with, and a little two gallon skeele to fetch water in, and two olde scuttles to carry up morter in, viz.; one for the server, and another for the thacker-drawer, if occasion soe require; and theire manner is to putte an handfull or two of dry-strawe into the bottomes of the scuttles to keepe the scuttles cleane, and that the morter may goe readily out and not cleave to the scuttles.

A thatcher hath usually to folkes to waite on him, viz. ; one to drawe out the thatch and make it into bottles, and the other to make morter and serve him ; unlesse it bee when they come to morter the rigge of an howse, and then the thacke-drawer giveth over (p146) clrawinge, and worketh amongst the morter, and filleth the scuttles as the thatcher throweth them downe; and the other doth nothinge but carry up to the toppe….

The mudde-wall, that goeth from the ende of the West- howse to the Gardens bricke-wall-side, served George Wise two whole dayes afore hee got it eized, and the eize cutte; it was eized with stubble and haver-strawe mixed togeather, and wee had three folkes imployed aboute it beside the thatcher, viz.; a woman that drewe thacke constantly, a boy that did nothinge but tewe morter and carry it up, and the third did sometimes help to drawe thacke, and otherwhiles make morter, and helpe to tewe it…

att the last of all, hee taketh a girlinge of stubble, and lyeth over thwart the other strawe; for it is layd eaven forwards as a wall goeth; and thereon hee lyeth his morter: hee standeth upon the wall himselfe, and carryeth up aboute halfe a yard, or betwixt a foote and halfe a yard, att a course, to which hee constantly useth three scuttles full of morter; and in layinge on of his morter, his manner is to take the strawe that is in the bottome of the scuttles, and thrust the morter downe as lowe as hee thinketh good, and then to plaine it with his trowell.

Plat H (1653) The Jewel House of Art and Nature, containing Divers Rare and Profitable Inventions, together with sundry new Experiments in the Art of Husbandry…London Bernard Alsop

P73

92. A profitable and cheap Morter for building wherein either no Lime or small store of Lime shall be requisite.

A Wise, wealthy,and ancient Sope-boiler, dwelling without Algate, hath for the better encouragement of others , long since erected a fair and stately edifice of brick for his own habitation, upon the good successe whereof, he hath also very lately built one other house of some charge and good receipt, the morter whereof did consist **of two loads of waste Sope ashes, one load of Lime, one load of loam, and one load of Woolwich sand.**
So likewise one other of the same faculty, being likewise of good credit and great experience, hath used onely loam and sope-ashes tempered and wrought together instead of morter, whereby he hath laid both the foundations, chimneys, and their tunnels in his dwelling house (p74) in Southwark, and they have endured those storms already which have overturned many others, both new and old tunnels, that hath been built with the ordinary morter. It may be many limemen, and some of those Bricklayers that are in fee with them, may bend their force against this new practice, and labour to

discredit the same by all means possible, but there is no reason that can hold against experience nor no malice so great, but that truth in her time shall not be thought a competent number to give credit to a new invention. I will upon reasonable request and warning, back and confirm them, with threescore more at the least, which I can produce, already made and executed within the City of London, and the Suburbs thereof, insomuch that whosoever will take a careful view of our late buildings that consist of Brickwork (especially within the Suburbs of the City) he shall find great store of these waste ashes to be imployed in them.

Fitzwilliam Misc Vol 50.

Building of new stable 1674

Accompt of what Money paid to severall men for the carridges and other materials for the Building of a new stable at the Bull in Setchy (*Setchey in Norfolk)*.

May 15 (to two men) a daies work to take ye stone out…at ye Brewhouse yard at ?? Bridge
May 20 to ye same men for pulling down a wall at ye Bridge
June 2 paid for loading 3 carts at Mr Goodings of Lynn with spars and deales
June 5 paid Rich Kempe for 12 load of Clay digging in Runton (Runcton, near Lynn and Setchey).

June 11 paid for loading 4 carts with timber
June 15 paid Alcock for 6 chalder of lime at 10s per chalder
Paid Francis Lamkin the mason
Paid Mr Pepper in full for 65 loads of stone
Paid Robert Sill in full for carting worke
Paid Francis Lamkin more in part of his work at ye Stable
Paid James Everall for carting stone, sand, clay & 3 loads of timber from Lynn
Paid smith for spikens for the rofe of ye stable
Paid for one hundred of nailes
Paid Francis Lamkin more in part of ye same worke
August 4 paid Bonhall for 8 chalder of lime…
Paid Thacker in part for sufficiently laying a coate of Read upon ye new stable
To Wm Rogers for 4000 & a halfe of brick
To Wm Rogers for 10 dozen of rush rope
To ironwork

September 4 Paid Mr Case of Stow Bridge for 2000 of Brick
Sept 5 Paid James Everall more for carting
Paid for 2 load of Thack to Rofe the stable with
Paid for 30 loads of sand
13 payment in full for the thacking the stable
24 paid Francis Lamkin Mason for one daies work of himself and 5 men more at the Bull wall

29 paid the carpinder in part
October 4 paid more for thack
6 paid more for 5 dozen of rush rope
9 paid for carrying and fetching of Mr Dickenson's ladder…
(timber and deale)
19 paid Kemp for levelling the Barn floore
24 paid for 1000 & ½ of nailes for paleing worke
28 paid Nicolas Love, Carpinder more for worke
Nov 6 paid Mr Spencely for 6500 of Read
14 paid Kelke for two chalder of Lime
16 paid Rogers of Magdalen for 500 of Brick
17 paid Love, Carpinder in full
paid Setchly smith for hooks and hinges for the windows
paid Lamken in full

1675 General accounts

October 10 paid Tho: Handly Mason for worke at Tho: Wilsons House
Paid for brick for the same worke
Paid for a load of clay for the same worke
Paid for a load of sand for the same worke

…21 paid Gurton for **2 load of Clay carrying for Sam: Barker's house in Westwinch…**
August 9th paid Wm Grasby the Mortarman for 6 daies worke

1693

paid (Edwd Seyton) what he paid John Sutton in full for digging mortar for himself and ye other men…
paid Goodman Shaw for 4 loades of Sutton stone Coins
paid Seyton and he paid Bradery wife for digging Mortar by the Loade- 33 loads

Fitzwilliam Misc Vol 96 1714 wages.

Wages paid on Saturday night at the Angel Coffee House.

Robt Smith 25 loads of Rubish at 4d; 10 loads of stone at 9d
Paid Francis Baxter in part for sand
Robt Arnold for freestone work
Paid the Ruff masons this week £4-6s…

May-June Deliveries of stone, sand and lime to the Angel

To 12th June
Paid John Draper for 10 loads of Mortar at 10d
Paid the freemasons in part this week

Paid the Ruffmasons in part
The bricklayers in part this week
Paid John Manningson 2 chaldron ½ of lime

To July 1st
Paid the Ruffmasons this week £10-10s
Paid the freemasons this week £4
Paid Robt Smith for Mortar & carriages £3-15-6
(Timber and carpenters wages)
paid Wm Dunton for throwing the water
paid the carpenter for making the gutter at the Coffee House
(lots of timber)

to the 4th July

toll for 3 teams at Deeping
Nicholas Church for 6 loades of Mortar
Paid for landing 14000 Bricks at the Market Side 4 men
Paid the bricklayers this week
Paid the Ruffmasons this week
Paid John Loving loading of stone 1 day at 16d
Old Holmes labourer 4 days at 12d…
Paid Shaw of Sutton for 1 load of Sutton (stone)

To 18th July – disbursements this week at Peterborough
Toll for 1 load of rotten stone
John Loving 1 day loading stone
The ruffmasons this week in part
The bricklayers this week
John Coy John Baxter throwing the water in the Lane…
Anthony Ward for removing 6 load of Lime from the Coffee House to the Angel

To 8th August
Paid for carriage of stone & mortar
The bricklayers this week
The ruffmasons this week
Mr Wilkinson of Ketton for stone
Paid for carrying of 14500 bricks from the Rudge to the Coffee House & Angel
Paid for carrying of 3 loads of Lime from the Coffee House to the Angel at 8d the load

To 29th August
….paid the carpenter for slotting a beam & hewing several others that came from Lynn
paid Anthony Ward for carrying 12 loads of Mud from Bongate for the Arches
paid Mr Westwood of Wisbech for bricks
paid for carrying of 4 loads of stone from the Coffee House to the Angel

paid Anthony Ward for carrying of 9 loads of timber from the Bishops Yard to the Angel

To September 5th
Paid the ruffmasons this week
Paid for carrying of 117 loads of stone from Mr Wallsoms
15 loads of brick from the water side
8 loads of stone from Mr Billings
55 loads of mortar from Mr Turners barns carried
3 loads of stone
8 loads of timber
robt Smith 30 loads of stone from Mr Wall's house
5 loads of brick from the water side
4 loads of stone
47 loads of mortar and carriage at 2s the load
paid for carriage of mortar and stone
(Labourers wages)..
paid for carrying Timber for the roofe of the Little Stable
lime 1 load at the Angel.

To the 24th October
Paid for 1 bushell & ½ shells & 2 bushells of Dust for the bricklayers to pave the Cellar Flowers

To 29th May 1715
…Gave to the workmen for making mortar 1 night
paid for making 4 trays to hold mortar…

Machin R (Ed) (1983) The Building Accounts of Mapperton Rectory 1699-1703. Dorset Record Society

(Quarrying account)

1699

May & June

Pd Wm Crowther for 5 days work and a half at opening the Quarry and drawing of stones in the Parsonage orchard
Pd Wm Crowther for 6 days at drawing stones in the said quarry 5s…
Pd Arthur Evans for 4 days work at drawing stones in the said quarry 3s 4d

(Both are paid for the sameuntil September when both are paid for ‘throwing earth’ and ‘filling the earth’ into the quarry.

(Quarrying begins again on April 12th 1701, but by Crowther and Richard Burbridge. and continues into August, with 36 man days expended in October).

(Hamstone account)

1699

July. Pd for Ale given to the Carters at bargaining for carriage of the stones from Ham Hill
31st July. Paid the freemasons in earnest for and in part of their money to be paid them by agreement for the Windows etc…
Nov 27th. Paid the Hamhill Masons more in full for the Windows, Tunns (Turns?). Somers, Trusses and 60 foot of water table for the Parsonage house….
Pd Tho: Knight and Sam Strood for half a days work each for putting the Windows into house to preserve them from frost.

1701

Dec 13th Pd Hamhill Quarries for 13 foot of Natched water table to perfect the house.

1700

August 26th Pd the Newmans in part for carriage of the Hamhill windows
Sept 9th. Pd the Newmans more in full for the carriage of the 20 two-light Windows
Nov 19th. Pd the Newmans more in part for the carriage of the 4 single-light windows, tunns, etc (‘turns’ are likely the hood mouldings over the windows, though the glossary says chimney stones)

1701
July 26th. Pd Richard Hardy for bringing the great Parlour Clavel and jamb (Clavel the fireplace lintel).
Sept 9th Pd the Newmans in full for bringing the Tuns, Water Tables, Somers, Trusses and other stone
Nov 20th Pd John Munden for bringing of a pair of Trusses from Hamhill to perfect the work.

(Carpentry account)

1700
Nov 19 Pd John Clark in consideration of the carriage of the binding beams etc
Jan 4th Pd John Clarke in part for the timber for the roof

1701
Aug 16th Pd Danial Wade for a day’s work in making of Centers for the Arches of the Windows and doorsand felling and hewing the clavel for the kitchen both himself and son…
Oct 22nd Pd Will Clift for making 88 deal window Barrs
Dec 6th Pd John Clarke in full of his bargain for the Roof of the House
Jan 23rd Pd George Shepherd for 1600 of Heart Lathes at 17d per 100
Jan 23rd Pd Tho: Wilkins for 102 foot of Inch Oake Board at 2d per foot
Mar 7th Pd Richard Brodrepp Esq for 150 deal boards…
Mar 11th Pd (Clarke) for 17 jysts and 16 foot of square timber in two pieces…
Pd him for lathing of 11 Lathes of the parsonage house

1702
June 17th Pd Mr James Daw of Evershot for 34 Oake Boards containing 244 foot at 17s 6d per hundred

Pd Mr Daw more for 50 Elme Boards containing in the whole 439 foot at 12s per hundred
June 20th Pd John Roper the Carpenter for 12 ½ days work at framing Speers at 1s 2d per day…
Pd Dan: Wade for 6 days work for himself and son viz two days at sawing Jysts for the Kitchen and four days for sawing timber for roofing the Brewhouse…
July 18 Pd Wm Clift senr for 9 days work about planning oake and deal boards for Laying ye Rooms…

(Thatching account)

1701
Dec 2nd Pd farmer Hounsel for half a hundred of Reed and carriage
16th Pd Wm Angel for 1400 of Osier Twigs for the house
Pd him for 1400 of Ledgers for thatching the house
Jan 17th Pd Mr Hallet of Wooth for 200 reed sheaves…
Jan 20th Pd the Thatcher for Thatching the house 50s and gave him to drink 1s
March 11th Pd Mr Banger of Burcombe for 91 reed sheaves and carriage…
1702
March 26th pd Mr John Hennell for 100 reed sheaves
1703
May 10th Pd Mr Hain of Catstock for 100 reed sheaves …
Oct 15 Pd Wm Cole the Thatcher for 4 ½ days work for himself and boy
Pd Wm Cole for 500 Sparrs used on the skilling (lean-to)
Pd him for 200 Osier twigs used on the same
Pd him for 120 Hooks for the same use
Pd farmer Nich: Pitman for half a hundred of Reed.

(Masons account)

1700
Jan 9th Gave the masons to drink on conclusion of the Bargain for the House
21st Gave the masons the consideration money given them by agreement to find themselves in drink whilst about the building.
March 6th Pd Edward Hitt for a Grinding stone for ye Masons and Carpenters

1701
Oct 18 Pd the Masons in part for building the House £20
Nov 22 Pd the Masons more in part for building ye House £28
Pd them for work done in the Quarry in cutting out Clavell & Jambs & Durnheads
Pd them for hewing the Clavel & Jamb of one of the chamber chimneys which was not included in their Bargain
Pd them for hewing the Skew Stones that were not included in ye Bargain.
Dec 3rd Pd Mr Stone for a Dozen of Hurdles for scaffolds
1701
Feb 21st For Paper & Stamp duty on which the Articles of Agreement with the Masons were written.
1702
March 25th Pd Thomas Gale the Mason for 48 days work about the Skilling house and hewing the partition stones at 1s 2d the day.
March 25th **Pd Rich: Brodrepp Esq for Lyme for ye house and Skilling 0-2-11**

25th Pd Sam: Gale for 2 ½ days work about ye Skilling
Pd him for 9 days work for his boy attending them.
April 30th Gave the Axminster Quarries to drink upon concluding for the Pavement.
June 20th Pd the Axminster Masons for 577 foot of pavement and for Laying and bringing ye same at 4 ½ d the foot
Pd Tho: Gale of Lostcombe for 4 days work at daubing of Speers in the Lower Rooms…
July 4th Pd Henry Knight for 2 days work at mixing Mortar and carrying the same for making the Spears (this may be earth or earth-lime mortar)
11th Pd Tho: Knight Junr for a day's work digging Earth against Ryelands to daub ye Spears
Aug 12th Pd Tho: Gale the Mason for 2 days work laying the partition stones in the Rooms
Pd Tho: Gale ye Mason for 5 days work daubing ye Spears
Pd him for 5 days work about hewing stones for the Kitchen Buttry pavement
Pd Tho: Gale the Mason for 3 days work about walling in the Lyons and Laying ye window boards
Oct 3rd **Pd John Lack Jnr for 4 days daubing ye Chamber Spears 4s**
Pd Tho: Gale of Melplash for 4 days work with him 4s 8d
March 20th Pd Tho: Gale ye Mason for 4 days work at ye same 4s 8d…
Paid him for 16 days work about hewing and setting of the pavement in the porch and Kitchen chimney and the 3 Thrasholds and ye 2 small chimney hearths.
(Gale and boy working on making furnace and oven.

(Other expenses)

1701
May 31st Pd Sam'll Stroode & Abraham Crandon for pulling down the timber and walls of the old Parsonage House
Pd Wm Cole the Thatcher for pulling down ye Thatch…
Pd Tho: Banger for a cheese for the Masons & Carpenters ay=t their setting up ye Couples
Pd for half a peck of Wheat to make a Loaf for them
Pd Mr Purchase for 3 bushells of Malt, old measure, to Brew half an Hogshead of Ale for them…
Pd Ric: Hine (for) Clamps, Boardnails and Iron crooks for the scaffolds.
(Payments for many nails, for casements, bolts, staples, latches and catches, iron bar)

(Carpenters and Joiners wage account and timber beginning August 1st 1702 – stairs, doors, door casements, oak boards, bottle racks and shelves, joists, partitions)

Paid the Plaisterers etc and for Materials etc

1702
Sept 4th Paid a Lyme Burner of Uplime for 5 sacks of Lyme for plaistering at 2s 8d per sack ***Uplime is on the Lower Lias formation but also had deposits of much purer lime – would a hydraulic lias lime be used for interior plastering over earth base-coats already applied by the masons?)***
Oct 22nd Pd George Shepherd for 30 hundred (3000) sap lathes
29th Pd the Lime Burner of Uplime for 6 sacks of lime more
Pd Elias Combe for 3 Hogsheads of Lime for Brown Mortar ***(is this earth-lime mortar?)***

Nov 7th Pd for 10 bushells of white Goat's Hair net bought at Preston for the white Mortar *(Blue Lias lime would not deliver 'white mortar', lest White Lias was used)*…
Dec 23rd Pd John Manning for plaistering my Wives closet with 2 Mortars at 2d per yard
Pd John Manning for plaistering the Kitchen chamber with two Mortars…
Pd him for plaistering the Hall chamber (and the passage chamber, little Parlour, Kitchen and passage out of the Hall)
Dec 23rd Pd John Manning for plaistering the Hall being 77 yards 4 foot 11 inches…
Pd him for plaistering the Buttry next the entry with one Mortar…(also the Kitchen Buttery)…<u>Pd him for pointing of 27 windows now glazed at 1 ½ d per light</u>
Paid him for going to Preston to buy Goat's Hair for the White Mortar
Pd him for his Man helping home of sand for the work

Jan 2nd Pd Jno Legg the Tanner for 10 bushells of Color'd Hair at 6d per bushel
Pd him for 2 bushells and half of white hair at 1s 6d per bushel
Pd James Shepton for 41 bushells of Black and White Hair…

1703
April 15th Pd John Leg's Wife of Hook for 4 bushells of color'd hair
19th Pd John Manning for Rusticking the Dutch Cap Windows as by agreement with him
Pd him for white washing the two Butterys
Pd him for Glew he bought to make size
Augt 11th Pd him for plaistering the Porch with two Mortars…
Pd him for plaistering ye study with two Mortars
Pd John Manning for pointing of 15 Window Lights
Oct 14th Pd the Lime Burner for 2 Hogsheads of Lime used about the plaistering of the Porch, Studdy etc

(Account for glazing and painting).

