TWENTIETH-CENTURY EARTHEN BUILDINGS OF SARDINIA: ARCHAEOMETRY AND CONSERVATION

VOL. I

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This thesis is submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy

The University of York
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The King's Manor, September 2001

To my father

ABSTRACT

This thesis is a study of the traditional manufacturing processes and repair methods of twentieth-century earthen architecture of Sardinia. A fundamental concern of the work is to propose guidelines towards better repair, prevention of decay, and maintenance of these buildings. The methods employed are multiple and interdisciplinary, and the work was carried out as follows:

(1) the traditional manufacturing processes of the following building materials were studied as explained through interviews with elderly Master Craftsmen: mud brick and mud plaster, and also the related traditionally-used materials such as tiles and fired brick, stone, lime, and vegetable materials;

(2) the principal symptoms and mechanisms of decay were investigated by undertaking a questionnaire based on a population of 288 earthen building users;

(3) the traditional repair methods for earthen buildings were studied as explained through interviews with Master Craftsmen;

(4) mud brick and lime renders were analysed in the laboratory in order to complement what had been explained by Master Craftsmen (point 1). For the same reason, and in order to study recent conservation practices, two buildings were selected as case studies.

It should be noted here that the above four points are all original contributions made to knowledge in the subject of traditional earthen construction of Sardinia, as the available literature focuses on building types and not on the analysis of building materials.

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PREFACE

After having written my MA dissertation, I started with the assumption that some autochthonous repair techniques must have been developed by generations of Master Craftsmen in Campidano, a region of the island of Sardinia. This conjecture found no confirmation in the existing literature, which does not even mention the possibility. When my conjecture was suggested to certain local academics and architects, they were sceptical about it and thought it was not a relevant topic of study. The standard procedure for the repair of earthen buildings in Sardinia is nowadays carried out by means of modern methods and materials, and from this derived the frustration of how to study repair methods which would be more appropriate and sympathetic to the historic fabric of earthen buildings in that culture.

As a next step, several Master Craftsmen were interviewed and, when asked if they employed any traditional repair methods, they gave extremely fruitful information. As opposed to the academics' lack of interest, Master Craftsmen were on the contrary enthusiastic to explain what they had done in the past. They explained that they had employed standard techniques for specific symptoms of decay. It was in this context that a survey of the main decay symptoms was then felt necessary. It is a recognised fact that in the field of conservation the study of decay mechanisms is as important as repair techniques. Following this, a questionnaire was conducted amongst dwellers of earthen buildings in order to unravel the main symptoms of decay. The answers to the questions posed were also found useful for understanding the appropriate and traditional conservation of earthen buildings.

Master Craftsmen were not only interviewed about traditional repair methods, but also about the traditional manufacturing processes of building materials during the first half of the twentieth century. Although their answers were satisfactory, it was observed that they were too empirical to be relied on wholly. It was felt then necessary to conduct an experimental survey of two building materials: lime and loam. The results of the experimental analyses were grouped into 'atlases' to be used as references at a later stage. This experimental survey was also considered to be complementary to what had been explained by the Master Craftsmen about the traditional manufacturing processes of these two important building materials. It was also decided to test the findings of the experimental analyses by means of two case studies. The two parallel case studies proved significant and also useful to assess the repair work which was in progress while this thesis was being researched and written. The assessment was conducted by comparing the different traditional repair methods explained by the Master Craftsmen, by investigation and enquiry of how philosophy and ethics had shaped the choices, by means of comparison of experimental data of historic materials and replacement materials, and also by means of comparison between replacement materials and the atlases for lime and loam.

To conclude, the overall results of the research have been:
(1) to confirm that this was a valid and worthwhile subject of enquiry;
(2) to enable a number of conclusions to be reached, which help out in understanding the several changes of building culture during the twentieth century, and to provide some pointers for future and more authentically-bound conservation and repair;
(3) to widen the debate so as that the research experience may be seen as relevant and of value to other building cultures in the Mediterranean basin;
(4) to form a basis for future research.

ACKNOWLEDGEMENTS

This thesis would not have been possible without the support of several individuals and institutions. First I am grateful to the Regione Autonoma della Sardegna who provided me with the scholarship.

I am also grateful to the following individuals:
Diego Agattau, Maria Laura Angius, Daniela Aru, Carlo Aymerich, Ubaldo Badas, Alessandro Baldussi, James Barrett, Alasdair Brooks, Sue Buckam, Fabrizio Cadeddu, Anna Castellino, Alessandra Corona, Stefania Dore, Alessandro Falqui Cao, Barbara Fodde, Ignazio Garau, Linda Garavaglia, Tim Gates, Bjarne Gaunt, Peter Goldsborough, Peter Goodchild, Ben Gourley, Jane Grenville, Krisprantono, Elisabeth Louden, Patricia Haywood, Rossana Martorelli, Sandro Mezzolani, Daniele Mura, Ratish Nanda, Lucio Ortu, Eduarda Paz, Carlo Pillola, Phil Piper, Silvano Piras, Janet Powell, Massimo Rassu, Julio Sampaio, Antonello Sanna, Giulia Setzu, Miriam Spano, Michael Stratton, An Suy, Carlo Tronchetti, Alceo Vado, Grazia Villani, Songyot Weerataweemat, Kevin Walsh, Pam and Gavin Ward, and John Warren.

Special gratitude goes to my two supervisors, Peter Burman and John Hurd, for their encouragement and help with my work. Grateful acknowledgement should be given also to the Master Craftsmen and the professionals who agreed to be interviewed for this work.

I am also grateful to the staff of the following archives and libraries: Archivio Materiale Fotografico della Soprintendenza ai BAAAS di Cagliari e Oristano (It), Archivio Storico

(Cagliari, It), Archivio Storico Comunale (Quartu Sant'Elena, It), Archivio Storico (Iglesias, It), Biblioteca Comunale (San Sperate, It), Bilioteca del Consiglio Regionale della Sardegna (Cagliari, It), Biblioteca del Dipartimento di Archeologia (Cagliari, It), Biblioteca del Dipartimento di Ingegneria Chimica e Materiali, Facoltà di Ingegneria (Cagliari, It), Biblioteca dell'Istituto di Architettura della Facoltà di Ingegneria (Cagliari, It), Biblioteca della Facoltà di Lettere (Cagliari, It), Biblioteca della Facoltà di Geologia (Cagliari, It), Biblioteca della Facoltà di Teologia (Cagliari, It), Biblioteca della Soprintendenza ai BAAAS di Cagliari e Oristano (It), Biblioteca di Geologia Applicata, Facoltà di Ingegneria (Cagliari, It), Biblioteca Universitaria (Cagliari, It), Bibliothèque Internationale de l'Architecture en Terre, CRATerre (Villefontaine, Fr), ICCROM Library (Rome, It), King's Manor Library (York).

AUTHOR'S DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of York. It has not been submitted before for any degree or examination at any other universities.

Date Dec. 2001

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Chapter 1

RESEARCH FRAMEWORK

1.1 The selection of the topic

This thesis is a study of the past craftsmanship involved in the construction and repair of the earthen architecture of Sardinia, and the cultural aspects of a traditional architecture which incorporates an understanding of buildings which dates back centuries. Expanding the existing knowledge of these earthen heritage properties, examining their behaviour in the Sardinian climate and the preservation of traditional craftsmanship as part of a sustainable conservation future are the other prominent concerns of the thesis.

This first chapter contains a discussion of the thesis background (including the aims and basic hypothesis) and structure, but a brief introduction of some terms found throughout this thesis is necessary first. The selected area of study in this thesis, Campidano, is the primary plain of Sardinia, and stretches diagonally from Cagliari to Oristano, a valley of roughly 100 km in length by 30 km in breadth (Fig. 1.1). In this region, the only traditional building material is mud brick dried in the sun, locally known as *làdiri*. The latter is the term used throughout this thesis to refer to mud brick. Campidano is not only defined geographically and geologically, as a plain of alluvial soil surrounded by mountainous land, but also historically: travellers who visited Sardinia from the Roman period until the early twentieth century reported on the equable attitude of people from Campidano for instance compared to the neighbouring population of Barbagia, a mountainous region of the centre of Sardinia. Through the centuries Campidano developed social and cultural dissimilarities from Barbagia, which are also visible in the building types and in the locally available materials used in their construction. The unity of the area under examination can also be explained by the fact that communication between its villages was considerably easier on the plain, while significant communication difficulties existed for the surrounding mountainous areas.

Two building types are under examination in this thesis: the courtyard farmhouse and the palazzo (Figs 1.2-1.10). These types are both widespread in Campidano and can both be considered as courtyard houses, the second usually being a turn of the century evolution of the first. Two other expressions are frequently employed in the present thesis: 'vernacular architecture of Campidano' and 'earthen architecture of Sardinia'. They both are used to refer to the earthen architecture of Campidano, as this is the only region of Sardinia whose traditional built heritage is entirely constructed from loam. The word 'vernacular' is usually associated with those spontaneous, native, dialectal, or indigenous buildings which employ locally-available materials, as opposed to 'polite' architecture. Vernacular architecture, as debated by Turan (1990,14): '... is not an isolated phenomenon in society, but rather is a total attitude or comprehensive way of environmental response. It is practical knowledge, ranging from skills derived from concrete experience and availability of materials and techniques to the considerably more general knowledge of an appropriate response to the environment'.

It is clear from this definition that the word vernacular can be applied not only to traditional rural architecture, but also to more urban buildings. This is indeed true for Campidano where earthen buildings can be found in urban areas and in small towns such as Oristano. It should be also noted that the definition given by Turan employs the word 'technique' (the building know-how) and not the term 'technology' (the building methods used). However, in the specialised literature on vernacular architecture there is a tendency to use the word 'technology' for referring to the building know-how. This thesis has been written with the conviction that the first use is the most appropriate for discussions of vernacular architecture and this is the term which will therefore be employed in this thesis. Following Turan's definition, the earthen architecture of Sardinia can certainly be positioned in the vernacular field of study as its construction derives from affirmed methods developed through empirical knowledge over the centuries on the use of locally-available mud. The passing of practical knowledge and skills from one generation to another is considered in this work as a cultural aspect of Campidano's heritage. The cultural significance of these buildings can be extended to a larger scale in order to consider overall the dwellings forming the historic core of villages. Many of these village nuclei are today in a state of abandonment caused by past town council policies and uninterested owners, therefore necessitating a review of conservation strategies.

1.2 Defining the problem

1.2.1 Aim and objectives

As this author has previously contended (Fodde 1997), Sardinian earthen architecture is an expression of Sardinian tradition and culture. This statement has important implications for this research; if these dwellings are truly an expression of Sardinian culture, then they need to be conserved in order to staunch the loss of cultural identity in contemporary living standards. Another important reason for the conservation of this heritage is the demand for sustainable housing in Sardinia. Furthermore, the fact that the endangered heritage of Campidano requires immediate attention was recently stressed by the report Heritage at Risk (ICOMOS World Report 2000 on Monuments and Sites in Danger) where it was stated that '...this entire heritage will be gradually destroyed as soon as the houses are abandoned or replaced by horrible construction in concrete and plastic' (Bumbaru 2000, 222).

The specific aim of this work is therefore:

to understand the traditional construction of earthen architecture of Sardinia, by making a close inspection of the materials employed therein, with the intention of identifying and proposing guidelines towards better repair, prevention and maintenance practices of these buildings.

The long-term ambition of the thesis is to promote awareness among owners about the state of the abandonment and neglect of these dwellings caused by changes in Sardinian social organization. These changes have to be understood in order to develop new attitudes and future directions in conservation.

1.2.2 Research questions

The thesis was written by focusing on two sets of research questions directly related to the aim of the thesis, but which also helped to structure the work:

1) Why did earthen building construction stop in 1960, and why is traditional architecture today neglected by its inhabitants? When such buildings are repaired nowadays, how are they repaired, and what are the consequences of that repair? What are the main symptoms and mechanisms of decay which affect historic earthen buildings today?

(2) What were the manufacturing processes of vernacular architecture materials in Campidano between 1900 and 1960? Based on the analysis of materials, what suggestions can be made for a more appropriate conservation of the Sardinian earthen architectural heritage?

The different aspects of the research questions were analysed through different research methods. Each set of questions was studied with one or more tailored methodologies considered most appropriate for that specific question or topic. The first group of questions was explored by analysing the data from specially constructed questionnaires (for the symptoms of decay) and interviews with traditional craftsmen (for the traditional repair methods). The second group of questions was explored by interviewing traditional craftsmen, by the study of specific case studies, and by carrying out experimental analysis in the laboratory.

1.2.3 Hypothesis

During the early stages of this research, particular attention was given to the non-Italian literature. In this respect, the early thesis hypothesis was that adequate repair and maintenance techniques for Sardinian earthen architecture could descend from proven methods developed in other countries with a similar climate.

However, after further advice and review, this approach was reversed. It was decided to focus the research on the traditional maintenance and repair systems of Campidano itself and to the fact that these might be applied to similar regions of the Mediterranean basin. The points that gave birth to the new approach were as follows:

(1) It is advocated that a study of the conservation of the earthen architecture of Campidano is worth a DPhil thesis because of the originality of the topic as evidenced by the absence of previous proper research.

(2) The earthen architecture of Campidano is the reflection of geology, geography, climate, and past colonizations by several peoples of the Mediterranean basin. These issues are especially evident in building types, but also in building techniques and craftsmanship.

(3) As well as the manufacturing processes of these buildings, it is important to understand the symptoms and the mechanisms of building failure.

(4) Adequate repair techniques should be studied through an investigation of traditional manufacturing processes and of repair methods. The examination of historic features allows the formulation of a hypothesis on the philosophical issues related to the conservation of earthen architecture; ethics and philosophy of conservation are indispensable guides, especially if emphasis is given to minimum intervention and to traditional materials in repair which preserve cultural identity intact.

(5) Finally, such conjectures may be applicable to Mediterranean countries with similar climates to Sardinia.

Therefore, the refined thesis hypothesis is as follows:

appropriate repair methods for Campidano's earthen architecture can evolve from autochthonous techniques and from the past experiences of Master Craftsmen.

This statement will be used as a focus throughout the thesis and also for identifying the boundaries of the research (Fellows and Liu 1997, 99).

1.3 The meaning of building conservation research - a scientific approach?

> *'The task of the scientist is no longer "to search for the truth", or "to praise god" or "to systematize observations", or to "improve predictions". These are but side effects of an activity to which his attention is now mainly directed and which is* to make the case stronger *as the sophists said, and thereby* to sustain the motion of the whole.'
>
> *(Feyerabend 1975, 30)*

Until quite recently, little attention has been given to research methods for building conservation, which has led to a consequent lack of literature on the subject. As a result, available books on research methods for other disciplines close to conservation were adopted as guidelines for this type of work. The Concise Oxford Dictionary (1995) defines the word 'research' as:

(1) systematic investigation into and study of materials, sources, in order to establish facts and reach new conclusions;

(2) an endeavour to discover new, or to collate old, facts by the scientific study of a subject or by a course of critical investigation.

Both definitions stress the importance of investigation during the research process specifically if there is an intention to develop the investigation by following a scientific approach through which data are gathered together before starting the analysis (Robson 1993, 20). The science of building conservation implies that, in order to obtain information about a specific building material, it is necessary to carry out laboratory experiments and surveys (field surveys and questionnaires). In this respect, some authors have pointed out that scientific tests can be falsified and therefore a theory is hardly ever proved to be true (Fellows and Liu 1997, 10) which implies the importance of the control of data in the research process. This is also postulated by Morin (1988, 38) who has argued that scientific theories, like icebergs, have an enormous submerged part which is not scientific, but is necessary for the development of science.

It is nonetheless important to stress that the discipline of earthen building conservation also foresees an empirical aspect. Through the medium of interviews, elderly craftsmen made useful suggestions based on past experiences, and guidance was given on the traditional way of conserving *làdiri* buildings by using empirical methods developed through the centuries which - while not being based on scientific procedures - may be appropriate answers to the decay that affects these buildings. Deciding not to consider the application of these methods would reduce the cultural significance of the dwelling itself. It can therefore be stated that the research design is an interdisciplinary negotiation between empirical and scientific methods. Further emphasis will be given to this issue in the following section.

1.4 Collecting information: a pluralistic methodology for the study of vernacular architecture

Traditional architecture is difficult to predict, is full of variety and change, and this observation is particularly applicable to the vernacular heritage of Campidano: supposed codes and rules were often violated, and this was indeed necessary for improving the quality of an individual building. The building apparatus can contain such diverse materials as mud brick, stone, fired brick, cane, reed, timber, wrought iron, clay tiles, lime, and terracotta. Each of these was traditionally manufactured and repaired with particular techniques. At the same time the field of conservation embodies a variety of disciplines such as history, engineering, chemistry, physics, art history, etc. Following the plurality of these specialities, the methodology to be used for studying the conservation of Campidano's vernacular architecture was considered carefully in order to cover the requirements for the disciplines referred to as above. Using a strict and inflexible non-pluralistic methodology would thus have been inadequate for traditional building research. This is also explained by Feyerabend (1975, 306) who states that:'The separation of science and non-science is not only artificial but also detrimental to the advancement of knowledge. If we want to understand nature, if we want to master our physical surroundings, then we must use all ideas, all methods, and not just a small section of them'.

The multidisciplinary methodology used in this thesis is structured as follows:

(1) the theoretical framework was defined by reading the literature on the subject and by contacting leading experts in the field;

(2) interviews with craftsmen from Campidano were undertaken to study the manufacturing processes of building materials used between 1900 and 1960;

(3) questionnaires were given to building users to provide data on the main symptoms of decay that affect these buildings;

(4) interviews with craftsmen from Campidano were also used to inform the author about conservation practices in use in the past, but now abandoned;

(5) analysis of samples collected in Campidano was undertaken through laboratory experiments in order to study and characterise mud bricks and lime renders;

(6) case studies were examined for testing the hypothesis and the findings referred to above. Samples taken from the case studies located in the region were also analysed through laboratory tests, and findings were analysed through comparison with the results of the analysis of the samples from the whole area. Following the analysis of data, it became clear that the work should be cross-checked to see if the resulting schemata were valid and universal to different contexts, areas and building types.

Introductory discussions of these points follow in the next few subsections of this chapter, but more in-depth coverage can be found later in the relevant chapters of the thesis.

1.4.1 Historiography and the lack of research

During the first year of work, the theoretical framework was finalised through literature reading and through meeting Sardinian professionals. The generation of a historiography was found to be useful in finalising the subject of study and in understanding the content of originality of the thesis.

The Sardinian architectural heritage is the most extensive in Italy and, certainly from a formal point of view, one of the richest in the Mediterranean basin. The importance of the houses of Campidano in the Italian context has been recognised by the geographer Osvaldo Baldacci (1958, 28) who stressed that the earthen architecture of Sardinia fully embodies functional, structural, rural and urban characteristics which are missing in the other regions of Italy, apart from the flat area around Marengo in Piedmont. In addition to this, the importance of Campidano's building type lies in the impressive number of surviving earthen villages. A rough calculation shows that more than 30% of all of the historic cores of the island's villages are made of *làdiri*, the largest being Quartu Sant'Elena with its 1500 buildings (Sanna 1996, 125). By comparison, the earthen architecture of the peninsula is smaller in number and characterised by an earlier cessation in construction.

That this study is a significant, original topic and indeed necessary is clearly evidenced can be supported by the fact that there is at present a large lacuna in the literature on Sardinian vernacular architecture; the traditional processes of production and the traditional methods for repairing earthen houses require proper documentation. Literature on the subject is scarce and is mainly about typology and anthropological issues. This point is also stressed by Baldussi (1993, 134) who points out that 'the study of earthen structures of Sardinia is in the deep dark from the building technique point of view' (author's translation). Literature concerning the conservation of earthen structures of Sardinia is even scarcer and - when it exists - lacks any scientific knowledge of the material (Fodde 2000a, 125). This again is recognised by Baldussi (1993, 134) who argues that 'Sardinia lacks reasoned and rational studies on building technique, on analysis and maintenance of the building itself, and an overview of pathologies and solutions' (author's translation). In this respect Orazi (1995, 228) argues that 'a sort of condensed handbook on conservation techniques could be prepared by universities or research centres under the coordination of the relevant department of the Regional Council concerned'. The creation of an updated and possibly complete corpus of work on the conservation of Sardinian earthen heritage is therefore necessary.

Another objective of the historiography was to make a summary of the 'state of the art' on the topic (Fellows and Liu 1997, 52), and consequently to strengthen it. Practice and research have reinforced the author's knowledge of conservation regulations and of the literature on the conservation of earthen architecture of Sardinia. Existing literature can be categorised according to its subject: archaeological studies, anthropological studies, and typological studies. In generating the historiography, the relevant works on the topic were classified by following the above structure, in order to provide the reader with a selected picture of the current state of knowledge and major questions in the subject area being investigated (Bell 1993, 35).

Archaeological studies

Earth is a building material which has been employed by the majority of the civilizations that have occupied Sardinia over the centuries. The discipline of building archaeology is still under development in Sardinia, and the available studies tend to concentrate on the pre-Roman period. The available literature is limited to either articles on specialised journals, or to sections of excavation reports. A satisfactory monograph on the archaeological evolution of building techniques of Sardinia is therefore yet to be written. Some excavation reports, for example that by Pesce (1957), contain descriptions of several earthen walls dating from the seventh century BC to the Roman period, as found in Nora. Valdès (1986a) found evidence to suggest that the technique of *tapies*, or earthen blocks, was used in Sardinia in 1567 and then abandoned in favour of mud bricks. A study of Campidano's building archaeology based on the literature review and on interviews with archaeologists is contained in section 2.7 of Chapter 2.

Anthropological studies

The most important work on the evolution of the structure of Sardinian society in relation to land use is that by Le Lannou (1979). A non-Italian and geographer, he provided an unprejudiced description of the geography and of the cultural landscape of the island. The study includes a section on the dwellings of farmers, together with a fine portrait of the changes taking place in the society in his time. Even though the book shows a deficiency in the analysis of buildings types (as Le Lannou was not a specialist in this field), it can be considered as a stepping stone for subsequent works. Le Lannou's study was followed by that of the anthropologist Angioni (1976) whose work represents the most important attempt to illustrate the relationship between farmers and the farmhouse. Angioni and Sanna (1988) edited a book on the relationship between the cultural landscape and its buildings from an anthropological-historical point of view in order to investigate the *genius loci* of the region.

Typological studies

Baldacci's (1952) monograph on the rural houses of Sardinia represents the most complete work on stone and earth construction, however his plans and representations are poor from a communication perspective. This weakness in this pioneering study has been superseded by the work of Mossa (1957) who provides a sounder overview of 1950's Sardinian villages. The books edited by Selva (1990), Sanna (1993), and Copez (1994), employing similar research methods, further upgraded the previous studies. They narrowed down the study of types to earthen buildings only, with consequential increase of information about building forms.

The inevitable conclusion of this historiography is that of all the authors who have looked at the earthen architecture of Sardinia, no one has yet initiated any work either on the manufacturing processes of building materials of traditional Campidano, or on their traditional repair methods.

1.4.2 Survey-questionnaire

In order to understand the most common symptoms of decay that affect lived-in earthen buildings, and to uncover the accumulated knowledge of those residents with the longest experience of their buildings in Campidano, a questionnaire was designed for this purpose by the author.

The structure of the questionnaire was based on that designed by Baldussi (1994, 183). The questionnaire was undertaken only after the topic and the issues that had to be identified had been defined. Questions were then designed to gather information on the symptoms of decay that affect different parts of the building by questioning the inhabitants directly. The questionnaire included 39 questions, the first section dealing with enquiries about the history of the dwelling, the second section dealing more specifically with different parts of the building and their pathologies. A copy of the questionnaire is available in Appendix 3. The questionnaire's design was dictated by the fact that simple questions were preferable to more complicated ones. It was felt that the population to whom the questionnaire was addressed might be encouraged to answer more easily if enquiries were put in a more straightforward and simple way.

Preference was given to this method as it is a better way of collecting information than direct inspection (Bell 1993, 75) - which was nonetheless also employed when circumstances made it possible and when owners allowed. Moreover, it was impractical in terms of time and cost to carry out a survey of private houses unaided. The survey was restricted to the Sardinian villages that have a substantial earthen architectural core. The selection was initially undertaken by using a random method. Randomisation was felt to be important because it allows for the *averaging-out* of the eventual interference of uncontrolled variables. In other words, the random method is more likely to obtain 'true' results (Fellows and Liu 1997, 73; Robson 1993, 80).

The percentage response rate for the questionnaire was calculated in the first period as:

(1) people not at home	50.50%
(2) people refusing to be questioned	24.44%
(3) people agreeing to be questioned	25.06%

These percentages emerged during the first two weeks of work, by calculating the response rate of 200 contacted families. As the percentage of people agreeing to be questioned was so low, the author slowly ran out of villages to visit. It was therefore necessary to investigate communities that displayed mixed traditional building materials (stone, mud brick) with a consequential increase of time needed to find earthen dwellings. After these villages were visited, the overall number of completed questionnaires was 288. This population size was appropriate for the region of Campidano and all of the buildings to which access was granted were surveyed. It is important to stress that the questionnaire covered only those earthen buildings which were inhabited at that time (from 2 September to 15 November 1998). The list of surveyed villages can be read on Table 4.47 and they can be located on the map on Fig 1.17.

Preference was given to questioning inhabitants over 30 years of age as they typically knew the building well enough to be able to answer most of the questions adequately. The process was slow, with a pace of one questionnaire completed every twenty minutes. This was due to the fact that, once having reached the village, the author had to find earthen buildings still standing, then to find earthen buildings still inhabited, then to find out if the owner was actually in or out, and to convince the owner to open the door and answer the questions. People in Campidano today are not as trusting as in the past (especially when home holders are elderly and live alone) and therefore they often tend not to make themselves available for this type of research.

Undertaking the questionnaires in front of and with the householders, was clearly the best method available as inhabitants had to be encouraged to answer without being forced to do so. The initial idea of sending out the questionnaires by post and waiting for the answers would have been totally inadequate. It was also observed how much more difficult it was to convince people to listen if they lived in a village closer to the capital, Cagliari. The more the author moved away from Cagliari, the more forthcoming the householder was. The reliability of the data was examined and analysed by understanding to what extent the questionnaire procedure produces similar results under the same (constant) conditions (Bell 1993,64).

1.4.3 Interviews

Interviews with craftsmen

Several elderly craftsmen were interviewed by the author in order to collect data on the traditional process of building a house in Sardinia (Figs 1.11-1.16). Their names and professions are listed on Table 4.46. The very fact that building with earth stopped on Sardinia as late as the end of 1950s made it possible to visit villages where the relevant local craftsmen could be found. The author, not knowing any key people in these villages who could introduce him, realized that the only way to contact traditional craftsmen was to ask the older people who meet in the village piazza, and to ask them for the craftsmen's names and addresses. The average age of the craftsmen interviewed was 68. This means that in 1960 - the year by which when concrete had definitively replaced mud brick in Sardinia - the average craftsman was 30 years old, an age that shows he had at least 12 years experience in the field. However, it is known that apprenticeship in that period commonly started earlier, with evidence of 13 year old boys working as assistants so in fact the work experience would usually have been even longer. To show the importance of this oral evidence, it was explained to the author by other Italian researchers that this kind of inquiry could not have been carried out in other parts of Italy (i.e. Abruzzo, Sicily) where building in mud ceased around 1930 with a subsequent loss of unrecorded oral history (Barbara Narici and Anna Paola Conti, pers. comm.).

As the *Maistrus de Muru* (the Sardinian expression for 'Master of the Wall', used more often than 'Master Craftsman') were not limited to specific materials - the title applies to the supervisor of the whole building - this required the drawing up of a series of questions about different materials and issues. The aim of interviewing local craftsmen through semi-structured interviews was to increase the scanty information about the local, traditional techniques of construction and the materials used. Master Craftsmen often asserted that repair and maintenance techniques were a normal practice amongst Sardinian craftsmen until 1960. Every interview was undertaken with the help of a tape recorder and of a semi-structured set of questions which were read to the interviewee. Sometimes questions had to be put in Sardinian (a separate language from Italian) with some difficulty by the author. As most Sardinian speakers also understand Italian, the most common procedure was for the interviewer to speak in Italian and for the interviewee to speak Sardinian. The interview was then typed out on the very same day, sometimes with the help of a Sardinian speaker.

It is important to stress that when comparing the map of Campidano with the locations of villages visited for the purpose of data collection, it can be noticed how the area examined by these undertakings is very evenly covered (Fig 1.17). It should be noted here that the same sets of questions were asked to every craftsman in order to facilitate the cross-referencing of the answers and to make the data more reliable.

Interviews with conservators

More informal conversational interviews were undertaken with current conservation practitioners in order to analyse the methodologies they have adopted for solving problems related to conservation. Great emphasis was given to the general nature of the findings of enquiries because what has been uncovered through this method should be applicable to other cases and contexts.

Sardinian professionals frequently involved in the conservation of earthen structures are uncommon, and this made it easier to contact those that do exist. A letter explaining the research being undertaken and the aim of the interview was sent before contacting professionals by phone and arranging a meeting date. Most of the potential interviewees did not show any interest in being interviewed and, when they accepted, the impression they sometimes gave was to divert the author's questions in order to show themselves in a better light.

To conclude, the difference between interviewing craftsmen and interviewing conservators was due to several factors. The craftsmen had more time to spare and, because they had worked for so many years using traditional materials, tended to be more enthusiastic and knowledgable about what they did in the past and talked about it with more detail and vigour while, by comparison, conservators - perhaps because they were younger than the craftsmen - did not show the same commitment. It was decided that the involvement of conservators would be more appropriately considered when designing the case studies. Dates for personal communications are supplied in Table 4.46.