July ye 3rd 1706

Pd for plaistering my Parlour and the chamber over it as followeth:
Pd Wm Clift for three days work for himself and son
Pd for 5 Hogsheads of Lime
Pd Legg the Tanner for Black & White Hair
For lath nails
Pd John Stone for plaistering

(Later Accounts)

Oct ye 27th 1704
Laid out for repairing My Chancel as followeth:
For Lime 13s 4d
For 300 of Potter's Tiles & 4 Cresses (ridges)
For lath nails
For 17 foot of Water Table & a Summer
For laths
Pd Dan: Wade for work…Pd John Stone for 16 days work for himself & son….

May ye 3rd 1706

Pd for Building my Barn & Stable, as followeth:

Pd Sam: Gale & son for building the walls 10-5-0
Pd Dan: Wade for 42 days work about the Barn & Stable for himself & son 3-13-4
For a Bushell of Lime 0-0-6 *(this is a relatively small quantity, indicating that the primary mortar will be earth, with a little lime added)*
Pd George Demot for Lath & other nails 0-16-0
For hooks for the Stable Door 0-1-0
Pd Hugh Silt for Lathes 0-7-6
Pd for 300 of Reed 2-19-0
Pd Phil: Shinner (Skinner?) for twenty days work in thatching my Barn & Stable & for flakes, spars, hooks & twigs 1-16-?

July ye 25th 1720

Laid out for Tiling My Chancel
For 4 sacks of Lime 0-10-0
For nails 0-10-6
For carpenters work 0-3-6
For a piece of timber 0-2-0
Pd for 600 of laths 0-9-0
Pd for a bag of lime 0-1-3
Pd Henry Townser for work done about my Chancel 1-15-6
Pd for a peck of Hair 0-0-4
Paid the Pottman for 1000 Pan tile *(clearly locally made)* 1-0-0
Pd the Potteman for 4 Creas Tile 0-1-0

Appendix. Contracts for Building a House at Evershot. (DC- Ilchester Collections D124).

(This clearly shows that separate agreements were made with each tradesman for their part in the construction process. It also quantifies the traditional measures and hee).

Mem: about the house of John Biddells intended to be built in Evershot.

14th May 1715

Agreed with Joseph Chiles as followeth viz that hee shall worke, fitte and sett up in a good Workmanlike manner the Timber work of the floores viz Girders, Jestes etc and of the Roofe and also the doore cases and Windowes att 9s per square viz **10 feet square** and hee is to use as much of the old stuffe that comes out of the house as possible hee cann.

Also agreed with Robert Crew, a Mason, for doing all the Mason's worke att 1s 6d per perch reckoning 15 ½ (ft) to the perch, and to be measured from Bottom of the Sellars to the Topp att one and the same price and for working Quines 2d per foot; windows 3d per foot heading

Also agreed with him stones 1d per foot for the Masons worke of the two Stackes of Chimleys that are to be built in the house, each of which stackes are to have 4 separate flews or draughts for carrying Smoake, that is 4 Chimleys in each stacke for which I am to pay the said Robert Crew £12 10s and the back of the Chimley which stands in the wall is to be measured as wall.

November 1715

Agreed with Robert Crew for Arching my Sellars in the said house, strongest with Graines or otherwise as the said John Biddell shall thinke strongest and the same is to be done with Chaulke stone, which stone is to be drawed, fitted and laid and all the Masons worke about the same completely done by the said Robert (Centers, lime and carriage of the stone only excepted), for all which said worke the said John Biddell is to pay the said Robert Crew the sume of Ten pounds.

!st August 1716

(Agreement with carpenters for making and fitting stairs and partition walls, joists)…

Agreed with Paul White for 6s a perch superficial Measure for my Tyling worke, a perch sup-ficiall measure is 15ft square.

Agreed with William Chinnocke to give him 6d a square for my Shash windows and 6d per foot for what other new glass hee doth (supply) and 3d per foot for Leading and soldering my old glass and also 1 ½ d for the Shashwaites. *(Early for sash windows)*.

11th January 1716
Agreed with John Parsons for putting boxes for Seates in the Windows of the Hall and little room and making window Shutts to the same windows and hang them and to make and hang fower Doores to the same rooms and to Case the Darrnes of the same Doores and to make and sett up a Chimley peece against the Chimley and to putt Moulding att the Corners of the Windows and to make Shelves in the Little Roome as I shall direct and to sett up a boarded back in the back of the Roome and to make a place in the Little Roome for writing on and for all this worke I am to pay him £3 10s

16th Sept 1717

Agreed with William Churchouse of Yeovill, Joyner, to make me a doore for the Kitchen Chamber of Deale in a strong wainscot way, another doore between the Kitchen Chamber and little Chamber, wainscutt way with 2 pannells, the Panells to be of Beach & ye rest deale and to make two double doores against the Kitchen of Oake, that is Doores in two parts to open each side and the Face to be done with Mouldings as in Wainscutt. He is also to fit on bolts and lockes on the said Doores and to hang them, I finding hinges, lockes and bolts for the same. He is to cleanse over the floores and Stairhead which he laid with the Plain and he is to putt up sealing Jests in the Kitchen Chamber and over the staires and fit the same for the Plaisterer….For all this worke he is to have 1 10s and 1s 10d for one dayes worke.

Agreed also with Richard Budding to plaister my House, the Kitchen and Staires with 2 Mortars and all the Seelings and the two Chambers with one Mortar only and for the Seelings he is to have 3d a yard and for the walls and stairs 2d per yard.

The History of the Royal Society of London Vol 4 (1872) A Millar London.

P363.

A letter of Mr Musgrave to Mr Aston, dated at Oxford, January 31 1684/5 was read, containing an answer to Sir William Petty's query about mortar and plaister, as follows….

Clay mortar, or loam mortar is made with clay and as much chopt straw as the clay will take in, by the help of water.

Mortimer (1708) The Art of Husbandry; Or the Way of Improving of Land.— Book I.

If you design to make your Cisterns under your House, as a Cellar, which is the best way to preserve it for culinary Uses, you may lay the Brick or Stone with Terrace, and it will keep Water very well; or you may make a Cement to join the Bricks or Stones with, with a Composition made of slacked sifted Lime and Linseed Oyl tempered together with Tow or Cotton-wool. Or you may lay a Bed of good Clay, and on that lay your Bricks for the Floor, then raise the Wall round about, leaving a convenient space behind the Wall to ram in Clay, which may be done as fast as you can raise the Wall: so that when it is finish'd, it will be a Cistern of Clay walled within with Bricks, and being in a Cellar, the Bricks will keep the Clay moist (altho' empty of Water) that it will never Crack.

Or you may make a Cistern or Pool to hold Water by daubing of it with Clay and Mortar, and after draw it over with Mortar; if any cleft happen, stop it with **a Cement of clean Hair and Tallow mix'd with unslack'd Lime and Yolks of Eggs well beat, and made into Powder, and mix'd well together.**

G23/1/67

Sarum, Ambrose Perry, agent. Building new Farmhouse at Laverstock, West Dorset.

An account of the charges necessary for repairing the house at Lastock (Laverstock). It is most proper to take off the stone from the roof and lay on theck (thatch), the roof being much decaid and is to weak for stone: first I will give an account of the cost of the materials wanting to perfect it:

There is wanting 40 loads of stone at 8s per load 6-0-0
There is also wanting 36 hogsetts of lime at 2s 6d per hogsett, the carriage of lime and stone included 04-0-0
There is wanting 8 hundred of read at £1 8s per hundred 11-04-00
There is wanting a hundred and a halfe of dealboards at £10 ?s per hundred carriage included 15-07-06
There is wanting 4 thousand of nails at 2s 6d per thousand 00-10-00
There is also wanting two thousand of flouring brads at 8s 4d per thousand 00-16-08
There is also wanting two thousand board nailes at 10s per thousand 01-00-00
There is also wanting 58 pound of ironwork as hooks and twest spike nailes and bolts at 4s per pound 00-18-08
There is wanting 6 thousand of nailes at 1s 8d per tho: 00-10-00
50-15-04

I hath not taken any notice of lafts and square timber, I suppose that will be had on the same estate labour.
I am come now to give an account of the cost of the 55 parch of masons work at 1s 8d per perch 04-11-08
Pointing and mending the old walls 01-04-00
21 square of carpenters work now framed in the roof and partition at 6s 6d per square 06-16-00

the stairs must be new and will come to 01-10-00
the mending the old roof 02-15-00
making doors and windows 01-04-00
10 square and a half of frowering (flooring? Lathing?) at 6s per square 03-11-06
the thecker's work 03-10-00
150 yards of sealing at 3d per yard 01-17-06
Sawing 1400 foot of square timber at 2s 8d per hundred 01-17-04
For making 3 thousand of lafts at 3s 4d per thousand 00-10-00
Fileing and thirt cutting timber 00-12-00
29-19-00
50-15-04
80-14-04

The farmer complaines of the
badness of the barnes walls
and it will cost five pounds
to repair them 85-14-04

I have bought as much timber more as comes to 4-5-0
I have 2000 of bricks to pay for 2-0-0
I have 6 lode of ston to pay for 0-10-0
1 have 12 sacks of lime to pay for 1-5-0
and nex week must By som Bords & more Ston.
Am in debt for carige to ye farmer…
the weekly bills for labor will not look large. I have brought them to use Spar but Cannot bring them to mak use of moss.
I think to make use of heling ston. *Heling means roofing; Hellier. Roofer)* I do not like the tile.

Laverstock July 30 1720

The lathmaker made 2300 of laths…Paid Mr Poll for 6 lode of Ruf Ston…5 lode of ston. One lode of brick; one lode of lime…

Laverstock August 13 1720

…I desire you would let me have a Bill nex week for fifteen Pounds for I am in det for 2000 of Bricks and 32 sacks of Lime & 12 lode of ston and shall have in nex week 6 or 7 tun of heling ston wich must be paid for att the deliverie…

Costs.

Paid Richard Huchins for six hundred of Elm boards…10 lode of ston…one lode of Lime…

Laverstock September 24 1720

…the work is non likle to be complete in a short time. I supos the farmer hath been with your worship, what account he give I no'not. But I supos he makes the worst of Every thing…

Paid for helers more…paid for hair…nails, **lime & hair** will be the onely materials I shall want more of…I have had 4 lode of heling ston from Hamton Hill at six pens the hundred, I shall want no more….the Carpenters work will be complete in 12 or 14 days time…

(date illegible) 1720

…here is nothing but the helers work as I no of that can hinder. The wether have been very bad for such work…otherwise I should finish before….altho' I have don many things beyond your worship's orders, for which I beg your pardon, the farmer is still Grumbeling & sais the house is never the better, only kept dry. Therefore I hope your worship for better satisfaction will send somebody down to see the work…

Costs for heling stone, hew'd stone, brick and lime.

The weekly accounts of the workmen & materials at Leverstok Farm. **Began the 5th of July 1720**

Will Cran *IIIII 5 day 0-7-6 for 3 lode of walling ston
Robt Cran *IIIII 5 day 0-7-6 for one lode of timber and one lode of brick
William Jarvis **III* 3 day 0-4-6 Paid for one Pees of timber
Henry Clark ****I* 1 day 0-1-6 paid for 1000 of 4 nails

July ye 11, the second week. Spent at Bimister with workmen 0-1-2; hors & carriage to Bridport 0-1-6…

Thomas Canterby **IIII 4 day 0-6-0 paid the Lathmaker…
Will Canterby **IIII 4 day Paid Mr Pall for 6 lode of Ruf ston & 2 lode of hewed ston 0-14-0…
Danil Ston II**** 0-3-0 for 5 lode of ston 0-16-8; for one lode of Brick 0-8-0; for one lode of Lime, 10 sacks 0-5-0

July ye 13 the third week.

Will Cran, Robert Cran, John & Henry Clark; Will Jarvis; Thomas & John Canterby on site. Paid Mr Phelpis for timber 4-5-0

August 1…the 5 week.

Thomas & Will Canterby (7 days each); Will and Robt Cran; Wm Jarvis; John, Will and Danil Ston on site.

Paid Rd Huchins for six hundred of Elm board 3-12-0; bought at Bridport 500 nails 0-1-3…Paid the farmer for carriage- for ten lode of ston 1-13-4; for one lode of Bord 0-8-0; for one loade of Lime, 20 scaks 0-10-0
For to lode of Sand 0-4-0; for bringin the timber home 0-4-0; for the use of his hors 0-2-0

August 8 the sixth week.

Paid the Limeburner 1-10-0

Paid Brag for 2000 of Brick 2-0-0
Paid for Cres till (ridge tile) and Guter till (gutter) 0-9-0
Paid the ironmonger 1-12-0
Paid the Smith 0-6-1
Paid the Limeburner 3-2-6
Paid at Crashorn & Bimister for Haier 0-5-6
Paid for making Laths 0-2-10
I let the helers work by measure:
A eleven Pearch at 11s the Pearch 6-1-0
For Lathing & Paisting at 2 ½ d ye yard, 99 yards 1-0-7 ½
For Plaisting upon wall 39 yards, one penny ye yard 0-3-3
For work heling the oven, mending the porches & whiting the hous all over when it is proper 0-11-0.

(lime being burned as roofing and plastering proceeds)
The carriage of my Boxes home 0-8-8
My first Jorny down to Leverstok 4 days 0-18-0
Myself 19 weeks & 2 days -2-6 per day 14-10-0
My Boy 10 week & 3 days 02-12-6
Paid hors hyer for myself & a man the first time to Hampton Hill & charges 0-4-6
Paid one hors hyer to Bridport & one hors hyer to hamton 0-1-6

I had the misfortune to Breck one of my Ribs, being throwd of ye Coach. The charge of ye surgons at Dorchester and Bimester with a hors & boy from Dorchester to Leverstok 0-16-0

For building and hanging Stable Wall 0-7-0
For Read and Thacking 0-13-4
For work for the mason about the barn, stable and pig-stye 0-3-6…
For two sacks of lime and hair 0-6-0
For two Masons two days to plaister the Milk house & other places where wanting 0-5-4
For glazing the windows 0-4-6…
For lime and pointing the windows 0-2-6

For three days work for the Mason to plaister the Chimney and (?) the Underground gutter 0-3-6
For thecking the Carthouse all over 1-11-0
For thecking the pig-stye…0-16-8
For thecking the Stable 0-15-0
For thecking the barn the most part 2-5-0
For for thecking the Straw house all over 1-7-0…
For a Carpenter for making of gets and other repairs about the houses 18 days 1-1-0

Laid out for Plaistering the Milkhouse at Laverstock Farm

For 6 hundred of 3d nails 0-1-6
For 2 hundred of 6d nails 0-1-0
For gathering 7 hundred of brindles (? Brambles?) 0-0-7
For ? hundred of Sape Larts 0-0-6
For 2 sacks of Lyme 0-4-0
For one sack of hair 0-2-0
For 3 days work for one of the plaisterers at 14d 0-3-6
For 3 days work for the other plaisterer at 16d 0-4-0
0-17-1

(Lime is regularly delivered, but no sand is mentioned. The mortar is almost certainly being made with earth and subsoil from the site, with lime added (or without). Lime deliveries are generally for finish plastering and for pointing and for lime washing)

Nathan Bailey, John Worlidge (1726) Dictionarium Rusticum, Urbanicum & Botanicum: Or, A Dictionary of Husbandry, Gardening, Trade, Commerce, and All Sorts of Country-affairs: Volume 1. Third (revised) Edition.

But though burning of Bricks be necessary for building of Houses, &c. yet a Wall or House may be made with un-burned Bricks; for which end, 1. Let your Earth be high and well temper'd, smooth and well moulded, as already hinted, and this done in the hottest Season; then dry'd and turn'd after the manner of Brick-making; only it must be longer exposed to the Sun and Elements, till they become hard and tough, and then use them after this manner: **Take Loam or a Brick-earth, and mixing therewith some good Lime, temper them very high till they become tough, smooth and glewy**; let the Wall of your House be one Brick or one and an half thick, and your unburnt Bricks being laid in this well-temper'd Mortar, they will cement and become one hard and solid Body, as if the whole were but one entire Brick or Stone:

When you have raised your Wall 4 or 5 Foot high from the Foundation, let it dry 2 or 3 Days before you proceed further; then build thereon 4 or 5 Foot more, making the like Pause as before, and so proceeding till the Wall is finished: Afterwards temper **some of the same Earth the Wall was made of,** with a little more Lime that was used for the

Wall, which you must be sure to temper very well, and with this Mortar plaister all your Wall well on the other side, which will keep off the Weather; and if you would have it more beautiful, it's only putting more Lime to it and less Loam; and when this is dry, you may colour and paint it, with Red, Blue, or any other colour that you like best.

But the usual way to make Pools of Water on Hills and Downs for Cattle, is to lay a good Bed of Clay near half a Foot thick; and after a long and laborious ramming thereof, they lay another course of Clay about the same thickness, and ram that also very well; and pave it very well with Flints or Other Stones, which not only preserves the Clay from the tread of the Cattle, & c. but from chapping by the Wind or Sun at such time as the Pool is empty. Note also, that if there be the least Hole or Crack in the bottom, it will never hold Water, unless you renew the whole labour.

... Tiling is measured by the ten Foot-square, Workmanship of which is three Shillings and Six pence a Square in the Country, to find all but Tiles, is twelve Shillings, and to find Tiles and other Materials is one Pound six Shillings a Square. **Three Bushels of Lime will do a Square of Tiling, but I prefer Loam and Horse-dung mixed together, and laid about the Middle of the Tile, so as not to touch the Pins or Laths, nor to be so near the point as to wash out, because Lime is too corroding, being apt to make the Tiles scale, and to grow with Moss. _**

'Plasterers. The Plasterer's Work is commonly done by the Yard square, for Lathing, Laying and Setting is Eight-pence a Yard, rendering on a Brick-wall is Three-pence a Yard, stopping and whiting one Penny half-penny a Yard, whiting a Penny a Yard; but Lathing, Laying and Setting with Oak-Laths is ten or twelve Pence a Yard. **To daub a Partition-wall with Clay on both sides is Three-pence a Yard, and to rough cast it without, and render it on the inside, Four-pence a Yard in the Country.** Heart-Laths of Oak are one Shilling and Ten- pence a Bundle or Hundred. Sap-Laths of Oak are one Shilling and Eight- pence a Bundle. Fir-Laths are Twelve-pence a Bundle. A Bundle of Laths they reckon will do a Square . of Tiling, and five hundred of Nails.

... To complete this article let us just take notice of the flooring, which it would be a considerable saving to the occupier to be properly secured: a mixture of lime, cut horse-hair, drift-sand, temper'd-clay, and horse-dung laid pretty thick, will make the floor impenetrable to vermin.

Neve R (1726) The City and Country Purchaser and Builder's Dictionary or The Complete Builder's Guide. Newton Abbot. David and Charles Fascimile edition 1969.

Earthen floors are commonly made of Lome, and sometimes (for floors to make Malt on) of Lime, and Brooksand and Gun-dust, or Anvil dust from the Forge; the particular Method of both which I must at present omit; but I cannot pass by that receipt (given us by the Ingenious Sir Hugh Plat, to make an artificial composition, wherewith to make smooth, glittering and hard floors, and which may also serve to plaister walls with. Take (says he) Ox-blood, and fine Clay, tempering them well together, lay the same in any Floor (or Wall) and it will become a very strong and binding Substance; as I have been told by a Gentleman and Stranger, who affirm'd to me, that the same is of great use in Italy.

Lome: A sort of reddish earth, us'd in Buildings (when temper'd with Mud Gelly, straw and Water) for Plaistering of Walls in ordinary Houses.