1.4.4 Laboratory experiments

A further investigation of building materials was undertaken through laboratory tests in York of samples of lime and earth taken from Sardinia. Buildings from which to take samples were selected not by using a random method, but by following three requirements suggested by Gil (1989, 79):

> *1. Choose typical cases. It is about exploring objects which, according to previous information, seem to be the best expression of the ideal type of that category;*
> *2. Select extreme cases. The advantage of employing extreme cases is that they can give an idea of the limits between which variables can operate;*
> *3. Choose marginal cases. This is about finding atypical or anomalous cases in order to, in contrast, know the parameters of normal cases and the possibilities of causes of deviation.*
> (Gil 1989, 79; author's translation)

In so doing, it was hoped that conclusions would present a high degree of accuracy and results could be generalised to other cases. The number of samples was limited by restrictions of time and resources and therefore they should be considered as the minimum population necessary to cover the whole area. Samples were collected in two different field expeditions and include: 70% typical cases, 20% extreme cases, and 10%

marginal cases (as per Gil's classification). All *làdiri* samples were collected from buildings, whilst the sampling of natural earth samples was not carried out due to the urbanisation of the village outskirts. A small survey for studying natural samples of limestone was, however, considered possible. The geographical distriution of the samples can be also visualised in Fig. 1.17.

Two different sets of experiments were carried out for the soil samples in order to complement the information given by master craftsmen: characterisation tests and physical tests. The first set includes the following tests: soil colour, measurement of pH, particle size and size distribution, carbonates content, plastic limit, liquid limit, and plasticity index. The second set includes the following tests: erosion test, wetting and drying test, shrinkage test, and abrasion test.

Three tests were carried out on the samples of lime renders in order to complement the information given by master craftsmen: dissolution in hydrochloric acid and analysis of aggregate, void ratio and open porosity test on the aggregate, and embedding a sample in resin. A more detailed description of the methodology adopted for the sampling and the analysis of *làdiri* and lime renders can be read in Chapter 7, section 7.3.

1.4.5 Case studies

The employment of two case studies was suggested to the author during the final stages of the research. Two earthen structures were selected for this purpose. They were chosen as representative of the available building types, and also because of their construction date. One aim of the analysis of the case studies is to compare their conservation techniques to the traditional methods explained by the craftsmen during the interviews. Another aim is to analyse the samples of earth and renders in order to compare the results with the findings which emerged from the analysis of the samples of the whole region of Campidano (as explained in section 1.4.5). This testing method allowed the assessment of the applicability and general nature of the methods explained by craftsmen applied to the whole area under examination.

The ability to test results is important in terms of the growth of knowledge because its requirement is that: '...new theory should be independently testable. That is to say, apart from explaining all the explicanda which the new theory was designed to explain, it must have new and testable consequences (preferably consequences of a new kind); it must lead to the prediction of phenomena which have not so far been observed.' (Popper 1963, 240)

1.5 Thesis structure

The thesis is divided into two main sections: *analysis* and *conservation*. The section titled *analysis* (Chapters 2-4) starts with a study of the cultural aspects of the vernacular architecture of Sardinia, of the environment in which these structures were built, and of the building materials and their decay. Additional objectives of this section are to trace the history of the use of earth as a building material in Campidano, to show the social characteristics that influenced domestic architecture (physical, natural and socio-cultural environment) and how attitudes towards its use have changed. Further, the purpose of this section is to explore the major techniques used in the production of building materials and their application when the houses were built. The concluding chapter of the *analysis* section deals with the study of the decay of earthen buildings. The section titled *conservation* (Chapters 5-8) will describe the traditional repair methods and strategies used by past craftsmen.

Chapter 1 (the current chapter) provides the introductory reference points for the whole work. The aim of this chapter is to explain to the reader the methodology adopted during the investigation of the vernacular earthen building of Campidano, the identification of the research questions and hypothesis, and the structure of the thesis as a whole.

Chapter 2 consists of a description of the natural and historical environment of earthen architecture in Campidano as derived from the literature review. The last part of the chapter examines the issue of the cultural significance of earthen architecture in Campidano in an international context by describing the external influences, especially from the Spanish period (1479 to 1717), reflected in traditional architecture.

Chapter 3 describes the traditional construction process of producing a house in Campidano between 1900 and 1960. This is considered to be an overall view of the building, its craftsmanship and the materials employed. As the study of the traditional building materials of Sardinia is an original topic in the framework of vernacular architecture, particular emphasis is given to the analysis of sequences of manufacture of materials.

Chapter 4 contains a discussion of the most widespread symptoms and mechanisms of failure and decay that affect earthen buildings by analysing the data gathered from the questionnaires and by site analysis.

Chapter 5 features an examination of the traditional techniques of repair of earthen buildings in Campidano; as no literature on the topic is available today, interviews with craftsmen will be the only source of information for data. The aim of the chapter is to provide a study of the main components of the building fabric in order to explore the potential traditional repair techniques for the most common pathologies, as identified in Chapter 4.

Chapter 6. This chapter will describe two case studies of two buildings conserved during the last two years, in order to give an overview of best practice in Campidano. Once samples taken from the building are analysed through laboratory experiments, and once samples from the whole region are similarly analysed, it will be possible to undertake a comparison of the findings in order to understand if the conservation methods used in the case studies can be generalised and applied to the whole region of Campidano.

Chapter 7, the longest chapter of the thesis, offers a highly detailed discussion of the experimental analysis of the nature of lime and loam used as building materials in Campidano.

Chapter 8 is the concluding chapter, where the research findings will be discussed and summarised. The research questions will be answered throughout the chapter in order to provide recommendations on the future direction of the conservation of the earthen buildings of Sardinia, to provide recommendations for the conservation of similar architecture in the Mediterranean basin, and to provide suggestions for potential future research on the topic.

Chapter 2

THE CONTEXT: CAMPIDANO

2.1 Introduction

This chapter engages in a contextualisation of the archaeological evolution of the nonmechanised building materials of Campidano. The span of time dealt with here encompasses hand-crafted practices from the pre-Nuragic period until 1960. This information will be useful for understanding the changes in craftsmanship which occurred before the adoption of mechanisation, and for presenting a more rounded approach to conservation. The information in this chapter is supplemented by two sections on geology and on pedology, as the period between 1900 and 1960 was characterized by an almost continuous use of locally available materials.

2.2 Geography

Scholars have debated on the origin and meaning of the word *Campidano*. The term is synonymous with the Latin *campus* (Pittau 1957, 61), meaning *field* or *open region*, an accurate description of the morphology of the area. As Pittau explains further, the word is a combination of the Latin *campus* with the suffix *-itanus*, the latter meaning *coming from*. It might be possible that the term *Campidano* was first used when referring to those peoples living in the region, but it is today used for indicating the region itself. Often described as a *graben* (rift valley), Campidano is a land defined by the following physical boundaries: the limestone hills of Cagliari and the Arcosu Mountain in the south, the Iglesiente chain in the west, the Gulf of Oristano and the Ferro Mount in the North, and the limestone hills of Trexenta and Marmilla in the east (Figs. 1.1 and 2.1). Another strip of land connected to the main area of Campidano is the plain of Cixerri, between Siliqua and Iglesias, running by the Cixerri river (Le Lannou 1979,182). A rough calculation gives an idea of the extension and the altitude of Campidano: dimension 110 km by 15-21 km, with hills of 50 metres maximum height.

Sardinia is characterized by annual average temperatures ranging between 18°C and 14°C (Mori 1972, 35) and the climate can be considered as typically Mediterranean. Winds play an important role in the climate of the island since the number of windless days have been calculated to be between only twenty and thirty per year (Mori 1972, 38). In addition to this, the region - sheltered by the mountainous formations of the west - is exceptionally dry as the rain concentrates on the western ridge of the mountains. These climatic factors influenced the making of Campidano's vernacular dwellings, and geology and pedology also played a significant role.

2.3 The geological history of Sardinia

Sardinia, together with Corsica, is a more geologically ancient land than the peninsula of Italy and in this context should therefore be considered as a separate entity from the mainland, quite apart from the physical separation of the sea. As Bennett (1938, 9) explains, 'Sardinia, as a geological unit, is the worn-down stump of a mountain-group formed in the Hercynian period, modified to some extent by fracturing resulting from the pressure set up during the subsequent Alpine movement'. After this process, the earth's crust crumpled and folded into mountains and the heat generated was great enough to 'melt the rocks in the heart of the folded region and the liquid thus formed has been forced into parts of the disturbed area...This liquefied rock has cooled and set into granite, and, thanks to the weathering-down of the rocks formerly resting above it, is today frequently found as the core of worn-down mountain areas' (Bennett 1938, 9). The island therefore is made of crumpled rocks formed before the Hercynian folding, characterised by granite intrusions (Fig. 2.2). This granite is now exposed at the surface and occupies the following areas: much of the centre and east of the island, some patches in the south and north of the Iglesiente, and the small islands of Asinara and Mal di Ventre (Bennett 1938, 9). Limestone formations were heavily deposited in the Jurassic period when the whole area declined and was submerged below the waters of the 'greater Mediterranean' which, during the Jurassic and Cretaceous periods, extended from Germany to the Sahara (Bennett 1938,12). The resulting deposits of this sea covered Sardinia with a mantle of white and grey limestone, fragments of which are still visible as a block standing in the older surface (Bennett 1938, 12).

In order to have a more precise view of the geological history of Sardinia, a table was derived from the studies of Arangino (1986) and Vardabasso (1972). It provides a good account of the evolution of the stratigraphic formations of the island during the main geological eras and refers to the Figs. 2.3 and 2.4.

Geological era	Description
Cambrian	Sardinian Cambrian rocks are of sedimentary origin, with formations of (from top to bottom): sandstone (in the area around Nebida), dolomite (magnesian limestone) and limestone, schists and sandstone
Ordovician and Gothlandian	Emergences are widespread especially in the south of the island. Formations include sandstone and argillaceous stone, these preceding the volcanic activity which produced grey quartziferous porphyry and pyroclastic rocks, especially in the area of the Sarrabus-Gerrei
Devonian	Devonian emergences are located in the areas of Gerrei, Sulcis and Fluminese
Carboniferous	This era is characterised by clastic rocks, widespread in Sulcis, and of granites in the eastern part of Sardinia
Permian	Permian Sardinia is composed of the following stratigraphy (from top to bottom): basal conglomerate (formed at the beginning of the era), schists layered with anthracite and porphyrite strata
Triassic	Red sandstone, dolomite, limestone, marl and gypsum are located in the west of Sardinia and specifically in Sulcis, Anglona, Nurra (Alghero) and Arburese. In the east of the island these formations are located in the Flumendosa valley
Jurassic	The Sardinian Jurassic Era is characterised by two main areas of sedimentation: - The west area (Nurra), where oolitic limestone, marl, quartziferous sandstone and dolomites are prevailing; - the east area (Barbagia of Belvì and Seui), where the Jurassic succession started with facies of sandstone and of conglomerate on which calcareous-dolomitic lithofacies deposited
Cretaceous	The Cretaceous is characterised by two areas of sedimentation: - The west area is a formation of limestone, lacustrine marl, clastic deposits and bauxite; - the formations of the east areas, especially around the Gulf of Orosei
Eocene	Eocene sediments are represented by the following sediments: basal conglomerates, sandstone, epicontinental limestone. The south-west of Sardinia is a composed of lacustrine sedimentations as the lignite formation of Sulcis
Oligocene	This is a sedimentary formation located in the valley of Cixerri and in Campidano. Main formations include layers of quartziferous sandstone alternated by marl and clayey chests. The Cixerri valley is covered and sometimes crossed by andesite and trachyandesites, with volcanic tufa and volcanic breccia

Miocene	This is the most important geological era for the purpose of this thesis because of its reference to Campidano. Formations of Miocene Campidano include: - the marl stone of Ales is layered in thin beds and widespread in Marmilla; - the white-grey limestone of Villagreca is limited to east Campidano between Nuraminis, Villagreca, Serrenti and Furtei; - the formation of Marmilla is the following: grey-green sandstone on top and pyroclastic rocks on the bottom; - the marl of Gesturi is widespread in the south of Campidano and in Trexenta; - the so-called clays of Fangario are common in the whole island, consisting of grey and yellow marl; - the green-yellow sandstone of Pirri, characterised by a medium size of grains, is also widespread in the whole island; - the hills of Cagliari are characteristic limestone formations in layers of different consistency. The superficial stratum is a shell formation mainly used in the construction of the most ancient buildings of Cagliari as it soon became scarce. It is called *pietra forte,* and is hard because it consists of white compact bioclastic limestone. Under this layer another stratum of hard rock, more widely available than the first layer, was used for the construction of the most important buildings. The third layer is a yellow marl limestone called *pietra cantone,* with low mechanical strength, being soft and highly permeable. This is the reason why this marl was extensively employed in the construction of housing; - the formation of Capo S. Marco (Sinis peninsula) consists of sands and basal conglomerates, marl and limestone on top
Pliocene	The Sardinian Pliocene is characterised by the following formations: - the formation of Samassi, made of the following layers (from bottom to top): basal conglomerates, clayey silts, sandstone; - the volcanicity known as 'of the 2nd cycle' in order to distinguish it from the volcanic activity 'of the 1st cycle' (from the Oligocene to the Miocene), gave Sardinia the following formations: olivine basalts and trachytes
Pleistocene	The Quaternary is an important era in the geological time-scale because the formations include: - The Tyrrhenian formation made of sandstone and organic limestone and - rarely - clay. It is widespread in Nurra, in Sinis, in the Gulf of Oristano, and in the Gulf of Cagliari; - the aeolian formation is composed of aeolian deposits, mainly in the coast, weakly cemented but sometimes in the form of sandstone; - the lacustrine formation is characterised by fossil dunes interlayered by calcareous lenses; - the alluvial formation consists of continental sediments, mainly alluvial detrital material which formed the plain lands of Campidano, Nurra, Cixerri, Siniscola and Muravera. The continuous formation of alluvial deposits created terraced landscapes which then eroded in time until the actual shape was formed. The nature of the detrital material transported by the rivers is complex, originating from sedimentary, metamorphic and igneous rocks. The soils generated by the river Mannu of Campidano will be described in the following section

2.4 The wide distribution of superficial deposits

The genesis of Sardinian pedology arises from the weathering of rock into particles of sand and the main sources are the following stones (Mori 1972, 48):

(1) Granites, rich in potassium but poor in calcium and phosphorus, form thin layers of soils;

(2) schists, basalts and trachytes form deeper soils;

(3) calcareous stones, depending on their composition, give birth to sterile soils (from dolomitic limestone) or to dark brown soils derived from the so-called red earths.

The soils of Campidano are of alluvial origin and their composition differs from area to area because the patent material has been deposited by rivers and floods. Campidano can be sub-divided into three sectors (Mori 1972, 50):

(1) The axial area along the river Mannu, constituted by siliceous gravel rich in clay, is locally called *isca* (meaning field suitable for cultivating legumes) or *tuerra* (meaning humid field);

(2) the area on the east part of this axis is made of alkaline soils on hills derived from formations of trachyandesite and Miocene marl. The composition of these fine soils is silty, clayey and carbonatic;

(3) the area on the west side of the axis, the region between the Iglesiente mountains and the river Mannu, is made of coarse Palaeozoic materials of granitic and schistic origin produced by the action of streams running especially from the Linas Peak (1200 m). The composition of these soils is sandy, from fine to medium grain size. These soils are often dry as they are extremely permeable, are suitable for sheep grazing but not for cultivation, and are therefore known as *gregòri* (from the Latin *grex*, meaning flock).

Mori (1972, 50) further explains that this classification of the pedology of Campidano is not applicable to the area around Oristano where the section on the east is characterized by *gregòri* and the section on the west is formed of sandy soils and of young alluvial soils called *bennaxi,* typically along the strip of land running by the river Tirso. Soils to the north of Oristano are of basalt origin (Arangino 1986, 19). Moreover, the soils to the south of Oristano's gulf are sandy and arid because, being poor in calcium they give an acid reaction, whilst the central and southern area of Campidano is characterized by thinner and clayey soils (Le Lannou 1979, 55).

Soil formation in Campidano has been brought about by different agents through a slow process which started in the Palaeozoic Period and is still in progress today. The formation of the *graben* of Campidano started in the Oligocene period when earth pressure created the geologic fracturing of the Sardinian region. As a consequence, volcanoes along the fault ejected lava which consolidated as trachyte (Bennett 1938, 14). Furthermore, the Miocene period was characterised by a shallow sea stretching from Asinara to Cagliari and by the deposition of fossils. Then the area became elevated and the marine belt drained off, appearing as today's fertile plain known as Campidano, leaving lagoons which are the remains of the old shallow sea (Bennett 1938, 14). The Cixerri plain is an alluvial landscape which is characterized by similar soils to those of the east of Campidano (Arangino 1986, 18).

2.5 Campidano's vernacular architecture in the Mediterranean context

The antiquity of the tradition of using sun-dried bricks as a building material has been acknowledged by excavations in Jericho (Davey 1961, 22) and in China (Easton 1996, 4), which revealed mud-brick buildings dating from 6000 BC. The most ancient mud brick sample in Europe is dated 4500 BC and it was found in Malaga, Spain, whilst Edinburgh University is working on a mud wall structure from 4000 BC in Cyprus (Bruce Walker, pers. comm.). The oldest mud bricks were formed by hand in the shape of a loaf of bread, while the technical jump of using a timber mould took place in the Middle East in the Early Bronze Age, circa 3000 BC (Woodforde 1976, 23). In this respect the technique of moulding mud bricks originated in the Middle East and was then imported to Europe. It seems that the technique of mud brick making was introduced to Eastern Europe through Mesopotamia and to Western Europe through north Africa. In the VIII century BC Phoenicians colonists introduced the use of earth as a building material from Africa to the south of Spain and Sicily, while in the VI century BC Greeks had brought their skills to the region of Catalonia and the south of Italy (De Chazelle

1993, 161). Furthermore, during the XVI C and XVIII C, largely due to the rise of the Ottoman Empire, the Italian peninsula became a refuge for eastern-European refugees, especially from Albania, Yugoslavia and Greece (Galdieri 1982, 187). These populations transferred their skills to those areas where they settled, particularly the regions of Marche, Abruzzi, and Calabria. Across Italy, there were three primary forms of construction adopted in history: dwellings, temples (i.e. the *agger terreus carinarum* documented by Varrone) and fortifications such as those of Gela, Lavinium and Ficania (Galdieri 1982, 191).

Starting from the north of Italy, the geographical areas featuring more recent developments in earthen dwellings were the following: Val Venosta and its *Fachwerkhaus* (mud bricks as infill in timber-framed buildings); Veneto where few *casoni* made of mud brick survive out of the original thousand; Ferrarese and its *partecipanze* made of mud brick, which are part of a system of land subdivision dating to the XII C, Alessandrino and its sub-areas characterised by *pisé de terre* (rammed earth) and by *tru* (mud brick) buildings, Tuscany and its scarce remains of *pisé* (rammed earth) walls, Abruzzo and Marche and their *massone* (cob) buildings, and finally Calabria with its *casedde* made of mud bricks (Scudo and Sabbadini 1997, 14). In the Italian peninsula, living in an earthen building was - generally speaking - considered to be socially acceptable by its dwellers until the turn of the twentieth century. But around 1920 social changes occurred, which brought a different attitude towards the material. Since then a feeling of shame has been associated with living in earthen buildings (Galdieri 1982, 200), which were therefore neglected in favour of modern construction.

A brief survey of a few earthen dwellings in other parts of Europe provides some additional contextualisation. The popularity and influence of classical authors such as Pliny and Vitruvius on sophisticated Renaissance (and post-Renaissance) men is of great importance, together with the first Encyclopaedias that contributed to make many north-European architects more familiar with the Mediterranean building techniques explained in these texts. It is possible that the reading of Vitruvius' explanation of how to manufacture good-quality bricks (Granger 1944, 89) could have been adopted in various European countries in different historic periods. For example, recent studies by Walker and McGregor (1997, 15) speculate that the Scottish *clay-and-bool* technique was probably transferred from the Mediterranean to Laigh O'Moray (Scotland) by architects who undertook the Grand Tour to Italy. Walker and McGregor (1997, 15) note further similarities between the fifteenth century castle in Romagnano Siesa and the vernacular architecture of the Laigh O'Moray. Another example can be seen in East Anglia, where clay-lump technique was probably introduced in the nineteenth century by French refugees when it was considered a new and experimental technique (McCann 1987, 1). The reason why building with clay-lump was limited to the region of East Anglia may be due to the fact that the area is relatively dry and windy, when compared to the rest of Great Britain. Where sun is not available for the drying of mud bricks, wind plays a relevant role. Earthen building is still practiced in North Africa and in general in several European countries, for instance in Hungary mud walled huts have been found with 1950 and 1960 dates (Bruce Walker, pers. comm.).

Earthen architecture was therefore popular around Europe and the end of its period of popularity varied from region to region. In France, earthen architecture was built until the end of the second world war (Bardou and Arzoumanian 1979, 78). According to Alceo Vado (pers. comm.) the technique of *làdiri* making was introduced in France by Sardinian slave-craftsmen when Sardinia was part of the Piedmontese kingdom. He also suggests that the same technique was introduced in the Piedmontese Piana di Marengo, but this time by Piedmontese engineers who had worked in Sardinia. The confirmation of this suggestion comes from the dimensions of the bricks which are the same as those in use in Sardinia.

2.6 The archaeology of building materials of Campidano

The aim of this section is to explore the historical evolution of building materials in Campidano in conjunction with the evolution of its dwellings. It stems from the studies of Baldussi (1994), Mossa (1957a), Terrosu Asole (1965), and from interviews with Ubaldo Badas (Director of the Archaeological Museum of Villanovaforru, 3 September 1999) on the Nuragic period and Carlo Tronchetti (Director of the Archaeological Museum of Cagliari, 9 March 2000) on the Roman period.

2.6.1 Pre-Nuragic Period

Natural and artificial caves were the first shelters to have been inhabited by Sardinian man in the Prehistoric Period, especially in the hilly regions around Campidano where the morphology favoured this. The tombs of Cuguttu of the early Nuragic Period provide evidence of three limestone mallets used for excavating artificial caves (Zervos 1954, 140). The same author (1954, 150) also discusses various stone and bronze axes used for the cutting of wood, which reached an impressive degree of refinement in the Early Bronze Age period. Gradually abandoned (but not completely, as some were still inhabited into the twentieth century) most of these shelters became unused in the Pre-Nuragic Period (the Nuragic Period spanning from 1500 BC to 230 AD) when circular huts made of timber branches covered by daub were widespread (Terrosu Asole 1965, 198).

2.6.2 Nuragic Period

The Nuragic Period was characterised by two different types and construction methods: (1) Circular fortress buildings (called *nuraghe*, from which the term *nuragic* derives) were completely made of locally available stone, sometimes with mud mortar as bonding material, and (2) circular huts made of a plinth of dry-stone walling into which studs covered with wattle and internal daub were inserted (Terrosu Asole 1965, 198). Huts were domestic constructions built around the fortress in a concentric pattern.

It is worth noting at this point that nuragic villages were made of a combination of different circular dwellings forming a labyrinth of narrow streets. Roofing techniques for the fortress type were based on heavy corbelled domes made of stone, whilst roofs of those humbler huts built around the fortress were made of timber and thatch. The nuragic village of Genna Maria in Villanovaforru is a typical Iron Age example, having been built between the IX and VIII centuries BC. The village was built with local marl stone and mud as bonding mortar. Investigation carried out on the site by archaeologist Ubaldo Badas showed that the mortar included shards of pottery and organic remains, and both were found to be relevant for dating the site (pers. comm.). The mortar was in some areas galletted with cork wedges. Roofing was made from branches made of timber branches covered with a layer of mud mortar which was periodically replaced. Two lumps of this mud were found at the site of Marra Mutta (IX -XIV century BC) and are today displayed in the Archaeological Museum of Villanovaforru. Having been baked by an internal fire, these lumps are so well preserved that they still carry the imprint of those branches to which they were applied. The nuragic village of Genna Maria was also characterized by internal surfaces rendered with a mixture of mud and chaff applied by hand; this is still visible in the room known as 'the well', where fingerprints can be seen on the existing render. Most importantly, some specimens kept in the Archaeological Museum of Villanovaforru provide evidence that mud was moulded in the shape of mud bricks. These examples were excavated from hut No 12 in a half-baked state after an internal fire. It seems possible that these bricks were used for filling gaps left in the stone wall. The specimens also prove that mud-brick making in the area started as early as the period between the IX and VIII centuries BC. Further excavations carried out on other sites gave clear evidence that as early as the XII century BC native islanders had developed the technique of mud-brick making.

Mossa (1957a, 68) suggests that this technique might have been introduced by the early civilizations of the Middle East or Ancient Egypt as similarities have been found not only between the dimensions of local mud-bricks, but also between contemporary building plans from Egypt and Sardinia. Another important use of earth as a building material has been discovered in the nuraghe of Teti (VII-VIII century BC) in Mandrolisai, where floors were made by ramming a mixture of earth and crumbled cork. But the main building material employed in the construction of *nuraghi* was stone. In the Nuraghe of Genna Maria, marl stone was finished with bronze chisels while harder stones were probably worked with hard pebbles in order to give a rough finishing. Timber was probably limited to the building of staircases and roofs, and it has only been excavated in the form of charcoal; it was cut using bronze axes of different shapes and dimensions as have been excavated from different sites. A peculiar type of hut from the same period has been studied by Terrosu Asole (1965, 1999). It consists of a square plan with more than one room with rough dry-stone wall plinths and interior mud render on timber.

It should be noted here that these stone building types and construction methods were developed by the first inhabitants of the island, the very first Sardinians who probably colonised the island from mainland Europe.

2.6.3 Carthaginian and Roman Periods

Archaeological research and investigation into the Palaeolitic and Nuragic periods has been carried out extensively in Sardinia, but comparatively little research has been undertaken on the Carthaginian and Roman periods. Until recently, the Carthaginians were wrongly thought to have been the first to introduce mud-brick making in Sardinia, but they certainly improved the use of earth as a building material during their period of domination (510-238 BC), as demonstrated by a necropolis close to Villamar where some mud-brick walls were excavated (Unione Sarda, 3 Feb 2000). During this period dwellings were characterized by pitched roofs covered by slate on canes, mud brick walls, mud mortar, earth floors, a hearth, and no windows (Wagner 1921, 318). This type developed into a more sophisticated dwelling, which included a loggia on the main façade, with the double function of providing shelter from the sun and of allowing the collection of rain from the roof (Terrosu Asole 1965, 203). This is a significant aspect, as it could be the first use of the loggia element in Sardinia. Mud bricks in this period were laid with mud mortar, sometimes on a stone plinth, measured between 20 and 25 cm in length, 15 cm in breadth and 7 cm in height (Barreca 1986, 272). Barreca (1986, 272) further explains that in the archaeological site of Nora, a mud-brick wall dated VII BC was excavated. This was a rarity, as earthen walls more often tend to be found in the form of debris on the foot of the stone plinth. The identification of a mud wall in the latter case was suggested by the presence of a stone wall of constant height, presumably the plinth.

During the Roman period (238 BC-476 AD), dwellings were influenced by the Pompeian square type, with pitched roofs covered by roof tiles, a building material which - together with fired bricks - made its first appearance in this period in Sardinia. The Romans improved the local building techniques with the introduction of other new materials such as lime, which was employed in a two-fold manner: in the rendering of mud walls and in the rubble infill core of sandwich stone walls (Terrosu Asole 1965, 206; Maetzke 1966, 166). Excavations in Nora and Sant'Antioco revealed that a mortar of lime and *coccio* *pesto* (crushed roof tiles) was used for the paving of floors and for the coating of tanks, while there is no evidence for this type of mortar to be used for the rendering of walls. In San'Antioco floors made of lime and *coccio pesto* were applied on a base of rammed earth on stone and was found in layers, meaning that after deterioration a new coat was applied. Fired clay and lime visibly changed the look and the durability of Campidano dwellings. The considerable experience of the production and use of lime developed by the Romans and the skills they transferred to the local population remained virtually unchanged in Sardinia until 1960 - when lime making was still carried out in exactly the same way, without any influence from later technique. This was also applicable to the tradition of firing bricks and tiles. Evidence of the use of loam as a building material has been provided by the excavations of Roman Nora where several earthen walls have been described by Pesce (1957, 37), the best conserved being wall No 15, south of the building known as No XIII. Further evidence was given by Tronchetti (pers. comm.) who commented that ninety percent of the Roman residential structures of Nora and Sant'Antioco were built with mud walls on plinths made of stone and lime or mud mortar. Wall thickness varied according to the importance of the building but no evidence was found on how mud walls were built. As noted, the only manifestation of the presence of an earth wall is usually loose soil found at the base of the wall. But more definitive evidence of a mud brick wall was found in Nora, in trench AB of the new excavations. In this area a sample of a lime render was dug and its analysis showed the imprints of the mud-brick wall to which was applied. But Nora was mainly a stone town. Stone construction was improved there by the Roman builders with the introduction of the *opus africanum*. It consisted in the erection of rough stone pillars (*ortòstati*) and in the filling in of the space between two pillars with small and roughly dressed stones bonded with lime or mud mortar.

Evidence of the use of compressed earth in Sardinia is given by Maetzke (1966, 166) and was discovered in the Roman site of Porto Torres. His description unfortunately does not give any detailed explanation of the precise building technique, an investigation is now probably impossible as the wall might well have crumbled some time after its excavation. It seems anyhow that the wall was made of rammed earth (*pisé*), a building technique used by the Romans (Adam 1984, 63). The system had little popularity in Sardinia, apart from a little resurgence during the much later Savoy period.

The art of potmaking in Sardinia goes back to the First Iron Age (850-550 BC), during which villages were characterised by specific buildings used for the manufacture of pottery and iron wares (Tanda 1998, 67). It was probably the Romans who introduced tile kilns to Sardinia, especially for the production of fired clay products used in the construction of non-public buildings. In describing a Roman brick-kiln near St Albans, Davey (1961, 66) provides an impression of what was used in Sardinia until the twentieth century, showing that firing tiles was carried out by using a technique which was virtually the same. But until today in Sardinia no evidence has been found neither on tile nor on lime kilns of the Roman period. In Olbia and Mores roof tiles carrying the stamp of Liberta and Nero have been excavated (Mamuta 1933b, 11), but it may be possible that these tiles had been manufactured in the central area of the peninsula and then shipped to Sardinia. However, excavations found out that some tiles carry some stamps which are unknown in any other part of the Empire and this should suggest that the Romans might have started a local production in Sardinia.

2.6.4 Medieval and Spanish Periods

The early medieval period is one of the most frustrating in Campidano's history. Little evidence exists for the nine and a half centuries between the end of the Western Roman Empire and the arrival of the Spanish. Literature on medieval Campidano is sparse and fragmentary, but hypotheses have been made on the use of building materials around this period. The Medieval house of Campidano seems to have developed into a humble mud-brick dwelling with loggia, portal features and tiled roof (Terrosu Asole 1965, 207). Lime as a plastering material was considered to be expensive (as during the Roman domination) and therefore was often replaced by mud, whilst fired brick was considered a special material for important buildings (Terrosu Asole 1965, 208).

The Spanish occupation of Sardinia lasted for almost four centuries (1324-1700), this being the reason for considering this period as the most relevant in the development of more recent building styles and techniques of Campidano (Galdieri 1982, 197). It is also important to stress that the Spaniards found local craftsmen to be reasonably skilled and ready to adjust their own technique of mud-brick making and laying for the new styles brought over from Spain. The long Spanish domination was influential, especially with reference to the improvement of the use of building materials; this is also evident in the actual nomenclature of structural parts and details in the Sardinian language (Galdieri 1982, 198). This nomenclature demonstrates both Latin and Spanish influences; if, therefore, the house is called *domu* (from the Latin *domus*), its ceiling is called *bòvida* (from the Spanish *bòvida*, meaning vaulted ceiling) and its partitions are called *tabìcu* (from the Spanish *tabique*, meaning partition). Also, archival research carried out by Valdès (1986b, 208) enumerates a series of documents dated September 1567 stipulated between the customer and various craftsmen of the area around Cagliari for the manufacturing of *tapies*, the Spanish word for mud-brick.

Under Spanish influence dwellings became grander, windows were more frequent, and elegant stone decorations started to appear (Mossa 1957, 91). The loggia was originally made of timber posts carrying the weight of the roof structure. It was used as a shelter for the animals and later developed as a domestic feature, becoming the most important of the house. The loggia, a feature heavily distinguishing the house of Campidano, seems to have been a native feature which evolved over time, and not under Spanish influence (Mossa 1957, 91). Significantly, the Sardinian word for patio (*lolla*) does not have a Spanish origin. It therefore seems possible that patios slowly developed in vernacular buildings of Campidano as autochthonous elements. This characteristic is important in order to stress the relevance of Sardinian earthen architecture in the Mediterranean basin as a feature which gradually developed through many outside influences, but which also expressed its own native characteristics.

2.6.5 From the Savoy Period until 1960

The period of rule by the House of Savoy and the Piedmontese Kingdom (1720-1861) was characterised by technicians (engineers and architects) who had received their training in the Piedmontese capital of Turin, and who imported their knowledge and building techniques to the island for the construction of civic buildings. The system of ramming the earth into shutterings was in use in the Piedmontese region of the Piana della Frascheta. The latter area is characterised by a red clayey and gravelly soil, ideal for this technique (Bertagnin 1999, 83). Evidence of the use of rammed earth in Sardinia during the Savoy period was given by architects Alceo Vado (pers. comm.) and Lucio Ortu (pers. comm.), the latter through two rammed earth walls discovered in Cagliari. The walls were located in the areas known as Marina (Via Lepanto) and Villanova (Vico Settimo San Giovanni), and were found during Ortu's work as a historic building consultant. The areas where the walls stand is characterised again by red sandy loam. It seems likely that rammed earth was considered in Sardinia as the building technique of the architects and engineers only (Alceo Vado, pers. comm.). This is probably the reason for the lack of popularity of this technique in an island where construction was in the hands of Master Craftsmen and not of professionals.

From the end of the Piedmontese period until 1960, the palazzo type gradually evolved from the courtyard farmhouse type with heavy inclusions of 'modern' materials such as wrought iron, terracotta, cement and hydraulic lime. During this period, Turin maintained continuous and close control of the island and its civil buildings through the institution of university courses on civil architecture and military engineering. Control was also facilitated by the construction of institutional buildings and infrastructures such as roads, reclaimed land and bridges, built by means of new and innovative techniques. This building activity was the main achievement of Sardinians under the Savoy domination.

It is difficult to estimate exactly when the types of decoration that characterise later buildings started in Sardinia. As Terrosu Asole (1965, 212) states, the Savoy domain was characterised by an opening-up of the courtyard type through openings to the outside walls and through a richly decorated pattern of street facades (Figs. 1.2-1.10). In so doing the courtyard type became transformed into the *palattu* (palazzo) type, especially when materials like terracotta, wrought iron, stuccowork, cementitious and stone decorations were added to the *làdiri* building structure. This urge for more complex decorative pattern and for openings to the exterior of the building was particularly evident at the turn of the nineteenth century when these materials were suddenly more widely available. This was a period during which the wealthier owners introduced balconies as a characteristic external feature. Balconies accentuated the slimness of the window itself by incorporating thin iron elements and protrusions that projected elegant linear shadows on the wall surface (Sanna 1992, 39). Building materials produced with mechanised systems (such as steel and timber) were imported from the peninsula and bartered with labour or with goods produced from farming (Angioni 1976, 23).

2.7 Availability of building materials (1900-1960)

The Industrial Revolution that transformed Europe impacted Sardinia to a much lesser degree, but Samuel's observation on Victorian England is still relevant:

> *The main thrust of technical innovation, such as it was, came in the direction of labour-saving materials rather than of mechanical devices. In the late 1850s and 1860s their influence was comparatively slight. The painter still mixed his own colours; bricklayers still cut and shaped their own bricks (so late as 1874 it was considered a more important part of their work than setting); carpenters and joiners worked, very often, to their own designs.*
> (Samuel 1992, 31)

Sardinian building materials were manufactured by the master builders themselves, with the exception of terracotta decorations, timber and iron elements, all imported from the peninsula because their production required a technique which was not available at that time in the island.

Lack of transportation facilities from the mainland to Sardinia influenced the persistence of the use of locally available materials. In the last quarter of the nineteenth century, travelling by ship from Genoa to Porto Torres - at that time the main shipping town of the north of Sardinia - took thirty-six hours. In 1941 the crossing was reduced to ten hours (Le Lannou 1979, 26). Internal communication systems were until recently - and certainly in the last quarter of the nineteenth century - inadequate to allow *modern* materials to be produced. A narrow gauge railway system was built by Smith and Knight and Co from London, and was completed on 1 July 1880 covering the route from Cagliari to Sassari - taking nearly eighteen hours to cover 200 km (Cugia 1973, 189). Only during the Fascist period were roads built with the consequential improvement of transportation facilities.

The delay in the introduction of *modern* materials to Sardinia can certainly be better appreciated by the analysis of some early industrial buildings in the area around the capital. *Làdiri*, roof tiles, lime and other locally available materials were employed in the construction of the following enterprises:

(1) Contivecchi Saltworks, Machiareddu (1921-1927);

(2) Maxia Kilns, Quartu Sant'Elena (1926);

(3) Zedda Piras Wine Cellars, Cagliari (1920s).

These three buildings still show *làdiri* as infill material together with the usual traditional building materials of Campidano, the only improvement being reinforced concrete acting as a structural element. They can therefore be considered as transitional between rural and industrial architecture in Sardinia (Aymerich and Palmas 1996, 135), pioneering a series of industrial construction systems later further developed and employed. With reference to domestic buildings, and especially to the palazzo type, the structural system characterised by iron floor joists and fired brick arches slowly replaced the traditional method used for the construction of floors.

These were the main developments in the use of building materials up to 1960 in Campidano. It should here be noted that the analysis of the introduction of cement and concrete in the area under examination is beyond the scope of this study and was therefore not carried out.

2.8 The distribution of earthen architecture and its social environment

The insularity of the vernacular dwellings which characterise the area of Campidano may be the result of a series of factors: morphology and natural borders, climate and geology, and the farming system.

2.8.1 Morphology and natural borders

As a flat area surrounded by mountains and by the Mediterranean sea, the region of Campidano was throughout history an easy target for the invaders - Carthaginians, Romans, and others - which characterise Sardinian history. It therefore seems probable that local dwellings are the result of the need for defence from these continuous invasions (Le Lannou 1979, 100). This explains why the dwellings of the south of Sardinia were never isolated buildings in the countryside but were always part of large villages which were never located in the coastal areas (Le Lannou 1979, 100).

2.8.2 Climate and geology

The presence of virtually only two main seasons - Winter and Summer - both characterised by extremes, made necessary the use of earth as a building material and the development of features such as the arcaded loggia together with mutual shading in order to cope with climate changes. The employment of earth as a building material is also due to the fact that it was the only locally available material in the alluvial land and because of the constant presence of the winds which are so essential for the drying process. As noted earlier in the chapter, the island is characterised by few windless days, rarely more than 30 a year in average, reaching the minimum of 20 days a year in Capo Sant'Elia, Cagliari (Mori 1972, 38).

2.8.3 Farming system

Another important influence in the introversion is related to the fact that the economy of Campidano was based on agriculture, particularly the farmhouses. In fact, the evolution of the form of vernacular housing in the south of Sardinia cannot be comprehended properly without being set within the context of the farming systems which were in use before the start of the twentieth century. The agricultural landscape of Campidano was organised according to peculiar rules with medieval origins, as Le Lannou explains:

> *Once out from the village, one may find an area where relatively small fields delimited by prickly pears are cultivated with legumes, almonds, olive trees and vineyards. But this is just a small strip that dissolves into the bare cultivated open fields, without boundary walls, hedges or trees that constitute the ancient* viddazzone *where paths are designed radially.*
> (Le Lannou 1979, 183, author's translation)

The *viddazzone* was a system through which agricultural land was organised in two halves: one half was cultivated and the other left to rest fallow for one year. The purpose of the system was to enable the harvesting of crops of dependable standard quality by yearly rotating cultivated areas with uncultivated areas. The remaining land beyond the *viddazzone* was known as *saltus* and was not populated but used mainly for grazing.

This concentric medieval organization of the area surrounding the villages of Campidano is reflected in the settlement morphology: villages have a circular layout because they are the result of the gradual addition of many courtyard houses over time while, by comparison, the mountain villages are lengthened because they are the result of the addition of multiple storeyed houses developed in height (Le Lannou 1979, 266). Moreover the morphology of the villages of Campidano is similar to many of the medieval conurbations of the Mediterranean basin, in that it is dictated by the need for defence and for the provision of mutual shade. The courtyard farmhouse type results from the agriculture-based economy of the region. It forms introverted spaces where the residential area, farm animals, and storage facilities are developed in the interior with few or no openings to the outer walls, creating a harsh street landscape, as explained by Rossi Vitelli in 1878:

> *Roads are paved with cobbles and dwellings are large, comfortable, with two-stories and characterised by a loggia facing south. The loggia serves as an access passage to the rooms, which are clean and furnished with good taste, almost with luxury. Each house has its courtyard, often a garden planted with flowers and citrus fruits. But nothing of all this is visible from the outside, as plain boundary walls are in a miserable and almost ruined state. But internal rooms are hung with tapestry and show the most fashionable furniture: wrought iron beds, mirrors with gilded cornices and whatever is considered to be proper of any town house.*
>
> *These domestic qualities are counterbalanced by those functional rooms necessary for the good management of a family: the room for bread baking, the kitchen, the accommodation for the servants, and the stable.*
>
> *Farm labourers live in a separate dwelling where agricultural instruments are also kept and animals are sheltered in a separate stable. Some dwellings are more sophisticated, featuring rooms for wine making and storage, and also for cereals storage.*
>
> (Rossi Viltelli 1878, 94, author's translation)

In the context of the relationship between farming and residence discussed above, Alvito (1997b, 1546) recognises that '... courtyard areas are proportional to the surface area of the cultivated land' and also that 'this peculiar introverted system expresses the centrality of the enclosure space in Sardinia's vernacular architecture'. Being therefore the grandest form of vernacular architecture in Campidano in relation to the amount of estate, the wealthy owners of these buildings could afford to build the most highly sophisticated houses that incorporated a series of annexes such as the mill, the well, a house for servants, storage rooms, the stable and the barn.

2.9 Conservation regulation in Quartu Sant'Elena since 1850

This section is crucial to the understanding of traditional conservation regulation of the south of Sardinia and to the important role covered by building inspection in the process of maintenance. The research in this section represents an important contribution especially to the drafting of the history of conservation regulation in the south of Sardinia. Its scope is to give an overview to how conservation regulation was carried out from 1850 until today.

An impressive number of unpublished records on conservation regulation was found in the Archivio Storico Comunale (Historical Archive of the Commune) of Quartu Sant'Elena, and partially in that of Iglesias. Quartu Sant'Elena is an important village from the point of view of its architecture as it embodies a vast number of twentieth-century *làdiri* buildings. The village can be considered therefore as representative of the region. The reason for focusing on the historical evolution of the village's conservation regulation is also due to the amount of material unearthed in its archive. It was not feasible to delve into archival documents kept in other villages due to personal and bureaucratic time constraints.

Archival research reveals that in 1850 Quartu Sant'Elena was characterised by a legislative system called *Regolamento di Polizia Urbana e Rurale* (ASQ 1850). While this was not directly or explicitly conservation-oriented, it was important in setting the groundwork for later regulation. The document is structured into seventy articles that regulate a multitude of aspects of urban and rural life, including maintenance of road surfaces and of buildings. When a building was seen to be in need of repair or reconstruction, the Delegated Council informed the owner on how many days he was allowed to carry out the repair works. If after that period the building was not repaired and was a menace to public security, the Council could order its demolition at the expense of the owner himself (ASQ 1850, 8). But the most illuminating article of this regulation explains that the owners of those buildings which did not face any streets were required by the commune to assist financially those poorer families whose houses faced the street and were in need of repair (AS 1850, 8).

An updated version of the *Regolamento Di Polizia Urbana e Rurale* of the village Quartu Sant'Elena was found dated 1 August 1855 (ASQ 1855). The peculiarity of this record is that it shows a handwritten chapter of 12 pages, called *Dei Fabricati* (On Buildings), entirely devoted to construction and conservation regulations. The four main conservation themes tackled by the document are:

(1) Any form of decay of buildings facing the street was reported to the Council which forced the owner to repair it and carry out the necessary finishing. More generally, before any conservation work could be carried out on a building facing a public space, the owners ought to notify the Council. The Mayor himself then inspected the work in order to see if it was carried out without intruding on the overall appearance of the urban landscape;

(2) The upgrading of single-storey into a double-storey building was allowed only after it was certified that the ground floor walls had the sufficient load-bearing capacity. After the construction was completed, rendering of new buildings had to be carried out before the end of twelve months. Specifications on building materials are also given: a mix of lime and sand was advised for renders, whilst a mix of limewash and pigments was preferred to white washing;

(3) Derelict buildings representing a threat to the safety of citizens were not allowed to be conserved. Demolition was carried out instead after its state was assessed by a surveyor;

(4) If any unfinished or partially collapsed building was not completed by the owner, the works were started by the Council. The owner was then charged for the expenses undertaken and fined.

By 1896 Quartu Sant'Elena had its own *Regolamento Edilizio* (Building Regulation), an updated version of the *Regolamento di Polizia Urbana e Rurale* of 1855. This document

(ASQ 1896) shows for the first time the requirement of obligatory projects for the conservation of buildings of architectural or historical importance. When architectural drawings evinced lack of craftsmanship or of common sense, they could be rejected by the mayor and the Council. Moreover, the text of the *Regolamento Edilizio* also shows the word *Monumento* and, more generally, an increasing awareness of the built heritage. For instance, if a public element or artifact of historic or artistic importance was identified as a consequence of restoration or demolition, the mayor ordered the conservation of the *Monumento*. Another relevant innovation contained in the document of 1896 was the intention of creating a list of the most significant artistic or historic buildings. This is probably related to the fact that, five years earlier, the Regional Office for the Conservation of Monuments (Ufficio Regionale per la Conservazione dei Monumenti) was instituted in Cagliari with the function of listing and conserving the island's architectural heritage (Lilliu 1993, 13).

Since the turn of the last century conservation and building regulation became more specific about building materials, and not only in Quartu Sant'Elena. To illustrate this, in the 1863 *Regolamento di Ornato della Città di Iglesias* (Regulation on the Decoration of the Town of Iglesias) detailed articles can be read about repair work to be carried out on those buildings that were inside the historic centre (ASI 1863). This increasing content of details and specifications is again apparent in Quartu Sant'Elena where in 1897 its *Regolamento di Ornato* gave specific information on elevation details such as cornices and terracotta decorations (Sanna 1994, 37).

In 1906 the town of Iglesias saw a series of posters affixed to its walls (Fig. 2.5), with the intention of informing citizens that '...on the 25 September, between 10 and 12 o'clock, the Commune's engineer will be carrying out an inspection of the balconies and shutters for reasons related to safety of citizen' (ASI 1906b). After the tour was completed, a report was made to the mayor who then sent an ordinance to the owners to whom an average of five days was given to carry out the repair works (ASI 1906c). Archival records found in Iglesias demonstrate that the population was regularly notified about building inspections to be carried out at different levels. These could include the inspection of floors, chimney stacks, wall cracks, gutters, cornices, and lintels (ASI

1906c).

More recently, regulation became more focused on building materials such as mud brick. Two manuscripts kept in the Archivio Storico Comunale of Quartu Sant'Elena (ASQ 1913) explain the conservation policy adopted by the municipality with reference to earthen buildings at risk. The first manuscript is the letter of the building inspector to the mayor, where a detailed description of the state of decay of a specific building is given. The letter, dated 16 June 1913, ends with the recommendation of urgent repair. This followed by the second document, dated 18 June 1913, a letter of the mayor to the owner of the building. The mayor explains the pathologies of the building and the risk occurred by citizen after eventual collapse. The owner is then given a maximum of five days to carry out at least the necessary repair work for maintaining the building in sound condition. The first specific regulation on earthen architecture of Quartu Sant'Elena is dated 18 August 1930, and it is titled *Construzioni in Mattoni Crudi* (Mud Brick Construction). The first section of the document (ASQ 1930) is dedicated to new construction, whilst the second section relates to the conservation of the built heritage. The section on new building recommends the employment of mud brick only as a walling material, whilst more appropriate materials (e.g. stone and tiles) are advised for the construction of elements such as plinths and floors. The employment of mud brick for structural purposes is discouraged in the text and bricks are advised to be bedded with lime mortar. This is relevant because it shows that as early as 1930 owners were discouraged from using mud brick as a load bearing material (as it had been used for centuries in the island). Mud brick then started to be viewed with suspicion. This is also true for lime, in fact owners were also encouraged to render their new buildings with either lime or cement-based coats. The section of the document related to conservation is extremely detailed. It was advised that plinths should be rendered with a cement-based coat (10 cm in thickness and 130 cm in height from ground level, and with a mix of 0.8m^3 : 0.4m^3 : 300kg of gravel : sand : cement). Mixes of cementitious binder and coarse aggregate were traditionally used to coat plinths and this is a traditional feature of many villages of Campidano, including Serramanna (Lucio Ortu, pers. comm.). This was probabaly a device against coving effect, and was very effective, as inspection carried out by the author proved that most of such coats do not show any alarming state of decay today. The document advises that prior to rendering a new-built wall with a mix of lime and cement ($1m^3$: 200kg), the vertical joints of the bricks should first be inserted with tile wedges.

Between the second world war and 1960 buildings were still investigated with reference to their need for repair. After investigation was completed, building inspectors wrote detailed reports on the main symptoms and pathologies, followed by a letter to owners. The main preoccupation read in several documents (ASQ 1942, ASQ 1957, ASQ 1958) seems to have been the structural condition of earthen buildings and the potential harm for inhabitants and pedestrians. Another important aspect of past regulation was the respect towards neighbouring dwellings in terms of water and height of buildings.

If common sense for the protection of earthen architecture is the key-note of all regulations prior to the cement era (pre-1960), in contrast what subsequently follows seems to deny local building cultures. It appears likely that since 1960, cement lobbies played a role in the way earth as a building material was perceived in Campidano, with the consequence that demolition and rebuilding with reinforced concrete increased at high speed. This is visible in the section on conservation of the *Piano Regolatore Generale* (General Building and Conservation Plan) of Quartu Sant'Elena, which does not manifest much respect or regard to traditional earthen buildings (ASQ 1965). The more recent *Piano Urbanistico Comunale, Variante Centro Storico* (Urban Plan for the Commune, with Reference to the Historic Core) is protective towards the historic centre. Moreover, degrees of freedom are given, for instance traditional windows can be replaced with PVC windows (Corti, date unknown, 12). A similar lack of consideration of the historic fabric can also be read in other recent conservation regulations, such as that of Settimo San Pietro (Castangia 1995, 16). Plastic windows, however, will not adapt to any movement in earthen walls and will look incompatible with eventual neighbouring windows. This kind of criticism was previously raised by Quarneti (1992, 2) who stressed that historic centre regulation often imposes the use of inadequate materials for repair works.

The archival research carried out by the author shows that at the end of the nineteenth century every village had its own Regolamento di Ornato. However, the lesson that can be learnt from conservation regulation between 1850 and 1950 in Sardinia is still undermined, if not ignored. This can be reflected in the neglect in favour of modern architecture which perseveres today amongst owners who tend to abandon their mud dwellings in favour of modern construction on the outskirts of villages. As Orazi (1995, 227) puts it, 'Italy's attitude towards its historic architectural heritage alternates between absolute neglect and equally absolute devotion'.

2.10 Conservation as a recent interest in Sardinia

The ethics of buildings conservation can be simplified as either 'good' or 'bad' behavior when action is taken on any work (Warren 1992, 15). The aim of this section is to discuss the sudden decline of conservation ethics which occurred in the conservation of earthen buildings of Campidano during the second half of the twentieth century.

Modern notions of conservation were introduced to the island in the mid nineteenth century, following the Italian nation's ultimately successful drive for cultural and political unity (Ingegno 1987, 18). The span of time between the turn of the last century and the 1960's was characterised by a defined division between the conservation of major buildings (by means of conservation methods imported from the peninsula) and the conservation of vernacular buildings (autochthonous methods based on effective practices developed over the centuries). However, the development of heritage and conservation awareness in a true twentieth-century sense is a recent evolution in Sardinia because traditionally the island was - and still is - culturally dependent on the peninsula. According to Ingegno (1987, 17) this is still apparent nowadays in the lack of specific literature on the conservation of the Sardinian built heritage. This modern idea of conservation was initially introduced to the island with reference to polite architecture made of stone, while the conservation of humbler buildings followed a less recognised path. It is abundantly clear that every village of Campidano was characterised by several craftsmen who specialised in small repair and maintenance work which was carried out economically (Murru Corriga 1994, 55). The role of such local craftsmen was less prestigious than that of the more skilled master builders who carried out not only repair work, but also construction of new buildings. It is legitimate to say therefore that, before the 1960's, the conservation of earthen buildings was characterised by centuries of indigenous practices that were considered at least as significant as the building process itself.

As indeed happened in other parts of the world (Krishna Menon 1994, 40), indigenous conservation practices carried out by Master Craftsmen were rendered intellectually invisible during the 1960's with a process similar to the drawing of a veil. The elimination of these practices equalled the erosion of centuries of building and conservation culture. In order to illustrate the propaganda against traditional earthen buildings during this period, a section from an article in a contemporary journal is reproduced below:

> *Let's have a look at the earthen architecture illustrated by painters and sung by poets...the traditional dwelling of Sardinia lacks those requirements that constitute the idea of a house as a proper space for living. Often 'beautiful', it is nevertheless the poor wreck of a disappearing world. Its presence in the village constrains the community life into absurd ways of living that do not correspond to what nowadays is considered as a peculiarity of renovation and of well-being. The unchanging nature of the building type and of the urban shape of villages have consequential effects over interpersonal contacts. The entire village is in fact made of these farmhouses, the real centre of the most unexpected infections.* (Virdis 1961, 77, author's translation)

This gives an idea of the lack of understanding of vernacular architecture during the period when new building materials and types started to be heavily introduced to rural Sardinia. In this context it can be mentioned that this can be also compared to what happened in the inter-war period in some regions of Great Britain such as Wales and particularly the Hebrides. In this repect, it is worth quoting the British traveller Douglas Goldring who, in the memoires of his trip to Sardinia wrote that 'At first glance nothing looks more depressing and monotonous than the Campidano around Cagliari. It is dotted with uninviting villages built of brown adobe, and divided up into fields, vineyards, and pasture-lands by hedges of prickly pear. In winter the main roads are morasses of brown mud: in summer they must be made almost impassable by the dust.' (Goldring 1930, 150).

During the 1960's the professional figure of the 'architect-conservator' was heavily introduced to the island. (Architects are to this day trained in the peninsula because Sardinia has no architectural school, with conservation therefore acquiring the status of a specialised activity requiring a special knowledge.) Simultaneously, modern materials and methods were introduced and traditional craftsmen lost pride in their work as they were forced to abandon traditional materials. As is also the case in India (Krishna Menon 1994, 43), traditional repair methods were considered to be more challenging, and the Master Craftsman experienced pleasure and pride when told it was difficult to distinguish between old fabric and repair work (Master Craftsman Dante Sotgia, pers. comm.).

But the psychological barriers towards the conservation of vernacular buildings of Campidano resulting from the occupiers' perceptions of the materials is also important. From circa 1960 earth was portrayed negatively as the material of the poor and dwellings were abandoned in favour of modern construction 'as is commonly intended today, as part of an organised system to coordinate daily life' (Virdis 1961, 81). Consequently, since the introduction of reinforced concrete, the outskirts of villages gradually became clustered with unfinished buildings because as they were oversized in scale, their completion would be too expensive. Probably because of the still difficult financial situation of many households of Campidano, the general belief is that the larger the house, the more beautiful (Angioni 1989, 20; Angioni 1998, 72). This conviction has its roots in the traditional farmhouse, as its size tended to increase with the value and size of owned land. The consequence of this belief is the use of incremental construction systems in reinforced concrete, to permit the addition of further improvements. The tendency is not limited to contemporary Campidano, but is also widespread in some areas of Sicily, Calabria, North Africa (Angioni 1998, 72) and Northern Portugal, where this phenomenon is identified as the *casa de emigrante*, or house of the immigrant (Viegas Guerreiro 1982, 158). This can be also found in Cyprus where during the last thirty years the traditional building culture was altered dramatically, both in terms of building types and building construction (Loizides 1999, 6).

Giulio Angioni, an eminent scholar who worked for more than thirty years on the ethnography of Sardinia, defines this occurrence as an 'anthropologic catastrophe' and as a 'modern cancer' which attacks and modernizes the traditional architecture made of stone or *làdiri* (Angioni 1998, 72). In order to have a broader view of the phenomenon, interviews were carried out amongst Sardinian practitioners (architects and engineers) who are experienced with the conservation of earthen structures. The analysis of these interviews concluded that the main reasons for the abandonment of vernacular architecture and for the consequent heavy introduction of unfinished architecture can be identified in the social changes which occurred in the island:

(1) The sense of shame associated with the material is still strong in the island because, as noted earlier, earth is considered as a peculiar resource of the poor (Vado 1999a, 507; Daniela Aru, pers. comm.; Alceo Vado, pers. comm.);

(2) a further important reason is related to the traditional construction system. Campidano's dwellings were traditionally built by the addition of cellules, according to the financial situation and to the need for more rooms. Cellules were called *domus* (houses), so that there was no distinction between the terms 'room' and 'house' (Lucio Ortu, pers. comm.). This organic growth of Campidano's dwellings was characterised by the use of traditional materials and unchanging architectural codes. During the second half of the twentieth century this tradition of building by using incremental systems was applied with catastrophic consequences to modern materials and design. The need for innovation modified traditional architectural references, which shifted from the past vernacular heritage to styles seen on television. This slow media-driven corrosion of tradition is also observable in the first names of some of the adolescents raised in modern homes; traditional names such as Emanuele, Francesca and Paola have been replaced with television-influenced names such as Kim, Samantha and Pamela;

(3) another reason can be related to the improvement of transportation facilities and to the consequential drop in thecosts of purchasing building materials. The construction industry has a strong motivation for keeping modern materials and methods in the market as these are profitable. At the same time they have little to no interest in using traditional skills and repair methods because these are too low-key and employ local materials - in other words they are far less profitable. The popularity of modern building materials for repair purposes can be quantified as in the responses to the questionnaire given in Table

4.3. The Table shows that 59.7% of the total number of buildings included in the questionnaire have been repaired by means of modern materials such as cement, whilst only 14.9% are repaired with traditional materials such as lime and earth. It is at this point relevant to understand what percentage of those buildings is located in the historic centre. The total number of buildings inside the historic centre included in the questionnaire is 137 (Table 4.4). It can be therefore demonstrated through a cross-query (Table 4.44) that only 18.2 % of the buildings located inside the historic centre have been conserved by means of traditional materials. This survey paints a picture of a gloomy landscape of the region, giving evidence of the phenomenon's complexity;

(4) another important reason for the abandonment of earthen buildings involved the continuous complaints about the need for the constant maintenance of earthen buildings (Lucio Ortu, pers. comm.; Giulia Setzu, pers. comm.; Miriam Spano, pers. comm.). Maintainance is strictly related to the issue of purchasing traditional building materials: if the culture of maintainance is kept active, the reopening of quarries and kilns could be benefited;

(5) lack of scientific research on local building cultures and materials (Orazi 1995, 228; Vado 1999a, 507);

(6) building a new house in the outskirts of villages is preferred to reparing an historic building in the village core where regulation is considered to be too conservative and restrictive (Giulia Setzu, pers. comm.).

(7) 'In some villages emigrant remittances constitute the most important source of income. This money is often used in improving or enlarging village homes. The construction industry, which employs a wide range of skilled and unskilled workers, and uses a range of materials (cement blocks, tiles, timber), has thus become an important part of the village economy. This mechanism of financing construction work also accounts for the half-finished state of many building projects, for the work takes place sporadically according to the supply of money sent' (King 1975, 119)

2.11 Conclusion

This chapter gave a geographical and archaeological introduction of the region of Campidano as derived from the literature review. Furthermore, research carried out in the archives of Quartu Sant'Elena gave evidence of several conservation legislations that were in use in the village between 1850 and 1960. In giving an illustration of this example, the point which was made is that the attitude towards earthen buildings and their conservation in the specific context of Quartu Sant'Elena, and more generally in Campidano, had a dramatic change during the 1960s with the advent of modern materials.