White Mortar: this is used in plaistering of Walls and Ceilings, that are first plaister'd with Lome and is made of Ox or Cow-hair, well-mixed and tempered with Lime and Water (without any Sand). The common Allowance in making this kind of Mortar is one Bushel of Hair to six Bushels of Lime.

…A wise, wealthy and ancient soap boiler, dwelling without Aldgate has…long since erected a fair and stately edifice of brick for his own habitation…the mortar whereof did consist of two load of waste soap-ashes *[wood ashes], one load of lime, one load of lome, and one load of Woolwich sand*.…Another gentleman…has used only lome and soap-ashes, tempered and wrought together for mortar…in Southwark.

Plaistering

Some masons in Sussex tell me, that for lathing and plaistering of walls with Lome on both sides, they have 3d per yard; but if it be done with white Lime and Hair mortar on both sides, they have 4d per yard. …

With rough mortar or rough-cast. In some parts of Kent they commonly rough-cast (as they call it) upon old Lome walls, that is, they give them one coat (upon the Lome) of rough mortar or rough cast, tho' it be commonly struck smooth like Lime and Hair. For this work they have 3 ½ d per yard, only workmanship; but if the wall be new and lathed, and plaistered with Lome on both sides, and a coat of rough mortar on the outside, then they have 4d per yard, only workmanship. But if the rough-cast be wrought in flourishes, then they have 8d per yard…

Of Whitwashing. Whitewashing with Size upon plaister'd walls, is commonly reckoned at 2d per yard.

Walls. Plaistered or Mud Walls.
These kind of walls are common in Timber Buildings, especially of ordinary buildings; for sometimes the walls are made of brick betwixt the Timber: but this is accounted no good way; because the mortar corrodes and decays the Timber.
These mud walls (as they are called in some places) are thus made: The walls being quartered and lathed between the Timber (or sometimes lathed over all) are Plaister'd with Lome…which being almost dry is Plaister'd over again with White Mortar.

Thornton Estate Archive. Private, now at NYCCRO but as yet uncatalogued.

From Account Book 1733-34

To Wm Grey for leeding 181 load of stones from Appleton Comon to Normanby at 2s per load - £18 18s
To Idem for leeding **86 load of mortar *(earth mortar)*** at 3 ½ d per load - £1 5s 1d
To Idem for leeding 10 load of Thatch – 5s
To Idem for leeding 1 load of bricks from Kirbyovercarr – 4s
To Ld Blomberg for 650 bricks – 9s
To Wm Westday for cleaning the rubbish out of the new house – 4s 2d
To 1 load of Oake wood to make a Helme for Wm Grey - £1 8s
To Wm Grey for damage done in his ground by building the house - £1

To Wm Grey for leeding 1 load of Chimney Stones from Pickering – 4s
To Buckett for Wm Grey well – 1s 2d
To James Sparling for 1 threave Straw – 1s
To Ellin Hind for ale the workmen when they built Grey House – 1s 2d

East Sussex Archives. ACC 8648/3/25/5

An account of the expence of building the Oasthouse at Hole Farm 1736
Paid the Sawyer's bill 6-8-4
Paid the Carpenter's bill 10-6-0
Paid the Mason's bill 6-1-9
Paid for deales and carriage 3-3-6
Paid for nails, hooks & rides 2-14-3
Paid for bricks and tiles 8-17-0
Paid for 5 load of Lime 3-0-0
Paid for a Bushel of Tarris 0-5-0
Paid for carrying Loam & sand
Paid for drawing Timber 1-19-0
For 13 tun of timber also 19-10-0
Allowed for the Rearing 0-15-0

An Account of the expence of enlarging the dwelling house at Hole Farm in the year 1737 as follows:
Paid the Carpenter's bill 24-8-0
More for cleaving of Laths 1-5-6
Paid the Mason's bill 14-3-8
Paid the Smith's bill for nails 6-10-0
Paid for Bricks and Tiles 31-5-10
Paid for 8 Load of Lime 5-2-0
Paid for hair for the walls 1-10-0
Paid for Deals for the Flowers 4-10-10
Paid for locks & nails about 0-19-0
Paid the Glazier's bill 0-3-16
Paid for carriage of Loam & Sand 6-2-6
Paid for drawing Timber 2-14-0
Allowed for the Rearing 0-1-0
For 18 tun of Timber 27-0-0
£130

Note: the Carpenter's work 9/- per square & take the timber upon the stem
& the oak flower boards at the same price
& the Deal flower at 5/- per square, joined down & door cases 8/- each; plain door & case 5/- & window lights at 15d.

The Prices of the Masons Work was as followeth, viz
For Tiling in mortar 3/- per square
For weather tiling 4/- per square

For 14 inch wall 10/6 per square
For 9 inch wall 6/- per square
For lath & plaister wall & ceiling 3d per yard
For brick pavement 3d per yard
For brick ditto, brick on edge 4d per yard
For building the Parlour chimney 1-11-6
For building the Brewhouse Chimney & Oven 0-1-0.

Malton Estate Agent's Memorandum Book (1734 – 1808) Fitzwilliam Estate Archive North Yorkshire County Council Records Office NYCCRO ZPB III 5-2-1

July ye 7th 1736. Agreed with Will. Ellis, James Luccock and Parlour to wall all the stone walling thorough which shall be wanting at Wm Foxe's House, to make the front wall of Pye Pits wall stone & as good as Mr Carr's house, the whole walling to be done at seven shillings and sixpence per Rood and one shilling per arch for every arch in the front turned & that they shall find all materials whatsoever & the best mortar that can be got & to have six pounds for carrying up Eight Chimneys in the said house & twelve shillings per thousand for laying on Tyles & finding lime & sand & to give them one shilling & sixpence per yard for flagging what there will be occasion for & to give four pence per yard for all plaistering against the walls, finding lime etc & to give them eight pence per yard for every Cubical yard for digging the seller & carrying off the rubbish from the first to the last. We promise to begin forthwith and to finish with al spede as possibly we can, as witness our hand, John Freer, James Luccock, Richard Smith, Robert Owram, John Seller, Wm Ellis.

January ye 5th 1737. Agreed with James Luccock & John Frear to build a house for Widow Rowntree 31 foot long from end to end and 18 foot broad and sixteen foot high and to carry up a kitchin chimney, a little parlour and chamber chimney, the workmen to find all materials whatsoever & to fetch the best mortar and to point the outside walls with lime & to have all the old stone & to receive six shillings per rood & forty shillings for carrying up the 3 chimneys. No money for the chimneys if they smoke. As witness our hands, James Luccock, John Freer.
January 5th 1737. Agreed with **Robt Owram & Richard Smith** to do all the **Daubing & Plaistering** work that is necessary to be done at Widow Rowntree's House & to have three pence a yard, they finding, **mortar, lime & hair,** and twelve shillings per thousand for laying on the tiles & pointing. As witness our own hands, Richard Smith, Robert Owram.

July 6 1738. Agreed with James Luccock, John Freer, Richard Smith & Francis Stephens to wall a stable round as was set out & to receive seven shillings per rood & to carry up four little chimneys & to receive Two Guineas & to dig the foundation & clear off all the rubbage & receive two pounds ten shillings & to have twelve shillings per thousand for tiling & pointing. The walls to be pointed with lime and to receive one Guinea now at John Willoughby's House & to be finished ten days after Michaelmas or half the sum to be forfeited. Witness our hands, John Freer, Richard Smith, Francis Stephens, James Luccock

June ye 28th 1739. Agreed with John Freer to make a wall by Castle Dyke Side & to be equally as good as the wall below and to make it twenty two inches broad & to put throughs which shall reach into the bank & the said Freer to find all stone and mortar & to cope it with Beilby's Quarry stone the same as the other wall & to lay it on with lime & to receive when it is finished four shillings & 6 for every rood and to begin on it the next week, John Freer.

1st July 1748. Agreed with Percival Luccock for himself and (sic) behalf of James Luccock, his partner to build a wall to Fenton and Robinson's yard adjoining Water Lane 7 foot high with the coping at 5s per rood and to do it with old stone in the yard. They are to have two chaldern of lime allowed to mix with the mortar which is to be taken fresh out of the kiln, and Mr Turner to see it measured. Witness my hand, Percival Luccock.

Campbell Robert (1747) The London Tradesman, Being a Compendious View of All the Trades, Professions, Arts, both Liberal and Mechanic, now practised in the Cities of London and Westminster. London. T Gardner.

(The Plaisterer) is employed in plaistering and white-washing the Ceiling, and such Part of the Walls as require it, or are not to be wainscoted.

He first nails on the Laths upon the Ceilings, **upon which he lays a Coat of Clay, mixed with Hair, or hay; over which, when dry, he lays a Coat of fine Plaister.** He is attended when plaistering by a Labourer, who holds the Plaister up to him in a hod; he takes it off the Hod with a Trowel, like that used by the bricklayer, and lays it up on a Trowel peculiar to his Business; which is a flat plate of iron, with a Handle fixed upon the Back of it instead of the End.

For Walls and Mouldings he uses another kind of Plaister, especially for Walls that are to be done, **commonly called Stucco**: **This is prepared only of Stone-Lime and two or three parts sand,** according as the Lime is of Strength, or as the Work is to be finished. If the Work is designed to explain, there is a coat of Mortar laid on rough; that is permitted to dry.

B43/29

1740. Thing Hill, Hereford.

Labourers digging ye foundations, raising of stones and levelling ye ground.

To Anthony Lawrence for raising and halling stone, clay and timber.

Nov 62 loads of stone
Feb 26 9 loads of clay
27th 5 load of stone and raising;
8 load of clay.

March 3 7 loads of stone
4th 22 loads of clay; 2 load of scaffold poles

5th 24 loads of stone and clay; a load of poles
6th 9 loads of stone and clay
7th 15 more
9th 15 more
10th 18 loads of stone
11th 19 loads of stone and clay
one load of lath, 5? Of heart and 3 ? of sap
12th 20 load of stone and clay
13th 44 loads of same
14th 48 loads of stone and clay
16th 9 of same
17th 8 loads of stone.

Similar through 1741:

April 22 to May 29: 340 loads of 'stone and clay'; 243 loads of stone; sap and heart lath; poles; load of tiles.

May 30 – August 21: 384 loads of stone; 28 loads of tiles; 189 loads of stone and clay; 6 hundred of paving; 18 loads of sand (after June 19).

(Also 1741):
1 load of crests (ridge- tiles).
To halling 56 tuns and 3 foot of timber from Cowhorn's Wood;
For moss for ye tyles
For more moss
To 14 tuns timber
11 ½ of large lath for ye barn
3 ditto, 1 ½ of sap lath
oak board.

Langley B (1750) London Prices of Bricklayers' Materials and Works Both of New Buildings and Repairs, Justly Ascertained. London Richard Adams 2nd Edition.

Of Pargetting Mortar.

This Kind of Mortar is chiefly used for to plaister the Insides of the Funnels of Chimneys and is also very good for to point common Pan-Tiling, &c. and is thus made:
To 1 heaped Bushel of fine skreened *clear Lime* add about a 4th Part of fresh Horse-dung clear from Dirt and Straw; which incorporate with the Lime by well beating it, as is said of Terrace Mortar.

1 Bushel of *fine lime,* taken out of 2 bushels of unscreened Lime	0	0	4 ½
Horse-Dung and Labour to get it	0	0	1 ½
Labour to ***slack, sift, turn up*** **and** ***beat***	0	0	4

Of Furnace or Fire Mortar.

This Mortar is made either of Woolwich Loam, or of Windsor Loam, viz. Loam brought from Woolwich in Kent or from the Brick Kiln at Gerrard's Cross by way of Windsor. Both these Kinds of Loam endure very great Heats before they will vitrify.
The Manner of making them into Mortar is to well chaff and beat them, as outside common Mortar is done, and of such a Consistency as to work easy.

Of White Plaister Mortar.

Plaister prepared (vulgarly called Plaister of Paris) when mixt with Water, becomes a Mortar or Cement that sets very soon and hard; and **by Bricklayers is used for setting of Galley Tiles in the Covings of Chimneys, Cold Baths, Pastrys, etc.**

And as common Lime is made of Chalk calcined so Plaister is made of Alabaster-stone, or Talk, calcined and pulverized or first pulverized in the Raw stone and calcined afterwards in a Boiler.

To Calcine Alabaster-Stone, and to make Plaister commonly called Plaister of Paris, Beat the Stones to Pieces, about the Size of a Hen's Egg; then burn it or bake it, until the Shining Quality within each Piece (which is easily known by breaking some of them) be entirely gone, and they appear entirely white within like Chalk, then beat it on a flat Purbeck Stone, enclosed with a Frame, about 3 Feet square, and sift it through a fine Wire or Lawn Sieve into a Tub for Use.

Dossie R (1771) Memoirs of Agriculture and Other Oeconomical Arts Vol 2

The manner of preparing this mortar is as follows: **Take of unslacked lime, and of fine sand, in the proportion of one part of the lime to three parts of the sand,** as much as a labourer can well manage at once: and then, **adding water gradually**, mix the whole well-together by means of a trowel, till it be reduced to the consistence of mortar. Apply it immediately, **while it is yet hot,** to the purpose, either of mortar, as a cement to brick or stone; or of plaster for the surface of any building.

It will then Ferment for some days, in drier places; and afterwards gradually concrete or set; and become hard. But in a moist place it will continue soft for three weeks or more; though it will, at length, attain a firm consistence, even if water have such access to it so as to keep the surface wet the whole time, After this, it will acquire a stone-like hardness; and resist all moisture *[this is very likely a feebly hydraulic lime].*

P23 Chalk-lime, which is the kind most commonly used in London, is not fit for this purpose, on account of its containing flints; which makes it required to be skreened before it can be tempered with the water and sand. This skreening renders the slacking the lime previously necessary: and the slacking it before it be mixt with the sand prevents its acting on the sand, so as to produce their incorporation; which power it loses, in a great degree, after its combination with the quantity of water that saturates it. Lime made of limestone, shells, or marble, must be therefore had for this purpose: and the stronger it is, the better the mortar will be….

The superiority of this to the common mortar is **owing to the intimate commixture of the lime with the sand, at the same time it is combined with the water**, before its attractive power, be diminished by its combination with water: and **this shews the defect in the common method of making mortar: where the lime is slacked before it is (p25) commixed with the sand; and where, in part, old mortar, <u>common earth, or other substances, with which lime has no peculiar specific attraction, are generally added, or used wholly in the place of sand.</u>**

(the 'common method' to which Dossie refers is the slaking of the quicklime in a ring of sand, with which it will be mixed as soon as slaking is complete and whilst the just slaked lime remains very hot. He goes on to indicate that the principles of this method should be more generally adopted)….

Northants Archive Th 2444-2479

Accounts of James Fremeaux, merchant to the Levant, in the building of Kingsthorpe House, Northants, 1774.

Bills:

James Freemeaux Esq to Wm Boswell to 104 load of stone at 1s 6d per load
To 6 loads of Lime stone at 1s 3d per load
To 21 load of stone at 2s 6d per load
To 60 feet of window sils (?) at 2d per foot
To 7 window heds
To 6 springers
To 3 top stones
To 172 feet of table at 4d per foot
To 29 feet of chimney hed at 4d per foot
To 109 load of molter at 9d per load

Received Oct 1775 in full of all demands.

1774 James Freemeaux to Wm Boswell
to 21 load of stone at 1s 6d per load
to 11 load of molter at 9d per load
to 2 colames

to 5 hearth stones, 24 feet
to 3 springers
to 32 feet of table at 4d per foot
to 8 days work working of paving
to 303 feet of coping at 8d per foot

received October 1775 in full

James Freemeaux to Wm Johnson 1775

To whitewashing, mason and labourer each a day: 9s 2d
To 25 pound of Witeing and a pound of Glue

West Yorkshire Archives, Leeds. WYL/678 acc 3810

Building a dwelling house and schoolhouse at Headingley 1783-1805

(no lime in this account, Earth and sand.)

Stonework or walling at 1s per rood
Slating and pointing at 3 ½ d per yard
Chimney pieces at 3s each
Stone steps for the chamber stairs at 4d per foot.

Dwelling house – 18 feet long by 20 broad with a chamber above.

Schoolhouse to be 27 feet long by 20 broad.

The said Harrison and Walker to find all materials in wood and iron doors, window shutters, boults, bars, hinges, nails, crook locks, laches and catches, boards and all other materials in wood and ironwork and sufficient honest workmanship for 16-0-0.

Dimensions of the timber:

3 baulks, two in the schoolhouse, one in the dwelling house, each 10 by 6; 2ribs each side 4 ½ by 6 1/2 ; principals 10 by 3 ½ ; spars 3 ½ by 3; joice 4 by 3. All to be good, sound red deal. The pitch to be 5 feet; the floor to be laid with good red deal of an inch thick.

Mr Kirk, leading:

1782 To leading stones 1 day

to leading 3 load of wood
to 3 days one day, one horse cart leading earth

March
To leading stones
To leading sand and stone
To fetching timber from Leeds and paying turnpike
Stones – more leading; more sand.
One day leading brick, sand and stones
One day leading slate
Leading flags, slate and rigging

Joseph Kirk account 1784

To leading stones
To leading 3 load of wood
To 3 days, one horse cart leading earth
Stones, sand
To paying Wilson for removing clay

1783 stones, timber, sand.

January 1st 1784

Paid Benjamin Harrison for meat and drink at the raising 0-9-0
Paid Hartley for him and son one day carrying or filling earth
1 horse and cart for laths, nails and brads
paid for a wattering pan
slate, rigging, flags.

May 25th Paid Robinson for lime 1-1-0
For lead and paint
For 4 quarts of oil and a bladder.

Paid for wheeling earth and carrying out stones and rubbish and levelling the floors for flagging.

Marshall W (1788) The Rural Economy of Yorkshire Vol 1

CEMENT. **Formerly, ordinary stone buildings were carried up, entirely, with 'mortar'; that is, common earth beaten up with water, without the smallest admixture of lime** [*but see below for contradiction of this - earth mortar with lime lumps present*]. The stones themselves were depended upon as the bond of union; the use of the 'mortar' being merely that of giving warmth to the building, and a degree of stiffness to the wall [*we would disagree with this assumption]*.

The event, however, proves that walls built without lime have, in many instances, stood for ages. Even part of the walls of Pickering Castle, formerly esteemed a fortress of considerable strength, have been carried up with a cement which, *to appearance,* seems little superior to common mortar: nevertheless, such is the effect of time, upon walls which are exposed on every side to the atmosphere, that they now hold together with considerable tenacity…

EXP 1 CEMENT OF PICKERING CASTLE: - the coarser specimen, taken from the ruins of the central tower.
In *general appearance* it resembles dirty chalk, thickly interspersed with small gravel; some of the granules as large as peas. Its *tenacity* that of common writing chalk; the asperities easily broken off with the fingers. One hundred grains, pounded, dried, immersed in water, and balanced together with the menstruum lost in solution 25 1/2 grains of air, and yielded by filtration 40 grains of residuum; which afforded…35 grains of gravel and rough sand, and 5 grains of suspendible mudlike matter; the solution yielding, by precipitation, 64 grains of calcareous earth…

From this analysis it appears,

14. that the proportion in this case (supposing crude limestone in lumps fit for burning to be of equal weight with sand and gravel) was three measures of unslaked lime in lumps to two of sand and gravel. *[probably the opposite by volume, since lump lime 40% lighter than unburned limestone]*.
15. That the sand and gravel, in this case, has been washed; either by the brook, which runs at the foot of the Castle mound, or more probably, by hand; the proportion of dirt being smaller than that which is generally found among *drift sand*.
16. That the lime had not regained the whole of its fixed air.