Chapter 3

THE CONSTRUCTION OF THE EARTHEN ARCHITECTURE OF CAMPIDANO

The study of the traditional materials used by our ancestors for the construction of those buildings which make our land so noble is of greatest importance because they allow us to appreciate the static consistency of our monuments and to predetermine the action of time and weather: this action being sometimes embellishing, but is more often destructive. And is also true that it is only when we deeply know the trachytes and basalts, that we will be able to appreciate the building techniques of the ancient craftsmen, to explore many of their impressive constructions, and the reasons for the conservation of the latter through the centuries.
Scano (1908, 5, author's translation)

3.1 Introduction

The above quotation by Dionigi Scano, the most important Sardinian conservator of the turn of the 19th century, illustrates the goal of this chapter, which is to study the traditional manufacturing processes of the main building materials employed in the twentieth-century vernacular earthen architecture of Campidano. In this context, the recording of tools and equipment is central to the understanding of craftsmanship. Sometimes simple in their shape and function, tools and techniques are particularly important because they are the result of the development of centuries of building practice (Angioni 1976, 122). The recording of historic - and now lost - craftsmanship is extremely important, not only because it provides empirical evidence of original practice, but also because it can be directly applied to practical conservation which will be further explored in Chapter 5.

The content of the present chapter derives from an analysis of the information gathered whilst directly interviewing craftsmen such as mudmasons, carpenters, tile-makers, and stonemasons. The major contributions of these craftsmen are acknowledged in the text, but since the interviews were oral, not every remark is formally attributed. The reader should however be fully aware of the author's debt to the knowledge of these individuals who are listed on Table 4.46. The anecdotal information from these interviews has also been placed in a wider historical and conservation perspective.

3.2 Craftsmanship and organization of the building site

This section describes the role of the Master Craftsman not only in the manufacturing of building materials, but also in the construction and repair of earthen buildings in twentieth-century Campidano. It starts with an historical illustration of the Master Craftsman figure and of his role as supervisor of the building activities of his native village.

The maistru de muru

Building techniques were certainly primitive in Campidano during the Nuragic Period, but as Mossa (1957a, 33) elaborates, the number of *nuraghi* scattered in Sardinia gives evidence of an impressive building activity that needed specialised craftsmen. It can be suggested here that these craftsmen might have been itinerant because of the stylistic similarities in the building of *nuraghi*.

According to Di Tucci (1926, 34) during the last part of the Roman period there were only two main crafts active in Sardinia: the *navicularii* (ship builders) and the *metallarii* (blacksmiths). This appears to have been due to fact that the economy was principally based on the agriculture and sheep-breeding which did not encourage other corporations in the field of construction to flourish. However Bonazzi (1979) found evidence that 'maistriu de fravika et de linna' (specialised craftsmen in walling materials and timber) were also working in the Roman period. This tradition is well known in the period of the XI to the XIII centuries when 'maistrus in pedra et in calcina et in ludu et in linna' (specialist craftsmen in stone, lime, mud and timber) were widespread in Sardinia (Solmi 1905, 28).

During the period of Pisan domination, a system for controlling the wages of craftsmen, blacksmiths and carpenters was imposed by the *ordinaciones,* the ordinances which were also extended to other types of activity (Di Tucci 1926, 327). This was a period characterised by specialised forms of workmanship which were imported from the peninsula to the island, especially for the construction of civic buildings.

In the XV century, craftsmen made a clear distinction between *maistros de pedra* and *maistros de muru* (between stonemasons and craftsmen). However, during the Spanish domination the Spanish word *picapedrer* (stonemason) was used to refer to all kinds of craftsmen (Mossa 1989, 156). The most ancient guild of the capital was located in the Church of Sant'Anna. Its general purpose was to invoke a saint, to whom a chapel of the church or of the convent was dedicated, and to take part in religious rituals, especially during ceremonies and on the feast day of the patron saint (Corda 1987, 78). The regulations of this guild also ordered that colleagues should assist each other charitably in times of need, and specified the terms of apprenticeship and exams considered necessary for being upgraded to the status of master craftsman (Di Tucci 1926, 41). A document of 1615 (Loddo-Canepa 1961), the most ancient known guild statute of the capital, explains that no distinction was made between the *tegolai* (roof tiles makers) and the *terraioli* (floor tiles makers) as they shared the same guild.

In XVI century Cagliari, a clear distinction was also made between *maistros de mura* and *maistros de linna,* the last being carpenters; this distinction was influenced by the local guilds whose control was more complicated and indirect in rural Sardinia (Dore 1983, 224). During this period those apprentices practicing in main towns could move to nearby villages where they could carry out repair work characterised, according to Dore (1983, 224), by a low professional level. This is probably the reason why these apprentices - called *remendons* - were allowed to practise mainly in villages and seldom in towns. The Archivio Storico of Iglesias keeps four documents dated between 1702 and 1754, which show that building repair nevertheless played a major role in the economy of the construction sector of the town (ASI 1702-1759). These deeds explain that owners had to loan sums of money for repairing their houses and that an agreement was stipulated between lender and borrower.

The professional qualification of 'architect' was only introduced in Sardinia in the twentieth century to replace the role of the building site supervisor, the *maistru de muru* (Mossa 1989,156). In the first half of the twentieth century, craftsmen were hierarchically organised according to the level of experience gained during the apprenticeship:

a) the *manovaleddu* was the young non-experienced worker started in the profession by carrying out the lightest work consisting of menial or basic tasks;

b) the *manovaleddu* could be upgraded to a *manorba* only after a couple of years of apprenticeship after which he was allowed to lift heavier building materials and to mix mud and lime;

c) the *manorba* generally became *apprendista* (apprentice) at the age of eighteen and was expected by this stage to be experienced in laying bricks and stone. Some skilled craftsmen were also called *mezza palitta* (literally translated: half trowel), meaning that they were soon to be upgraded to *maistru de muru*;

d) only a few *apprendisti* went on to become specialised craftsmen or *maistru de muru* at the average age of twenty-five. These were the most experienced craftsmen who knew the workmanship involved in all aspects of building and the necessary stages of building a house from its foundations to its roof.

It is also important to stress the status reached by a specialised craftsman and the role he covered in the social life of villages. A key factor in the more recent development of the craftsmanship of many Sardinian craftsmen was the involvement of many of them in military construction in Libya and Sardinia, especially with the construction of the fascist town of Carbonia (Murru Corriga 1994, 45).

During the first half of the twentieth century villages were not organised in a cash economy, as the term *aggiudu torrau* - which means *returned help* - suggests (Atzeni 1989, 66; Angioni 1973, 111). Bartering for mud bricks with labour, vegetables, wheat, or with farm animals was in fact the most common method of their acquisition until the 1940s. Bartering was widely carried out between craftsmen who had crafted something for the farmers and the farmer himself who in exchange worked in the fields owned by the craftsmen. As Angioni (1973, 111) points out, the *aggiudu torrau* was typically widespread amongst those craftsmen whose work was strictly related to farming, and this system seems to go back to the Nuragic Period (Mossa 1957a, 39).

Organization of the building site

Both verbal and written agreements between Master Craftsmen and clients were common by the twentieth century, but these had deep roots in historical practice. The earliest contract between a craftsman and client for the construction of an earthen building dates to 20 September 1567 and is kept in the Archivio Storico di Stato of Cagliari (Valdès 1986a, 327). Once this kind of agreement was stipulated, the *maistru de muru* had to gather together the necessary men for the construction of the specific building. No work was carried out prior to construction, except for a full scale sketch which the master craftsman usually made on the ground with wooden sticks and string. This was designed to provide the patron with an idea of the layout and the size of the building. After the layout was agreed, lime putty mixed with sand was used for building stone plinths. The craft of plinth building was considered to be sound if stone courses were laid on the whole perimeter of the construction without interruption (ASI 1901).

The working routines of workmen involved in the field of construction during the first half of the twentieth century were related to the weather necessary for the production of *làdiri*. The working day started at dawn and ended at dusk, with two breaks: one in the mid morning for breakfast (*a murzai*) and a 'siesta', or *sa barrilocca* from lunch time until three in the afternoon in order to avoid working in the hottest hours. Scaffolding was made of timber boards which rested on four timber pillars or two walls made of *làdiri* set without mortar. The first appears to have been the most common method. In some villages scaffolding was cantilevered by inclining two round-sectioned iron bars (*trampabis*, 30 mm in diameter) inclined upwards in the vertical joints of the mud brick wall (in the *cummussura*). This prevented the timber boards from slipping. These boards usually carried the weight of those *làdiri* ready to be laid. Bricks were often thrown up from the ground to one intermediate level of the scaffolding and then thrown again to another craftsman positioned on the top of the wall. They were collected on top of the wall, and then mud mortar which had been transported to the wall head in wooden baskets on the upper surface of the wall on which bricks were subsequently laid. These formed a platform for the craftsman to stand on during the construction of the next course. At this stage it became important to assess the humidity content of the mud brick. *Làdiri* had to be completely dry because their interface with the fired bricks used for dressing corners (*contonara*) or the arches of portals would be subject to dislocation if substantial shrinkage occurred whilst drying out.

3.3 *Làdiri*

Now that the role and history of the master craftsman has been discussed, the aim of this section is to describe the manufacturing process of *làdiri* as revealed through the interviews with Master Craftsmen (Figs 3.1-3.7).

3.3.1 Soil selection

Soil selection and the making of *làdiri* in Campidano differed from area to area, according to the availability of materials and the practical influence of adjacent villages. *Làdiri* makers moved to those fields where mud was readily available and the land owner often charged the craftsmen by the brick, one lira per brick being the fee in Serramanna in 1958 (bricks then were sold at 13 lire a brick). The following section explains the most common techniques of selection and mixing by using three examples which are typical of three different areas of Campidano: Villaurbana (north), Samassi (centre) and Assemini (south).

Soil selection in Villaurbana

The soil used in the making of *làdiri* in Villaurbana was of three types:

(1) the topsoil was composed of a clay which required the use of a large amount of straw in order to avoid cracking when used for bricks. This was the white soil which tended to be excavated when the foundations of a building were dug and was often employed by the humblest families;

(2) the best soil was considered to be *terra è anea,* which is found in alluvial deposits adjacent to streams and which was naturally mixed by flowing water. This soil only required a small amount of straw because the proportion of silt : clay : sand within it produced an extremely compact form of brick;

(3) the third type of soil contained a small amount of sand and a high percentage of gravel. This bound the lumps of clay together and also made the surface of the brick more resistant to weathering. Bricks made of this type of soil were only rendered when the surface had been eroded by rain. In fact, after more than one year of rain erosion, the grit became exposed on the mud brick surface. In so doing, this rendering process created a natural 'key' within the protruding stones on the wall surface.

Mud brick making in Villaurbana was organised along the strip of land stretching from S.Giovanni to Crannaxiu, where alluvial deposits produced the best quality of soil (*terra è anea*). The proximity of the stream was also important for the water needed for mixing, while straw had to be transported with a solid-wheeled cart from the village or from nearby fields. The mix of soil and straw was brought to the moulding area by using the *scivu* - a trapezoidal wooden container which held exactly the right amount of mix for two mud bricks.

Soil selection in Samassi

Làdiri moulders of Samassi were usually the poorest farmers who, when not working in the fields, gathered together along the alluvial soils of the river Flumini Mannu. Straw was carted from the fields or from the village and the available soil exploited in order that they might exchange manufactured bricks for other goods or labour.

Cossu (1996, 169) emphasises that the soil used for *làdiri* moulding was also available from the inner lots of the village itself, especially in the areas of Giuventu and Axrobas (red soil, medium clay content, gravel diameter 1-2 cm), and Pobàziu (red and more clayey, but same gravel size). Brickmaking in Samassi was otherwise similar to what carried out in Villaurbana.

Soil selection in Assemini

The soil used for the making of *làdiri* in Assemini was of three types:

(1) the *terra dessu forraxi*, a clayey soil. It was strong under compression, but it did not allow itself to be gripped by render. It also did not perform well during the wet season

because it tended to be washed away too readily;

(2) the *terra gravosa* was extracted in the Xrobedda fields, which contained gravel and, according to the craftsmen interviewed, did not act well during compression, being 1/4 weaker than the *terra dessu forraxi*. However, it was said to have greater resistance to weathering;

(3) the third type of soil was gravel-free but the proportion of clay : silt : sand made it more resistant to weathering.

Before moulding the bricks, the *ladiraiu* (*làdiri* maker) ensured the evenness of the drying ground (*a ponni sa prazza apparisi a marru*, making the drying ground even with a mattock). The soil was then mixed with water and blended and turned in order to get the right degree of plasticity and homogeneity. The mix was allowed to soak overnight (*à ascerai*, to ferment) with a similar process to bread making, as described by Maistru Benigno Spina. The next day the bricks were moulded and, when dry, cleaned of all imperfections (*incambarausu*) with a tool called *sa pudazza*. The average time for the drying of *làdiri* was five days. On the first three days the main face of the brick was set on the ground and then turned over onto its other main face in order to dry evenly. When *làdiri* were not sold or used immediately, they were stored in the field where they were produced and covered with branches or fodder in order to shelter them from the rain. In fact, it was not uncommon for building sites to continue in active use during the winter months as the bricks were still available.
The quality of *làdiri* making was the responsibility of the *ladiraiu* himself and this was particularly true when the quality of soil was inadequate. In this case the *ladiraiu* had to draw on his skills to compensate by adding an appropriate proportion of straw in order to mould bricks of a sufficient standard.

Admixtures

Organic admixtures were probably employed in concentration close to 2-5% for all *làdiri*, irrespective of the region. This makes identification difficult because there are no laboratory tests available today for such low concentrations (Torraca 1990, 15). The employment of admixtures in mud brick making was considered to be especially necessary when the soil was not coherent enough. Additives such as cow dung or oxblood were added to the mix to give it a remarkable cohesive strength; the resulting increased water resistance of the *làdiri* was an unintentional - though welcome - side effect (John Warren, pers. comm.). Mud-brick ovens were the features that required the largest amount of admixtures in their bricks. The base of the oven, being the layer where the bread was baked, was characterised by an admixture of sheep dung and soil because this made possible the achievement of a higher internal temperature. For the same reason, the oven base was also made of an admixture of soil and *merd'è ferru*, the latter consisting of impurities of coal derived from the hammering of iron and provided for free by the local blacksmiths; this mix was also heavily employed in pot making in order to obtain the red colour for their artifacts by adding the *merd'è ferru* to the glaze.

3.3.2 *Làdiri* making

Mixing techniques

Traditional mixing techniques were numerous. The simplest method consisted of digging the soil with a mattock in order to break the largest lumps of clay, after which it was wetted with buckets of water and left to soak overnight. A more sophisticated mixing technique, as described by Melis (1993, 152) and Cossu (1996, 169), consisted of piling up the soil in the shape of a truncated pyramid to a height of one metre. Craters were dug on the top of this pyramid and then water was poured in and left to soak overnight (*ammoddiài*). The following day the soil was mixed by bare feet, watered again, and mixed with wheat straw in percentages which varied from village to village. The amount of straw and water was directly proportional to the content of clay in the soil. In this respect Cossu (1996, 170) explains the method used by brick moulders for the assessment of a well mixed soil: if a sample of mix could slowly slide from the shovel (or from the mould), it was considered ready for use. Cossu (1996,175) also gave the proportions amongst soil : water : straw, which are 1:1:0.23 cubic metres. These proportions would allow the moulding of 125 bricks.

Mud brick moulding and drying

When the mix was ready (Fig. 3.2), bricks were manufactured (*pesai su làdiri*) with a wooden mould (*sestu*) made of four sides, without a base and with two handles (Figs. 3.3 and 3.7). The mould was filled with mud and its four corners compacted (*accraccangiài in is orus*) in order to make crisp bricks that would later form straight walls. The mould was then hand-levelled with the help of some water and emptied to the flat drying ground covered with straw. Bricks were turned and left to dry for a number of days according to the weather conditions (Fig. 3.4), but in the summer it was common to dry them for five days before use. When the drying process was over, every brick had to be checked and its corners trimmed and made sharp (*arrasigadura*) with a hooked tool called *pudazza.* After drying was achieved, bricks could be either stored (*abbigadura*) away from rain and damp (Fig. 3.5), or instantly used for building (Fig. 3.6). During storage, a gap of at least three centimetres was left between bricks and this allowed complete drying.

Mud brick moulding was often reported during the interviews as being an exhausting activity. Angelico Medda explained that on the 15 August 1958 he moulded 501 bricks, after which he had to rest for three consecutive days. His average was of 80 bricks a day when he was fifteen years old, 120 bricks when he was seventeen, and 250 bricks when twenty years old.

In Serramanna *làdiri* were tested by moulding one brick and putting it to dry for four days; if the brick did not show any cracks, it was considered to be of good quality and as a consequence the process of brick making was started. Mud walls were built in layers of 50 cm height, corresponding to 4-5 courses of mud bricks, in order to allow drying of the mortar. When mud bricks were irregular in shape, courses were kept flat with the insertion and the dry packing of wedges of mud brick. The mortar for laying bricks (*ludu po ghettai làdiri*) was sieved (aggregate size not larger than one centimetre in diameter) from the same soil for mud brick moulding.

Tools for làdiri *making*

Tools for the making of mud bricks vary little from one part of Campidano to another (Fig. 3.7). The mattock (*ciappa*) was used for the mixing of soil with water and straw (Cossu 1996, 173). The mix of soil and straw was brought to the moulding area by using the *scivu* - a trapezoidal wooden container which could hold exactly the right amount of mix for two mud bricks. This container was filled in with the help of a shovel (*pabia*).

The moulds were made by the local carpenter with four boards of 2.5 cm thickness, with two handles (*màniga*). The dimensions of dry bricks were 10x20x40 cm and other dimensions maintained the proportion 1x2x4. Bricks for use in the construction of hemispherical ovens were called *ladireddu* (small *làdiri*) and were made with a truncated pyramid mould (*sestu pitticcu*) with two handles. These smaller bricks were 18x10.5 cm wide on the principal face and 12x8.5 cm on the minor side and 20 cm high (Cossu 1996, 172). Their shape facilitated the construction of the dome of the oven without the need for centering. The tool called *pudazza* was made of a timber handle 10 cm long and a hooked steel knife 15 cm long. Its main use was in the pruning of vines, but it also was used for the cleaning of corners of the *làdiri* after drying occurred (Cossu 1993, 173). Bricks were then transported to the building site and laid with concave side down. In so doing bricks could set firmly in the mud mortar and water could be forced to move downward to the outside of the surface where evaporation could occur (Uviña Contreras 1998, 56). After a course of bricks was laid on the mud mortar, every *làdiri* was gently beaten with the top of a pickaxe (*piccu*) in order to improve bonding (Cossu 1993, 173). Mud mortar for the laying of bricks was transported with buckets passed from hand to hand along a human chain. When bricks had to be cut, especially for conservation purposes, a special tool called *marteddu a tallanti* was used. It was basically a hammer with one sharp side similar to an axe. After four grooves were impressed in the four sides of the brick to cut, the hammer was used to cut the brick and to clean eventual protruding lumps (Cossu 1993, 174).

3.4 Tiles, fired bricks and terracotta

3.4.1 Introduction

This section will explore the traditional process of producing roof tiles in Campidano. The great emphasis given to this section is due to the importance of roofs in the protection of earthen structures. In this respect tiles were the sole roofing material used in vernacular architecture of Campidano.

A survey of 1927 estimated that the 81 kilns in Sardinia, with their 436 employees, could only have produced half the materials required in the construction of Sardinian buildings, whilst the other half were imported from Tuscany (Mamuta 1933b, 11). Rassu (1999, 66) explains that villages often comprised blocks such as Su Forraxi in Albagiara, Su Forreddu in Dolianova, Su Furraghe in Macomer, Su Foreddu in Villasalto, all indicating an ancient presence of tile kilns. However, the main production centres of the Campidano region were four villages, which were all active until the 1960s - Sillì, Segariu, Assemini and Quartu Sant'Elena. The following sections will concentrate on the manufacturing processes of tiles in the first three villages.

3.4.2 Roof tile making in Sillì

The population of Sillì moved during the first Iron Age from the Monte Arci towards the river Tirso, close to the complex of Bau Mendua. Mud was more locally available here and some primitive kilns have been discovered which are similar in form to those used until fairly recently elsewhere in the island. Baldacci (1952, 66) and Mossa (1957a, 113) both emphasise that twentieth-century Sillì was the single most important centre for the production of roof tiles in Sardinia. The economy of the whole village was based on the production of tiles. This can be demonstrated by the fact that some villagers were tile-makers by profession. This was possible because the production process occurred between April and October and a sustainable economy could be maintained by selling the overproduction at higher rates in the winter. In this way every family in the village was involved in the production of tiles until 1965, when the tile production activity ceased. In some cases, moulders in desperate need of money could sell their dried tiles to a colleague to fire them. Bartering tiles for other goods was also common, and at particular times of the year such as the feast of the patron saint, one hundred of the best tiles (called *floriadas*, slightly whitish on the surface) were offered to the parish church.

There were nine stages in the manufacturing process:

Stage one: construction of the kiln

Kilns were located along deltas where the alluvial soils of the river Tirso had been deposited over the centuries. In order to disperse as little heat as possible during the firing process, to avoid the need for high retaining walls, and to create an access escarpment that could lead down to two fire canals, kilns were built over a pit. The construction process was carried out in three different stages:

(1) excavation of the square pit;

(2) after the excavation was completed, the vertical surfaces were covered with a layer of *làdiri* parallel to the wall surface (Figs. 3.8-3.10). On reaching the natural ground level, usually one metre up from the bottom, another course was added perpendicular to the previous layer of bricks, in order to create a wall which could function as a thermal mass. Walls were built with *làdiri* whose dimensions were slightly smaller than those used for house construction, being 35x17x8 cm. The soil employed in this process was never local but brought from elsewhere. Therefore the thickness of the kiln wall was 35+17=52 cm and its height from the ground level was 2 metres;

(3) the *anteas*, the arches made of *làdiri* whose function was to carry the weight of the charge, were placed parallel to the kiln mouths and constructed with wooden centering.

The *anteas* were placed seven centimetres apart from one another, leaving fire and smoke outlet slots. The arch forming the opening was usually wider than the *anteas* in order to provide the tile-burner with a wider view of the kiln interior. Having built this series of arches, the next step was to raise the partition wall necessary for distributing the heat into two sectors (*fogheras*). The function of this was to simplify the inspection process. Over the *anteas* a series of courses of *làdiri* were added to create a horizontal layer on which a flat single-course perpendicular floor (*trappa*) forming a grid on which the tiles laid for burning could be built, with fire slots 7x7cm wide (Figs. 3.8 and 3.9).

The interior wall surfaces of the kiln were usually mud-plastered and its four external corners were also often strengthened in the twentieth-century practice by angular steel elements connected to horizontal tension rods which resisted outward pressure.

Kilns varied according to their capacity: the smallest holding 8,000 tiles and the largest

16,000. The standard dimension of the base of the kiln seems to have been 5x5 metres. In 1950 the area around Sili still had the following kilns in active use: five kilns located in Su Pezzu Mannu, one kiln located in Funtanbella, one kiln within the village Sili itself (known also as the kiln of Ziu Giuanni Manca), one kiln owned by Boi Porru, one kiln located in Inbrusinu. These kilns were located in the vicinity of the best soils for tile making, which contained the following strata (Fig. 3.11):

(1) *terra mozza,* which included organic matter and stones, and was therefore never used;

(2) *su chinzu è s'anea,* which was considered too slim and sandy, and was therefore never used;

(3) *terra niedda,* which was damp and less sandy, and considered the best soil by the tile-makers.

Stage two: the preparation of the drying ground

The second stage was to keep the drying ground smooth and flat in order to avoid defects in the shape of tiles. The area was cleared of vegetation, watered and a mattock was used to fill in any pits.

Stage three: building the strutturi

The bench for moulding tiles was known locally as *strutturi* and was entirely built with *làdiri* (Fig. 3.12). It therefore had to be re-built every season before production work started. The *strutturi* was constructed by the tile-maker together with his family. It consisted of four masonry faces to a rubble-earth core. The working surface of the bench leant towards the operator to facilitate the easy working of the lumps of clay in the moulds (*cannas*).

Stage four: building the hut

The hut was essential for the storage of dried tiles in a sheltered place prior to their firing; the production of a certain number of tiles through a fully-charged kiln was essential for keeping the whole firing activity financially viable.

The hut was built by the tile-maker and his family and was a simple square room of four metres width and 2.5 metres height. It usually had one entrance door which was usually built with a lintel made of a bunch of canes tightened together with reed. The most interesting feature of the hut was its four *làdiri* walls which were characterised by 10x10 cm wide ventilation holes which formed a characteristic honeycomb pattern. The need for ventilation might have been the reason for not using mortar to set the tiles when roofing the hut. Tiles were instead set dry on the roof structure itself therefore increasing the level of ventilation.

Stage five: the technique of soil extraction

The plain region around Silì is a landscape of alluvial deposits of the Holocene (Aru, 1982). It is formed by the Tirso river whose deltas provide a soil mix of clay and silt. This was used for the making of tiles which did not require any additional mixing. However, when all the river deposits had been exploited, it was necessary to dig for two or three metres before an adequate soil was found; the quality of this dug soil was not, however, comparable to that found by the deltas of the river. Its extraction was traditionally carried out in two ways: some preferred digging in layers and others in tunnels. In both cases the maximum depth of excavation tended to be four metres because any deeper than this, the physical effort of excavating soil from the trench became too cumbersome. When digging in layers, the excavation area tended to be 100x100 metres wide. The soil was carried in baskets along sloping paths by women. This soil of lower quality required stabilisation through one addition of a pure clay called *lùggiau*. The procedure involved in this process is further explained in the following section.

Stage six: the raw material

The raw material was usually mixed in the late afternoons, before the end of the working day, in order to secure an adequate amount of clay for moulding on the following day.

Soils were worked in two different ways according to their quality:

(1) soils of the best quality were watered early in the morning and foot-trodden at least

twice on the same day. The first mixing activity was called *a murigai*, the second *a scaffai*. The following day, after the soil had 'fermented' and softened overnight, the mixture was turned over again (*sa scioffa*) together with wheat chaff which was spread on the mixture and then foot-stamped and trodden. After this mixture became uniform, another layer of chaff was then spread on top and the mixing was carried out. This mixture was once again spread with chaff in order to make it easy to roll out. It was brought to the bench and placed adjacent to it in a pyramid prior to moulding;

(2) soils of poorer quality were stabilised by the addition of pure clay, called *lùggiau*. This finer clay had to be dried in the sun in order to allow it to allow it to be easily broken down into smaller lumps that were then spread on the earth to be improved. The mixture, roughly 6x6 metres wide and an average height of 30 centimetres, was dampened with buckets of water and left to soak for three hours before it was turned over. This stage was critical because it was essential that any unsoaked lumps of clay were crushed into smaller fragments with the back of the mattock blade. When the mixture had reached the optimum level of dampness, it was ready to be covered with chaff and turned over again with the mattock (*scaffadura*) and left to soak overnight. The following day this mix was foot-stamped and trodden at least twice, after being spread with chaff again.

Wheat chaff was employed in precise quantities (one wheat-sackful of chaff was necessary for the production of 700 roof tiles) and had a similar function to wheat straw in mud brick making. It prevented the development of cracks and enabled the tiles to carry their own weight whilst drying. It was freely obtained from the threshing-floor because it could not be used as fodder. It was sieved with a special rush sieve in order to create a finer product that, after firing, would not leave any deeper holes in the tile. This is the reason why experiments carried out with rice and broad bean chaff were unsuccessful since the holes they created were considerably larger.

Stage seven: tile-moulding and drying

The traditional Roman roof tiles of Sardinia, also known locally as Sardinian roof tiles, were moulded with two instruments: a washing-off frame, known locally as *cannas*, and a splayer, which is a curved piece of wood with a handle known locally as *mollu* (Fig. 3.13).

The bench for moulding was divided into two sections (Fig. 3.12). On the right hand side of the operator was a sand compartment and on the front was the actual moulding area, composed of a terracotta trapezoidal base (called *pedra*, the stone) on which to place the washing-off frame (Fig. 3.14). The roof tile-maker had to sprinkle some sand on the pedra, then place the washing-off frame onto it, grab a lump of clay, press it into shape in the frame, cut off the clay from the frame with a ring string, move the resulting flat clay over the splayer in order to assume a curved shape and position the roman tile to dry on the ground. In all circumstances roof tiles were dried in the open air, avoiding direct exposure to the sun, and laid with the longer side parallel to the direction of the movement of the sun in order to allow the tiles to dry uniformly and avoid cracking (Fig. 3.15). In July, the warmest month of the year, tiles could dry in one full day whilst in August and September, after having dried for one day, they were kept in the hut and then laid out again the following day to ensure complete drying.

Stage eight: the setting and firing process

Roof tiles were set vertically over the grid of the kiln and juxtaposed one tile up and one tile down to allow the maximum number to be fitted inside. Setting the kiln was a delicate process because smoke, vapour and fire gaps had to be created by setting the tiles apart from one another. After setting the first three layers of tiles vertically, the order was then changed so that the tiles were positioned horizontally, so that the heat which came through the first three layers was not dispersed but stopped and absorbed by these layers. Setting the tiles was also a difficult task because the whole charge had to be kept sufficiently compact to avoid movement during the firing process. For this reason pieces of older broken tiles were inserted as packing between the tiles whilst firing occurred. When the kiln was completely charged, it was covered with old tiles without any mud mortar and the burning process was started.

The kiln was continuously fired from the first to the last stage by using a long steel pitchfork which was used to position the kindling. The firing process developed through the following stages:

(1) during the pre-heating stage - the drying stage - the kindling had to be gradually inserted, in order to ensure that the kiln did not overheat too soon. This is the reason why the firing-holes were sealed up with kindling. When new ones were to be inserted, the fire operator pushed in the seals and inserted replacements. Oxygen could draw inside and therefore the kiln can be classified as an oxidising kiln;

(2) during the second stage, it was important to enlist the supervisory advice of a skilled operator who would understand whether the firing process was uniform or whether more heat was needed in a certain spot. This expert figure was also necessary to prevent the melting of tiles due to overheating. If this did occur the melted tiles were recycled for use in building foundations. The average time needed for completing phases 1 and 2 was ten hours;

(3) the last stage was the cooling down process which in total lasted thirty-two hours. If the second stage had been finished in the morning, the kiln could be discharged in the afternoon of the following day.