EXP 2 - finer specimen of the central tower.

General appearance that of stale lime, run together with water, and baked to a crust; almost a pure white; surface rough; shewing the cells and the unbroken granules of the original lime. *Contexture,* more brittle than common chalk; full of pores; the materials do not seem to have been well incorporated, at the time of preparation.
One hundred grains yield, in decomposition, 21 grains of air; 42 grains of whitish grit, 5 grains of suspendible dust like particles; 56 grains of pure chalk.
OBS. The residuum…is evidently *the powder of free stone.* The particles are small, and of irregular figures, very different in appearance (when magnified) from common sand. I was at a loss to ascertain their nature, until pounding some freestone, and washing it in the manner I had done the residuum, I found it to resemble exactly the 42 grains of washed grit of the experiment. It appears to have been pounded or ground very small, and to have been put through a fine sieve…no fragment so large as a pin's head.

It is observable that the cement of this experiment is *weaker* than that of the last (different aggregate; less lime content)….It is also observable that, in the decomposition of the specimen, a urinous smell rose, during the solution…**It is at present a practice, among some plasterers, to make use of urine in the preparation of plaster.**

EXP 3 - taken from the ruins of the old outer wall facing the northwest. Collected in three or four different places; a few feet above the foundation; and mostly from the inner parts of the wall, not from the outer surface.

In appearance that of sandy loam, interspersed with specks of chalk *[quicklime, surely],* some of them larger than peas *[we see this pattern locally where quicklime has been added to earth mortar]*. Its fragility similar to that of dried brick earth.

100 grains…yield 13 1/2 grains of air; 30 grains of rough sand, and a few large fragments; 37 grains of silt and fine sand; 36 grains of calcareous earth.

OBS. There are two causes of the *weakness* of this cement: the small proportion of lime, and the impurity of the base…chiefly of mere mud, or of sand so fine as to be impalpable between the fingers. [*all consistent with the simple use of locally sourced sub-soil and modest addition of quicklime - the sand and silts being naturally part of the subsoil. Fairly typical of modern disaggregation in this area]*.

EXP 4 - taken from a fragment in the northwest corner of the fosse.

The general appearance somewhat resembling the last-noticed specimen; but in *contexture* very different. The crust of the outer surface, which has been exposed to the influence of the atmosphere, probably during many centuries, has acquired almost the hardness of limestone; nor is any part of it to be broken with the fingers; nevertheless, this specimen also, is **full of lumps of unmixed lime;** some of them the size of small hazel nuts, and, at the time I took the specimen (the season wet), as soft almost as butter; when dry, they are of the consistency of very soft chalk.

One hundred grains of this specimen yield 15 grains of air; 8 grains of fragments; 12 of coarse sand; 36 of fine sand; 3 of size-like matter; 45 of chalk. *[linseed oil?]*.

…GENERAL OBS:

1. All these cements, whether weak or strong, have laid hold of the stones with a degree of firmness proportioned to their respective strengths. **Every crevice of the wall is filled with cement; whole form one united mass.**

Hence, it is more than probable that these cements have been poured into the walls, in a liquid state, in the state of *puddle*…

2. The subjects of EXP 3 and 4 are strong evidence that, in the preparation of these puddles, the ancient builders were very deficient *[we would probably disagree]*. Not more than half of the lime they contain appears to operate *[as binder, but will seed carbonation as porous aggregates]*. The lumps, whether large or small, are *more* than wasted; weakening, rather than strengthening, the cement *[Marshall is going somewhere with this argument - see below].*

3. From the whole of these experiments, it is evident , that the several cements had acquired the principal part of their fixed air; chiefly, perhaps, after they were deposited in the buildings *[by carbonation]*. Hence it is entirely probable that the stonelike tenacity of old cements is chiefly owing to the transmutation of lime and sand to calcareous earth and sand; a substance resembling the original limestone *[the lime cycle]*.

On examining a wall, which has been built with loam alone, without any admixture of lime, and which has stood about a century, I find that the loam has laid not hold whatever of the stones, and that time has made no alteration on its contexture. It is still the same friable substance it probably was the day it first became dry in the building; without having the smallest appearance of **acquired tenacity** obtained during the century of time it has been exposed to the influence of the atmosphere.

It is therefore probable that the atmosphere imparts nothing *voluntarily* of a cohesive nature to the mortar of walls which are exposed to it.

But it is more probable that cement, **containing a portion of lime, imbibes from the atmosphere something, which gives it a degree of tenacity, superior to that which it had on its first becoming dry in the wall;** and it is a fact well established, that lime begins to imbibe, the moment it grows cool from the kiln, that which the fire has deprived it of, namely, fixed air; which fixed air being imbibed, after the cement is deposited in the walls, is *probably* a principal cause of tenacity.

Cointeraux F (1790). Rural school of architecture or lessons from which we will learn ourselves how to build in a good manner several story houses in earth only, or in other most common materials, the cheapest way. Paris, Chez l'Auteur.

Introduction
The potential to raise a house to two, even three stories with only earth; to carry on their floors the heaviest burdens and to install the heaviest materials, surprises everyone or, rather, those who have never been able to see these original constructions. It is to convince them that I will start with the art of rammed earth, this lesson is urgently to be taught in order to accelerate the multiplication of these smalls properties in the countryside so desired by the king and repeated by a thousand authors.

If I am happy to satisfy my compatriots, I should hope from them sufficient assistance, since without it I could not complete this essential enterprise. They see at least, perhaps, in the purchase of this little treatise, a patriotic contribution, to help me spread in all parts of the kingdom a new art which on its own can prevent the countryside from the scourge of fires, for it can be achieved by the poorest owners.

P5 Origin of rammed earth
Rammed earth is a manual operation, really easy; it is [done] by compressing the earth in a mould or in a formwork by which means we can build small, large and tall houses. 'Le pisé' [meaning the choice of word] would have more meaning if we would use 'massive' or monolithic because the building is a true monolith - it has no joint, whereas mortar offers innumerable joints for the binding of the stones. But we have to abide to the workers' terms, in all these vulgar denominations that we had been forced to adopt in the French language, however I inform you that I will use, indifferently in this book the words piser, massiver, presser (to press), comprimer (to compress) or battre la terre (to beat the earth).
The origin of rammed earth, somewhat unknown in France, forgotten in the others countries goes back to the first centuries according to Pliny, and it seems Noah was the inventor 'who learnt from the swallows' nests. Whatever it is, it is clear the ancients knew and practiced this art.
M. Goiffon claims the Romans used rammed earth : '*we easily conceive why this custom which does not have in principle a real utility can be circumscribed in a province'*

But we cannot understand this reason of this localism, if we can express ourselves in that manner, for [this custom] is for the common good by its economy of raw materials and by the diminution and the speed of the work. The art of the rammed earth worker, we maintain, has these advantages. This art of building in rammed earth has been transmitted from generation to generation in the region of Lyon, in an uninterrupted succession going back to the Romans who used to live there and presumably brought it, such as they did with the culture of vines and many other arts in the practice in which we still find their terms and their genius.
M. the Abbe Rozier discovered the use of rammed earth in Catalonia. Spain, as well as France, has, therefore, at least one region where they have perfected this ancient method of building.

Here, we use it in the surrounding provinces of the Lyonnais, it is only in parts of Dauphinois, Bourgegne and Vivarais where we use it. La Bresse has excellent earth to use but they still build in wood. Rammed earth spreads very slowly. It needs to be propagated, particularly in the regions north of Paris, where the materials are rare and lacking. It also needs to be used in the mountains, in the valleys, where transport is difficult, often impossible, for rammed earth's only cost is the workforce, excluding all sort of materials, any transports and all sorts of preparation. Lastly, we need to build farm buildings in the countryside with this method. Because we have to make these big for the farm operation and for the voluminous crop, the buildings currently incur great costs and insufficient return.

(Describes the tools needed with drawings and then continues with : The other tools you will need are pickaxes or spades, shovels, baskets or hods, a gardener's watering can, trowels, a mason's lead (plumb-bob), an axe, hammer, carpenters' sergeant (a metal or wooden bar, ending with a flattened hook, used to keep pieces of wood tightly together), a mallet, a saw and nails.

p10 Construction of the mould

We take planks each 10 feet in length, of white wood in order for the mould to be lighter and to be pliable and more easily transported by the workers. Fir is without doubt the most suitable wood because it is less subject to deformation. It is also for this reason we choose the driest, straightest and healthiest boards in which there are fewer knots.
The most usual height of the mould is about 2 feet 9 or 10 inches if we put three boards for each side of the formwork. […]
The six or seven chosen boards have to be smoothed on their interior sides with a plane. However, this can be omitted on the outside, for it is only the interior sides that should form the smooth façade of the wall. However, my experience taught me that this negligence has repercussions. The soil sticks on the exterior sides which were not whitened, making the mould heavier, particularly during raining times, whereas when smoothed or made uniform with a plane, we can always keep it clean with a straw cloth.

p17 Tools with which we beat the earth

The most important tool for rammed earth, upon which depends the building's solidity, its strength for several centuries, in a word, its perfection, or on the contrary, its bad quality is [the tool we use] to work the soil. We should not be mistaken, this type of construction has two extremes, whether perfectly good of excessively bad. This tool is called the pisoir (rammer).

We begin by taking a piece of hard wood, whether oak, ash or beech and everytime we could get the shoulder or roots of these trees, even of elm and walnut and others. We must prefer them because of the close union of their pores or ligneous parts. (*After that so many details of dimensions etc.)*

p19 <u>The practice of rammed earth</u>
We should not be mistaken! Rammed earth is quite different from those miserable constructions made with kneaded earth, or mud, mixed with straw or hay that most people mistake for this precious art. I even saw clever (skilled) people who did not know or did not want to distinguish this noble science from the routine we can see in the countryside to raise a few walls with kneaded earth - most vicious constructions, for they only support themselves if given a batter.
The art I am presenting contains all the principles of the best masonry.

Then he says he'll take an example by building a house with the reader.

We will start by making the foundation of this house with an ordinary masonry which we will raise at first to 2 feet above ground. This cost is absolutely necessary to prevent humidity from the ground. Moreover, this also protects the walls from the rain water from the gutters. When all the levels of the walls are 18 inches of thickness, we will draw on top of them with black or red stones, trenches to receive the mould key. Their distance should be of 3 feet from centre to centre. […]

After marking these trenches, we will build another 6 inches of masonry, which will leave room for the keys and at the same time with those extra 6 inches, would give in total 2 and a half feet of substructure in stone and mortar. This height is enough to avoid damaging the earth wall from the rain and snow. On top of this fresh masonry, we will set up right away the formwork, placing it at one angle of the house […].
When everything is in place--> : Each mason enters his space; we need three men for the 4 rows of uprights form three spaces. We place the best worker in the angle, it is him who is in charge and from time to time checks to see if the formwork is leveled. However, each mason should have with them their *lead* (plumb bob and line) to also check.
Before putting in the soil, we will spread a glaze of mortar, only around the formwork and cover with a few stones the trenches where the keys are. This glaze only serves to stop the earth that we will throw in from going into the joints and also to allow compression of the soil in the angles of the formwork.
The other workers, who dig the earth, prepare and carry it to the formwork. They give some to the three rammer workers. They first spread it with their feet and then use the rammer, being careful to only lay in each time from 3 to 4 inches of thickness. The first hits they give are around the angles of the mould, after that, they beat evenly everywhere in the mould. After that, they cross their beats in order for the earth to be compressed in every direction. When two masons meet around the edge of their space, they coordinate their beat to hit at the same time under the cords because they can only compress the earth with difficulty and diagonally. With this method, the entire length of the mould is equally rammed. The one who is in the corner beats with care against the head of the mould and for vanity, or for reasons of solidity, he lays on the compressed earth every six inches of height, a thin bed of mortar against the formwork, which imitates the joints in stonework.

Piseurs (rammer workers) do not add any earth before the first layer is well compressed, indicated when the rammers no longer mark the soil. When they are assured of its perfection, they call the labourers to carry them new soil which they will compress again, layer by layer until the mould is completely full.
When achieved, we will have no fear of removing the mould right away. The earth wall freshly made, about 9 feet in length and 2 and a half feet in height, will stay on his foundation, straight, and in no danger of falling. We will then immediately slide the formwork along the wall and touch the newly made one by just an inch, above the slope. We will have left on the opposite side of the corner, a slope. […] this slope is usually about 1 foot and a half of width horizontal. With this method, we do not leave any joint, we bind each segment of wall together for the second time we compress the earth, we will compress it in this inclination, as we beat new soil on the older earth already rammed.

To make the work goes faster, I made a new tool I call *pioche tranchante* (sharpened pickaxe). One side has an axe, the other has the shape of an ox- tongue, it does not finish as a point like a needle but it extends of the same width, slightly curved and sharpened. I would recommmend forging this tool as it is very practical and alows you to work faster. *(A mattock)*

(Then he goes on, saying if you start your wall on the left side, you start the next level on the right side and back and forth until the wall reaches the required height).
With this precaution, we locate all the inclined junctions of the walls opposite directions, which contributes in its solidity.

On these elevations (refers to two drawings at the end of the book), we will find this simple construction is as good as the best masonry.

Such is the rammed earth method used in the Lyonnais for centuries. The houses built that way are solid, healthy to live in, cheap, and they last a long time even when left in a bad state. I destroyed some where the titles of ownership went back to 165 years. The rich merchants of the city of Lyon had their country houses made the same way. The render (plaster) with the paint, which is again very cheap, deceives the eyes as to the nature of theses houses, and, covering the earth, decorate it exquisitely.
This fresco paint is happier, fresher, shinier than other paints because water does not alter the colours. Thus, we do not use glue or oil The cost is almost only in the labour, for the rich as for the poor. With a bit of money spent on red ocre, yellows or other colours, the owner can make his house sparkle.

Every stranger who has traveled on the River Saône, or in a stagecoach, has never doubted, upon seeing these beautiful, charming country houses raised on the hillsides, that they were built of earth. How many people have visited or even stayed over in these castles, without noticing their singular construction? …The wealthy farmers limewash them (or whitewash, no precision). Some of them, more glorious, add pilasters, doorframes, ornamentation of various colours.

Allow me to say that we should employ this type of building across the kingdom, whether for the decency of the villages and the honour of the nation, whether to spare the wood we use in such great quantities, whether to avoid fires, or whether to guarantee the farmer against the cold and excessive heat and also to conserve his health, or whether for so many other reasons, too many to say, so useful to the state

and to the owners. For example, because [this type of construction] offers a diminution of work and a faster building technique, as well as the benefit of being able to move into these houses almost immediately after they are built. It is why, when the roof is installed, we do not block immediately the (putlog) trenches, because the air circulation passing through the walls, helps to dry them out faster, which make the houses even more habitable sooner.
We leave the openings of doors and windows during the building of the walls. Everytime the mould meets a wall where a door or window will be, we put two head moulds, or one, to form the jamb. We put them oblique on the inside to give the necessary flaring […]. The door and window framings can vary. The wealthy use ashlar or bricks, the less fortunate use wooden frames. But wood is harmful to the decoration as wood cannot bind with rammed earth. This bad effect is shown here *(Drawings but the quality of the PDF is bad, can't really see anything)* where we will notice, despite great precaution, the renders are detaching from the pisé and fall from these wooden frames; whereas stones and bricks bind really well with the pisé, and hold the render tight, so that the paint lasts much longer.
Stone or wooden fireplaces are installed into the rammed earth as easily as into a masonry wall. Pipes can also be fixed in a very solid way.
But what is singular and greatly advantageous is that we can decorate with nobility (great, expensive taste), without having to put any jambs in the interior doors neither in stones, bricks nor even wood. They can simply be made in earth. And why would we spend on jambs when we can simply install the doors on the wooden panels?
We can see how much we could save on this admirable type of construction. By which turn of fate did this art remain confined to one region? Why even today, is it forgotten or ignored by the whole universe. Again, it is only by spreading this cheap method to all parts of the kingdom, as well as other ones, as I will discuss further, that France will maintain the priority of growing its agriculture, commerce and industry.

It is only too true that the simplest methods, thus the best, stay forever in villages where a few geniuses invented them. The one I now am going to talk about will surprise the reader who will not conceive why and how the Lyonnais does not use it.

<u>The other method of rammed earth</u>

It is in some part of Bugey in Bourgogne where an imaginative skilled worker, even an illiterate, discovered this new method. The entire population of the township (canton) adopted it for its great simplicity and, so much so, that they do not know any other method.

We are pleasantly surprised to see houses which seem to be built in one piece; when examining them closely, we cannot see any joint, there are no holes unpleasant to the eye that we forced to create for the keys.

If the question, published 6 years ago, of preventing fires in the countryside hadn't forced me to work seriously and, for this reason, to travel to make record in the villages, the various methods of building and the singular materials, particularly the ones we can use with success and economy against this disastrous occurance, I would not have come to know this method of making rammed earth.

However, being close to Bugey in Grenoble, where I imagined there would be all sorts of ways to build against fire and cheaply, my experiences even brought me to discover that we can build vaults in earth only, but I never thought it possible to shorten the work of the Roman rammed earth.

To my surprise and joy when I arrived in the Bugey, I realised we could build in earth differently than by the method I saw in Lyon, in my youth, that my grand-father, master mason, and that I myself, practiced all our lives. These are big houses all in one piece….We cannot see on the rough facade, usually from the hand of the worker, any keys or joints on the walls. Everything is whole from the ground floor to the roof.

Practice

This method consists 1° commonly build a stone wall substructure of 2 feet and a half. 2° to put in parallel wooden poles, 3 feet apart, in the ground on each side of the stone wall. 3° Space the poles of at least 2 inches from the wall 4° fill in the holes we made from one to 3 feet deep depending on the tenacity of the terrain. This filling in should be done by compressing the earth around the poles and a bit more above ground level with the rammer.

The poles, once put in straight all around the building and on the interior side of the wall, it remains to attend to the rammed earth work. We avoid thus all the repeated labour of the other method such as making trenches, of continually moving and replacing the keys, the putlogs and quoins.

Starting the house at a corner, we place between the 4 rows of poles, the large boards and we tighten them with 4 cords. We place at the same time the head to form this corner and to stop it, we put the *sergeant* (wooden or metal bar with a flattened hook) that we hit with a wooden mallet. A metal mallet would soon damage the *sergeants*.

After having rammed the first phase of the wall, we loosen the cords but the workers should support the mould and together slide it between the next poles where the cords are once again tightened for the second segment. We follow the same process all around the building and then do the same with the inside walls.
For the second course, we start again at the same corner on the left, if we left on the right to cross them and link them together, by stopping however against the partition walls […].

p42 We use the same method for the third and all the others up to the correct height. It is useless to remind you that we have to put the mould at least 3 inches on the lower segment under it, that the workers should check the formwork has not moved with the hits of the rammer and at last, that the centre of the wall they are building should be straight or perpendicular, and that it is only the inclination of a line that reduces the thickness of the wall for every course.
The unique cause for the courses not to have any joints are the omission of the mortar around the mould. The workers of Bugey pushed economy to the extreme. But we know that with little lime and sand, we could joint all courses of a house.
The people of Bugey are not only great savers but also very skilled. They have no problem to lay, align or work in a short amount of time, these big poles which seems quite difficult for a theoretician. It is true, practice overcomes all obstacles and I have no doubt, once the workers get used to this method, they will execute it with an ease and dexterity in all regions of the kingdom.
I have to say in the Bugey, the buildings are not as high as the ones in the Lyonnais, because we understand the difficulty of keeping the poles straight in the ground, almost

as tall as the corn we sow in the village, for it is possible to build with earth a house more than 36 feet of high. I built my own house in Lyon, which is very solid, higher than this.