The kilns of the village of Silì were usually run by groups of four different families within the framework of an association which allowed burning costs to be kept at a sustainable level. Each of the four families set their production according to a system known as 'one fourth' (*quartas*), which ensured an equal distribution of those tiles, set in the core of the kiln, which were the better fired. For example, if the hold of the kiln was 8,000 tiles, then each family had 2,000 tiles to fire - the convention was to set layers of 1,000 tiles in the kiln in order to alternate with another 1000-tiles of each family. In so doing the final product was more uniformly fired and each family could ensure that they received tiles of equal quality to the other members of the 'fourth'. It was also common for every family - during the moulding process - to impress or stamp its own symbol on the tile (e.g. a small nose, fingerprints from one to five, a vertical strip, a horizontal strip, a dot, an S) so that when the kiln tiles were unloaded they could be identified by their owners.

Stage nine: unloading the kiln

When the cooling down process was finished, the kiln was unloaded (*sciorrài*) and the tiles could be sold to brokers who then loaded them on to trains bound for important centres like Bolotana and Giave, where they were sold instantly and used for building (Figs. 3.16-3.18).

3.4.3 The craftsmen working in tilemaking in Silì

The figures working in tilemaking were several. This section analyses their role by classifying them according to their skill:

(1) *the kiln builders*;

(2) *the families*: the making of tiles was an activity in which the whole family was occupied. Women and children usually helped with lighter work like the digging of sand, the setting of tiles in the kiln and the unloading of the kiln;

(3) *the unskilled workmen* took care of the kiln by feeding it with kindling in the first stage of the burning process;

(4) *the skilled firers,* also called chief kiln firers, only took over the activity of feeding the kiln during the last stage of the firing process because when the *anteas* became incandescent, feeding the kiln became a delicate operation - especially when the *anteas* were finally hit with a pitchfork. It was possible for the whole charge of tiles to collapse if this stage was done incorrectly. The chief kiln firer was also vital for checking the firing condition of the tiles and for understanding when to stop feeding the kiln. The chief kiln firer had to compensate in the event of a bad firing process or in the case of a poor firing quality. This both demonstrates the importance of this role and explains why there were more than twelve chief kiln firers operating in Silì during the 1950's.

3.4.4 Roof tile making in Segariu

Segariu was the second most important centre of Campidano in the production of tiles. It employed a similar manufacturing technique because the business was started by expatriates from Sili who settled in Segariu. The soil was locally available from the deltas of the Lanessi river close to the village. Kilns were located along these deltas and in those areas called Baccuradroxiu, Barregusu and Sant'Antonio. The following section will therefore be limited to an explanation of slight differences in technique between Segariu and Sili.

The main difference rested in the fact that mixing the soil for roof tilemaking in Segariu was a much quicker activity since it required only two hours of soaking after which the clay was considered ready to be mixed with chaff. One wheat-sackfull of chaff was required for the production of 900 roof tiles. Also important was the fact that the burning time was limited to six hours and the cooling down process only lasted eighteen hours. These differences can be explained by the fact that probably the Segariu kilns were smaller in size and therefore needed a shorter burning and cooling time.

Another peculiarity of the making of tiles and bricks in Segariu was the fact that the local clay contained calcareous elements. After the burning process was over and the kiln was discharged, tiles and bricks had to be soaked in water in order to avoid cracking and this was probably due to the fact that those lumps of lime were slaked.

3.4.5 Roof tile making in Assemini

The fluvial land around the mouth of the river Bau-aréna, Assemini, is a plain of alluvial deposits of the Holocene period which produced clay soils (Aru, 1989) employed locally in the manufacturing of tiles and bricks. Some fields in the outskirts of the village were characterised by these best soils but, after these deposits had been exploited, tilemakers were forced to buy clay excavated during the digging of wells. This activity was also useful for identifying the location and the depth of the best deposits of soil for future action. The best soils for the making of tiles were not too clayey. Pure clay was preferred for the making of pots which is still today a major business in Assemini. The tilemaking process in Assemini was otherwise similar to that from Sili.

3.5 Miscellaneous and other

3.5.1 Floor tiles

The traditional floors of 20th century earthen buildings were made of cementitious tiles which replaced earlier floors made of fired clay tiles, which had in turn replaced earthen floors.

Earthen floors (*pomentu*) were traditionally built in layers. The first layer (6-7 cm) was made by the men of the family over the rough surface that was to be paved. The prime material for this layer was unsieved loam which was moistened and rammed with a special wooden rammer called *battidori* (Lallai 1989, 33). Only when the first coat had dried, was the finishing coat (1-2 mm) applied by hand by the women. Its composition was similar to that of mud renders, but with added clay and no straw. Before the drying process was complete, they wetted the finishing coat with salted water and smoothed with a stone (*coccodula*) - more recently this has been done with a trowel. Cracks were avoided by dampening the coat with water. No waterproofing material was added in the final stage and this is the reason why the last layer was renewed annually, especially during festivities.

The production of fired clay tiles was a parallel activity to roof tile making but the soil used contained less clay because floor tiles, being flat during the plastic process, did not need the supportive structure of clay which was so necessary for the curved rooftiles. Typical dimensions were 20x20x1.5 cm, 10x10x1.5 cm. Glazed tiles were not common in the vernacular architecture of Sardinia, probably because their manufacturing process was too sophisticated. They were imported from main production centres of the peninsula like Naples, Vietri sul Mare and Santo Stefano di Camastra (Marini and Ferru 1993, 180) and used for high status architecture only. Cementitious tiles were produced locally by small enterprises such as the one in Serramanna run by Vittorio Concas (b. 1909) which counted five employees until the late fifties.

3.5.2 Fired bricks

Fired bricks were employed as structural elements in pillars, round arches, segmental arches, flat arches, stairs, and also for paving and for decorative purpose. Bricks dimensions were variable, 6x12x25 cm being the most common, and were traditionally produced with a wooden mould and with a similar procedure to the roof tile making. Bricks colours varied according to the type of clay and to the firing temperature. Yellow bricks were extremely common in Sardinia and manufactured in Cagliari, while red bricks were produced in Monte Arcosu where clay and firewood was locally available; they were carted from there to Cuccura Mereu and then shipped to Cagliari. The colour was also a function of the constituents of the clay itself: yellow bricks tend to have a high content of magnesium oxide whilst the redder bricks have a high content of iron oxide (Brunskill 1990, 40). A more detailed explaination of the production of fired bricks is given in Appendix 1 where an unpublished document dated 25 March 1773 is reproduced. It was written in Iglesias during the Savoy domain by the Piedmontese engineer Daristo and it is the oldest known description of the process of brick making in Sardinia. Daristo explains why the construction of the Episcopal Palace and Seminary of Iglesias would have been more convenient if sound bricks had been employed instead of stone.

3.5.3 Drain pipes

Terracotta drain pipes were often used for collecting rainwater into tanks and were as common in the houses of the wealthy as in humbler buildings; and in urban as well as rural buildings (Marini 1993,180). They were handmade by potmakers and usually never longer than 70 centimetres, so that sections could be fixed with a socket and spigot interlocking system. These elements were self supporting and their thickness could therefore be circa four centimetres and their diameter 20 centimetres.

3.5.4 Terracotta decorations

Terracotta as a decorative feature was widely employed in Sardinia around the end of the nineteenth century when humbler buildings emulated the style of sophisticated palazzos in order to impress contemporaries and to reflect the wealth of the owner. The reason for employing terracotta decorative elements rather than stone reflects the fact that terracotta was considered to be a *new* material and because the same decorative element would have been more expensive if made in stone. These styles of decoration were imported from Tuscany and widely employed especially in villages close to the capital such as Quartu Sant'Elena where the competition with the wealth displayed in the capital and regulation, such as the 1897 *Regolamenti di Ornato*, encouraged owners to embellish their buildings with terracotta decoration and, from 1920, with cementitious decorations (Sanna 1994, 37). Cementitious decorations were also popular and often manufactured by local craftsmen such as Basilio Putzu and Nino Putzolu who worked in Serramanna.

A survey of facade decorations was carried out through the questionnaire and the main result was to demonstrate how small a percentage (6.3%) of buildings are characterised by these decorations (Table 25). The most widespread facade decorations are the following: floor string courses made of various materials (6.3%), terracotta mouldings and decorations (4.1%), pilasters made of various materials (1.4%) and stuccowork (1%). It is also important to note that the general state of decay of decorations was found to be from moderate to low (Table 26).

3.6 Stone

3.6.1 Uses of stone as a building material

Stone is the second most widespread building material of Campidano's vernacular architecture after earth. It was employed in the construction of plinths in mud buildings, as a structural element in portals and arches of loggias, and also in the form of cobbles for paving courtyards and streets.

Stones for plinths were carted from the nearest river (the cart being the unit of measurement) and, being rounded, needed a skilled mason to lay them properly. In the Gerrei region, stone plinths were bonded together by using a specific mud mortar called *ciniscìu* which was made of sieved soil, ashes and water; this mortar was known in the region for having a high bonding activity (Lallai 1989, 28). Stone plinths were often pointed with wedges (*scaglie*). The popularity of stone for the construction of plinths can be quantified with Table 4.6 which derived from the questionnaire analysis.

Courtyards were cobbled with a layer of river or field stones (*imperdàra*) applied either on the wet ground or on a bed of sand of 15 cm. Stones were then beaten with the help of a wooden tool called *dama* (probably because function made its design vaguely shaped like a woman) and covered with a layer of coarse sand.

The following sections contain a description of the traditional workmanship involved in the quarrying and dressing of the stone known as 'Serrenti's stone', with special reference to its use in the portals of earthen buildings.

3.6.2 Serrenti quarries and stoneyards

The nature of stone in use in vernacular earthen buildings of Campidano varies according to local availability and geology (Fig. 3.19). This section will consider a single representative type. The reason for choosing the stone quarried in Monte Atzorcu near the village Serrenti for more detailed study (Fig. 3.20), lies in the popularity of this material and the extent of its use in the mud-brick buildings of the area around the village. This stone was also extracted in neighboring quarries such as Monte Ibara and Serra Pogusta and carted to the surrounding communities. The most ancient evidence of the use of the quarries is represented by a document dated 30 July 1355 which explains that 'the cost for the transportation of one charge of stone of Serrenti amounted to three *soldi*' (this document on the construction of the castle of Sanluri was obtained by Giorgio Corongiu, Serrenti, 7 September 1999, and kept in the castle archive).

The stone is locally known as *trachyte of Serrenti* because it was wrongly named by Della Marmora in his *Viaggio in Sardegna* (1927, 438 and 441). More recently - and more correctly - the rock has been classified as a piroclastic dacite formation which includes primary minerals such as plagioclase, amphibolite, biotite, opaque minerals, silicates and secondary minerals such as chlorite, calcite, opaque minerals and silicates (Buffoni 1996, 1). The harder intrusions are traditionally referred to by stonemasons as *neus de ferru* (iron moles), because sparks can be produced when they are cut with a punch. The rock is grey-green in colour and becomes reddish when exposed to weathering. It contains minerals which are a maximum of six centimetres in diameter, which allows the rock to be classified as a volcanic breach. The quarry also has a pink version of the same stone but this was hardly quarried. The rock is isotropic, but masons recognised that the tendency for the stone is to be harder when quarried from depth.

The vertical section of the quarry of Monte Atzorcu shows the following strata: a first layer of earth and organic matter (2-3 metres deep), a second layer of rock (10cm- 10m deep) which crumbles easily because it was in contact with the earth - and therefore was never used for building - and finally the stratum where good-quality rock for building is found. The latter occurs in blocks with natural fault lines of two centimetres thickness, often containing a red earth. The quarry was found to have main natural fault lines (roughly 2.5 metres apart) and main bedding planes (2.8 metres apart), whilst diagonal fault lines are fewer.

Quarries

The success of Serrenti's quarries was due to its central location in the southern part of Campidano and due to its transportation facilities. Quarries like that in Serrenti essentially produced quoins for arches and portals, reaching their peak of productivity between the end of the nineteenth century up to the 1930, when the characteristic round-arched portal made of grey Serrenti stone replaced the conventional mud brick or fired brick portal of the past centuries. But another important source of work for the quarry was the cutting of quoins for the construction of stone buildings. It was calculated that for the construction of a building with four rooms of 16 square metres each, one needed to order at least 100 cubic metres of stone quoins. The stonemasons (*tagliatori*) of the quarry of Monte Atzorcu made out stones in different sizes and textures: rough blocks measuring 25x25x30 cm (*quadrilotti*, sold in 1950 at lire 500/cubic metre), undressed stone of various dimensions (*pedra scappa*, sold at lire 300/cubic metre), waste fragments or chippings (*scarto* or *scaglioni*, sold at lire 100/cubic metre). Decorative stones were also produced, made by specialised stonemasons (*scalpellini*) who worked in the quarry. They were at the top of the hierarchy because they used the square, while the *tagliatori* quarried the stone and used rough tools for its shaping. Archival research shows that the wage of the trade of the *scalpellini* was nearly 17% higher than that of the master mason, of the cart maker, or the blacksmith (ASQ 1926).

Stonemasons wishing to work in the quarry of Monte Atzorcu had to pay a relatively small monthly fee to the land owner, which in 1950 was of 350 lire and this allowed the unlimited exploitation of the quarry. The most productive stonemason could quarry 10 cubic metres of rock a day, but another day of work was necessary to shape the rock into rough blocks (*quadrilotti*) which could be sold at lire 500/cubic metre.

Stonemasons' yards were located in a flat area in the vicinity of quarries in order to facilitate transportation and stone-breaking and cutting because the stone is still moist and much softer to work when it has just been quarried. The stone was dressed on top of two other stones and stonemasons sat on a timber box, which also functioned as a tool box. In Serrenti there was a distinction between professional stonemasons, of whom there were very few, and the rest of the craft production which was done by farmers who worked in the field during the day, and then moved to the stoneyard where their unskilled labour was required for rough work. The area around the quarry was scattered with stonemasons and farmers who formed associations. These reached a peak in the 1940s of 200 men who worked and kept their tools in the open.

The above quarries were abandoned during the 1960s with the result that in September 1998 only one stonemason, Antonio Argiolas, was still working in a traditional way in the quarry. According to Marras (1989, 71) the reason for the abandonment of quarries and stoneyards was due to high extraction costs and, more importantly, to the decline of agricultural work. Because intensive agricultural regimes reduced the multi-functional aspects of the farmhouse unit, the skills of craftsmen were made redundant. This is reflected by the fact that the village of Serrenti reduced its tertiary employment from 64% in 1951 to 14% in 1981 (Marras, 1989, 71).

Extraction and cutting

Stone was extracted by splitting it along its bedding planes (*piòda,* and the expression was that the rock was cut *in pioda*, or *si piodava*) and along its natural fault lines. The rock was also sometimes cut along its vertical grain (*in contro pioda* or *in truncanti*). Blocks were extracted by inserting coping wedges (*punciotti*) between four and eight centimetres apart, on a straight line (Figs. 3.20-3.22). This was confirmed by an inspection in the quarry where a monilith measuring 2.35x0.25x0.30 metres was found to have 28 grooves on its long side; the monolith was probably to be used as a paving stone. Wedges were hammered with blows in succession for at least three times and always starting from the same end. After these three successive series of blows, the stone was left to rest and then it was split with the help of a pry-bar. If the size of the stone was such that it did not allow easy splitting, quarriers had to step on it and try to split it by inserting wedges along the line that connected the volume with the quarry wall (along the *recisa*). Until recently the equipment in use was rudimentary since it was composed of two sizes of hammers, some wedges and a lever. When wedges were not available or when masons could not afford them, stone blocks were split in the following way: grooves were carved on the stone, water was poured in them and wooden wedges were inserted and left to soak overnight until the expanded timber would have split the stone, without the need for any subsequent hammering. More recently stone was, and still is, quarried using explosives. After being quarried, the block was subsequently split into smaller parts by making holes on a line and hammering in point chisels. The block was then squared and shaped using cardboard templates. Once the *maistru de muru* had agreed with the owners of the building about the kind of decorative pattern and about the type of stone preferred, he had to measure the span of the arch to be built and explain every detail about the requested arch to the stonemason.

One of the main improvements in the workmanship of stone of Serrenti seems to have been the result of the teaching of Gabriele Palandri who moved to the village in 1890 and - together with his son Omero - brought his experience gathered whilst working as a stonemason in Montelupo (Firenze). The most important dynasty of stonemasons trained by the Palandri was the local Tiddia family; Emanuele Tiddia was the first to be trained and his descendent Pietro Tiddia today deals with mechanically-cut stone.

The art of stone masonry in Sardinian vernacular architecture reached its greatest refinement in the cutting and carving of quoins for arches. Whereas portals only show two main types of arches, i.e. the semi-circular arch and the semi-oval (or three- centred) arch, an incredible variety of arches can still be found in loggias: semi-circular, semi-oval, pointed, and also more elaborate. After the span had been established, the geometrical outline of the arch was first drawn on the ground with the help of a cane called *sintellu* which was nailed to the ground at the position of the centre of the arch and a pencil on the other end. When the stonemason was satisfied with the outline, this geometrical construction was transferred to a cardboard sheet and then divided into sections (templates) representing the voissoirs. The cane and pencil method was considered to be more precise than a steel wire or string. The latter was unpopular because it could be affected by expansion. Piers and pedestals were the first elements to be cut, followed by the capitals, and then the arch itself of which the central keystone (*serralia*) was carved first. Key-stone decorations were copied from pattern books and letterings were transferred through templates. Voissoirs were surfaced according to the client's financial situation and to his taste: the least expensive finish was the punching (*pietra rasata* or *pietra sbozzata*), followed by the hammer bushing (*pietra bocciardata*), by the pitched with tooled margins (*bugnato*) and by ashlar (*pietra liscia*) which was carried out by using the pumice stone (*pietra pomice*). After a month's work the quoins were numbered with lime on their back and transported to the building site where they were erected with the aid of formwork, which was made of timber but sometimes out of a wall of *làdiri*. These ashlar quoins were mounted by the maistru de muru with the assistance of the stonemason himself and bonded together with a thin lime putty, with fine sand. Voissoirs were set on their natural bedding plane because if set wrongly, decay was noticed to be considerably higher.

Tools for quarrying

The survey of tools for the quarrying and dressing of the stone of Serrenti has been carried out with the help of the following craftsmen: Giuseppe Medda (quarryman, b.1927) and Antonio Argiolas (stonemason, b. 1938). Tools for quarrying included (Figs. 3.25-3.26):

(1) *punciotti* (or *punzotti*), coping wedges of various dimensions according to the size of the stone to split. Traditionally made by a local blacksmith and tempered by the stonemason himself. Every quarrier owned at least one set of 15 wedges;

(2) *agullinu*, punch for the making of the grooves in order to accommodate the coping wedges;

(3) *mazza piccola* (weight 800 gr), also called *mazzetta*, a small sledge hammer used in

driving the punch and the coping feathers;

(4) *mazza piccola* (weight 1200 gr), also called *mazzetta*, a heavier sledge used in driving the agullinu and the plugs. Weight was proportional to the hardness of the stone;

(5) *mazza grande* (weight 7000 gr), the heaviest sledge for the final driving of plugs. Also used for roughly shaping blocks;

(6) *palanchino*, pry-bar used for helping the separation of two blocks after splitting.

Mason's tools

The survey of tools for the quarrying and dressing of the stone of Serrenti has been carried out with the help of the following craftsmen: Erminio Putzu (stonemason, b. 1927), Pietro Tiddia (stonemason, b. 1929), and Antonio Argiolas (stonemason, b. 1938). Mason's tools for the dressing of stone included (Figs. 3.25-3.26):

(1) *riga di legno*, timber ruler;

(2) *squadra*, small and large steel square for setting out small and large voissoirs;

(3) *capezzino* (also found as the Sardinian *accapezzino)*, steel pitching tool used for the first rough shaping of the quoin, useful especially in vertical position for the removing of large amounts of surplus stone. It was made for use with a hammer;

(4) *ferru ladu*, steel chiesel with a flat tip. Exclusively used with a hammer for the cutting of the *fascetta*, or dressed margin;

(5) *bocciarda* (also called *bugiarda*), or bush hammer, with teeth varying in number and in size according to the required finish. It was used with one hand in order to give a perpendicular blow to the stone surface. Stonemason Giuseppe Medda owned two bush hammers, numbered 8 (made in Massa Carrara and characterised by a replaceable head) and 6 (purchased in Cagliari).

(6) *ungietta,* steel chiesel with a concave round end, was used with a hammer for decorations and finishings;

(7) *modine*, cardboard templates;

(8) wooden box with a double function: for storing tools and for sitting on it while carving

3.7 Traditional production of lime

The aim of this section is to discuss the vernacular industry of lime making in Campidano. A description of the use of lime in earthen buildings is also made as opposed to the use of mud plaster.

3.7.1 Introduction

Lime was a relatively expensive material, and as a consequence of the economic problems suffered by Sardinia in the first half of the twentieth century, the use of lime was limited in many villages, especially for the construction of humble buildings. In these dwellings the use of lime was limited to interior limewashing, and to the laying of the roof tiles over the cane structure. More rarely lime was used for rendering, but renders were generally made of mud. Internal lime-washing was carried out annually so that increasingly thick layers created a protective skin over the soft mud render. In more prestigious buildings lime was employed for rendering, for interior decoration, and as mortar. In order to minimize transportation, lime kilns were located in those areas where limestone could be easily quarried, making the transportation of quicklime easier than the same limestone from which it has been produced.

3.7.2 Lime burning in Campidano

Flare kilns

Where limestone was available in flat settings, as found in Nuraminis, square section small-scale flare kilns were built in the shape of towers. The village kiln located in Via Roma in Nuraminis will be described in this section (Figs. 3.27-3.29). The construction was used until 1956 and it consists of a double-membrane wall made of rubble stone (not necessarily limestone) on the outside and refractory bricks on the inside. Bricks measure 20x11x6 cm and carry the manufacturer's stamp (TR). Replacement of the brick skin (*ri-incamiciare*) was carried out after bricks had decayed because of overheating. The burning process was carried out in two days and three nights:

(1) In the afternoon of the first day a horizontal grate was positioned at the base of the kiln for holding the charge and for preventing the stones from collapsing. The grate was made of parallel iron rods (10 cm apart, 1.6 cm of diametre) with a hooked end in order to facilitate extraction. The operator had to climb on a ladder carrying a basket in order to set a layer of stones. This first course was made of large stones of 25-30 cm in diameter and was covered with a layer of faggots. Then the limeburner lit the faggots and climbed on top of the kiln from where to throw pit coal on the fire. Then layers of stones of smaller size (10-20 cm in diametre) were set by alternating them with layers of pit coal (10 cm of thickness). In so doing, during the first day the kiln was charged until half its capacity. The charging process required two men inside the kiln plus two men over the kiln. Charging the kiln was also made easier by the use of a pick characterised by eight prongs four centimetres apart. A platform was also necessary for helping the charging; it was built on top of the kiln with steel and juniper boards which had to be kept continuously wet. In 1950 these boards were replaced by a concrete slab which is still part of the actual fabric. Stone size was dictated by the type of kiln itself as traditional flare kilns are not designed for burning large blocks. Therefore larger blocks had to be split into smaller size;

(2) the charging was completed on the second day of work, while the content of the kiln was continuously burning. At 11:00 pm the top was covered with flat stones in order to allow the heat to increase inside the furnace. During the burning process the draw hole - a brick segmental arched door - was left open in order to allow oxygen to improve the burning process, the kiln therefore can be classified as an oxidising kiln, with a temperature regime of around 900°C;

(3) on the third day, when the carbon dioxide had been eventually driven off from the limestones, these were allowed to collapse after extraction of the grid.

This technique of lime burning was probably introduced in the Roman period (Adam 1984, 69) and was characterised by a slow heat firing method.

Hillside kilns

In hilly or mountainous settings - as in Villamassargia, Laconi and Domusnovas - the most common type was the small-scale hillside kiln with a circular base and a barrel shape, measuring roughly five metres in height (Figs. 3.30-3-32). This method for the preparation of lime might have been again introduced by the Romans (Adam 1984, 69). The hillside kiln had three advantages when compared to the flare kiln: its top was more easily accessible for loading and its bottom for firing, it had a higher thermal capacity because it could take advantage of the natural slope of the hill itself, and could therefore also function more effectively under expansion during the burning process. The reason why hillside kilns are more widespread in mountainous areas can be related to the massive amount of kindling necessary for sustaining the burning process (flare kilns require less fuel in comparison), kindling which was most readily available in the wooded hill areas.

The burning process started with the gathering of the best limestone, which was quarried by hand. In Iglesiente, the region around Villamassargia, limestone is intruded by mineral veins of zinc and lead (Bennett 1938, 10) and this was considered to be the best quality stone (*marmorina*, marble-like stone), a compact stone that gave a 'good' sound (*pietra sonora*) when knocked. Quartziferous limestone was rarely burnt because it cracked too easily. Mamuta (1933, 14) pointed out that the best lime of Sardinia was burnt from secondary limestone found in the regions of Nurra, Algherese and Iglesiente.

Before the charging process, the retaining front wall of the kiln had to be reconstructed seasonally with limestones. A rough dome (*trappa*) was then built at the bottom with the help of timber props. This was necessary for holding the charge of the stones and occasionally cantilevered monoliths protruding from the wall surface were used for this purpose. Larger stones (the largest being one metre in length) were set at the bottom over the rough dome, followed by stones of a decreasing size until gravel of four centimetres in diameter was placed on top. This arrangement was necessary because larger and harder stones, which required a higher burning temperature, had to be closer to the source of heat. On the contrary, smaller sized and softer stones could be more distant from the fire. The top was then covered with a layer of clay daub and air inlets were left at distances of 50 centimetres. The daubed kiln had the advantage of producing a more even firing and also of allowing the limeburners to control the firing process by checking the colour of the smoke rising from the inlets.

Kindling was inserted through the draw hole which was made of three rough limestones forming a lintel over two pillars. The hole width carried the same dimension as the average thickness of kindling because of the loss of heat which would result if it was larger. Logs were avoided because their flame would have been too small and limeburners emphasised that the *flames* were more important than the level of heat because stones had to *burn*, not simply to heat up.

The lime burner was a skilled professional who could judge the progress of the burning process simply by checking the colour of the smoke rising from the inlets. If the smoke rising from a specific inlet was black, it meant that the kiln was not burning properly. In this case the opposite inlet was blocked to force the malfunctioning inlet to leak. When the smoke became white, it signalled that the burning process had been improved. Burning lime was time and energy consuming as it lasted for eight days and eight nights and the kiln needed to be fed constantly. After this period, lime burners waited for at least five days until the kiln had cooled down. With a kiln of 4.5 metres in height, 40-45 tons of quicklime could be produced by burning 20000 faggots, with a feeding speed of one faggot every two minutes. Quicklime drawing was carried out by using steel hooks, especially when stones were to be melted together because of the high temperature. Quicklime was carted to the nearest village where it was sold in baskets by the quintal or bartered for other kinds of workmanship.

Slaking was carried out in two settlement tanks on different levels in order to achieve filtering. The first tank (*scalladori*) was made of timber and equipped with a door that allowed the slaked lime to be conveyed with a mattock to the tank below, a simple rectangular pit in the ground. The first tank was 1x1.5x2.5 m wide and 40 cm deep, while the pit in the ground could contain the product of the whole kiln. Sometimes, if necessary, a second pit in the ground was connected to the first pit. Lime was filtered by sedimenting impurities (such as lumps of unburnt limestone and quartz) in the wooden settlement tank. Sieving was important because otherwise unslaked lumps could have slaked when applied on the wall and this could have caused *bursting* of the render. Monolithic stone mangers (*su lacccu*) were also used as slaking tanks but it was not uncommon for poorer communities to build up a tank on the ground from four buttressed *làdiri* walls equipped with a door. This lime putty was commonly stored in the pit itself after being covered with a layer of sand, or sometimes with branches. It could be used after a minimum period of three weeks, but it was quite common for it to be kept for a year before being used. In so doing, after slaking 30 Kg of quicklime one could manufacture one cubic metre of lime putty.

3.8 Lime plaster and mortar

Non-hydraulic lime was employed in the rendering of mud brick structures in order to make sure that the render was sound and adhered to the wall, to give a protective layer to the masonry, to be permeable and reversible and to give aesthetic value to the building. However Mamuta (1933a, 14) has pointed that in 1933 hydraulic lime was seldom purposefully produced in the island but rather imported from the peninsula. The quarrying of limestone for the production of quicklime was a more widespread activity, and in the period from 1926-1929 the amount of quarried limestone on the island amounted to 48,200 tonnes.

Plastering was carried out just after completion of the building when the soil used for the making of bricks was clayey. On the contrary, when the soil included coarse sand or gravel, one had to wait for three or four years before plastering. This was necessary for allowing rain to wash off the gravel and making it protrude to form a key for the plaster. Before plastering a clayey *làdiri* wall, its friability was inspected. A first coat of mud or lime slurry was applied (*rinzaffatura*) in order to prevent detachments between mud-brick walls and lime plasters caused by friability of the earthen wall. Soil for this coat was the same used for the construction of the earthen wall so that bonding was achieved without detachments of friable parts. Then a scratch lime coat was applied (*arriccio*), followed by a skim coat (*intonaco*). In many villages lime plasters were made to adhere to the *làdiri* wall by hammering flat stones, tiles or juniper wedges in the vertical joints beween bricks. The protruding wedge (*ancraba* or *scadradura*) could therefore form a key for the lime coat (Figs. 3.33-3.34). The difference between mixes for interior and exterior lime plasters was explained by Elvio Murgia, Master Craftsman of Serramanna. According to Murgia, exterior plasters had to be fatter (richer in lime) than the interior plasters because they had to cope with weathering. This was agreed by many other Master Craftsmen and it was a common practice in villages such as San Sperate. Lime plaster was mixed by hand and the common working mix was:

(1) 90 kg of sand for every 50 kg of hydrated lime, or:

(2) 30 kg of sand for every 10 kg of lime putty.

However, these mixes varied slightly from village to village, as for example with Sinnai, where 35 Kg of sand was necessary for every 10 kg of lime putty. Measurement of lime and sand was undertaken often by volume with the help of a wooden container measuring 100x100x50 cm.

A specific example of the use of *artificial* hydraulic lime during the interviews with traditional craftsmen. In the village of Assemini a mixture of lime putty and crushed old roof tiles used as pozzolanic additive (*coccio pesto*) was often used for rendering the internal walls of loggias. Only those roof tiles burnt at low temperature could be used for this purpose because they were more porous and therefore contained interstices which could be filled in with lime to create a bond that strengthened over time. Another example of a *coccio pesto* plaster was collected in Gonnesa and analysed in the laboratory (sample name: Gonnesa 2). This showed the proportion of lime : sand : *coccio pesto* of 25% : 28.4% : 46.1 %, which is very close to the traditional mix of three parts aggregate and one part lime. Evidence of the use of pozzolanic additive to lime plaster is given by archival research which shows that in the Public Slaughter House of Quartu Sant'Elena the plastering was mixed with a proportion of three parts lime putty and seven parts Roman pozzolana (ASQ 1900a). Interior renders were sometimes made with a mix of lime and marble dust in order to make smoother surfaces and to prevent srinkage (Malinovski 1979, 67), but this practice seems to have been used only in those villages close to Cagliari, probably for reasons related to fashion. Sand was instead the most popular aggregate for lime renders.

Most of the Sardinian sands are of siliceous origin and therefore are excellent for building purposes (Mamuta 1933b, 10). Sand is the product of the decomposition of rocks, deposited by the action of water in river banks and streams. The heavier material drops first, followed by sand and then maybe silt and clay. Craftsmen could therefore choose between two different kinds of fine and coarse sand according to the degree of refinement they required. Every craftsman was extremely familiar with those river banks and locations where the best quality sand was to be found before the 1950s. The quantity of dug sand necessary for building was so small that the river could replenish the amount annually. Some craftsmen suggest that the quality of the regenerated sand increased year after year. The streams of mountainous areas were said to carry the best quality of sand because it is rarely mixed with clay or silt in these locations. This is the reason why the streams adjacent to the hills or the mountains were preferred over those located in the plane of Campidano. Clayey and silty sand was washed in order to obtain an aggregate that could allow lime mortar to achieve proper setting (ASQ 1900a; ASI 1906a). Transportation was provided in special wooden containers stacked in carts which were also used for agricultural purposes.

3.9 Mud plaster

Mud plaster was widespread throughout the Campidano region, especially amongst those owners who could not afford a lime plaster. It was widely used during the nineteenth century after which it was generally replaced by lime plaster. The most popular soil for the making of mud plaster had a high content of clay which required a high percentage of straw in order to prevent fracturing after application. This mud was white in colour and unusually constituted of topsoil, which was the same soil dug during the excavation of the foundations. It was to be considered to be the soil of the poorer families who could not afford to buy better-quality materials.

The mix for the first rough coat of mud was sieved in order to exclude aggregates larger than one centimetre. It was prepared the day before and left to soak overnight in order to avoid cracks caused by unsoaked lumps. It was applied directly to the *làdiri* wall to fill in the cavities between bricks and, after being leveled with a feather-edge rule, enable the next layer to adhere. Rough coats were applied in strips in order to make the leveling process lighter, the number of strips being proportional to the strength of the operator. For instance, rooms with walls of four metres required three vertical strips of rough coat which were applied in different stages. The process is similar to the *pontata* and the *giornate* of the fresco technique, with hardly visible joints. The application of the finer coat of mud was often carried out after three days (Cossu 1996, 171) by hand by the women (*ludu a pranta è manu*) or by using a gauging trowel and a timber feather-edge rule (from one to two metres long) in order to make straight surfaces. The skim coat was sometimes smoothened with a wet cloth. When ceilings (*bòvidas*) were not built straight and showed an irregular surface, craftsmen learnt how to camouflage this by spinning a cloth and impressing a series of circles on the wet clay, the final effect being a rendering which hid the irregularities. In the Gerrei region mud was sieved and often mixed with cow dung because of its higher bonding and thermal coefficient (Lallai 1989, 33). The finer coat was often lime-based and called *pastina di calce*, followed by a limewash.

The advantage of using organic fibres in mud plastering has yet to be revealed by current research. However, it is certain that the use of straw produces thicker renders, and that its use in soils with a high clay content reduces the risks for cracks (Fadli 1995, 6). Torraca (1982, 98) also emphasised that 'organic fibres may improve the resistance to water, introducing a stronger connection between clay wafers and hindering dispersion'. Winter wheat straw was the only organic fibre used in mud brick making in Sardinia and according to John Hurd winter straw creates a higher waterproof layer on its surface than spring wheat straw, allowing mud bricks to be more impermeable (John Hurd, pers. comm.).

3.10 Vegetable materials: cane, rush and timber

Vegetable materials played a role in the construction of earthen buildings, and the workmanship involved in their use is discussed in this section.

3.10.1 Cane and rush

Cane (*Canna*, family *Cannaceae*) is a native species of Sardinia, growing close to rivers and streams. It was an important material used in the building process, especially in roofing and partitioning. Canes were cut in the period between full moon and half moon, in February (from the first to the ninth), because this is the period when they attained maturity (*cann'è ossu*) and were fully grown before sprouting (*canna drommìa*). They were then cleaned of all leaves with a special knife (*guatteddu*) and dried vertically because this was their natural growing position and prevented them being damaged by incidental water when drying. They were then sold in faggots by the hundred. Twisted canes were made straight by being impressed with longitudinal cuts by the *guatteddu*, and extremities were cut in order to obtain an even cane sarking. This could then be mounted on the rafters before adding a layer of lime on which the roof tiles were set.

Canes were used also for building the *tabicu* (Fig. 3.35). This form of partitioning consisted of a primary frame made of a row of partition studs, set at 50-80 cm centres and fixed to the ceiling and to the floor with nails, and a secondary frame made of vertical canes (*canna maistra*, master cane) on which two horizontal layers of cane sarkings were tied with rush symmetrically to form a lathing. These two layers had to be tied simultaneously. Both surfaces were then rendered with a mix of straw and sieved mud and then limewashed and sometimes decorated. This technique was also often applied to the making of ceilings (*bòvidas*), as in Fig. 3.36.

Another important vegetable material used in Campidano's buildings was rush (*Juncus*, family *Juncaceae*), also a native species of Sardinia, which grows in close proximity to rivers and swamps. After being pulled - never cut - it was longitudinally halved and placed to dry in the sun for three or four days, according to the weather. When dry, it could be stored for up to two years without rotting because it was a species suited to damp environments. The same can also be said for canes. It was then bound into fasces of a hundred and sold. Rush was subdivided into two types according to its strength:

(1) soft rush (*sessìni*), which was rarely employed in building and used mainly for

manufacturing ropes;

(2) strong rush, which was employed in construction for tying cane sarkings.

In both cases, rush had to be worked carefully before use (*àddu mùlli a unu a unu*). It was soaked (*à ammoddiai*) for one or two days and then flattened by foot in order to prevent it from breaking and to make it more malleable.

3.10.2 Timber

Timber was essentially employed for the construction of roofs, floors, staircases, and fenestrations. The questionnaire undertaken amongst building users shows that 69.4 % of the buildings visited still have a timber roof structure, whilst 19.8% of the buildings saw their traditional roof replaced with a cement-based one (Table 4.32). The also survey found that 88.2% of the roofs are pitched, whilst only 1% are flat (Table 4.31).

Amongst the native hardwoods, Juniper (Juniperus, family Curpressaceae), oak (Carcase, family Fagaceae) and sweet chestnut (Castanea, family Fagaceae) were the most common types of timber used in Sardinian buildings. The state of Sardinian woodlands was praised by a document dated 1768 kept in the Archivio Storico of Cagliari (ASC 1768), where the artillery second-lieutenant De Bouttel gave a description of the woodland of the Kingdom of Sardinia and of the areas where timber for construction purposes could still be cut at that time. From 1860 coal mining, tannin extraction and the construction of railways played a significant role in the deforestation of Sardinia. This can be illuminated by the account by Le Lannou (1979, 62) who estimated that in 1863 the railway company cut down 20.000 hectares of fine quality woodland together with 200 thousand hectares of scrub vegetation. Because of the level of deforestation of most of its woodland, after the second half of the eighteenth century the import of squared Swedish coniferous softwood expanded, together with the import of pine from Corsica (Mamuta 1933b, 14). Foreign timber gradually replaced native production, reaching a peak in 1940 when only imported wood was available in Sardinia because of the level of deforestation of most of its woodland. By this time imported pine was used for roofing and for fenestrations.

Three types of craftsmen were related to the timber work in Sardinia:

(1) the *maistru e muru* (also called *maistru de muru* and more often simply *maistru*, meaning in all cases master of the wall). In addition to his role as supervisor of the building site (discussed earlier in this chapter), the *maistru* was also in charge of the splitting and cutting of timber. It was common for the *maistru* to carry out this work personally with the use of an axe, especially if the cutting, splitting and joinery work was basic;

(2) the carpenter was the specialist in cart-making (*maistru de carru*). His skills were necessary on the building site only when the *maistru de muru* found the level of craftsmanship required to be too complicated;

(3) *the maistru e linna* (the master of timber), whose principal activity was the cutting and working of softwood (pine and fir, but also oleaster and ilex) for windows, doors and portals. In some villages like Villamassargia and Samassi he also was in charge of the production of floor boards and roof trusses.

Amongst the native species, juniper was considered to be the best construction timber in Sardinia. Its nodular structure together with the long time it took to mature produced a timber of fine quality. However, it had to be cut in the period of the full moon and left to season at least for one year before being used as building timber or at least two years before being used for fenestrations. Juniper is strong in tension, resistant to beetle infestation, and its naturally curvilinear form makes it ideal for the construction of the *quaddu armau*, an ancestor of the truss. Timber for trusses was never cut longitudinally on its axis but was roughly squared with an axe. Then natural seasoning was carried out for at least one year before use. The baulk forming the *quaddu armau* was fixed at both ends to the wall whilst its central curved section supported the weight of the roof. This simple form of truss was then improved by a more complicated system, especially under the influence of Palladianism in more polite buildings where trusses made of square timbers were used. Squared timbers of various dimensions were sometimes purchased locally, but more often from the main shipping town, Cagliari, and chosen by the *maistru* *de muru.* This expert craftsman was skilled in selecting a tree grown in the shade (*pabas à soi*) rather than one grown in the sun. The latter needed less seasoning but was considered to be of inferior quality because it had probably grown too quickly. Wind was another important factor in the cutting of timber. In order to explain this influence, the *maistru de carru* Antonio Atza carried out a simple experiment. He cut the same tree partially under the north wind (*bentu estu*) and partially under south wind (*bentu è soi*), concluding that the first was stronger while the latter was in the long term easily attacked by termites. Rafters (*crabiolas*), being small in size, were cut locally in Villamassargia and were left to season for at least one year before use. Floor joists made of squared timbers were widely employed in the construction of granary floors which had to bear the weight of wheat sacks which could be of 1-2 metres in height. Floor joists were set 50-60 cm apart and were surmounted by floor boards in the house of the wealthy and by a cane sarking covered with mud in the houses of the poor. Wooden staircases had also to be load-resistant and were therefore made using eucalyptus wood and were usually jointed without the use of nails (*scala è gattu*). Sometimes the *maistru de muru* provided the cartmen with the dimensions and specifications of timber which was then purchased from Cagliari. Most of the time the cartman - being afraid of misinterpreting the requirements of the *maistru de muru* and therefore purchasing the wrong timber - preferred to be accompanied by the *maistru de muru* himself.

The tools used by timber craftsmen are those in Figs. 3.37 and 3.38.

3.11 Decorative interior features

Decorative interior features are sufficiently widespread in the twentieth-century earthen buildings of Campidano to warrant a separate section of discussion. The aim of this section is to describe the role of the decorator, the tools and the materials he used, and the craftsmanship involved in his work.

3.11.1 The role of the decorator

Interior decorators worked mostly in the capital and in villages close to the capital but seldom in smaller villages where living standards and the desire for the conspicuous display of wealth was not so strong. In villages like Monserrato the figure of the interior decorator was considered to be essential; in the mid- twentieth century six main painters were active. Having to deal with different materials and different degrees of refinement, decorators specialised in specific fields:

(1) *stuccatori*, who were decorative plasterers;

(2) *apprendisti pittori*, apprentices who started to be trained at the age of thirteen and had to execute humbler works like mixing pigments and cleaning brushes;

(3) *imbianchini*, who were also known as *pintori de muru* and were limewashers whose aim was to paint an even background in a specified colour to use as a background for the decorative painter;

(4) *pittori*, who were the decorative painters, whose skill was concentrated on refined decoration and the painting of fenestration. Painters usually worked in pairs so that each could take care of a particular aspect of the work in which they were skilled. It was also common for decorative plasterers, limewashers and decorative painters to work together in a group. According to Muscas (1994, 231), the *pittori* were considered by the laymen to be artists because they were part of a higher-status profession compared to the simple *pintori de muru*. This can be also explained by the fact that some of them, especially those working in the capital, came from an art school background.

3.11.2 Tools and equipment

Brushes used by painters were of four kinds (Fig. 3.39):

(1) round section brushes used for limewashing (no. 1-2). Locally produced brushes were manufactured with the native dwarf palmtree hair of Sant'Antioco, while imported brushes from Ciccognara (Mantova) were made of *tampico* vegetable hair (Fig. 3.40). Limewashers preferred native brushes because they were said to be more suited to the physical technique used by the decorators. In humbler buildings straw brushes were also used for limewashing;

(2) special round section brushes made of *tampico*, used for painting windows, doors and

portals;

(3) thin brushes made of pig bristle which were used for interior decorative painting (these were numbered from 1-6; no. 1 being the thinner, and used for achieving the most delicate decorations);

(4) straw brushes were manufactured by the painter himself and were used to reduce the cost of decoration, as the price per square meter of a bristle brush decoration was higher than that made with straw brushes.

Amongst the equipment necessary for the painting of frames and wainscoats were the ruler and the string. Painters owned their own scaffolding, which usually comprised two stands and some boarding.

3.11.3 Limewash and pigments

Walls were rendered with lime or mud and limewashed before being decorated. The mix for wall paint was made by adding pigments to limewash and to sheep's milk in the ratio of ½ litre of milk for every 30 litres of limewash. But this ratio changed from village to village and probably from craftsman to craftsman, as in Serramanna where ½ litre of milk was added to five litres of limewash. This was necessary to prevent the lime from being rubbed from the wall, to make cleaning easier, to increase its longevity, and to give a brighter shine to the pigments. As Holmes and Wingate (1997, 55) explain, milk can form a glue (calcium caseinate) by reacting with the lime. This is the reason why, in order to avoid bubbles caused by moisture, it is important that walls are dry before application. Fish glue was a substitute for milk; half a bar of fish glue could be liquefied and added to fifteen litres of limewash. This was the base for the background paint and for the various paints used for decorating.

Pigments were sometimes added to the limewash and sometimes first mixed with water and then added to the limewash. The essential pigments were:

(1) White lead, this is one of the oldest white pigments;

(2) lithopone, consisting of about 66% of sulphate of barium and the remainder being zinc sulphide (Seymour Jennings 1950, 30). It was essential for painting the shine in cornices and decorations;

(3) Prussian blue, called *azuleddu*, azurite;

(4) yellow and ochre colours, made from natural clays occuring in the Peninsula;

(5) umbers, also made from natural clays occuring in the Peninsula;

(6) red pigments, made from iron oxides.

Chimney-stack ashes (*nero di fumo*) were sieved and used to make black and grey tones. In some villages animal blood was admixtured with limewash in order to produce pink or red-brick. The latter was often used for wainscot strips at the bottom of walls. Local red earths were also a common colouring agent but had to be dried, crushed, sieved and added to lime. Ready-to-use powdered pigments were manufactured in the peninsula and imported into the island in a variety of tones and colours. When the owner could not afford to limewash the interiors, clay was diluted in water and applied as a substitute wash.

It was only in the 1960's that painters realised how good traditionally burnt lime actually was, when they were forced to replace it with industrial water paints. When industrial lime was initially used, it became apparent how much less cohesive it was especially after the addition of pigments. This was due to the fact that industrially produced lime is burnt at the lowest possible temperature in order to save fuel. A more detailed explaination of this was given by Michael Wingate in a letter to Sir Bernard Feilden dated 6 March 1986 which can be read in the Appendix 2.

A survey of the nature of the finishing coat of external façades was carried out through the questionnaire (Table 4.11). The resulting analysis explain that synthetic paints are today employed by 63.2% of the buildings visited, whilst limewash is found only on

21.9% of the buildings visited (this latter figure embodies also those buildings that have never been maintained since construction). The survey confirms the suspicion that limewash is today seldom employed, probably because of its lack of availability in the market.

3.11.4 Decorations

Once the background limewash had dried, it was ready to be decorated. The outline of the design was transferred to the wall with the help of a 'pouncing', a cardboard sheet on which a pencil drawing had been perforated. A dark pigment (*terra d'ombra*) could therefore penetrate through the holes and was fixed to the wall where it was brushed in with a sponge. Cardboard pouncings were roughly 30x50 cm and, after the advent of bagged concrete, the bags themselves were used as pouncings. After the wall was patterned, it was ready for decoration: the most fashionable styles of the first half of the twentieth century were the *chiaroscuro* and the so-called *stile 900.* The former style was probably derived from imitating the illustrations from catalogues of stucco-work which were so widespread from the turn of the century and which were imported from the peninsula. This is why this type of wall painting uses the dark and light tones of only a few colours to achieve the effect of different depths on the wall surface. The latter was characterised by multi-coloured overlapping motifs representing flowers and plants. Some painters stressed the fact that imitating wall painting motifs as seen inside churches and grand palazzos was a common practice. In this case the skill of the painter was to fix the decoration in his memory and then to reproduce it in the building to decorate. Styles and colours were dictated by the owner of the house, while decorative patterns were usually chosen by the painter himself. Green was the most popular background colour because, according to some painters, it was believed to convey a sense of happiness. Stencil decorations were heavily used in the nineteenth century, but went out of fashion at the end of that century, when they were replaced by pouncing and freehand techniques. Wainscot was made by using a chalk line. When these painted decorations had dried, isinglass was sprayed on top as a fixative. In villages located in damp areas like Monserrato isinglass was only sprayed on the decoration and never on the base of the wall where rising damp could occur and cause detachment of the limewash.

Decorative plasterwork was of different kinds: run mouldings with lime and sand, run mouldings with lime and stone dust (ASQ 1868a), run mouldings made of cement, and ready made cast gypsum mouldings to be applied to the wall with gypsum mortar. The use of cement in the mix for external run mouldings was common especially for exterior decorations, probably to provide further resistance against weathering. The analysis of such mixes of lime and cement being outside the scope of this research, nonetheless archival inspection provides that lime was proportioned to sand and cement as follows: 125 kg : 1 cubic metre : 50 kg (ASI 1902). It was an important procedure to saturate the mouldings by soaking them in water before application.

3.11.5 Paint for windows, doors and portals

Doors and windows were painted with a mixture of linseed oil, white lead known as *bianco di Monteponi* (lead carbonate or zinc carbonate) and pigments. The bianco di Monteponi was added to the linseed oil and mixed: it was then ground in order to break down the grains. Yellow pigments were most commonly used in very small amounts to obtain an ivory colour. Pigments were added to the binder not by grinding, because this technique not been adopted in Sardinia, but by the mixing of the three ingredients in a jar with a stick. Two coats were applied on to the bare timber: the first coat being a mixture of linseed oil and turpentine (the latter was necessary for the oil to evaporate quicker) and the second coat being the finishing coat (linseed oil, white lead and pigments). The first coat of linseed oil was necessary for impregnating the timber and for making it more resistant to weathering and to water ingress. In this way the last coat could last for twenty years before needing to be repainted. In some villages like Nuraminis doors were simply painted with cow's blood. Window panes were fixed to the frame by using a putty made of five parts of white lead and one part of linseed oil.

The process of painting portals was slightly more complex than that for doors and consisted of four stages:

(1) one or two layers of a mixture of linseed oil and turpentine were brushed on the surface of the portal and left to dry for 24 hours. This was the most important stage as one had to be careful not to over-paint the portal with linseed oil which could cause

cracks on the following layers (stages 2, 3, and 4);

(2) when the layer of linseed oil had dried out completely, imperfections such as uneven surfaces, cracks and holes were filled in with putty;

(3) the layer of paint (linseed oil, white lead and pigments) was then applied;

(4) sometimes a finishing coat of painted decoration featuring landscapes was applied to the inner side of the portal.

3.12 Wrought iron

The popularity of wrought iron in Sardinia increased particularly in the Middle Ages when blacksmiths started to be incorporated into guilds with ordinances (hordinamentos) and in guilds, as happened from 1381 until 1760 in the main towns of Cagliari, Sassari, Alghero, Oristano and Iglesias (Marrosu 1933). Blacksmiths had to pass a guild exam in order to be able to practise; successful craftsmen were then provided with a mark (*senyal*) which was stamped on their ironwork. In fact, senior authoritative blacksmiths (*maggiorali*, searchers) controlled the quality of workmanship and the price in order to maintain high professional standard (Marrosu 1933). More recently, local blacksmiths - descendents of the medieval guild system - forged the following iron elements for construction purposes:

(1) nails of various sizes (*obillus*) to be used in the erection of timber elements such as trusses, for nailing floor boards to the beams, and for other minor works;

(2) belts, tie plates and nails for the repair of timber structures;

(3) bolts, locks, keys and other metal elements for portals and doors. Some of these elements were highly decorated with saw patterns that would have been too difficult to make by forging;

(4) grates for windows and wrought iron railings for balconies and staircases, especially

in palazzo buildings around the turn of the last century. These featured decorative patterns reproducing spirals, circles, leaves and flowers.

Iron was purchased in the shape of bars from the peninsula and from European countries like Sweden (ASQ 1926). A 1898 specification for the construction of the iron elements of the Palazzo del Comune of Cagliari gives the requirements for iron with reference to its strength and durability: 'iron should be pure, of even grain and when perforated on its margins it should not break' (Anon. 1898, 11).

3.13 Conclusion

This chapter provided an understanding of the traditional manufacturing processes of nine building materials of twentieth-century earthen buildings of Campidano. The chapter demonstrated that as an approach, the conservation of earthen structures is a complex undertaking because of the several materials which compose the building fabric and also because of the specialization of roles in the building (and conservation) process.

Chapter 4

DECAY AND FAILURE

4.1 Introduction

The aim of the present chapter is to survey the main decay symptoms and pathologies of the earthen buildings of Campidano. The principal building materials analysed in this survey of decay are mud bricks and renders, but reference is also made to those elements that are related to the decay of *làdiri* and renders. The study is a general survey of the area under examination, and not a detailed analysis of the peculiarities of single buildings. The gathering of data is based on a questionnaire whose design was stimulated by the distinct lack of available literature (whether minor or major) on the decay processes of Campidano's earthen buildings. Furthermore, the simple study of the topic through direct observation could not be considered sufficient because this type of survey would have been limited to the facade of the building only. Another factor influencing the necessity for the questionnaire was that the inclusion of queries on the decay of building interiors could be understood by questioning the building users themselves. A specimen of the questionnaire is given in Appendix 3.

The questionnaire was completed by inhabitants of Campidano's earthen dwellings and the majority of the relevant buildings were constructed between 1900 and 1960. In order to simplify coding and analysis, the questionnaire was structured by employing closed questions only. The 39 questions were grouped into 11 main themes: history of the building, plinth materials and decay, wall materials and decay, coating materials and decay, wall corner materials and decay, fenestration materials and decay, portal materials and decay, decorative façade elements and decay, ambulatory materials and decay, roofing materials and decay, and courtyard paving systems. The questionnaire was not designed to be operated as a simple question-and-answer investigation, but also to allow the formulation of a certain number of cross queries that were possible by employing the software Paradox 7. Cross queries were especially used for quantifying the mechanisms of decay of plaster and of *làdiri* walls.

The overall number of completed questionnaires was 288 (Table 4.47) and the majority of the buildings visited during the completion of the questionnaire were built in the 20th century (Table 4.1). Earthen construction in Campidano reached a peak between the end of the nineteenth century and the start of the second world war. This is demonstrated by the survey in Table 4.1 which shows that 9.1% of the buildings encountered were built before 1900, 31.5% were built between 1901 and 1960, whilst the remaining 59.4% of the respondents answered that the date was unknown. Definitions of the words 'pathology' and 'symptom' (and of all other technical terminology used in this chapter) are given in the glossary. Building decay is usually studied by analysing symptoms and pathologies that affect separate components of an ideally deconstructed building. However, for consistency's sake, the present largely (though not entirely) follows the same structure as Chapter 3.

The main limitation of this study is due to the fact that the analysis of the questionnaire was not carried out in statistical terms. This choice was dictated by the objective of this study which was to identify *trends* to be studied through frequency distribution. It is therefore wished that a more thorough analysis will be carried out in the future by using the questionnaire given in Appendix 3.

4.2 Principal mechanisms of *làdiri* decay

In a framework of a total absence of maintenance, the weathering of earth as a building material usually occurs at a higher speed than for other porous materials such as stone or fired brick. As Warren (1999, 75) points out, 'the conservator of earths will be conscious that decay in the structures rarely lends them the advantage of a weathered patina: it simply gives the appearance of decrepitude.' This statement also reflects on the contemporary phenomenon of non-acceptance of such dwellings. In fact while the appearance of stone and brick often benefits from weathering, and these are usually accepted as 'rich' materials, the same cannot be generally said about earth.

The main symptoms of decay in *làdiri* walls are those illustrated in Table 4.9. The research shows that 1/5 of the buildings encountered during the questionnaire suffer from minor or major structural cracks (this will be studied in more detail in the following section). Table 4.9 also illustrates that the comparison between decomposition and rising damp over plinth level (Fig. 4.3) reveals that these manifestations recur in parallel percentage, and are followed by the symptoms of basal erosion, presence of rodents, wall collapse and leaning walls. Furthermore, decomposition of earthen buildings that have not been rendered for a long period can be caused by ultraviolet light which can break down the molecular structure of clays. This irreversible process converts the clay into a non-cohesive clay which consequentially decays (John Hurd, pers. comm.; John Warren, pers. comm.). A recent study underlines that the investigation of the micro-mechanisms of decay and of failure of the physical-chemical matrix of soil as a building material is still in its infancy (Alva et al 2001, 7). The study speculates that the decomposition and decay of soil is affected by a multiplicity of factors such as liquids, suction, salts, wetting and drying cycles, and micro and macro organisms that might use the soil as part of their food chain (Alva et al 2001, 7).

Erosion of Campidano's *làdiri* walls appears to be caused not only by rain water (Fig. 4.1), but also by the combined action of sand and winds. This conjecture is supported by the special attention that was traditionally given to the rendering and to the maintenance of those walls exposed to strongest winds (Baldacci 1952, 66). The mechanisms of decay of these elements are easily explained, especially in the context of buildings affected by salt attack. After efflorescence or inflorescence of salts occurs at and above plinth level, the loose soil can be attacked by the combined action of sand and wind. Consequential detachment of loose parts can occur and debris is collected at ground level.

It should also be asked if there is any evidence as to whether the type of coating material influences the deterioration of *làdiri* walls. The answer to this enquiry was studied through a system of cross-queries given on Tables 4.38 and 4.39. The ideal scheme that allows earthen walls to manage water consists of a porous combination of soft coats on the outside and hard coats on the inside. Through this combination, water is driven from the inside to the outside of the building. The purpose of Table 4.38 is to show the number of buildings which were found to be characterised by a certain porosity of coats. In order to simplify the analysis, the principles of classification employed for the levels of porosity of coats is schematically defined in this study as follows:

(1) high porosity (porous coats made of lime or mud, and final layer of limewash);

(2) medium porosity (porous coats made of lime or mud, and final layer of synthetic paint);

(3) low porosity (impermeable cementitious coats, and final layer of limewash or synthetic paint).

The cross query in Table 4.39 quantifies and correlates the behaviour of *làdiri* walls in function of the porosity level of coats. The study shows that the erosion of *làdiri* is higher when walls are plastered with lime-based coats. The theory here is that the erosion of mud brick can be accelerated by the association between lime and water (humidity, rising damp, or rain) because this could increase the alkalinity of the latter. Several authors (Clifton and Wencil Brown 1978, 10; Chiari 1983, 34; Warren 1999, 110) agree with the fact that, generally speaking, high alkalinity should be avoided in clays because flocculation of the material is promoted. Laboratory analysis (Table 7.3) carried out by the author on nine *làdiri* samples (see Chapter 7) shows that the average pH is 6.8, which is considered by soil scientists to be a neutral value (Aru1989). It can therefore be speculated that the superficial deterioration of *làdiri* characterised in average by neutral pH levels might be accentuated by an increase of alkalinity of water (caused by its connection with lime).

Table 4.39 also gives some information on the superficial separation of components of mud bricks into smaller elements (decomposition) which is found to be seriously higher in case C (which is the situation with cementitious coats). In this respect it is important to emphasise that, even thought decomposition and consequential erosion might occur slowly, eventual wall collapse can arise in the future. A decrease in tensile and compressive strength (Chiari and Alva 1984, 2) and in frictional quality of soil particles

(Crosby 1987, 35) can take place when the base of the wall is saturated with water. In addition to this, walls usually erode 'behind the render and the debris falls and builds up against the underpin course' (Pearson 1992, 162). However, wall collapse does not appear to be a serious problem in Campidano, probably because cementitious coats are too recent to cause any dramatic failure. A close examination of columns C and D of Table 4.39 shows that generally speaking cement as a plastering material does not interfere much with the wall fabric and that therefore it might even have a beneficial property towards earthen buildings. But the way that cement coats work are different from those of porous materials. Cement coats tend to lose contact with the face of the earth wall to form a separate skin, allowing all sorts of concealed symptoms to develop. The reason that Table 4.39 does not show any relevant manifestations might be due to the fact that symptoms are probably hidden behind the render. It is also possible that the reason why those symptoms have not manifested themselves is that they simply are not there.