Often we cannot find poles of sufficient quantity or length, so we use the wood we have, removing the timbers as each segment of the wall is finished and replanting them along it for the following segment and so on, in order finish it. The workforce would be greater but the cost of wood less - one compensates for the other.

Concerning the length of these poles, if they are smaller than the height of the house we want to build, we can build a building up to the height of the poles and then place the keys to finish the house, particularly the gable, (by the old method).

Overall, I will observe that both methods are very useful, and should be equally adopted and spread in France because they can be used separately or used thein combination.

P45 The Bugey method would be excellent for barns, stables, farms and all other buildings related to farming. The Lyonnais method is advantageous to for building higher houses, such as for wealthy people, or manufacturers, factories, hospitals, presbyteries and public schools etc.

Thomas Luccock proposals for building a stone tenement in Old Malton 1799. Fitzwilliam Estate Archive NYCRO.

3rd Augt 1799. I agree to build a tenement in the cow pasture in Malton Fields according to the plan hereunto annexed or with such alterations as may be made therein before the building is begun at the prices within mentioned, and to compleat and finish the same in a good and sufficient substantial workmanlike manner and to the satisfaction of Mr Hastings, so as to be fit for a tenant to go into it on or before Michaelmas next or forfeit five guineas, Witness my hand the day and year above, Tho Luccock.

s	d	
6	-	per rood for walling stone
1	9	per rood for the stones, for loading nothing
2	6	per rood for leading stones
1	6	per rood for mortar without lime
11	9	without pointing [11s over-written]
12	6	if pointed [12s written in by Hastings]
1	9	per rood for brick of bredth walls
4	6	per squair for tiling
1	0	per yard for squaring and for laying common flags

1	0	per yard for each flew (flue)
0	3	per yard for two coat plastering
0	3	per yard for brick flooring
0	5	per yard for cellar digging and filling the stuff.

Marshall W (1796) The Rural Economy of Gloucestershire; Including Its Dairy: Together with the Dairy Management of North Wiltshire; and the Management of Orchards and Fruit Liquor, in Herefordshire, Vol II Cotswold Hills. Raikes. Gloucester.

CEMENT. Lime is excessively dear; and **sand not to be had**, I believe, at any price; nevertheless, an excellent mortar is here prepared, at a moderate expense. **Invention is seldom more successful, than when necessity prompts it.**

The scrapings of the public roads; namely, levitated lime stone, impregnated more or less with the dung and urine of the animals travelling upon them, are found to be an **excellent basis for cement**. For ordinary walls, the scrapings alone are frequently used. And, from what I can learn, the proportion, for the best building, is **not more than one part lime to three of scrapings.** Nevertheless, I found mortar, which had not lain in the walls more than ten years, of a stone-like tenacity: much firmer than the ordinary stone of this country: probably much harder, than either of the stones, from which the basis of the lime was made. Similar scrapings might be collected, in any district where limestone is used as a material of roads.

The method of PREPARING this CEMENT is, simply, that of **collecting the road-scrapings, slaking the lime, mixing them intimately together, and, as the mass is worked over, carefully picking out the stones** or other foulness, which may have been collected. **This, for stonework, is found sufficient: for brickwork, however, it might be necessary, that the materials should pass through a skreen or sieve; previously to their being made up**. The price of lime, here, is 8d. a bushel of eight gallons, level. The price of coals about 30s. a ton. The kilns small, with funnel tops; to carry off the smoke, and, by breaking off the wind, to give a more regular draught.

BARN floors are of a good size: 12 to 14, by 18 to 20 feet. The best of oak: some of stone: but a species of earthen floor, which is made here, is thought to be superior to floors of stone, or any other material, except (p20) sound oak plank. The superior excellency of these floors is owing, in part, to the materials of which they are made; and, in part, to the method of making.

The materials are the calcareous earth of the subsoil, a kind of ordinary gravel, which is found in different parts of these hills, and the chippings of freestone (calcareous granite) from the freestone quarries, in equal quantities. The method of making is founded on a principle which is peculiar, perhaps, to these hills. Earthen barn-floors are made, in other places, with **wet materials**;—a kind of mortar which, as it dries, is liable to crack; and requires some months, after it is made, to dry it hard enough for use.

On the contrary, the materials, in the practice under notice, **are worked dry: they of course do not crack; and are ready for use as soon as they are finished.**

The materials, mixed together, are sifted twice over. The first time, through a wide sieve, to catch the stones and larger gravel, which are thrown to the bottom of the floor. The next, through a finer sieve, to separate the more earthy parts from the finer gravel, which is spread upon the stones, (p21) and, upon this, the more earthy parts; making the whole about a foot thick; and trimming down the different layers, closely, and firmly, upon each other. The surface being levelled , it is beaten with a flat wooden beetle, made as the gardeners turf beater ; until the surface becomes hard as stone, and rings at every stroke, as metal. If properly made, they are said to last a length of years; being equally proof against the flail and the broom.

Rondelet (1803) Theoretical and Practical Treatise on the Art of Building.

(Rondelet was the architect of the French Pantheon and member of the Civil Construction Council within the French Ministry of the Interior).

p218 Adobe blocks with he calls in French briques crues (uncooked bricks)., he focuses on older constructions like Babylon, the Tower of Babel, the pyramids, Greeks constructions. He puts what Vitruvius said about abobe blocks. Then :

Anywhere that adobe is used, the adobe block is made with clay soil. [...]. *In Persia, and in the Orient,* the masons, to make abobe blocks, knead the earth with their feet, adding short cut straw. They shape them in very thin wooden moulds. The dimensions of these are about 22 centimetres in length, 16 centimetres in width and 7 centimeters thick. When moulding them to make them more uniform, they pass their hands over them, after having wet them in a bucket of water, in which chopped straw is mixed (a finer straw than the one used to make the blocks). After 2 or 3 hours, these bricks acquire sufficient firmness to be stacked in an open space, in the shade, to finish drying.

House walls built of adobe blocks are covered with a clay and chopped straw render, which is enough to protect them from the rain. The top is covered with a course of burnt bricks, and sometimes abobe, angled to shed water.

The walls of more important houses are rendered with a mortar of lime mixed with *(gypsum)* plaster, crushed and mixed with water. This type of render is very solid and endures well in the air. This plaster is not as beautiful nor as white as ours, its grain being coarser.

In several regions of France, such as in la Somme, l'Oise, l'Aisne and la Marne, we build timber frames and we pack the infill panels with a mixture of crushed earth and straw or hay, which we call *'torchis',* wattle-and-daub, which is no better than the use of adobe blocks.

Article II Rammed earth
Rammed earth is a method of building in earth which is even more simple than

building with adobe blocks. It is very much used in the regions of l'Ain, Rhône and Isère. This cheap method, which makes solid dwellings, safe from fire, would be worthy of spreading to other regions, where we build in wood, particularly for barns and other rural buildings.

When the walls in earth pise are well made, they form a monolithic structure and when they have a good exterior render, they can last several centuries.
In 1764, I was in charge of the restoration of an old castle in the region of the l'Ain; it was built in earth pise more than a 150 years ago. The walls had acquired a hardness and consistency equal to the soft stones of medium quality such as Saint-Leu stone. We had – to enlarge windows and make new openings - to use a pointing hammer and a cutting tool such as would be used on stone ashlar. This type of construction, which seems to have been the practice in this country since time immemorial, was known by the Romans, Pliny talks about it as an extraordinary thing which must inspire admiration.

Method of making Rammed Earth

Any soil which is not too fat nor too lean is good to be used for rammed earth. The best is the 'terre franche' *(agronomical soil stable in all its elements, assuring regular growth for vegetation, its theoretical composition would be: 65% sand, 15% of clay, 10% of humus and 10% limestone, souce Wikipedia),* which is a bit gritty. Any time a pickaxe, a spade, or a plow removes heaps of soil that need to be broken up, this earth is good for adobe rammed earth). Cultivated soils, garden soils, natural soils can be also used.
To prepare the soil, it needs to be beaten with a medium rake to extract any stones bigger than the size of a walnut. It the soil is too dry, we wet it by aspersion and stir it with a shovel. The soil needs to be humid enough that a handful, when thrown back into the mix retains the shape given to it in the hand.
When the soil is prepared, we throw it into a mould, or mobile box, where it is beaten by workers with a pestle.*)*

This box is formed with two boards of fir wood that the earth builders around Lyon call *banches,* composed of tongue and grooved boards, strengthened with other boards laid across-ways and nailed. To facilitate the positioning of these *formworks,* we put two handles on each.
These formworks are laid on transoms, and placed in grooves in the already existing wall. These four transoms are called *lassoniers* or *clefs*.
[…] We leave inside the formwork a space equal to the widest walls to be built - about 54 cm - and we decrease the width as the wall and the formwork are raised…
[…] such a wall will be 795 millimetres at the bottom and 108 mm narrower at the top…The *formwork* is usually 3,248 mm by 893 mm.

P233 Once the formworks are in place, we put mortar flashing, which we could do in plaster or even in earth, as it serves only to avoid the flowing out of the

first soil thrown (*between the formwork as it meets the already constructed wall*). We then cover the top of the transoms with a small plank, placing also along its length firmed earth mixed up with water, that is to say, a bit wetter that the rammed earth mortar.
Then we put as many rammed earth-makers as there are divisions in the formworks. After the bottom has been cleaned and wetted, the labourers carry the ready-made soil to the rammed earth builders in wicker baskets. They spread the soil with their feet to form a layer of uniform thickness, which should be no more than 10 cm.

Then, each of them a pestle, they ram this layer of earth, reducing it slowly to half its original thickness. This first layer compressed, the labourers bring more soil to form a second layer of the same thickness and do the exact same thing.

To talk about the pestle in detail: the flat part of the pestle with which the worker hits the soil is the most essential part. It needs to be very uniform and smooth. Good rammed earth builders are proud to have a good pestle that can hit the soil in any part in the box. We choose for this tool a hard wood, such as the roots of elm, ash or walnut trees.

We use the pestle by turning it after every hit, in such a way as to cross the imprints left on the layer, beating it everywhere equally.

When we begin a wall, we put at one end of the formwork, a closure of two boards joined with bars *(to prevent spillage and allow for full compaction)*. The other extremity is finished to a 60° slope. This is done to link the first section to the one that follows.

The first section finished, we dismantle the box to place it right next to it in such way that the formwork entirely surrounds the sloped area that ends the first one. We follow the same methods back and forth along the wall…

[…] When the rammed earth walls are finished, they need to dry for a time, the period dependent on the temperatures of the country and of the season, before being coated with a render, whether of plaster *(of Paris)* or mortar.

Even though rammed earth is made with just barely moist soil, whilst adobe blocks are kneaded with straw and water, it is important to be careful and remember the observation of Vitruvius about not applying a coating to a wall built this way before being certain it is dry. Rammed earth made during high temperatures is soon dry on the exterior but humidity will remain present to the interior, from whence it will escape slowly to the surface. If this surface has a coating, this will detach, the water being trapped between the surface and the coating. One should not be scared to let the rammed earth dry when it is done well, because the drier it is, the better the coating will stick to it. I saw, in the region of l'Isère, very old houses, built of rammed earth, that had never been coated/rendered/limewashed but had nevertheless been resistant to all types of

weather.
My advice to those who wish to use this cheap building method would be to consult the books of Cointeraux, Professor of rural architecture, who studied this type of construction with great zeal and success. He has published several books with infinite interesting detail essential to success. However, as I had the opportunity to run *(projects with rammed earth)*, I will conclude with an indication of the method which has suited me perfectly and which tends to give the rammed earth more tenacity.

The alterations I was in charge of to the castle before-mentioned, were to the main building, raised two stories and an attic. The soil I had to use was, to my knowledge, a bit dry and of mediocre quality. To compensate for these inadequacies, after beating it in the normal way and stirring it with a rake, I **moistened it with milk of lime instead of pure water**. This simple method produced a rammed earth with more firmness and consistency than the one made with good soil. Its surfaces were so hard and smooth that we did without any coatings on this and several other buildings. We only whitewashed the surfaces with lime. As to the main building, the walls were covered with a mortar layer made of lime and sand *(plaster)* because it was next to the castle's apartments and seeing it, we would have never guessed that it was a construction in earth.
It is clear that with this method, we could use rammed earth as the ancients did it, which would have more consistency and solidity.
[…].

Martin M E (1829) The Art of the Mason L'encyclopédie populaire ou les sciences, les arts et les métiers, Paris, Audot éditeur.

<u>Batifodage</u>
We often substitute for the plaster, for economy, or for obtaining a lighter and warmer plaster *(enduit),* **heavy soil, kneaded with care, mixed with a certain quantity of hair *(bourre)* and if we want, a fifth of old slaked lime.**

P 104 This mix we call batifodage can be used as a plaster for walls and ceilings, we give a white colour with white of Spain (fine crushed chalk) wetted with strong size. (eau de colle forte).

P113 **Rammed earth construction**

The construction of rammed earth being of the greatest importance in some regions, we believe it useful to understand the method, particularly today, with woods becoming rare and stone and brick often being materials too expensive in certain areas and particularly for rural construction.

If the art of rammed earth construction was practiced with the same care as in Lyon and in the Dauphiné, we would not doubt the number of healthy and suitable dwellings would multiply more quickly and the working classes would find it a great benefit.

This method of building was introduced into areas lacking in stone where previously we were using wood instead, and this circumstance hopefully would permit that such a useful way to build be introduced in other regions, where, due to the scarcity and the high price of materials, the poor citizen has to live in unhealthy and poorly roofed cottages.

We give the name of rammed earth to a construction in which masses of natural soil, made compact and hard through particular handling, are placed one along the other and one on top of the other to form the entire thickness of the walls as stones do. These masses are worked where they are placed in a type of movable mould that we remove only when the layer we have just finished has acquired all its necessary hardness.

Here how it is done: when the mould, which is a type of deep frame made of timbers, distanced by transoms, is placed where the wall has to be continued, we throw loose earth, about a foot square each time and then beat this soil very well before anymore is added.

P 115 In order that no soil will escape from the boards of the mould at the bottom, **we apply a bead of good mortar made of sand and lime, mixed**. These beads, also called *moraine* by the workers, can thus be used to see, once the wall is done, the given height of each course, or *banchée*. When raising the work, we will make sure to give the exterior side of the mould a batter, in such ways it results in a diminution of an inch for about every *toise* (old unit of measure for length = 2 m). We are certain to build rammed earth constructions on good foundations, 2 or 3 feet high to protect the rammed earth from the moisture of the ground and from the splashing of rainwater. The roof also has to be very well cared for because water would cause great damage in little time. As for the walls, we protect them with a good coating of lime and sand that we renew when necessary. With these precautions, buildings of this type have a lifespan as long as the ones in wood or rubble.

P116 In the Lyonnais and the Dauphiné, where this method of construction is very common, we see an infinity of these houses built 150 years ago that have not needed more significant nor more frequent repairs than if they would have been built in stone.
The height we can build the rammed earth without compromising its solidity is 20 feet above the foundation, and this height of two stories is enough for every need. Even though it is not usual in this construction to build the quoins in brick or ashlar, we suggest it only offers advantages and we advise this practice in every region where we would look to introduce the use of rammed earth, where it would not have been known from experience
Of the rest, the doors' openings and apertures should always be built in bricks, ashlar or wood. Bricks or ashlars are preferable as they bind perfectly with the rammed earth.

P117 The wood however, always detaches slightly and even though we paint it with oil, we obtain window frames of poor taste. The best is, when plaster is not too scarce, to lath the wood and to cover the jambs and lintels with plaster.
When we build in rammed earth, we usually do not tend to leave voids for every aperture of the building. Sometimes even, we do not put any and we simply carve them out, once the building is done, to accommodate the frames. When we have opened the space this way and we have placed masonry or wooden jambs, we wait until the building has dried well before putting a coat of plaster (enduit). Indeed, we should be careful not to trap humidity inside the walls because then, they could be susceptible to be damage by frost. Moreover the wall shrinking in its dimensions, the dried plaster

would be lifted in plaques and would fall.

P118 **Thus, the construction of rammed earth should always be done early *(in the year)* in order for it to have time to dry before the cold weather, and we should never plaster them before the moisture has come out. The plaster (crépi) with which we coat the rammed earth wall is done with a mortar of lime and sand that we prepare with care and where we only use good angular sand in the proportion of 3 parts of sand for 1 part of lime. This mortar should not be spread in water but it requires to be kneaded for a long time and be softened.**
When [...] we reach the level of a floor, we need to stop the building if this floor is only made of joists, whereas it can continue if these floor joists are carried by beams. In the latter case, after the building is done, we open the rammed earth for the spans of each beam and we install in these openings timbers 2 feet long and 1 foot wide, laid in mortar of lime and sand if it is fir tree and of plaster or earth mortar if it is oak.

P 119 The beams are then placed on pads (coussinets). We fill with bricks the part of the wall that corresponds to the extremity of the beams and the exterior part of the pad and we continue the rammed earth after that.

[...] p 120 The soil we can use for the construction of the walls is a mix of clay and sand in which the sand seems to be in greater quantity at first glance but which is, however, capable of being kneaded and moulded. Even if it is not usual to work it as the earth brick/adobe *(la terre à brique,* it needs, however, to be mixed well, because it only gets its good qualities from this method. It also needs to be rather moist to bind when it is beaten in the mould. We can make sure if a soil is good for rammed earth by packing a flared bucket with it. If it is good *(quality)*, the heap once removed from the bucket will stand the weather without crumbling *(loosing its shape)*.

Telford T 1838 Atlas of the Life of Thomas Telford, Civil Engineer. London. Paine and Foss

It was only in the latter part of the last century that the western border or march between North and South Britain was rendered productive or valuable by a regular system of improvements, when the good Duke Henry of Buccleuch, the kind father of his tenantry and the benefactor of the district, within my memory caused it to be intersected by roads, and assisted in the improvements of the farm-houses upon his extensive property. **Until then most of them consisted of one story of 'mud walls or rubble stones bedded in clay, and thatched with straw, rushes or heather, the floors being of earth, and the fire in the middle, having a plastered creel chimney for the escape of the smoke, and, instead of windows, small openings in the thick mud walls admitted a scanty light; in such hovels the peasantry usually dwelt within my memory, and examples still exist. Encouragement was afforded by paying the prime cost of the timber, slates and lime, the tenant performing the carriage and paying for the workmanship; and such expenses being considered at the end of the lease, he was thus enabled to effect desirable improvements, without employing too much of his own capital.**

P5 Under this judicious management the mud hovels have disappeared, having been replaced by comfortable dwelling-houses, with convenient offices, the walls of stone and lime-mortar, slated roofs, masonry chimneys and boarded floors; the plan having been furnished by the Duke's surveyor, the building was erected under his inspection, and the lower parts of Eskdale abounding with sandstone, limestone and coal, most of the materials were readily procured; and although in the upper parts of the country argillaceous schistus (not a very durable material) predominated, yet, being conveniently situated and easily quarried, it is generally employed for the bulk of the fabric, with sandstone dressings for the doors, windows, tabling and skews of the roof. With regard to timber, although the lower part of the valley of the Esk produces much fine oak, ash and pine, yet the Duke preferred purchasing Baltic timber, which was landed on the shore of the Solway Firth (as was the excellent slate of North Wales), and carted into the interior by the tenantry.