4.2.1 Thermal movements and structural cracks

Direct observations carried out by the author revealed that structural cracks often derive from inappropriate design or a lack of craftsmanship. *Làdiri* walls are seldom properly connected and are therefore free to move individually (connections between boundary walls and portals especially). The poor quality of craftsmanship was mentioned as early as 1828 by the English geographer William Henry Smyth in his *Sketch of the Present State of the Island of Sardinia.* With regard to traditional buildings Smyth wrote: 'Craftsmen use neither plumb line nor ruler, but take measurements with a cane by cutting off the surplus length with a bite. Measurements are calculated roughly because this is the less tiring and fastest way. Carpenters are very lazy, and rarely meet deadlines. The happy tranquillity of these craftsmen can be seen in the following drawing.' (Smyth 1998, 161) (Fig. 4.5). This issue of good craftsmanship is highly relevant to earthen materials. Being such a porous material, the durability of earth is heavily dependent on the skills of the original craftsmen. It should also be noted that several inhabitants argued vigorously that the cause of such frequent cracks is related to constant vibrations caused by traffic. There is, however, a lack of *direct* evidence to confirm this theory. The scientific study of vibrations and their influence on the size and extent of cracks is beyond the scope of this research.

Other causes of the formation of cracks are usually attributable to unstable ground, or to annual cycles of expansion and contraction (cracks tend to be larger in the winter and smaller in the summer). In this respect, vertical shears can take place every 10-12 metres on a wall because movement due to the expansion and contraction of earth walls is absorbed without failures for only that length (John Warren, pers. comm). Analysis of the questionnaire has determined that structural cracks are the main decay symptom of *làdiri* walls, as 21.5% of the visited buildings manifested this distress (Table 4.9). In this context, wall corners are sensitive points as the load of the roof structure could create cracks between the two walls (Tharan 1987, 508). Table 4.13 illustrates that the corners of the main facade were found to be mostly made of *làdiri* (64.6%), but also some of fired bricks (5.9%), some of cement blocks (4.2%), some of concrete (3.5%), and some of stone (3.1%). In the majority of cases facade corners were found to be in extremely good condition, probably because of the extra craftsmanship which was traditionally invested in such otherwise frail details. However, Table 4.14 indicates that typical manifestations of decay on wall corners are the appearance of cracks (8.3%, probably caused by poor connection between walls), followed by the erosion of joints (3.5%, especially in those corners made of fired bricks), and by the detachment of elements composing the corner (3.1%). The most adverse situation after cracking occurs is the presence of leaning walls, but this often appears to be a constructional fault. Generally speaking, out-of-plumb walls are not a severe problem in Campidano, as only 0.3% of the surveyed buildings appeared to be affected by this symptom (Table 4.9).

4.2.2 Decay caused by modern interventions

The aim of this section is to describe the numerous misrepairs carried out on several earthen buildings in the recent past. During the last forty years, the conservation of earthen buildings of Campidano has too often relied on the use of non-porous materials. This is principally due to the fact that practitioners tended to apply those skills and methods employed in new construction to historic buildings. Another cause is due to the conventional and simplistic idea that 'strong' materials should be used, with the resulting consequence that mortars are often rich in cement, if not made entirely of cement (Sandin

1995, 4). The outcome of this can be simplified into a historic building characterised by sharp corners due to cementitious coats, by new windows and roof, and by non-traditional paint colours.

Cement and concrete are still considered today in Campidano to be multi-purpose repair materials (Fig. 4.2). The deleterious properties of cement when associated with mud bricks can be explained by analysing their behaviour after they have been exposed to cycles of expansion and contraction. Specific studies on the coefficient of thermal expansion and contraction of *làdiri* are not available, but Burt (1995, 9) illustrates that mud brick has a coefficient which ranges from 0.50×10^{-6} to 1.7×10^{-6} per °C while that of concrete is 10.0×10^{-6} per °C. These figures indicate that the expansion of mud brick is at least five times greater than that of concrete, and this certainly affects the earth wall when associated with cement.

Cement is commonly used in Campidano in the shape of blocks for the replacement of deteriorated sections of *làdiri* walls, but are seldom at foundation level as a replacement for stone plinths, and more often as a rendering material. Owners and practitioners still today tend to replace traditional porous coats with a combination of hard cementitious renders and chicken mesh wich has the function of a gripping agent. This is nowadays causing more damage to the historic fabric than any other misrepair. The main disadvantage of using cementitious coats is due to their highly alkaline environment and also to the migration of salts towards the inner face of the render where they can crystallise and make the softer and more porous fabric (i.e. the *làdiri*) lose cohesion. This can be better explained by the fact that most cements have up to 12% of salts as part of their composition (e.g. sodium sulphate and other soluble salts derived from gypsum). When the cementitious coat falls off, salts start to migrate from the surface to the core of the wall where they can crystallise in the micro-cavities and cause major damage to the wall fabric. The rate of detachment of cementitious plasters finished with limewash was determined through the questionnaire to be 100% (all cases were found to have a partially missing plaster), whilst those cementitious plasters finished with synthetic paint show a detachment rate of only 37.1% (Table 4.41). When cementitious coats are applied to a wall both internally and externally, the moisture content can increase between clay wafers until the plastic limit of the soil is reached and then sudden bulging and collapse occur.

Another important finding of the questionnaire was that cementitious renders were found to be especially widespread in those buildings built between 1900 and 1940 (Table 4.42). It is likely that this is due to the fact that since 1960 (the date signalling the heavy introduction of cement as a building material in Campidano) those buildings built in the first 40 years of the 20th century started to be re-rendered with cement, probably because they began to show some decay. In contrast, a small decrease of re-rendering with cementitious materials can be noticed in those dwellings built between 1940 and 1960.

Cement is also a popular material for repair in the form of reinforced concrete, especially at plinth and at roof level. This kind of intervention was found to be supported by local literature that encourages the replacement of traditional stone plinths with concrete foundations and, when the load bearing capacity of the ground is low, encourages its stabilization through cementitious injections (Sanna 1992, 52; Corti and Sanna, date unknown, 52). Cement is fortunately seldom employed as a ring beam on the top level of walls, as the construction of diverse courses of hollow bricks laid with cementitious mortar is preferred. These courses are considered by practitioners and also by building users to be an effective tie for corners and a sound platform on which to build the new roof (Sanna 1992, 54). Another characteristic element introduced by modern conservation practice is the vapour barrier at roof level. When the barrier is in conjunction with cementitious renders, it has the capacity of sealing the building and of impeding ventilation, which is necessary for the managing of extra water vapour produced by contemporary living standards. Central heating and new windows can also increase moisture levels, whilst traditional windows allow management of extra water vapour through the drafts.

4.2.3 Decay caused by vegetation and animals

Vegetation

Seeds can be either transported to the wall by the wind, or can be part of the composition of the soil which was employed when the *làdiri* were originally made. Table 4.41 reveals that vegetation growth is nearly seven times higher on mud coats than it is on lime coats, whilst it is nonexistent on cementitious coats. Table 4.9 indicates also that, by comparison with other agencies of decay, vegetation growth is not a serious cause of failure of *làdiri* walls.

Animals

The survey showed that rat damage, sparrow damage, farm animals licking the bricks because they need the salts, masonry bee damage can all be present in *làdiri* buildings. Table 4.34 shows that nearly 1/4 of the buildings visited are affected by birds and rodents damage. For obvious reasons, both were found in higher concentrations on traditional roof systems, rather than in corrugated iron or in flat roofs. Another insect which affects earthen buildings is the termite. Burt (1995, 14) explains that 'termites have the ability to travel through walls in much the same way that they travel through natural soil. All the timber members within the adobe building are therefore susceptible to termite attack.' (Burt 1995, 14).

4.3 Roof tiles and fired bricks

Traditional tiles are still the main roofing material of Campidano's earthen buildings today (Table 4.33): 58% of the houses show a covering of traditional tiles, 17.4% have a corrugated iron roof, whilst only 10.8% have pantiles.

Before the questionnaire was completed, it was hypothesised that roof decay might be caused by a lack of maintenance and the consequential ingress of water. In order to quantify this, a cross query was designed (Table 4.45). Water and damp ingress from the roof is a relevant problem for most earthen buildings roofed with traditional tiles (Table 4.34). Table 4.45 shows that water and damp ingress respectively affect 38.9% and 15% of the totality of roofs made with traditional tiles. This is probably due to lack of annual inspection and maintenance. Plants and animals living in the roof structure were found to be another common symptom caused by water presence.

Another important factor influencing the conservation of earthen buildings at roof level is the system of gutters and downpipes. The survey quantified that 83.7% of the buildings of the area under examination are characterised by downpipes external to the building, whilst only 1.4% shows downpipes internal to the wall core (Table 4.35). This probably reflects the high percentage of elements (gutters and downpipes) found in good condition (59.7%) with no immediate need for conservation. Table 4.36 illustrates that only 5.5% of gutters and downpipes need complete replacement, while 19.5% need only maintenance work.

4.4 Roadways and courtyards

The aim of this section is to underline the importance of traditional permeable paving systems in terms of building conservation. Incompatible modifications of the environment around earthen buildings can be manifested as a change of water vapour circuits (Olivier 1993, 677). This is especially true with reference to roadways and paving systems. Moreover, before illustrating the symptom, it is essential to describe the traditional covering system for roadways. Archival research carried out by the author confirms that during the first decades of the twentieth-century roadways were built by employing the *massicciata* system, a variation of the Macadam system. The Macadam roadway 'is based on the use of materials of uniform size, none of which are large enough to act as a lever' (Walker and McGregor 1996, 77). The *Archivio Storico Comunale di Quartu Sant'Elena* holds a document dated 1926 that gives a detailed description of the roads to be built in that year by the municipality of the village. The document shows that the *massicciata* used in Campidano was convex in section and traditionally composed by four coverings (ASQ 1926) as follows:

(1) hard and compact limestone was used for the first layer. Limestone blocks (from the local quarries of Montemixi and Bonaria) were broken with heavy hammers in order to achieve a sound bed made of stones with varying diameter (from three to five centimetres). This first layer often contained a certain amount of soil. The reason for using limestone in the construction of roadways is due to its stabilising properties when associated with soil and water (Fois 1964, 9);

(2) the second covering was made of limestone measuring two centimetres in diameter and characterised by a small percent of soil impurities. The even size of this bed of stones

was achieved through sieving, and the resulting finer material was put aside;

(3) the material resulting from the sieving of the stones necessary for the second layer gave the constituents (*terriccio*) for the third covering;

(4) an important difference between the *massicciata* and the Macadam system lays in the finishing cobbled covering which is not a requirement of the latter type (Walker and McGregor 1996, 77). In Campidano round pebbles (maximum dimensions: eight centimetres in diameter and 15 cm in height) were laid on a sand bed of five centimetres thickness and were then tapped with the *dama* (or *mazzeranga*). In order to achieve an overall thickness of 20 cm, coverings were compacted with heavy rollers (ASQ 1910).

The beneficial properties of such traditional paving systems (*imperdàra*) for the conservation of earthen buildings has been acknowledged by several authors (Lallai 1989, 45; Sanna 1992, 53; Fodde 2000b, 43). In this respect, one of the scopes of the questionnaire was the correlation between the type of paving system and the presence of rising damp at plinth level. Every village examined through the questionnaire was characterised by an impermeable paving system for roads. In fact, traditional permeable coverings have been replaced in recent times by impermeable materials such as bitumen or cement. This characteristic was not a variable of the enquiry, and therefore it was considered sufficient to question owners about the nature of the courtyard paving system only. In so doing, with the help of a cross query, it was possible immediately to correlate the type of courtyard covering system with the dampness rising through the joints of the underpinning course (Table 4.43). It was accomplished that 70.7% of the buildings which show rising damp problems at plinth level are characterised by a courtyard paving system made of cementitious coverings. In addition to this, it was found that the influence of earth and cobbled pavings on rising damp problems at plinth level is minimal because the percentage of cases is respectively 12.2% and 7.4%. It can therefore be ascertained that concrete pavings are 3.6 times more influential on the growth of capillarity rise of damp than the totality of porous pavings (such as earth and cobble coverings). This is an important finding for the understanding of the mechanisms of decay of earthen buildings. It represents the first attempt to quantify the influence of impermeable paving systems on the growth of capillarity rise of moisture at plinth level.

Another important finding of the questionnaire analysis was that rising damp is a symptom which affects 65.2% of the buildings visited (Table 4.7). This is also reflected in the continuous complaint registered by the author when building users were approached for the questionnaire: several inhabitants lamented that they had to annually replace the plaster at plinth level because of the incessant recurrence of dampness. Table 4.7 also shows some other symptoms which affect the totality of buildings at plinth level: cracks (17%), erosion of stone joints (13.8%), decomposition of stone joints (4.8%), and stains on the internal plaster (3.4%).

The mechanism of decay of earthen walls caused by water movement and salts has been explained by several authors (Chiari and Alva 1984, 2; Tharan 1987, 514; Viñuales 1981, 44). The symptom of rising damp can be simplified as water movement rising up and out the wall, reaching the surface and carrying out soluble salts. Crystals subfloresce or effloresce and expand, loosening the bond of the material earth. This effect, combined with wind, makes the loose material flake off (John Warren, pers. comm).

4.5 Principal mechanisms of plaster decay

The analysis of the questionnaire revealed that in 1998 (the year of questionnaire completion) lime, mud and cement were the three plastering materials found in Campidano's dwellings. The correlation of various coat systems with their decay symptoms gives an estimate of the durability of the three materials used as external coats. The comparison between the three types of plasters confirms several expectations (Table 4.40). Erosion is higher on mud coats (probably because of their nature) and this is especially true if they are not regularly protected by a limewash layer. However, Table 4.40 shows that mud coats do not tend to detatch from the surface of the *làdiri* wall as much as lime renders do, and this is also confirmed by direct observation. As these are mud renders traditionally made with the sieved soil used for the making of mud bricks, they have a similar constitution and a similar coefficient of thermal expansion and contraction to that of *làdiri*. In addition to this, detachment of lime coats was found to be twice as high when the finishing is carried out with synthetic paint, by comparison with those finished with limewash (Table 4.41).This is probably due to the accumulation of moisture in proximity of the internal face of the synthetic paint layer with consequential bulging and detachment. Other typical symptoms of renders are cracks.

Short hairline cracks caused by shrinkage of mud after drying are quite typical of twentieth-century earthen buildings of Campidano, and cannot be considered as a serious symptom because they do not correspond to any wall fracture. The comparison of lime, cement and mud resulted in the latter being understandably the plastering material which shows the highest percentage of cracks, and this is followed by cement. In fact when cement render is applied on a mud structure, vertical micro-cracks generate in order to allow the wall to manage water (Dirk Bouwens, pers. comm).

Table 4.41 shows that decomposition affects all plastering materials, but it is higher in the presence of lime renders which are found to be radically decomposing especially when finished with limewash. It is also evident from the same table that the lime coats finished with limewash were found to be decomposing eight times more than the lime coats finished with synthetic paint. This could be attributed to the lack of maintenance of limewash layers.

4.6 Openings: doors, windows, portals and ambulatories

The survey of openings was carried out after the definition of a simplified classification system for the assessment of decay level: low (good condition, no need of maintenance), moderate (needing to be maintained), and high (to be heavily conserved or replaced). In so doing, the observation of failures was kept simple and facilitated.

Doors and windows

The survey given in Table 4.15 shows that the majority of the rough openings of doors (52.1%) are made of *làdiri*, and that other materials used for this purpose include: fired brick (18%), concrete and cement block (10.8%), and stone (3.8%).

The study of rough window openings was carried out in order to illustrate those building materials on which window frames are mounted, and their decay. The figures on Table

4.17 show that more than one half of the buildings show rough openings made of *làdiri*, and other building materials such as: fired brick (16.3%), cement (11.5%), and stone (4.5%). Another important survey is given on Table 4.18 which illustrates that nearly 1/3 of the buildings still retain the original window frames, 13.9% exhibit fenestrations replaced with new timber frames, and 7.6% with aluminum and PVC frames. However, in several buildings only a few windows were replaced, whilst the remaining were found to be original. Three sub-groups were studied, as on Table 4.18, which explains that 22.9% of the buildings show a combination of diverse materials: original timber and alluminum (14.9%), original timber and new timber (6.9%), original timber and PVC (1.1%). As for the study of decay of fenestration, Tables 4.16 and 4.19 show that doors and windows were mostly found in good conditions.

Portals and ambulatories

The analysis of the questionnaire undertaken amongst building users reveals some interesting results about the popularity of the portal as an architectural feature. Table 4.20 illustrates that 38.2% of the visited buildings are characterised by a monumental portal. Of these, 16% are round shaped, 13.9% have a concrete lintel, 5.9% are three-centred, and 2.4% have a timber lintel. The analysis of building materials was undertaken by deconstructing the portal into four elements: spandrels and abutments, plinths, arches, and doors. The popularity of concrete as found in Tables 4.21-4.24 is partially due to its employment during the construction of twentieth-century earthen dwellings, rather than for repair purposes. In many cases, if a concrete portal was found in a building it was because the portal was there since construction.

It is also interesting at this stage to compare the results of the analysis with those for the specific case of ambulatories. Table 4.27 shows that ambulatories are present in 21.9% of the visited buildings. Of these, 15.3% are made of timber posts and beams, 4.9% are characterised by a series of three-centred arches, and only 1.7% are constructed with round arches. Tables 4.28 and 4.29 show that concrete is the most widespread material with which ambulatory walls and plinths are found to be built (55.5% and 57.1% respectively). Other building materials for walls and plinths include fired brick (17.5% and 27%), mud brick (15.9% and 3.2%), and stone (4.8% and 9.5%). The overall level of decay of ambulatories was considered to be low for 3/4 of the cases, whilst only 3.2% of the cases was considered to be in a poor state (Table 4.30).

4.7 Conclusion

The chapter explained the results of the survey carried out through the questionnaire. It was felt that the creation of a more sophisticated system for investigating and measuring the extent of decay symptoms was not considered viable. This is a general survey which gives an overview to the state of decay of Campidano's 20th century dwellings. The survey does not consider many variables that have biased the survey. Amongst these are: man made deterioration, traffic being more frequent in some areas than in other, and the role of craftsmanship and its influence on the durability of building materials. However, this survey can nevertheless be considered worthwhile as there is no published literature on the topic in Sardinia.

The most important outcome of the survey is that modern building materials still play a relevant role in the repair and maintenance of earthen buildings of Campidano. This is not due to lack of awareness of building users, but also of professionals. The author has worked on the conservation of two nineteenth-century courtyard buildings of Campidano and during this period he noticed that the quality of conservation as generally accepted is not adequate for the material earth. Having tried in vain to convince the supervising architect to adopt a different policy from those standard techniques (e.g. chicken mesh and cement render, stripping off graffiti and decorations, replacement of traditional windows with metal windows, etc.), the author became aware of the issue of good practice and behaviour when dealing with building culture.

It is possible that today's unawareness of professionals working in the conservation of earthen buildings dates back to 1958. Sardinians were then panicked by the government to give up building with earth as it was then considered to be anti-hygienic (Galdieri 1987a, 261). Since then new construction has been built with modern materials and therefore the repair and maintenance of Sardinian vernacular dwellings has relied on the use of inadequate techniques and alien materials. It can be speculated therefore that decay is due more to a cultural problem and, in this respect, regulation and craftsmanship play their proper roles.

Chapter 5

TRADITIONAL METHODS FOR PRESERVING, MANTAINING, AND REPAIRING EARTHEN BUILDINGS OF SARDINIA

5.1 Introduction

The aim of the present chapter is to discuss the traditional repair techniques mentioned during interviews with 38 elderly traditional craftsmen of Campidano (Table 4.46). Furthermore, several contributions from meetings and interviews with key professionals (Table 4.46) - together with the relevant international literature on the subject - have been useful for supporting the arguments and are included when relevant. The structure of the chapter is based on the different steps that were traditionally followed by Master Craftsmen when conserving earthen buildings: first the roof, then the stone plinth, and then the *làdiri* wall.

It should be mentioned here that the traditional repair methods illustrated in this chapter can usually seldom be identified on buildings. They are often concealed by render or by roof tiles and their identification would require an approach similar to that of a building archaeologist. In some cases Master Craftsmen were able to show the author the repairs they carried out half a century ago on specific buildings. However, in the majority of cases the methods explained here are based on cross-checking the several explanations given by Master Craftsmen. A schematic reconstruction was carried out by the author in the form of line drawings which are collected in the second volume of the present work (Figs. 5.1-5.7).

5.2 Repair of roof

The aim of this section is to describe the traditional repair methods of roofs as complex systems consisting of different materials. Roofs, together with plinths and renders, are the most important elements in the protection of earthen structures and the Master Craftsmen of Campidano were fully aware of this. The care invested in the construction of roofs and the solutions adopted for their repair and maintenance show how important the role of these elements was.

5.2.1 Traditional prevention system

Traditionally, roof tiles were laid on a mud or lime screed by means of respectively mud or lime mortar. Master Craftsmen explained that the lime screed was applied as thin as possible over the cane sarking. The advantages of a thin screed were two: lighter loads over the timber structure, and less water absorbed by the canes after application and drying of the lime screed (and consequentially the canes did not become dark in colour). Tiles were laid with a varying juxtaposition from 12 centimetres to one third of the tile length. When mud mortar was used, the frost and thaw cycle caused the sliding of those tiles most exposed to harsh weather. As a consequence of this, ingress of water from cavities between the tile and the mortar could occur. Traditional craftsmen further explained that freeze-thaw attack and the consequent contraction and expansion could also cause sliding. When lime was employed, however, adherence would generally prevent sliding of the tile. But not every owner could afford lime, and therefore mud was used instead. In this case, detachment between the inner surface of the tile and its bedding mortar was frequent. This was especially true for those tiles positioned close to the ridge because they were exposed to harsher weather. The traditional remedy or prevention system was to allow a considerable overlapping between the courses of tiles close to the ridge in order to achieve a cover-up gap after sliding occurred.

Another important method of prevention was the 'bridge' (*ponti*) (Fig. 3.18). This was an essential device against the lateral swinging of roof tiles. Swinging could be caused by abrupt cycles of temperature change and the 'bridge' system was useful in providing craftsmen with a firm platform from which to carry out regular inspection. The 'bridge' consisted of the connecting and wedging of some of the under tiles to the lime screed by inserting broken tiles (*rinzeppatura, tobàccius*) over the cane sarking. This was carried out by following a rhomboidal grid module of one metre, which was applied also to the eaves and to the ridge (*schinabi*). This prevention system was known to and considered necessary by only the most skilled craftsmen. It should here be noted that traditional craftsmen explained that lime mortar for the laying of roof tiles should not to be too 'fat'. This was probably necessary in order to avoid cracks caused by too fast a drying itself due to strong sun on the roof surface.

As part of yearly maintenance practice, gutters and tiles were inspected every Autumn before the first rain in order visually to identify those which needed replacement. After being exposed to the strong Summer sun, tiles would usually dry and could therefore be easily broken if stepped on. For this reason traditional craftsmen agreed that it was important to wait until tiles became moistened after the first rain because flexibility was therefore recaptured. When craftsmen were doubtful about the actual state of decay of single tiles, a simple knocking on the surface was enough to give the necessary indication. Generally speaking, repairs were carried out either with mud or with lime mortars, while cementitious or hydraulic lime mortar were avoided because future extraction of single tiles would not be possible without breaking.

5.2.2 Roof tiles

Master Craftsmen explained that the appearance, and especially the colour, of traditional roof tiles can give information on their durability. Underfired tiles were not employed because they were too porous and permeable, whilst vitrified tiles were avoided because they were too brittle. Archival research showed that quality tiles were considered those that could carry a load of 70 kg without breaking (ASI 1906a), or in other words those which did not break after a person stepped on them. Yellow tiles are more resistant to water attack than red tiles because their firing temperature is higher. Skilled craftsmen were therefore aware that yellow tiles had to be positioned where water attack and stagnation was higher (under tiles), whilst red tiles had to be positioned where water attack and stagnation was minimal (over tiles). This rule was not only applicable to building work, but also to conservation work more generally. This was especially true when replacing single elements using salvage tiles and, in so doing, it was important not to break neighbouring tiles. Nowadays roofs are repaired by selecting integral tiles (as many as possible), by reusing them as over tiles (either yellow or red), and by replacing the under tiles with new hand-made ones. Precisely because the new tiles are used as under tiles, this technique has the advantage of hiding them as they are partially covered by the over tiles. The other advantage is that because new tiles are used as under tiles, they are more resistant to water attack. The only disadvantage is that replacement tiles can weather or age to a different colour, therefore becoming more obvious with time (Grimmer and Williams 1996, 12).

The manufacturing of traditional clay tiles has never stopped in Sardinia, but recently techniques have changed because they have been updated with mechanised tools and methods. Only a limited number of tile makers use the traditional moulding method for working non- local clay, but the firing is now carried out with gas ovens. For instance, one of the traditional tile kilns visited was the *Forru dessa Teula* (The Tile Kiln) which is located in the outskirts of San Gavino. The furnace was founded in 1940 by Antonio Sanna for the making of roof tiles, and it is now run by Agostino Montis who uses liquid fuel instead of the more traditional faggots. The moulding process is carried out in the traditional manner by employing a mixture of two clays: one quarried locally, and one quarried in Narcao (Sulcis). This example shows that tile making is still a dynamic practice in Campidano, even if the production is certainly not characterised by the beauty of those tiles manufactured until forty years ago. In some cases, as experienced in Assemini, the new tiles show some limitations due to the fact that the clay used for their manufacture is not local but is a standardised mix of different clays imported from Montelupo (Florence), a mix also used for pot making. The clay is worked by mechanical mixers employing minimum amounts of water, and the resulting tile is therefore less porous. The reason for using such a mix is that workability is improved and fewer cracks are found after the firing process. Another reason is related to the fact that shrinkage is reduced from 25% (local clay) to 5-6% (imported clay). As already mentioned above, most of the traditional kilns have been abandoned and neglected in favour of gas ovens which are usually set for twelve hours at a constant temperature of 960°C. This change of technique allows a drastic reduction of labour involved in the firing process when compared to traditional methods. However, the resulting unpleasant effect is that tiles look uniform in colour and have a smooth surface which reflects light in a rather different way than the traditional tiles. In any case the question as what is more important between performance or aesthetic, makes one think of the benefit involved in using new tiles.

5.2.3 Repair of timber

During the building process, beams and floor joists were traditionally prevented from rotting and sagging by painting the ends for a length of 40 cm (depth of the mud wall) either with vegetable tar or with animal fat. Vegetable tar is distilled from wood, and when applied to timber has the property of making it watertight and rot-proof (Masschelein-Kleiner 1995, 78).

As a general rule, repair intervention on historic timber was considered according to the degree of decay. Rotten beam ends were cleaned of all loose parts, impregnated with vegetable tar or animal fat and put in their original position. Elements with deep rot or with serious sagging were usually replaced with new timber. It seems that the most common practice was the replacement of decayed timber elements because this was considered to be safer than repairing them with a scarf joint. But it also seems that the reason why scarf jointing was seldom employed in twentieth-century Campidano is due to a lack of tradition. Only a few traditional carpenters and craftsmen agreed that timber elements with a rotten end were scarf-jointed (*unghia*) and tied together either with iron strips, with bolts or with long nails (*obbìbisi, obbillus*). According to Pastonesi (1998, 40), the following scarf joints were in use in Tortolì: scarf with square and vertical abutments, bridled scarf joint, and dovetail joint (Fig. 3.38). But it is also legitimate to say that with the advent of mechanisation in the production of timber, the tendency to over-replace timber elements became inevitable because of the small amount of energy and labour that the mechanised process requires. The introduction of modern sources of mechanical energy has had an impact on the balance between labour and building materials. Similarly to what happened earlier in Great Britain, when the process of working timber was carried out with hand tools carpenters had to know what kind of repair was needed so that the whole process could be kept financially sustainable and resources were not waisted (Richard Harris, pers. comm.). Replacement was carried out after shoring the beams and, depending upon the degree of decay, the shoring could engage the whole structure or parts of it.

When interviewing Master Craftsmen about repair methods for cane sarkings, no information was recovered for this roofing element. It therefore seems that replacement of the decayed sarking was the traditional procedure.

5.3 Stone underpinning courses

The aim of this section is to illustrate the traditional repair methods for plinths, as explained by Master Craftsmen during the interviews.

5.3.1 Minor repairs

Stone plinths built with mud mortar are obviously more susceptible to the erosion of joints than those built with lime mortar. Deeply eroded joints of the stone plinths were first cleaned of all loose mortar and then repaired by inserting a grid of wooden sticks in the joints. This was a method which was also used for the repair of eroded *làdiri* walls. A more detailed explanation of this method as applied to *làdiri* walls can be found in section 5.11.2. The sticks were necessary to create a structure on which to build the repair work of stone wedges and mortar which were inserted in the joints. Dry packing was then carried out in order to tighten the stone to one another. This technique was a step above the procedure of regular maintenance, which was typically restricted to the simple repointing of stone plinths and portals with lime or mud mortar.