1841 FARMER'S GUIDE COMPILED FOR THE USE OF SMALL FARMERS AND COTTER TENANTRY IRELAND.

The cottage walls should be built of stone, either dry or with mortar, the crevices in the former case being well filled with moss, or dry peat mould, and both outside and inside carefully pointed with mortar. The inside should never be without whitewashing, at least once a-year. This is of consequence on the score of health, and also makes your rooms lighter, giving a cheerful appearance even in the gloomiest weather; and there is a decency and propriety in a nicely whitewashed apartment, however homely the furniture, that is always pleasing. The floors may be of earth or, clay, well mixed with sand and lime, and beaten hard and smooth, and raised from eight inches to a foot above the level of the ground outside; the roofing ought to consist of beams and rafters laid properly on the walls, and the thatch may be of heath, bent, fern, or straw, and should be well laid on, at least one foot in thickness. Fern and heath make a durable thatch, either singly or mingled with straw; but the best of all roofing is slate, whether for the palace or the cottage.

Doyle M (1844) Cyclopedia of Practical Husbandry, Rural Affairs in General. London

Stones and bricks are often too scarce and expensive for the poorer classes of farmers and labourers; but happily for them, **clay walls, if properly constructed, and well plastered and dashed on the outside with lime-mortar, are cheap, durable, and warm**. The mode of preparing mud wails is as follows:

A sufficient quantity of cohesive clay, free from any stones, being collected, the labourer digs it thoroughly, and renders it as fine as possible; when well saturated with water, he works it with his shovel until it acquires the consistence and toughness of dough.

After lying eight or ten days, it should be again wetted sufficiently for use, and a small quantity of sound chopped straw (for if this be long and stringy, the surface of the wall will not be easily dressed and polished afterwards) is to be intermixed through the mass. The foundations of the walls are best laid with stone, or brick, two feet or more in depth, and two feet in thickness. On these, the mortar, being sufficiently turned and worked, should be placed in courses of two or two and a half feet in height. At this level it has been recommended by a recent writer, who himself attached great importance to the invention, to bed into the mortar at the angles, single or double ties or braces, of any timber, provided its scantling be not less than two inches and a half, and to pin them into the walls with pegs about nine inches long.

…Before the winter rains set in, the roof should be put on with double collars, and thatched with a considerably projecting eave, for the protection of the walls: walls left unthatched, soon become materially injured. Common farm-labourers are in many places very expert in building these walls, and smoothing them at both sides perfectly with spades. If the plastering and dashing, or either, be carefully preserved on the outside, such walls will last for a long series of years. The floor should be laid on a stone foundation, as well as the partition walls, and covered with tiles, bricks, or clay and lime mortar, well tempered and evenly laid.

In many parts of England walls of mud and straw are used about the farmer's house and yard, with a thatched eve; they last some time, if not exposed to severe frost, which soon crumbles them away; at best they are not very durable, and are much less permanent than wooden walls or paling, where timber is abundant and cheap.

Loudon J C (1846) edited by Loudon J W. An Encyclopaedia of Cottage, Farm and Villa Architecture and Furniture London Longman, Brown, Green and Longmans

Design IV. — A Dwelling for a Man and his Wife, without Children.

57. Construction, The walls of this cottage are here shown eighteen inches thick, with a view to their being built of rubble stone (stones rough from the quarry); of pise (to be described hereafter) ; of mud blocks (which is nearly the same thing as building in pise); or of compressed blocks of common earth (also described hereafter).

Design V. — A Dwelling for a Man and his Wife with Two or more Children, with a Cow-house and Pigsty. 61. Accommodation. This is a simple, economical, and comfortable dwelling, without pretensions either to ornament or style. It contains an entrance lobby, a; kitchen, b; back kitchen, c; children's bed-room, d; bed-room for the father and mother, and the infant children, e; tool house, f; pantry, g; place for fuel, h; privy, i; cow-house, k; and dairy, I. There is a yard behind the house containing a pigsty and the manure well. This yard is entered from the back kitchen, c; and also by doors in its boundary fence, m.
62. Construction. The walls may be of stone, brick, or earth; the two former materials will not only be found more suitable in reality, but more satisfactory to the eye; for walls of earth, when not whitewashed, have always a mean appearance, from the inferiority of the material; and when whitewashed, this meanness, though concealed, is still known to exist; for no building was ever whitewashed, but for the purpose of concealing something, and everyone must feel, with Wood, that the grandeur or the beauty of any building is never heightened by this operation. " The world in general," says this philosophical artist, " is exceedingly unwilling to acknowledge beauty of form when the material is bad; and, on the other hand, where the materials are good, it is

ready to praise the form also; the one is a much more obvious and indisputable merit than the other." {Letters, SfC. Vol. II. p. 96.) Where white washing or lime-washing a building, with any colour, contributes to the preservation of the wall, it is justifiable ; but no genuine lover of truth will ever admit that this operation can add to the beauty or character of a building. The idea which it conveys of the neatness and cleanliness of the inhabitant is its principal recommendation; and yet it is a fact, that where lime-washing is most employed, as in Wales and Scotland, the interiors of the cottages are less orderly and clean, than in the unwhitened mud and rough stone cottages of England….

158. Construction. The great art in building an economical cottage, is to employ the kind of materials and labour which are cheapest in the given locality. In almost every part of the world the cheapest article of which the walls can be made, will be found to be the earth on which the cottage stands, and to make good walls from this earth is the principal art of the rustic or primitive builder. Soils, with reference to building, may be divided into two classes: clays, loams, and all such soils as can neither be called gravels nor sands; and sands and gravels. The former, whether they are stiff or free, rich or poor, mixed with stones, or free from stones, may be formed into walls in one of the three modes already mentioned, viz., in the pise manner, by lumps moulded in boxes, and by compressed blocks. Sandy and gravelly soils may always be made into excellent walls, by forming a frame of boards, leaving a space between the boards of the intended thickness of the wall, and filling this with gravel mixed with lime mortar ; or, if this cannot be got, with mortar made of clay and straw.

In all cases when walls, either of this class or of the former, are built, the foundations should be of stone or brick, and they should be carried up at least a foot above the upper surface of the platform. In the course of this work, we shall describe all the various methods of building earthern walls, and we shall here commence by giving one of the simplest modes of con struction, from the work of a very excellent and highly estimable individual, Mr. Denson, of Waterbeach, Cambridgeshire, the author of The Peasant's Voice, who built his own cottage in the manner described below.

159. Mode of building the Mud Walls of Cottages in Cambridgeshire. After a labourer has dug a sufficient quantity of clay for his purpose, he works it up with straw; he is then provided with a frame eighteen inches in length, six deep, and from nine to twelve inches in diameter. In this frame he forms his lumps, in the same manner that a brickmaker forms his bricks; they are then packed up to dry by the weather; that done, they are fit for use, as a substitute for bricks. On laying the foundation of a cottage, a few layers of bricks are necessary, to prevent the lumps from contracting a damp from the earth. The fire-place is lined, and the oven is built with bricks. I have known cottagers, where they could get the grant of a piece of ground to build on for themselves, erect a cottage of this description at a cost of from £15 to £30. I examined one that was nearly completed, of a superior order; it contained two good lower rooms and a chamber, and was neatly thatched with straw. It is a warm, firm, and comfortable building; far superior to the one I live in; and my opinion is, that it will last for centuries. The lumps are laid with mortar, they are then plastered, and on the outside once rough cast, which is done by throwing a mixture of water, lime, and small stones against the walls before the plaster is dry, which gives them a very handsome appearance. The cottage I examined, cost £33, and took nearly one thousand lumps to complete it. I believe a labourer will make that number in two days: the roofs of cottages of this description are precisely the same as when built with bricks, or with a wooden frame. Cow house sheds, garden walls, and partition fences, are formed with

the same materials; but in all cases the tops are covered with straw, which the thatchers perform in a very neat manner. — Denson's Peasant's Voice, p. 31.

Design XXIX. — A Cottage Dwelling of Three Rooms, with various Conveniences.

219. Construction. This building is well designed for having the walls executed in compressed earth, because these walls are thick, have few openings, and the dwelling is only one story high. The roof is of a low pitch, and should therefore be covered with some description of slate, tile, or metal, and not by any kind of thatch. Beneath the floors may be flues heated from a fire under the boiler in the back kitchen. The windows are shown in the French style, shutting by an air-tight joint, as exhibited in § 19G, fig. 177. The panelled pilasters on each side of the door, and at the angles, a cross section of which is given in fig. 195, to a scale of half an inch to a foot, may be finished in plaster or cement.

Design XXXIII. — Two Cottage Dwellings, under the same Roof; each having Two Rooms and other Conveniences.

258. Construction. This building having only one story, the walls may be made of earth, smoothed, and lime-whited externally; and lathed and plastered inside. The columns of the porch may be portions of the trunks of fir or pine trees, with the bark removed, and the knots and other irregularities reduced. The roof may be of slate; and, as it is of considerable span, it may be constructed…with principal and, secondary rafters,

(p416) **Walls of mud**, or of compressed earth, are still more economical than those of timber; and if they were raised on brick or stone foundations, the height of a foot or eighteen inches above the ground, or above the highest point at which dung or moist straw was ever likely to be placed against them, their durability would be equal to that of marble, if properly constructed, and kept perfectly dry. The cob walls of Devonshire, which are **formed of clay and straw trodden together by oxen,** have been known to last above a century without requiring the slightest repair; and we think that there are many farmers, especially in America and Australia who, if they knew how easily walls of this description could be built, would often avail themselves of them for various agricultural purposes. We shall therefore here describe the **Devonshire practice,** as furnished us by the Rev. W. T. Elicombe, who has himself built several houses of two stories with cob walls, in the manner which he details in the following paragraph; and who, moreover, informs us that he was born in a cob-wall parsonage, built in the reign of Elizabeth, if not a few years earlier, which was only taken down last year (1831) to be rebuilt.

839. Cob Walls, as they are called, are composed of **earth and straw mixed up with water like mortar, and well beaten and trodden together.** Chappie, in his Survey of Devon, 1785, derives cob from the British word chwup (ictus), or from the Greek kotttos (contusus), because the earth and straw ought to be well beaten or pounded together." **The earth nearest at hand is generally used, and the more loamy the more suitable it is considered for the purpose.** These walls are made two feet thick, and are raised upon a foundation of stonework. The higher the stonework is carried the better, as it elevates the cobwork from the moisture of the ground. **After a wall is raised to a certain height, it is allowed some weeks to settle, before more is laid on. The first rise, as it is called, is about four feet ; the next not so high ; and so every succeeding rise is diminished in height as the work advances. The solidity of cob walls depends much**

upon their not being hurried in the process of making them; for, if hurried, the walls will surely be crippled; that is, they will swag, or swerve from the perpendicular. **It is usual to pare down the sides of each successive rise before another is added to it. The instrument used for this purpose is like a baker's peel (a kind of wooden shovel for taking the bread out of the oven), but the cob-parer is made of iron.** The lintels of the doors and windows, and of the cupboards or other recesses, are put in as the work advances, (allowance being made for their settling), bedding them on cross pieces, and the walls being carried up solid. **The respective openings are cut out after the work is well settled. In Devonshire, the builders of cob-wall houses like to begin their work when the birds begin to build their nests, in order that there may be time to cover in the shell of the building before winter. The outer walls are plastered the following spring. Should the work be overtaken by winter before the roof is on, it is usual to put a temporary covering of thatch upon the walls, to protect them from the frost.**

840. **In forming cob walls, one man stands on the work to receive the cob, which is pitched up to him by a man below; the man on the work arranging it and treading it down.** Each workman generally uses a common pitchfork, though sometimes a three-pronged fork is employed. **Cob houses are considered remarkably warm and healthy; and they are generally covered with thatch.** The durability of cob is said to depend upon its having " a good hat and a good pair of shoes;" that is, a good roof and a good foundation. The Devonshire thatching is very superior to that in most other parts of England. It is done with combed wheat straw, called reed, consisting of the stiffs unbruised, and broken stalks, which have been carefully separated from the fodder straw by the thresher, and bound up in large sheaves called nitches. In this way the thatchcr is enabled to finish his work much more neatly than in other counties where no reed is made. Instead of brick nogging for partitions, cob is used for filling in the frame work, which is previously lathed with stout slit oak or hazel. This sort of work is called rab and dab.

841. Cob walls thatched are very common for garden boundaries. The trees are trained against them by being pinned with maple hooks; but such walls in the course of time become full of holes, and afford a hiding-place for insects; they, therefore, frequently require a fresh coating of plaster.

842. In estimating the merits of cob walls, it must not be forgotten, that, when pulled down, the materials are good for nothing but as manure; whereas the materials of brick, stone, and sometimes even of timber walls may be used in rebuilding. It also deserves to be remarked, that **earth or mud walls are not in use in any district of Britain which is in an advanced state of improvement; they appear to be chiefly suitable to a rude state of society, where every man is his own builder, and where mechanical skill, and good tools for working in timber and stone, are scarce.** However, though they cannot be recommended for general adoption where brick and stone walls are common, yet the very circumstance of their being neglected, or not known, in such places, renders it probable that a great economy would be produced by their occasional use; on the same principle that, in a country where the common labourers live on bread and butcher's meat, one of them who should determine to subsist merely on oatmeal or potatoes would save money.

2443. Building Cottage Walls of Clay Lumps. John Curtis, Esq., of Rougham, informed us that he had built cottages, barns, and farm-yard walls, with what are called clay lumps. They are, he says, more durable than any thing except stone, very dry, and from 600 to 700 per cent cheaper than bricks. " I have built the walls of a farm-yard one foot thick with clay lumps; and, when at the desired height, made a coping for it of a frame-work of boards one inch and a half thick, and six inches wide. These, nailed together with cross pieces at every four or five feet's distance, are laid on the top of the wall, which thus forms the eaves, by projecting two inches on each side of the wall; the outer edges of the boards being beveled or sloped off to facilitate the drip of the water from the wall, similarly to a drip brick. The coping is then finished by covering it with worked clay, in the state that it is when ready for making lumps. This, with a little occasional repairs, will last for many years."

2444. To make Clay Lumps. Three loads of soft tender clay, which should be yellow, not blue, the latter being too strong, will make one hundred lumps; which, when dry, will weigh six stones, of fourteen pounds each. The three loads should be put into a heap, all large stones being carefully picked out, and soaked with as much water as the mass will absorb; then tread it with one or two horses, and, as it is trodden, mix as much short old straw as can properly be mixed with it, by adding more water as may be required. The edges of the mass should be turned into the middle of the heap from time to time; and the horses should be kept treading it till all the clay is thoroughly broken, and mixed so as to become like stiff mortar. All the secret depends on well mixing the clay with plenty of straw. It should not be made too thin. As soon as this quantity is properly prepared, men should be making it into lumps, which is done by putting sufficient clay into a mould of wood, of the following dimensions: eighteen inches long, twelve inches wide, and six inches deep, no bottom. The mould, when well filled, by the men putting in the clay with a spade, and pressing it with the foot, the top being smoothed with the back of the spade, should be lifted up, and the lump will then be left perfect. Wet the mould with a wisp of oat straw, to prevent the clay hanging to it, and place the mould about two inches from the first lump, and fill as before; then wet the mould and place it about two inches off, and proceed as before. This filling of the mould is best done on level grass ground. As soon as the lumps get a little stiff, that is, just enough to admit of handling them, they should be set on one edge, and as they dry be turned; and in doing this, place the wet side to the sun. The rough edges must be trimmed with a spade, or any edged tool, as they become dry enough to be haled (that is, built up in rows about three feet high, one brick wide, and the lumps one or two inches apart at the ends, as new-made bricks are before they are burned), so as that the wind can pass between each lump. Winter is the best time to get the clay into heaps, that the frost may pulverise and mellow it. In March, as soon as the severe frosts are over, begin to work the clay and make the lumps, and, if the weather is favourable, they will be fit to build with in three weeks or a month.

2445. To build a Cottage, Barn, or any Building, with Clay Lumps, the foundation must be good; that is, built with brick or stone at least eighteen inches above the surface of the ground. The larger the building, the higher the foundation should be; say three feet ; and it should be two inches wider than the lumps, so that one inch of plaster may be put on each side of the wall ; the width of the walls being according to the size of the building. Of course lumps can be made to any size, according to the building in tended. The expense of building the walls (which are eighteen inches thick) is 6d. per yard; and Id. per yard, covering each side of the wall with cement, which is only common clay mixed well with very short straw, being very particular in picking out every stone, and treading it more than usual. Let it lie in the heap till the autumn, and then (in October) apply it to the walls as a coat of plaster is applied to any common wall. — J.C. Feb. 1842. vol. xxxvi. p. 85).

2457. Cement Floors for Cottage Bedrooms have been strongly recommended for their durability, and as, in some degree, rendering cottages fireproof. They are common in Italy, and to be found in some parts of France and Germany, but they are comparatively rare in England. The best that we know of are at Houghton, in Norfolk, which we examined upwards of thirty years ago, and through the kindness of John Curtis, Esq., who sent us the information respecting building walls with clay lumps (§ 2443.), we are enabled to give the following account of them : —

2458. The Cement Floors at Houghton Inn, and in some of the farmhouses on the Houghton estate, are thus formed. The floor joists are laid in the same manner as if for boarding, but well stiffened by what is locally called bridging, which consists of pieces mortised into each joist…But as this mode weakens the joists by cutting into them, a better one would be, to use cross strutts in the usual manner. Some floors are first laid with reeds, so as to bear the cement on a floor of reeds; and others (which is the better way) are covered with double laths, but the ends of these laths should only just meet in the middle of the joists. The cement is then laid on, half an inch or two inches thick, and the floor must not be left by the workmen till it is quite finished, that is, they must keep beating and smoothing it over, night and day, till it is completely set, in order to prevent its cracking. This can only be done by having a swinging scaffold from the ceiling for the men to work from. The cement must be laid on directly it is made; therefore, while some persons are making it up, others must be laying it on. The cement is commonly called red plaster, which is red gypsum. It is burnt for this purpose, by making a fire with small billets of wood, and mixing small lumps of gypsum with the wood, and then covering the whole with turves to prevent the fire escaping, in the same manner as billets are covered when they are made into charcoal; or a better way is, to grind the gypsum in the flour stones of a mill, and then bake it in an oven, before mixing it into a cement, which should be done with the iron dust which falls from a blacksmith's anvil, and not with the smithy ashes ; the scales of iron being so much harder and better for the purpose. Chalk and lime are both unfit for the purpose, though ground floors for cottages and barns are frequently made of these materials, well beaten together. — J. C.

2461. Clay Floors, that is, floors formed of a mixture of clay and marl, were formerly a good deal used in Norfolk for barns, malt-houses, hay-lofts, cottages, &c. They are composed of clay and marl mixed with chopped straw, well trodden by horses, and mixed together in the manner clay lumps are to be made; and, when the mixture is to be used for malt-floors, bullock's blood is added. Much of the excellence of these floors depends on the thoroughly mixing and working of the material. — W, T.

Scott Burn R (1860) Handbook of the Mechanical Arts, concerned in the construction and arrangement of dwelling houses and other buildings. Edinburgh and London William Blackwood and Sons.

(Originally prepared for the exclusive use of COLONISTS and EMIGRANTS…This second edition of broader scope)

P124 Pise, or HARD-RAMMED EARTH.

TAKING into consideration the ease with which the material is obtained, worked into its requisite form, and the durability which undoubtedly characterises it, we are certainly surprised that it should have been so sparingly adopted. **No valid objections**

have yet been raised against it. It is admitted by all to be cheap, and no less efficient than cheap. Numerous examples have been carried into sheet with marked success, and abundant evidence is easily obtained to prove that it is lasting. The term “ pisé ” is derived from the name of the instrument with which the earth is rammed down, pisoir. The kind of earth or soil best adapted for pisé is that known as gravelly. By this term is meant a soil in which the pebbles or stones are round, not flat or angular. It is evident that in ramming the soil the packing will lie equally round the circular pebbles, while the flat or angular ones may resist the stroke of the rammer, and ward off in a measure the force of the stroke from some portion of the soil beneath them.
[most rammed earth structures in Spain have angular stone inclusions, however].

Brick earths are well adapted for pisé; but, owing to the capacity for retaining moisture, they are apt to crack, unless carefully shielded from the wet, during the process of drying the walls. All kinds of earth, however, may be used, with the exception of light poor lands, and strong clays: these, however, will do if judiciously mixed with other better-fitted soil. To show how this mixing may be most successfully carried out, a few sentences may be useful: the principle of mixing is simply to blend a light earth with a strong, a clayey with a sandy or gravelly kind. Where the best kind of soil that is gravelly cannot be obtained, small round pebbles, &c., may be mixed with it. All animal or vegetable substances that are apt (p125) soon to decay must be carefully kept out of the soil to be used. The following indications, which may be observed in order to judge of the fitness of the soil for pisé in any district, may be useful:

In digging, if the spade brings up large lumps at a time, the soil is well adapted for the work; this holds also where the soil lies on arable land in large clods, and binds after a heavy shower and a hot sun. Where vermin holes are smooth in the inside and firm, or where the small lumps generally found in plenty in all fields are difficult to be crumbled between the fingers, the soil is good. Soil of good quality is generally found at the bottom of slopes that are in cultivation, and on the banks of rivers. In preparing the earth for building, the first operation is breaking the clods or lumps, and thereafter placing the soil in a conical heap: this form facilitates the removal of large, flat, and circular stones, which, falling to the bottom, are easily removed from the mass by means of a rake. The teeth of the rake should be placed at intervals of 1 inch or thereabouts, so that only stones exceeding this in size may be withdrawn; or what would be better and quicker, a bricklayer’s sieve or “screen ” might be used, having the meshes about an inch square. Where two varieties of soil are to be mixed, the operation should be done at this stage. **Enough of soil should only be prepared to last a day’s working.** Care must be taken to prevent rain saturating the earth with water, as in this state it will form mere mud in the mould. It is necessary to note that the soil is in best condition for working when neither too dry nor too wet. It is very evident that less time will be lost in slightly wetting the soil, when too dry, than in waiting for it to dry should it get saturated with rain by a careless exposure.
The next point we have to explain is the construction of the “ mould.” This should be made of clean thin planks of pine, or other light wood, well seasoned, to lessen the chances of their warping. Their thickness should be about 1 inch, well planed on both sides. The length should be from 12 to 14 feet for ordinary work; but shorter moulds, as 7 feet, will be at times useful. The depth of the mould should be 14 inches—some recommend 2 feet 9 inches; but a practical experiment, where the former depth was adopted, showed that it was more convenient than the latter…

P131

UNBURNT BRICKS.

MUCH as many may dispute the fact, it is nevertheless true, that unburnt bricks form a much drier wall than ordinary burnt bricks, inasmuch as they are not so absorbent of wet or damp. To make these, any ordinary clay will answer. If dry when obtained, it must first be moistened, and thoroughly worked by the feet of cattle, or pounded by hand. Cut some straw into pieces about 6 inches in length. After being duly mixed with the straw, the clayis ready to be made into bricks. A mould of any size must be made; a convenient size is 12 inches long, 6 inches wide, and 5 inches deep : this mould should have a bottom, but not air-tight, in order to prevent the brick from sticking in the mould. The clay is put into this mould, and the brick formed much in the same way as ordinary bricks. . Should the clay be very tenacious, a little sand sprinkled in the mould will enable the brick to leave it freely. The bricks are placed upon level ground to dry, turning them on their edges on the second day; thereafter left in piles, protected from the rain, for ten or twelve days. The foundation must be formed of stone or burnt brick; and, to prevent damp rising, a course of slates should be laid above the footings in hydraulic cement. The walls formed of these bricks will be exactly 12 inches in thickness—that is, the length of the mould; the partitions are formed by laying the bricks length- wise, thus giving a thickness of 6 inches, the breadth of the mould. To obtain the necessary bond in the walls, the work is carried up in alternate courses of headers and stretchers— —one course having the bricks laid across the wall, the next course having them side by side. A good ordinary brick mortar is to be preferred, although a weak mortar of lime and sand will do for laying the bricks. The doors and window (p132) frames should be previously made, to be ready to insert when required. These frames should be of stout plank, the exact width of the thickness of walls—they will thus help to cover the joints and strengthen the walls. Lintels and sills of stone, when easily had, will much improve the appearance of the structure: pieces of timber 3 inches thick, width equal to thickness of walls, may be used in place of stone ; these should have a clear bearing of at least 12 inches on each side of the opening. Of whatever kind the roof is, it is essential, in this form of material for external walls, that it should be an overhanging one, in order to guard the walls from vertical rains. The outside of the walls is plastered with good lime mortar mixed with hair, and then with a second coat pebble dashed as in roughcast. The inside walls are finished in the usual way. A cottage may be built in this way for an in credibly small sum—warm, dry, and of course comfortable. As to its durability, it is only necessary to state, that it is by no means a difficult matter to adduce instances where such structures have existed in thorough efficiency for a great length of time; in some, for upwards of two hundred years. The method of forming the unburnt bricks will be described under the head of BRICKMAKING.

Jacques D H (1860) RuraI Architecture: Or, How to Build Country Houses and Out-Buildings

UNBURNT BRICK FOR BUILDING. The following particulars are compiled from the Report made by Mr. Ellsworth while Commissioner of Patents: Almost every kind of clay will answer; it is tempered **by treading it with cattle**, and cut straw is added, at the rate of two bundles of straw to clay enough for one hundred bricks. It is then ready for molding. It is found that the most economical size for the bricks for building such cottages is the following, viz., one foot long, six inches wide, and four inches thick. The cellar or foundation must be formed of stone or burnt brick. In damp soils, the dampness should be prevented from rising from the soil into the unburnt wall by laying one course of slate, or of brick, laid in cement or hydraulic mortar, at the top of the foundation. The walls of the cottage are laid up one foot in thickness of the unburnt brick. This thickness is exactly the length of the brick, or the width of two bricks, and the strongest wall is made by laying the work with alternate courses of leaders and stretchers (ie one course with the bricks laid across the wall, the next course side by side). A weak mortar of lime and sand is generally used for laying the bricks, but a good brick mortar is preferable. Where lime is scarce, a mortar composed **of three parts clay, one part sand, and two parts wood-ashes,** answers very well as a substitute for lime mortar. The division walls may be six inches thick, just the width of the brick; but when the cottage has rooms wider than twelve feet, it is better to make the first-story partitions two bricks thick. The doors and window-frames being ready to insert, the cottage is very rapidly built. These frames are made of stout plank, of the exact thickness of the walls, so that the casing inside and outside helps to strengthen the wall and covers the Joints. If lintels and sills of stone are not to be had, pieces of timber three inches thick, of the same width as the wall, and a foot longer on each side than the opening, may be used instead.

The roof may be of shingles or thatch, and it is indispensable in a cottage of unburnt clay that it should project two feet all around, so as completely to guard the walls from vertical rains. The outside of the wall is plastered with good lime mortar mixed with hair, and then with a second coat, pebble-dashed, as in rough-cast walls. The inside of the wall is plastered and white washed in the common way. Built in the simple way of the prairies, these cottages are erected for an incredibly small sum, costing no more than log houses, while they are far more durable and agreeable in appearance. But we have also seen highly ornamental cottages built of this material, the bricks made entirely by the hands of the owner or occupant, and the whole erected at a cost of not more than one half of that paid for the same cottage built in an equally comfortable manner of wood or brick. When plastered or rough-cast on the exterior, this mode of construction presents to the eye the same effect as an ordinary stuccoed house, while it is warmer and far less costly in repairs than any other cheap material is.

Wiltshire Archives 1461/928-940. Goddards of Swindon.

Mainly comprises work books of mason/bricklayer carrying out repairs across properties in the ownership of the Goddard family, including the Goddard's Arms, which still remains.

A L Goddard Account Book with R Horsell.

April.
Repairing and whiting the house stables etc at the Mews Farm:
3 men and boy 4-11-0
14 bushels of lime 0-7-0
76lb of plaster 0-9-6
2 (?) of whiting 0-9-4
2 firkins of size and coulours 0-6-6
laths, nails and hair 0-3-6

May 4
Repairing and whitening 2 cottages, Lower Town:
Man 4 days 0-14-6
3 pails of white and size 0-4-6
2 pails of coulour 0-4-0
12 lb of plaster 0-1-6

April 2nd
Work done at Beerhouse:
2 masons 1-18-0
150 bricks
2 loads of dirt 0-4-0
2 quarters of lime 0-8-0
Man 11 ½ hours (mixing) the same 0-4-7 ½

Wall at Quarry Cottages

2 masons 10 days 2-3-2
2 labourers 6 ¾ days 0-13-6
2 loads dirt 0-4-0
2 labourers 1 day each digging foundations.

May
Laying paving in garden by greenhouse:
2 masons 5 days 8 hours 1-3-2
Labourer 3 days 0-6-0
206 feet super of banked facing 5-11-7
mortar for same 0-6-0

Building closet at cottage:
2 loads dirt
1 ½ quarters lime

June
Repairing Hall
2 masons 11 days 9 hours 2-7-7 ½
labourers 10 days 8 hours 1-1-7
8 ½ quarters lime 1-14-0
6 loads dirt 0-12-0
3 loads ashes 0-6-0

1865

Feb 10
Repairing Mr Vincent's at Hiscocks, Newport Street and lime whiting:
Man and boy 1 ¼ days 0-6-6
Cement and mortar 0-2-0

Lime white and bricks 0-2-6
200 laths 0-3-6

March 3
Man and boy 2 days 0-9-0
2 pecks cement 0-4-6
2 bushels lime 0-1-0
hair and slates 0-3-0

Bruce Allen C (1886) Cottage Building, or Hints for Improving the Dwellings of Working Men and Labourers. London Crosby, Lockwood and Co.

Gravel is the best sort of earth for this kind of walling, and it should be of a loamy nature, with a large proportion of stones. It should be used as dry as possible, no cement being required, as it is held together by the force of cohesion alone.

The foundation upon which Pise walling is to be erected is formed of stone or brickwork, rising not less than six inches or a foot above the surface of the ground, and about six inches wider than the thickness of the intended wall. It should be covered with a layer of Roman cement, stone, or tile, to prevent the rising of damp. The foundation being completed, frames (p32) formed of planks of any convenient length are fixed by resting them on the edges of the stone or brickwork, on either side they are held together at the top and bottom by iron bolts, and kept apart at the top by pieces of wood called 'guides,' placed about three feet asunder. The Pise gravel is then thrown in, about half a bushel at a time, spread evenly, and rammed down till the surface becomes perfectly hard. The work proceeds in this way till the frame is filled to within an inch or two of the upper bolts. A portion of the wall being thus completed, the lower bolts are drawn out and the upper ones slightly loosened: the frame is then raised bodily, till the lower holes rise above.
One course may be raised upon another, as thus described, immediately it is finished; but it is found more convenient, and makes better work, to carry on the courses horizontally, and keep them of an equal height. As the work proceeds, the tops of the walls are kept dry by copings or other means; and when completed to the necessary height, the roof (which should be already framed and ready for fixing) is immediately put on and covered in.

The spaces for the doorways and windows are formed by placing partition boards, fastened to the frame-work by bolts, of the breadth of the wall and height of the frame, on either side of the space to be left vacant; and pieces of timber, two or three inches thick, shaped like truncated wedges, are then inserted, with their bases in the wall itself, and with their smaller sides touching the partition boards: to these timbers the door-posts and window-frames are afterwards fastened. If the building rises above a ground story, sleepers or plates are laid on the inner side of the walls, as in the ordinary manner, for the floor-joists to rest on, the bolts are then replaced, and, together the top of the wall with those at the top, screwed up, and the work is proceeded with as before.

*A great improvement in the Pise walling, and which would make it as durable as stone or brickwork, would be effected by forming the angles and door and window jambs of brick or stone. The solid Pise itself is found to be, when well and carefully constructed, so hard, that when struck with a hammer, the flints break rather than start from the work. Pis4 walls, if thus constructed with stone quoins, doorways, and windows, would be well adapted for churches and schools in poor localities. See Wild's 'Cottages for the Peasantiy and for Emigrants,' 8vo.

(p33) The above method of forming Pise walling is different from the mode of building common in Devonshire and the West of England, and known by the name of cob-building, as will be seen, and is greatly superior to it, and far more durable.
The substance of which cob walls are made is loam or clay mixed with straw and moistened with water it is formed in; frames, in the same way as that above mentioned, but in courses of not more than one foot or one foot and a half in
height it is then left some time to dry and become consolidated before a second course is imposed. The window and door frames are inserted as the work proceeds, and their respective openings cut out after the work is finished. The strength and solidity of cob walling depends much upon its not being hurried in the process of forming, and, when finished, it must be left some months to dry and settle.

Mud walls, or walls of clay lumps, are thus formed: The clay to be used is first freed from all large stones, and soaked with as much water as it will absorb; it is then well beaten, and a quantity of short old straw added, and the whole well and thoroughly mixed up together, continued by the treading of horses, or otherwise, till the clay becomes thoroughly broken, and of about the consistence of mortar: it is then put into moulds, 18 inches long, 12 inches (p34) wide, and 6 inches deep, without a bottom, and moulded in the same manner as bricks. These lumps are then dried in the sun, and laid in the usual manner with mortar.

DIBDIN W J (1901) Lime, Mortar and Cement, Their Characteristics and Analyses. London. The Sanitary Publishing Company Ltd.

CHAPTER II. CLAY.

BY the process known as 'weathering' rocks are gradually disintegrated, and the fine mud thus formed constitutes the very variable materials classed for convenience under the generic term Clay. The principal ingredient is a silicate of alumina, which when perfectly pure is white. In this form it is known as Kaolin, or white china-clay, pipe-clay, fuller's earth, &c. These correspond more or less to the composition A1,O3 , 2 Si(X, 2 H3O.. White marl, loam, c., are classes containing various (p 13) admixtures, such as calcium carbonate, oxides of ircn, magnesia etc
Fire Clay contains iron, and is nearly free from lime and the alkalies, soda, and potash. These are largely used for the manufacture of pottery, as at Stourbridge. The most refractory, used for the manufacture of articles which have to stand an intense heat, is composed of: Silica, 74 per cent; alumina, 16 per cent; ferrous oxide, 3 per cent.; alkalies, 1 per cent.; water, 6 per cent.; with traces of lime, magnesia, sulphuric acid, and chlorine.

Brick-clay is a term applied industrially to any variety of clay, loam, etc., used for making bricks and low-class pottery. It is very impure, containing large quantities of iron, etc The following may be taken as its approximate composition, but various samples differ very largely: Silica, 50 per cent.; alumina, 35 per cent.; ferric oxide, 8 per cent.; lime, 1 to 2 per cent; magnesia, 5 per cent., &c. The colour of the bricks is due to the quantity of iron present, and the extent to which the bricks are burnt.

Mudstone is a fine sandy argillaceous rock, free from stratification, and harder than the usual clays.

Shale is a clay which has been deposited in thinly stratified layers. These are capable of being split into hard sheets or leaves. There is a great variety of these deposits having very different characters, according to the nature of the clay originally deposited, gradually passing into the slates.

In the technical terms of the brickmaker, pure clays, composed of silicate of alumina, with but small quantities of lime, magnesia, etc., are known as "foul" clays. Loams, or "mild" clays containing sand, are known as "sandy clays."

Marl is a clay containing a large proportion of carbonate of lime.

Malm is an artificial imitation of natural marl, made by mixing clay and chalk in a wash-mill. It is generally known under the term " washed clay."

Pipe-clay is a greyish-white clay, greasy to the touch, and adheres strongly to the tongue. On being burnt it turns white. It is found in Devonshire, Dorsetshire, and on the Continent. It is used for the manufacture of clay pipes, hence its name.

Red Clay is distributed to an enormous extent over the bed of the ocean, and may be said to exist everywhere in the form of ooze, clay, or mud. It is generally of a brown colour, in consequence of the presence of the oxides of iron, with some manganese. It has not the same properties as fire-clay, as it fuses into a magnetic bead, due to the large quantity of iron and free silica, derived from the sedimentation of the skeletons of silicious organisms, such, as the diatomaceae, and volcanic minerals.

Burnt Clay is very largely used for many purposes. As a manure it has, in certain cases, considerable value, whilst it is in great favour with the builder and engineer for many purposes. Within the last few years the use of burnt clay has been extended to the sanitary world, being employed for filling the "Bacteria Beds," which are now so rapidly displacing the chemical and land treatment for the purification of sewage. The method of burning the clay is to first kindle a fire with suitable materials round a stout piece of (p15) oak or other hard wood. The clay is gradually piled up- round this, and sprinkled with fine coal slack or breeze. Care must be taken that the fire does not break through the surface, as in that case over-heating may result, unless the burnt clay is required for certain purposes, for which it cannot be too well burnt. The alternate layers of clay and breeze are gradually added from time to time until the heap may equal hundreds of tons. Constant attention is required to see that the firing is equally distributed, and kept well
within the heap.

Champly, René (1910-1914) Nouvelle encyclopédie pratique du bâtiment et de l'habitation. Volume 2, avec le concours d'architectes et d'ingénieurs spécialistes. Paris. H. Desforges.

Champly, René (1910-1914) New pratical encyclopedia of building and habitation. Paris, H. Desforges. Translated by Michel E 2018

<u>Construction in rammed earth:</u> Earth is used for fence walls, and houses or farm buildings in a great number of places where stones are scarce.
The departments of l'Ain, Saône-et-Loire, Rhône, l'Isère, l'Auvergne, Dauphiné and Normandy have a great number of cob buildings made of straw and soil and rammed earth, with beaten soil.
When rammed-earth walls are well made and suitably protected from direct rain, they can last several centuries. There is, then, in the use of earth for rural construction. a most interesting resource; the raw material is inexpensive and the labour cost very little thanks to the ease and speed of execution.
In his famous treaty on the art of building, the architect Rondelet wrote more than a century ago (passage on the best soil to use, no roots and if not a good soil, mix it with lime milk).

So, if you have on your property or in the neighborhood, heavy soil or sandy clay soil, you could use it for building. If this soil is too fat and is closer to potter’s clay, we can improve it with an addition of lean soil and sand, mixing it a little at a time with a horse.

Clay which is too fat is difficult to ram, it takes a long time to dry and cracks when drying, which makes it defective (imperfect) for rammed-earth. Lean soil obviously doesn't have the necessary consistency to form solid walls. Thus, follow exactly the precepts of the famous architect mentioned above when choosing the soil.
Do not be scared to leave in this soil any gravel smaller than a nut but do not leave any roots or manure as this would promote organic growth in the wall, or tiny animals which would compromise the solidity and integrity of the walls.
We would not ram the top layers of a soil, which have been cultivated and which contain all sorts of germs and fragments, animal and vegetable matter. First remove first this layer of humus and only use the virgin (pure) earth found at a depth of 40 or 50 centimeters for wall construction.
Often you will find a suitable soil when digging the foundations for a house- build. It is what almost always happens in the regions I mentioned above.

<u>Foundations and substructure of walls: It is essential to protect a rammed-earth wall from direct contact with the ground from which the humidity would rise in the rammed earth and soon destroy it.</u>
Thus, build the foundations and the substructures with dry stones if it is a simple fence wall or with **stones and hydraulic lime** if it is a house.

Build the stone wall sufficiently high that the humidity will not rise beyond it. If the terrain is naturally healthy and dried, a substructure of 20 to 30 cm height will be sufficient. If the building is being built on a humid soil or exposed to flooding, build the walls high enough that the water will not reach the rammed earth above. The substructure can, in this case, reach a meter of height and even a lot more, depending on local circumstance.
If you wish to build a solid attic above the ground floor, you will need to build the walls up to the floor boards of this attic and only start to build the earth wall above this level. Or you could build stone pilasters under the main timbers of the attic and use earth for the infill.
After the foundations, substructures or supporting pilasters are thought of and the choice of soil is made, there are two methods to use this earth.

1° Bauge ou torchis (cob) : make a very consistent mud by wetting correctly the clayish earth and mix to this paste straw or hay at the rate of one hectoliter (100 litres) to one cubic meter of earth. For the construction of the walls, use straw or hay in great length. To finish the building and the coatings, make a new cob with chopped straw or hay. Apply these mixes with a pitch fork in successive layers to form a wall of which the extremities and thickness will be determined by wooden pegs and stretched cords. Beat, level and smooth the faces of the wall with the shovel and the trowel.
Chopped straw cob and wetted earth are also used to fill the panels in a timber-framed building.
You would only, with this simple and primitive method, make light fencing walls or low-ranked constructions. It has the advantage of not requiring any special tools but [this method] **does not offer the solidity of rammed-earth.**

2° Rammed-earth : It is made from very little moistened clay soil and greatly pounded with the use of kind of a rammer in hard wood called *pison* or *pisoir*, in between a formwork made in boards called *banches*.
<u>(Too technical, some information --></u> for the formwork, use fir, 2 planks of 34 mm of thickness for 2 meters long. The width = 70-75 cm).

The thickness of the wall is usually 40 to 50 cm depending if it is a fencing wall, a house wall or for a rural building.

[…] bring the soil in buckets or baskets and spread it everywhere in the formwork by ramming it gradually in layers from 10 to 12 cm of thickness. When the formwork is full, you will have made a banchée, a sort of big raw compressed brick the extremities of which will be irregular.
Then dismantle the boards, pull out the transoms by leaving open the holes they made which would help for a quicker drying out of the wall and then reassemble the formwork along or above the portion of the wall already shaped, making sure to reverse the separation lines of the successive *banchées* (crossing the joints)
To join the banchées together, **it is customary in a few countries to spread a layer of mortar of lime and sand on the banchée already rammed.** This is not essential at all if the wall is not very high, with only three to four banchées on top of each other.
If, however, you want to build a house several stories high, apply in between the successive layers of rammed earth, a thick layer of mortar from 2 to 3 cm on all the surface of the wall already made. In this mortar, you will insert wooden lathes which will be imbeded in the mortar and the compressed earth forming a link between the *banchées*.

Also, you will link together the load-bearing walls with the exterior wall by putting wooden poles drowned in these layers of lime mortars.
The holes from the transoms across the banchées will only be blocked with lime mortar after the summer months have passed and drying the earth walls sufficiently
Concerning the quoins, make sure to join together the banchées from the two walls by building them one on top of the other at an angle and by putting poles or lathes in the mortar. Do not be afraid to build the inferior part of the coins with stones and mortars as this part of the building is subject to shocks which may damage the rammed earth.

In the areas where the timbers of the floor or of the roof rest on the wall, create a space with a few large stones and a bit of mortar in such a way the timbers do not rest directly on the rammed earth. This little amount of masonry has the advantage of spreading the load across a larger surface of the wall and it conserves the timber from the contact of the soil, which would tend to rot the wood.
You will build the window, door frames and lintels with bricks, stones or oak timber framing as in the case of a house built commonly in masonry.

Advantages of rammed earth: the price of the tools required to build a big building in rammed earth does not go above 50 francs; the soil doesn't cost anything and the workforce is a half lower than for a construction in stone or brick.
Once well dried, the walls are healthy, warm in winter and fresh in summer.
In some countries where we cannot find stones, we build very big houses of several stories this way.
The life of rammed earth walls is indefinite under the condition that we protect them in a suitable way from the weather, mainly from beating (heavy) rains by applying coatings made of animal hair and lime, a slate coating, or simply by extending the roof line wide enough.
Norman architecture offers in this respect precious teaching.
The best time to build rammed earth walls is in the spring, which would let them dry completely during the summer and receive the protective coating (render) before the winter.

<u>Special coating (render) for rammed earth wall</u>: Make a clear but binding paste with **one part of slaked lime, four parts of clay and some water.** Add and mix into this paste, as much hair as it needs for the mix to be full of it. Use hair from tanners or from the sheet shavers (the people shaving the sheets made from teaseling as short as possible for a smoother finish).
The hair has to be well divided and beaten, so that it does not form clumps in the paste.
Apply the coating in the autumn on a well dried rammed earth wall with a big paint brush or by throwing it and then spreading it with a trowel.
Do not apply it during heavy rains nor during frost, which would prevent the drying out.

Boynton R S (1980) *Chemistry and Technology of Lime and Limestone*. John Wiley & Sons.

Road Construction.

There is an old highways truism that no road is stronger than its base….As traffic counts and loads increase along with highway construction costs, engineers are necessarily becoming more scientific in designing highways….Even highly designed thick pavements and rolled stone base courses built on unstable clay are suspect. To correct such conditions, subbases are increasingly being constructed…In stabilizing the in-place soils or borrow soils or aggregate, lime can be used in the subgrade, subbase, or base course for soil stabilization.

Soil Stabilization. Lime's reaction with soils is twofold. **First, it agglomerates the fine clay particles into coarse, friable particles (silt and sand sizes) through base exchange with the calcium cation displacing sodium or hydrogen ions. Next, it provides a cementing (hardening) action in which the lime reacts chemically with available silica and some alumina in the raw soil** or with pozzolanic additives, forming complex calcium silicates and possibly aluminates.

In general, lime reacts readily with all clay soils, either the fine-grained clays or clay-gravel types. Such soils will range in Plasticity Index from 8 to 50+. Most soils with a P.I. lower than 8 are not as reactive with lime (although there are exceptions). For it to react with low-plastic to non-plastic sandy soils, generally a pozzolan (second additive) is needed. Fly ash is the most commonly employed pozzolan…although finely divided volcanic ash and burnt clay or shale can be effective. Under certain conditions reactive raw clays have been employed as an additive to react with the lime.

EFFECT ON SOIL. In soil stabilization lime actually alters the physical characteristics of clay-bearing soils (in varying degrees), transforming these soils into more stable materials for improved road durability. These physical changes are summarised as follows:

1. The Plasticity Index (or degree of plasticity of the soil) decreases sharply – as much as three- or more fold.
2. The Plastic Limit generally increases and the Liquid Limit decreases. (The difference between these two values is the Plasticity Index).
3. The soil binder (clay and fine silt sizes) content decreases substantially because of the agglomerating effect of lime.
4. The lineal shrinkage and swell drop markedly. Fine-grained clays without lime have greatest volume change in wetting and drying cycles as evidence of their instability.
5. Lime and water accelerate the disintegration (breaking up) of clay clods during the pulverisation construction step, resulting in coarser, more friable soils that can be manipulated more readily, thereby expediting construction.
6. **Unconfined compressive strength increases considerably – in varying amounts, but as much as forty-fold.**
7. **Load-bearing values, as measured by California Bearing Ratio (CBR) and triaxial tests, increase substantially from two to ten times**
8. In swampy areas or with soils exceeding optimum moisture content, lime facilitates drying the soil by increasing both the plastic limit and

optimum moisture content of the soil. This expedites construction under wet conditions.

9. A lime-stabilized subbase or base forms a water-resistant barrier by impeding the penetration of both surface and capillary moisture. Exposed but compacted lime-stabilized clay layers shed water readily during rains, thereby minimizing construction delays. This factor also provides some degree of protection against disruptive frost heaving.

RECOMMENDED USE. Lime stabilization can be divided into two main types – *subbase* (or *subgrade)* stabilization, involving fine-grained, cohesive soils containing little or no coarse material or road 'metal', and *base* stabilization, involving plastic granular materials, such as clay-gravel, which contains less than 50% No.40 mesh (0.42mm) soil. For 1-4% hydrated lime by weight of dry soil is required, depending upon laboratory tests, design requirements and engineering judgment for base stabilization; with the subbase, 3-6% hydrated lime is required. Either high calcium or dolomitic lime can be used. **Slightly sub-standard limes can be utilized, but at higher percentages than commercial products, since their results are not as predictable.** Quicklime is also at least as effective as hydrate. Many consider it more effective per unit weight because of its 20-25% greater lime concentration and heat of hydration. Quicklime was sparsely used in the United States until 1968 as a result of the peril to workers from burns. Since then its use in granular, small pebble and ground forms has grown steadily until it accounts for 17% of the commercial lime employed. In contrast, Germany, Belgium and Japan apply nearly 100% quicklime; France, the largest consumer of lime for soil stabilization in Europe applies both quicklime and hydrate about equally…
Lime can be applied dry or as a slurry composed of 30-33% lime solids. Slurry application eliminates dust nuisance, making it particularly suited for city streets and populated areas.

CONSTRUCTION PROCEDURES….For soil-in-place stabilization, scafifying to a depth of 6 inches (15 cm) and partial pulverization is the first step. Then the lime is applied evenly from bulk-drawn spreaders (in the case of slurry, from tank trucks) or from bags of hydrated lime spotted systematically on the road. Water is added up to the optimum moisture content of the soil, and lime, water, and soil are intimately mixed, preferably with rotary equipment. This mixture is then compacted to maximum practical or specified density, is moist-cured for 3-5 days, and then a wearing course is applied. All *lime-stabilized roads must be surfaced,* except for temporary or haul-roads. Because of its poor abrasive resistance to traffic lime does not provide a satisfactory unpaved road. (Or may be mixed away from site in batching plants).
Scope of Use. This method of road construction has been employed on every type of road from farm-to-market to interstate freeways, including city streets and military roads. Its use has extended to an increasing number of off-highway uses such as parking lots; airport runways, taxiways, and aprons; railroad beds; clay tennis courts and harness race tracks; under footings and foundations in building construction; and lastly under hydraulic conditions in earth dams,

embankments, river levees, the sides and bottom of irrigation canals and in lining reservoirs and cooling water ponds…

Transcribed by **Nigel Copsey** 2016; 2017;2018. French translations Emma Michel.

APPENDIX ELEVEN. ILLUSTRATIVE SAMPLE MORTAR ANALYSES.

Background to mortar analyses in Appendix 11.

No.1 Stonehouse, Brook Lane, Thornton Dale, North Yorkshire.

"Stonehouse' is constructed of Oolitic limestone to its lower story with a mixture of the same and calcareous sandstone. The original Schoolmaster's house, built 1656, was extended vertically during the 18thC. The earlier stonework was laid in a fine clayey bedding mortar, without apparent lime inclusion, although analysis of the bedding mortars was not carried out. This was originally pointed with a lime-rich mortar, the subject of this analysis. This is representative of lime rich, haired pointing mortars seen frequently laid over little-recessed earth or earth-lime bedding mortars in the region and similar in appearance to the lime-rich finish coats applied over earth-lime daub base-coat plasters regionally. A similar pointing pattern was observed to the later 18thC stonework, which was laid in a hot mixed lime mortar and pointed over with a different but still hot mixed lime mortar, with limestone – or calcareous sandstone – aggregate inclusion. The bedding mortar was given a once-weathered joint and pointed, again with little raking back of the bedding mortar. Both pointing mortars had survived in places – the later material more extensively than the earlier, although this had proved remarkably durable for its age. The discovered mortar proportions – 2 parts lime to 1 part limestone dust, with some added hair – deliver a mortar entirely composed of calcium carbonate with a high effective porosity, which may be considered essential over earth-built fabric and with which mortars of significantly lower calcium carbonate may be considered inherently incompatible. The early repointing mortar was hot mixed from quicklime.

No.2. Mortar from the Roman bath-house masonry, Vindalandia, Northumberland, considered to date from 100 AD.

This mortar has proved eminently durable in an exposed situation, part of the ruinous bath-house on the site.

It illustrates that a small volume of pozzolanic brick dust has been sufficient to offer such durability. Of 8% brick aggregate inclusion, only 5% was fine enough to offer pozzolanic reaction. Brick dust is one of the lower strength pozzolanic additives available to practitioners today. Brick aggregate offered porous aggregate inclusions, along with residual lime inclusions. The mortar had been hot mixed.

No.3 An earth-lime mortar from the interior stair-case wall of York House, Malton.

This mortar had performed very well. By volume, it was composed of a little over 3 parts local sub-soil with 1 part of slaked lime, interpreted as having been in the form of lime putty, although this lime putty may have been mixed whilst still very hot, or have been laid down a short while before mixing. The stair-case within York House was introduced circa 1604, although the plaster may be earlier than this. Notably, this is more lime than 10% or even 20%, considered to be the normal parameters of lime addition. On top of this, the sub-soil is from a calcareous geology. This mortar had no organic additives and this absence may explain the relative lime richness.

No.4 Earth-lime mortar from timber-frame infill panel, Calvados, Normandy.

Although the lime content of this sample was low, it had been prised from the pavement at the foot of the building and may have suffered some leeching out of the lime over time. Ample residual lime lumps were observed within the exposed, still in-situ daub. The sample was observed to be typical of earth mortars used in the region, for flint wall and other masonry construction as commonly as in association with timber-frame construction. Typical also, of all of these forms of construction from all periods, including, perhaps, from the 20thC.

No.5. Bedding mortar from the stepped footing of the medieval town wall, Hull.

The town wall was constructed of soft red brick during the 14^{th}C. Unexpectedly, the mortar of the footing, which would always have been underground, were found to have been of air-lime and the sampled mortar was fully carbonated. It was rich in lime: 1 part of lime: 1.34, consistent, however, with having been mixed at 1 pure quicklime to 3 aggregate. It had been hot mixed, probably to a dry-slaked coarse stuff initially to facilitate screening. The aggregate type and composition was consistent with its having been won from the shores of the River Humber, and included ash and brick in small volumes, which may have offered some very feeble hydraulic set.

No.6. Analysis of multiple mortars, Guild Hall, York.

This analysis is included as illustrating the evolution of typical mortar use over time, as well as the use in York of magnesian lime, although this was typically very low in magnesia and was effectively a high calcium lime in most cases. The Guild Hall is medieval, but buildings have been added over time. The site suffered bomb damage during WWII and underwent significant repair as well as some further extension with cement-lime mortars. The masonry units were variously magnesian limestone, sand-lime brick and red brick.

No.7 Four mortar samples from ironstone Calcining Kilns, Chimney Bank, Rosedale, North Yorkshire. The kilns were built after 1856 of local Jurassic limestone and sand-lime or magnesian lime brick vault linings. All samples were hot mixed using local high calcium quicklime. The dominant aggregates were calcined ironstone waste, as well as coal ash. Both offered some hydraulic set, depending upon their fineness, although the mortars were effectively porous and lime rich. One was somewhat harder and more brittle than the other three. This illustrates the use of industrial waste, immediately available and sourced, in the production of tougher mortars for wind and rain-exposed sites. However, mortars sampled from other industrial iron-mining sites on the Moors have shown the mortars to be generally non-hydraulic. The use of waste, therefore, may have been purely opportunistic and pragmatic, largely to reduce the cost of construction; the hydraulicity was simply a bonus. These mortars are generally sound and have been durable, although the kilns have been ruinous for many decades.

No.8 Mortars from Wayne County Courthouse, Wayne, Nebraska.

The courthouse is of red brick and red sandstone, built over one year in 1899. The bedding mortars were variously hot mixed with fine sharp sand or similar with red, iron oxide pigment addition. These have endured very well in general. It illustrates the default use of hot mixed air and feebly hydraulic lime mortars in the mid-western USA as late as 1899, using locally available limes and river sands. The iron oxide pigment represented a significant proportion and may itself have encouraged feeble hydraulic activity.

No.9 Analysis of bedding/pointing and interior plaster mortar, St Luke the Redeemer Anglican Cathedral, Calgary, Alberta, Canada. Built 1905-06.

These mortars have palpably promoted no damage or decay to the fine-pored Paskapoo calcareous sandstone of construction and remain robustly intact themselves. They illustrate the drift towards gauging otherwise hot mixed, high calcium mortars with small volumes of Portland cement, although a more primitive iteration of Portland cement, just preceding the construction of a more advanced Portland cement plant in Calgary after 1906. ‘Calcareous silicates’ comprise 10% by volume of the mortar. Portland cement is, in effect, being deployed as a ‘pozzolan’ in this case. The binder: aggregate proportion was 1: 1.13.

The interior plaster was also made of high calcium lime, probably slaked to a dry hydrate before sieving and running to a paste just before mixing. It was gauged with plaster of Paris and had added sawdust to resist shrinkage, once more illustrating a gowing trend in craft practice at this time, as well as the use of plentiful local materials, such as saw-dust. 7% gypsum was added by volume. The binder: aggregate volume was 1: 0.67.

No.10 mortars from Iron Calcining Kilns, Rosedale, North Yorkshire.

Very lime-rich pozzolanic mortars of high porosity despite their toughness.
Made with calcined iron waste and including fuel ash, these pragmatic mortars have performed very well in an exposed site with high wind-driven rain.
Mortars made recently with the same waste were eminently workable.

No.11 Interior plaster mortars, iron-stone workers cottages, Rosedale. The base-coat mortars were hot mixed with non-hydraulic quicklime and calcined ironstone waste aggregate. Mixed hot but probably allowed to cool before placement. The fine finish plaster was made with non-hydraulic lime putty with finely sieved calcined ironstone waste.

No.12. Finish coat plaster over earth-lime backing coat, York House, Malton. This is representative of haired finish plaster coats over earth across the region. It comprises mainly of non-hydraulic lime slaked to a thick paste but used very soon after slaking with a very small addition of fine silica sand and ample hair – in this case, horse-hair, with some ox-hair.