5.3.2 Major repairs: *the rincasciu*

Stone underpin courses attacked by salt content or by serious settlement were repaired with the method called *rincasciu* (Fig. 5.1). This consisted of the extraction of the stones of the central part of the wall for a length of 50-60 cm. This was the maximum length that gave craftsmen the freedom to prop up (or not) the wall above without causing collapse. Then the original (or new, according to the degree of decay) stones were re-laid with lime mortar. In order to cause a tightening effect, the last course (at a distance of six centimetres from the first mud-brick course) was built with battered faces on both sides and dry-packed with tile or stone wedges until it was flush with the wall (*rincasciai*). This procedure was necessary to avoid the last course causing cracks and detachment after shrinking. After the central section of the plinth was dry, the symmetric zones (measuring 50-60 cm in length) were propped up and repaired at both ends of the wall, at a minimum of three metres from the centre of the wall. After these two areas were repaired, the craftsmen could circumnavigate the wall and repair two more zones located at a distance of three metres from the last. In more recent practice, Master Craftsmen inserted a sheet of tarred paper at the base of the wall. The *rincasciu* method permitted continuous repair along the perimeter of the wall. It was, for example, successfully used by Maistru Luciano Casula (Assemini) in many buildings of the village of Uta after the historic flood of 1929, when numerous earthen buildings were found to be suffering from serious plinth erosion. The advantages of the methods explained above are many, especially because they could be carried out without causing any cracks in or collapse of the mud-brick structure. Once stones were extracted for a length of 50 cm, their original position in the plinth was certainly difficult to remember and the historic fabric was therefore changed. As a consequence of this, it seems possible that stones were often not placed in their original location when relaid. A potential alternative method could have been the extraction of single stones, the brushing off of loose mortar, the moistening of the original mortar and stone, and the bedding of the original stone in the original position. Master Craftsmen could not specify if the new mortar was made with a similar ratio lime-aggregate and similar grain size and shape of the original.

Decayed structural quoins in portals and loggias were commonly replaced with new stones. After the size of the stone was measured, the stonemason chose the most adequate block to be dressed in the quarry site. The stone was then transported to the site of the building and put into position by the Master Craftsman, who was often helped by the stonemason himself. The stone of Serrenti is today mechanically sawn, and repair work is still carried out. Blocks are roughly cut by machinery, but the setting out is carried out by the few local stonemasons who are employed by the stone yard and who still use traditional techniques.

5.4 Mid-wall structural cracks

The aim of this section is to illustrate two traditional conservation techniques for the repair of cracks on *làdiri* walls as explained by several twentieth-century craftsmen of Campidano. They explained that cracks could be prevented from developing after the construction of the building (section 5.4.1). Furthermore, they explained one method for the repair of structural cracks which was in use in Campidano (section 5.4.2).

5.4.1 Traditional prevention methods

When the soil used for making mud bricks happened to be of poor quality, or if the wall was built with poor workmanship, a preventive system of wooden ties against cracks was inserted in the wall corners during the construction of the building itself. When the building of the ground floor was completed, juniper or iron ring beams (*radicciamento*) were applied all along the wall and tied together with keys (*chiavi*) and steel straps (*bolzoni*). Archival research carried out in Quartu Sant'Elena shows that keys and steel straps were allowed to protrude from teh wall, whilst trusses and beam ends had to be keot flush (ASQ 1855). This is confirmed by the suthor's direct observation not only in Quartu Sant'Elena, but also in several other villages of Campidano. Juniper ties were applied on both internal and external sides of corners, alternatively and 50 cm apart (roughly every four *làdiri* courses). In recent practice timber ties were replaced with recycled railway tracks or with iron rods (diameter 1.8 cm) which were bedded with cementitious mortar to create a continuous ring beam. By comparison, the traditional practice of inserting fired bricks for the building of corners did not appear to be effective against lateral movement of walls because mud bricks and fired bricks have different porosity, density, and coefficient of expansion and contraction. As a consequence of this, detachment between fired bricks and *làdiri* walls is today visible in many buildings. Master Craftsmen explained that the regular inspection of gutters was of great importance towards the prevention of cracks because, if water was allowed to penetrate the wall, iron ties could rust and cracks could start to appear. In this case ties were replaced and the repair of cracks followed.

It is quite frequent in Campidano to see walls which are not tied to each other due to poor craftsmanship. This is especially noticeable in the connection between boundary walls and portals. The nature of these cracks seems to suggest that because boundary walls were not of primary importance, craftsmen concentrated their efforts in the building.

5.4.2 Traditional repair method

Cracks were traditionally monitored by craftsmen with a simple device. A tag in the form of piece of flat glass was fixed either side of the crack with gypsum mortar and checked regularly to see if movement was sufficient to have cracked it, indicating that repair was necessary.

In Villamassargia and San Sperate, structural cracks were cleaned of all loose material and plants, wetted and filled in with tiles or flat stones, mud mortar, and dry packed. More skilled craftsmen explained that structural cracks were repaired by inserting a series of parallel juniper or chestnut ties in order to establish a solid connection of the two parts of the wall (Fig. 5.2). The reason for using timber as a structural material is related to its compatibility with earthen buildings. Timber is both flexible and vapour-permeable (Keefe 1993, 3), which is not the case for iron and reinforced concrete. The outcome of the use of timber ties was the restriction of further movement, but not the elimination of the cause thereof. If, for example, a crack measuring two metres in length was to be stopped from expanding, two ties at 50 cm from both extremities of the fracture were inserted on the outer surface of the wall. A chase 20 cm deep - exactly half the thickness of the wall - was cut in order to accommodate the timber tie which was then fixed at both ends with two timber hooks. One end was fixed first and then the other extremity was fixed and tightened with a cross-tie end-securing method. Ties measured 10 cm in diameter and one metre in length and were characterised by two dovetail holes at both ends, and by two end-securing methods (*crai*, key, or *cravatta*) with a vertical and a diagonal side. Ties were fixed on the wall and keys were hammered in the holes and kept tight by simple friction (*attèsai*), without any nails (*obbìbisi*) or wedges (*tacciàs*). Some Master Craftsmen agreed that the longer the keys, the greater the benefit against cracks, but 50 cm was the normal length for keys. Then the timber tie was bedded in and packed with mud mortar and tile wedges in order to form the stitch. An iron strip was folded and nailed on both extremities to fix keys to the main timber.

It should be stressed here that a certain amount of original fabric was lost when cutting the chase on the wall. This method therefore can be criticised from the ethics of conservation point of view. However, the optional technique of pouring liquid clay into the crack was not traditionally contemplated by craftsmen as in their experience, clay could shrink after drying, and new cracks should consequently appear on the wall.

Master Craftsmen explained that the above method was in use in Campidano for the repair of vertical and diagonal cracks. This is also confirmed by the author's direct observation which showed that horizontal cracks are not present in mud-brick buildings of Campidano.

5.5 Holes caused by burrowing animals

Before dealing with the repair of rat runs caused by rodents, traditional craftsmen located the extent of the holes, as these could stretch through the whole depth of the wall. Holes and missing mud bricks were traditionally repaired by cutting a *làdiri* in the shape of the lacuna, following which the surface was wetted and a layer of mud mortar was laid in the cavity. The brick was then hammered in with the help of a timber board. The area of contact between old and new fabric was then packed with stone wedges and dry soil.

Erosion of lower level of wall by rodents was traditionally prevented by means of inserting sheets of chicken wire with a mix of mud mortar or by filling in the cavity left by the rodent with a mix of mud, stone wedges, broken tiles, and broken glass. The latter technique was also traditionally used for the repair of rodents damage in cob walls in England (William-Ellis 1919, 44).

5.6 Eroded *làdiri*

The aim of this section is to illustrate the traditional repair methods for eroded *làdiri*. Traditional craftsmen explained that wall erosion was repaired according to its depth. Two different methods were therefore used for the repair of shallow (<10 cm) or deep (>10 cm) erosion.

5.6.1 Shallow erosion

Shallow erosion was often accepted in Campidano as being a characteristic of the fabric of the earthen wall face and which therefore did not require any repair beyond good-quality plaster. The traditional solution for shallow erosion (<10cm) was the preparation of the wall by the insertion of broken tiles or flat stones in the vertical joints (*cummussura*) of the *làdiri* in order to form a keying system (Fig. 5.3). Before insertion, joints had to be dug in order to be able to accept the broken tiles and the lime mortar. After the system of tiles and stones was firm, a lime slurry was applied to the eroded area over which, after drying was completed, a coat of lime mortar of thickness 5-10 mm was plastered. A combination of coats was preferred to a single thick coat in order to avoid drastic detachment. Generally speaking, the thickness of every coat was proportional to the depth of the erosion.

Local craftsmen in the village of Dolianova developed a clever device for the moulding of *làdiri*, with the advantage of making the digging of the vertical joint unnecessary (Fig. 3.7). A flat wedge two millimetres thick was nailed to one of the inner short sides of the mould and this assured a shape which allowed the insertion of the broken tiles and flat stones without further need for hammering. This mould was used for the shaping of all bricks, and not only of those used for the construction of the facades of the building.

Another traditional method for the repair of superficial erosion entailed the use of broken roof tiles (*teullacciu*) and of flat stones applied parallel to the eroded area (Fig. 5.4). This created a continuous layer on which the lime render could grip and form a flush surface with the wall line. Patches of loose soil were traditionally consolidated by spraying a lime slurry in order to take the wall back to its original state. It was important to soak the broken roof tiles and the stones in water before use, and to moisten the wall before accepting them. This technique has an ancient origin, as demonstrated by discoveries in the House of Phaunus in Pompei (Adam 1984, 238) and in Sardinia in the Roman site of Nora (Carlo Tronchetti, pers. comm.). Here earth walls and stone walls were repaired with a coat of roof tiles applied with lime mortar, showing that this technique was most probably transmitted during the centuries of Roman control in Sardinia. A similar method was also directly observed by the author in the repair of some earthen buildings of Évora, Portugal.

5.6.2 Deep erosion

In villages such as Sinnai and Villamassargia deep erosion was especially frequent at the base of the mud wall (coving), and was repaired by using the traditional method known as *rincasciu* (Fig. 5.5). This procedure involved a preliminary brushing-off of all loose earth of the wall surface. If necessary, patches of loose soil were consolidated by spraying a lime slurry on the affected area. Then a square chase was hacked into the extremities of the eroded area to form a dovetail section in order to receive a series of pointed wooden sticks (*ancrava*) tapped into the vertical joints of the mud bricks. It should be mentioned here that this is an astonishingly similar procedure to that traditionally carried out to cob buildings in the UK (Pearson 1992, 93). Sticks were made of juniper or oleaster and measured 2-3 cm in diameter and were necessary when erosion was deeper than 10 cm. Hammering was carried out until the extremities of the sticks were flush with the original wall line. In order to avoid cracks caused by hammering sticks on a square grid basis, a diagonal grid (*pei tremini*) with sticks 30-40 cm apart was preferred. Maistru Dante Sotgia of Villamassargia explained that this was necessary to create a tight and solid structure that could form the basis onto which the subsequent step of the intervention could key itself. After a flush line was fixed, the chase was wetted and filled in with courses of broken roof tiles, fired bricks, flat stones (*mazz 'è cani*), and mud or lime mortar. Sticks therefore had the function of tying these courses to the wall. The use of chicken mesh and nails, typical of modern cementitious repairs, was traditionally avoided because of the certainty of rusting when associated with lime. In some cases pre-shrunk earth bricks were employed instead of fired tiles. Clay bricks were made of the same loam as the *làdiri* wall. When fired clay tiles were used instead, traditional craftsmen suggested that this had the disadvantage of sacrificing the surrounding mud bricks to the fired tiles because moisture could be drawn to where the material is softer.

In Serramanna the coving effect in mud bricks above the stone plinth was repaired by rebating the erosion, wetting the surface and building up courses of half *làdiri* bedded in mud mortar. The major criticism of this system is that detachment of the repaired area may occur if not connected by a device such as a pattern of spars tapped into the wall.

5.6.3 Replacement of mud-bricks

The traditional repair method for deeply eroded *làdiri* bricks consists of the extraction of damaged bricks followed by replacement with new ones (Figs. 5.6-5.7). Traditional craftsmen explained that extraction of mud bricks is sometimes difficult because further damage can be caused to neighbouring bricks. It should be noted here that replacing mud bricks works well from the structural point of view but has the disadvantage of making the identification of new bricks sometimes difficult, especially after the weathering process occurs. According to John Hurd (pers. comm.), a solution could be the insertion of flat bricks, or bats, that could be more easily identifiable because of their different size than traditional *làdiri*. In this respect Garrison (1990, 10) has pointed out that the identification of new mud brick can be made possible if during the manufacturing process a penny bearing the year of production is embedded in the new brick and if the replacement process is well documented.

5.7 Plaster and wall paintings

The aim of this section is to illustrate the traditional repair methods for plaster and wall painting. Surface treatment of mud-brick walls was traditionally considered only after ground water control and leaking roofs were repaired.

5.7.1 Lime plaster

Lime increased in popularity as a plastering material during the first half of the last century, and today 43.4% of the buildings encountered during the questionnaire show a lime-based coat (Table 4.10). The questionnaire shows that lime was the most widespread material for plastering if compared to other materials such as mud and cement.

Lime plaster was traditionally patched and patch-repaired. This was agreed by Master Craftsmen of villages such as Nuraminis, San Sperate, Serramanna, and coincides with what was found during archival research in Quartu Sant'Elena (ASQ 1870). Plaster was rarely stripped off and replaced as a whole. If in the past such practice had the advantage of being less labour-intensive and less expensive, today it is still more advisable because it can be defined as a minimum intervention technique, therefore contributing to the retention of authenticity. Another simple aspect which gives credit to such practice is the fact that the problem of understanding what to consider as a replacement does not persist (Torraca 1990, 13). Torraca (1990, 14) explains further that the idea of a 'sacrificial layer' which is periodically renewed cannot be applied to the practice of patching.

The procedure of tapping the plaster in order to see if adhesion had been lost (and the consequent elimination of hollow-sounding render) was traditionally considered only for loose parts. When sound render was revealed, maximum retention of the original coats was ensured. The repair of a patch followed five steps which in detail, were:

(1) The surface was cleaned of all plants, dust, and loose parts by brushing with a soft bristle brush. If the plaster had to be applied to a reconstructed wall, or a new wall added to an existing building, this cleaning was never done before shrinkage was completed;

(2) The vertical joints of the *làdiri* wall were first inserted with wedges (stone, tile or timber) bedded with lime in order to form a keying system. This was necessary because if the render was applied straight to the wall, water could enter the cavity between the *làdiri* wall surface and the render, and detachment could occur. This method was often used for external renders but seldomly for internal coats. After wedges were inserted, the wall was brushed off and moistened. Care was taken not to reach the liquid limit of the soil. Moistening was important for avoiding detachment of the render. The projecting stones were pushed in at about five centimetres and their length was 10 cm. Each stone or broken tile was a key on which the render could find a support. This system was not only used in walls, but also in the arches of mud portals. It should be noted here that this method is similar to the 'rajuela' keying system traditionally employed in Texas (Burt 1995, 6) and in New Mexico (Uviña Contreras 1998, 83).

(3) A slurry coat (*rimbussàra, rinzaffatura*) made of lime and fine sand was applied to the earthen wall with a trowel. The thickness of the coat ranged from two to four millimetres and the resulting surface had a rough texture. Lime slurry was definitely not popular as a gripping layer in traditional Campidano, whilst clay slurry was more widespread. The mix for this coat was: one sack of quick lime for one and a half wheel barrows of sand.

(4) The scratch coat (*arriccio*, 1 cm of thickness) had a levelling function and had a final thickness of no more than one centimetre so that carbonation and curing could be easily achieved. This has also been confirmed by the laboratory analysis undertaken by the author on ten samples, which gave an average thickness value of 1.24 cm (section 7.4.3).

(5) The skim or finishing coat filled in the eventual shrinkage cracks occurring on the

scratch coat, and then the wall was limewashed. Traditional craftsmen explained that a good skim coat was characterised by no cracks.

Traditional craftsmen explained that the use of soft plaster on the outside and hard plaster on the inside is the traditional practice for a good lime plaster. This will be discussed in depth in section 7.4.3 of chapter seven, but it is important to mention here that in Sinnai external renders were mixed with gravelly sand and with a higher percentage of lime if compared to internal renders. This allowed greater protection against weathering. Good protection against weathering is also a function of the external surface treatment. If a rough and irregular finish is acceptable because drying and carbonation can benefit (due to the greater exposed area), at the same time if the finishing is smooth the amount of water absorbed is less, the advantage being that water is washed off.

Interior and exterior structural stone elements such as arches and columns were commonly protected with a thin render or with a finishing coat made of fine sand mixed into a lime slurry. Today's lack of understanding of craftsmanship and of historic coats is visible in contemporary conservation practice in Campidano. Where stone and fired bricks elements were traditionally finished with a sacrificial coat, they are today often exposed to suit contemporary fashion.

5.7.2 Mud plaster

Amongst all the different types of plasters, mud has a natural tendency to adhere to the *làdiri* wall, is economical, and wears more evenly than lime plaster. But unexpectedly, only 6.7% of buildings included in the questionnaire had a mud render (Table 4.10). This section follows the explanation of practice by the Master Craftsman Dante Sotgia during a workshop on mud plasters held in Villamassargia on 11 June 1998. Sotgia advised that a good mud plaster was traditionally considered to be composed of a soil that matches that of the wall itself. He suggested that soil which was too clayey was avoided because of high shrinkage and possible detachment from the wall. He also explained that the application of mud plaster was traditionally carried out as follows:

(1) Walls were cleaned with a soft bristle brush so that loose material was eliminated. Scored surfaces were made damp by spraying water with a brush and then a layer of mud slurry was thrown onto the wall with a gauging trowel. In so doing, a firm surface was secured. The mix for this layer consisted of two parts of soil and one part of sand. After this first recoupment layer was dry, the resulting rough surface was ideal for the following coat to adhere.

(2) The mix for the second layer was: two parts of soil, three parts of sand and 3-4 cm cut straw. After drying occurred, this coat often showed some cracks which were not tamped because they were considered to be beneficial for the adhesion of the third and final layer. However, cracks were often tamped for the final layer before drying and after this stage the wall was draped with heavy material in order to force the plaster to slowly release the moisture and therefore to reduce the extent of cracks. This would allow the wall surface and the mud coat to shrink at the same speed while drying. Minor cracks (hairline cracks) were not considered harmful. Master Craftsman Dante Sotgia also explained that the plastering was usually finished in one day to avoid dry-clay/wet-clay joints.

(3) The mix for the skim coat was: one part of sieved soil (four millimiters sieve), 3/4 part of sand, and ½ a part of bagged lime. When the skim coat was still wet, sand grains were pushed in with a trowel so that the rendering was smoothed and, after drying, ready for limewashing.

(4) Limewash was added with skimmed milk and applied to the wall. Amongst the richest families of Campidano, interior surfaces were limewashed annually, but the more usual practice was to do this every three years. Amongst poorer families, interior *làdiri* walls were simply limewashed without any plaster.

The first step before coating with mud (*incroxai*) was the determination of the original plaster and of the earth wall and a comparison of the two to see if there was a correlation, in order to fashion a similar new mix.

5.7.3 Traditional repair methods for wall paintings and fenestrations

The decay of ceilings was often a result of poor craftsmanship, the main problem being canes which were too tight in the sarking, and which therefore did not allow lime mortar to form a key in the gaps. In this case, traditionally, the rendering of the lacuna was never carried out by the decorator himself but by the Master Craftsman who used lime, mud or (more recently) gypsum according to the original medium. Eventual rising damp problems were also tackled by the craftsman. Traditional wall painters were aware of the importance of using exactly the same material for the rendering of the lacuna because, if a harder or a softer material than the original was used, cracks would compromise the joints. The second step after the rendering entailed a survey of the decorative types and colours of the surface to be repaired. The work under consideration was therefore covered with a sheet of tracing paper (or any other transparent paper) in order to sketch its outline with a pencil. The drawing was then perforated on a cardboard pouncing in order to simplify its transferral to the rendered lacuna. During this stage, paint preparation followed a strict rule. After quicklime was slaked and sieved, it was left to rest in order to make the smaller lumps settle into sediment. In so doing, the putty improved in quality and smoothness. The decorator then diluted this lime putty with water in order to use it as a binder. The next step was to achieve the right tint to match the original background and decoration colours. This was difficult to achieve as the wet mix of pigment and lime is usually twice as dark than when dry. In order to choose the right tint, a small sample was painted close to the original colour after which the decorator had to wait until drying was complete. In presence of light backgrounds, the pigment typically brushed into the pouncing was the *terra d'ombra,* while for dark backgrounds the most common pigment was light in colour. Cracks were repaired with different methods according to their magnitude: hairline cracks were filled in with pure lime putty, while wider cracks were filled in with lime mortar. Wall paintings in buildings protected by the Soprintendenza were and are conserved through the *tratteggio* technique, which consisted of a pattern of small lines averaging one centimetre in length applied in the restored area by means of a pencil or of a thin brush in order to distinguish the original painting from the new one (Mora 1984, 309).

Traditional decorators not only carried out repair works on wall paintings, but also on doors. Repair methods for portals were traditionally carried out in five steps:

(1) cleaning the surface by spraying water in order to eliminate dust, and waiting until dry;

(2) spraying the surface with a mix of fish glue and water in order to provide an even surface to the next layer;

(3) painting with a mix of linseed oil and pigments;

(4) after the layer of paint had dried, imperfections in the timber elements of the portal were minimized by using a putty, a mixture made of gypsum, fish glue and pigments;

(5) after the putty had dried, the last layer of paint could be applied.

It is important to stress that the putty had to be applied between steps (3) and (5) because experienced painters agree that this was the most effective solution. The external face of portals was often protected from weathering with a coat of thin iron sheeting which was nailed on the timber. This method shows that painted surfaces were generally not removed but just cleaned.

Nowadays the art of wall painting and its conservation has to face the unavailability of traditionally manufactured building materials, especially lime. It was only in the 1960's that painters realised how effective traditionally-burnt lime actually was, when they were forced to replace it with industrial water paints. When industrial lime was used, as at first it became apparent how much less cohesive it was especially after the addition of pigments (see also Appendix 2). Traditional lime kilns are no longer active and therefore lime is purchased through industrial manufacturers. The disadvantage of such lime is that the firing process is carried out at the lowest possible temperature in order to save fuel, with a resulting high content of unburnt lumps. In this case it was suggested that lime in the form of quicklime should be purchased in order to carry out the slaking process in a more effective manner. It was also suggested that lime should be left to mature for at least three days, a necessary period for allowing unslaked lumps to sediment. Another important aspect is characterised by traditional brushes which are of considerably better quality than the modern ones because they tend not to be affected by the corrosive action of lime during painting process.

5.8 Conclusion

On the evidence assembled, the assumption is that the methods explained in this chapter are autochthonous to Sardinia. However, the author was not able to demonstrate this conjecture because of the lack of literature on the subject. Some of the methods explained in the chapter could be dated back to the Roman period, whilst some other methods are similar to standard repair procedures of other building cultures.

The need for testing the repair methods explained here should be urged as a future task. This would allow to ensure the long-term effectiveness of the methods explained in this chapter.

Chapter 6

CASE STUDIES

6.1 Introduction

The aim of the present chapter is to describe the conservation of the two buildings selected as case studies. The chapter is important for two reasons. Firstly, it gives an overview of best conservation practice in Sardinia, as opposed to what is described in section 2.10 of Chapter 2. Secondly, it serves as an introduction to the two buildings from which the samples analysed in Chapter 7 were taken. The two sites were selected only after undertaking several informal conversations with key local architects who work in the field of earthen buildings conservation. Their advice was fundamental for choosing the most appropriate sites because three main requirements had to be satisfied:

(1) Preference should be given to buildings dating not earlier than the turn of the last century. In this respect priority was given to the palazzo type and not to the simpler farmhouse type, because the first was more typical at the turn of the last century;

(2) Preference should be given to buildings that were in the process of being conserved, and were thus not in a finished state. This was necessary as the sampling of both historic and repair materials was therefore possible. This also allowed a more accurate documentation of the historic fabric and of the conservation and repair process;

(3) another requirement was that the two buildings had to be from different parts of Campidano, and not concentrated in one small area.

These three requirements were almost entirely satisfied by the two buildings chosen as case studies. The first building is located in Serramanna, in central Campidano, whilst the second is located at the southern end of the area, in proximity to the capital, Cagliari (see map reference Fig. 1.17). Only one requirement was not satisfied, in particular by the latter building, which was constructed some 30 years prior to 1900. The two buildings under examination will be analysed separately, whilst the concluding summary will be contained in a single section at the end of the chapter.

6.2 Case Study A (Casa Cadoni-Arcais, Serramanna)

The first building, Casa Cadona-Arcais, was recently purchased by the Commune of Serramanna as part of the regeneration project of the historic core of the village, and its purchase and conservation is part of a scheme financed by the *Regione Sardegna.*

This section owes much of its information to Lucio Ortu and Carlo Pillola, respectively the architect and the engineer in charge of the conservation of the building, and the considerable documentation that they generously lent the author. Lucio Ortu also answered numerous questions and shared several useful visits to the site with the author (March 2000, 24 August 2000, and January 2001).

6.2.1 The building

Casa Cadoni-Arcais is located in the historic core of Serramanna (Figs. 6.1-6.2). The village was until recently one of the most important centres of mid-Campidano in terms of farming and also, compared to other villages, in terms of the wealth that the farming generated. The style of the building - both in terms of size and quality - was influenced by the accumulated wealth of the prominent farmer who was the original owner. The building is a typical combination of a palazzo-type residence and several smaller units which were related to agricultural work. The site is also characterised by a wide cobbled courtyard towards which the units face. No research has been carried out on the exact date of construction of Casa Cadoni-Arcais building, but it is certain that the building dates between 1900 and 1910 (Ortu, pers. comm.).

The main wing of the house, or palazzo, is a two-storey construction which faces the street (Figs. 6.9-6.10). Traditionally, this wing was the residential part of the house and the ground floor was the area where guests were received. In particular, the main living room and its refined stencilled wall paintings had the function of impressing the visitor (Fig. 6.8). This was the room where important guests were received and where status could be displayed. There is also evidence that the entrance hall was decorated with painted blue motifs, but unfortunately most of its original render was not visible when the building was inspected as it was concealed by a layer of limewash. Another entrance to the property was the portal, which was a functional opening to the courtyard. This was the access which was traditionally used for allowing the carts and the farming equipment to be kept safe in the loggia. The site shows archaeological evidence of a grand storage building for wine and other goods which gives an indication of the extent of the farmland that might have been attached to the building. This storage area is now in a ruined state, and its reconstruction will be carried out by the municipality if more funds become available in the future.

When conservation is completed, the building will be dedicated to mixed uses: the upper floor will be converted into council flats, whilst the ground floor will host cultural and social activities for the benefit of the villagers. But the building will principally be given a residential use. In this respect the concern of Lucio Ortu (pers. comm.) is that potential building users might have a sense of non-acceptance or shame about living in an earthen building. This is in fact a typical feeling which the author also directly experienced in Campidano, especially amongst the poorer families. Another concern of Lucio Ortu (pers. comm.) is that, probably due to this negative reaction, building users might start a process of modernization of the interior of the building in order to conceal its vernacular aspect.

6.2.2 General condition of the building

The aim of this section is to illustrate the symptoms of building decay prior to its conservation. Probably because of its relatively recent construction, the general condition of the building was not too critical when it was purchased by the Commune. However, even though the structure was sound in most parts, the main evidence of decay was localised on three different levels:

(1) the stone underpin course showed some deterioration caused by rising damp, especially on the interior sides of walls. The plinth of the main facade, having been rendered with a strip of cementitious render carried out at the date of construction of the building, did not show any visible effects. By contrast, the north wall of the living room appeared to be particularly affected by rising damp because of a recently-discovered leak in the plumbing system of the neighbouring building. This occurrence severely influenced the decay of the lower part of the wall paintings which characterise the room.

Furthermore, the lower strip of the wall shows a render whose composition is different from that of the upper part, probably because this was traditionally scraped off and replaced every year;

(2) the *làdiri* walls showed several problems. Several bricks of the top courses were eroded by rain because of faulty overhanging eaves. Some of the bricks of the arches of the loggia were also decayed. A more severely damaged part of the building was the west wing of the building whose walls were in a perilous state of decay. Several cracks were also present in some of the *làdiri* walls, and especially in proximity to the corners. The main facade had virtually completely lost its coat and evidence from the laboratory analysis of a surviving fragment of render collected on the site shows that the original coat was lime-based. One sample was in fact collected from the facade and named Case Study A1 (Datasheets). Its analysis is contained in section 7.5.1 of Chapter 7. The elevations facing the courtyard were found in a decaying state and therefore were completely stripped off (Figs. 6.1-6.2). The internal coats were in better overall condition than the external ones, and especially those on the first floor as they obviously were not affected by rising damp;

(3) the overall condition of the roof was at risk, with several collapses caused by a timber structure that was too small for the roof (Figs. 6.5-6.6). The timber skeleton was not strong enough to carry the overall load of the cane sarking, the lime screed, and the roof tiles. Another deficiency related to bad craftsmanship, as identified by Lucio Ortu, was the lack of anchoring between the rafters and the main timber elements of the roof skeleton. This allowed swinging and therefore led to collapse. Some other rafters were simply anchored to the ridge beam, and their continuous prodding originated in the long term problems of lateral bulging of *làdiri* walls. In contrast, other parts of the building showed a better understanding of the craftsmanship embodied in the construction of roofs. This is also due to the fact that the building as a whole was constructed in segments, through the addition of units, with visible differences in craftsmanship and materials. The best-performing coverings were in fact those characterised by proper trusses and by rafters secured to the main skeleton by means of long nails.

6.2.3 Repair

Philosophy of conservation

This section deals with the philosophical aspects of the conservation and repair work carried out on the building. The main principle employed during the first stage of the conservation project of Casa Cadoni-Arcais was that of minimum intervention. But this initial objective was slowly corrupted, mainly by financial complications which arose throughout the conservation work (Ortu, pers. comm.). But it should also be noted that the work was carried out so that the techniques of survey and scholarly research preceded the techniques of conservation and repair. One of these was the involvement of elderly Master Craftsmen in the conservation of the building, which was guaranteed throughout the process by the close relationship that architect Lucio Ortu has with his own native village, Serramanna. The involvement of elderly craftsmen was especially necessary because of the lack of contractors specialising in the repair of earthen buildings (Ortu, pers. comm.). Ortu also explained that in order to train craftsmen on-site, his daily presence was required. An explanation of the repair carried out to the building will follow in chronological sequence.

Làdiri

Replacement *làdiri* were manufactured in the local enterprise founded by Stefano Cogodi, which retails bricks to the lower Campidano (Fig. 6.4). The specification of the best soil to be used for the making of mud bricks was carried out by Stefano Cogodi himself together with the assistance of the architect in charge of the conservation of the building, Lucio Ortu. The main problem encountered at this stage was that the traditional quarries on the outskirts of the historic core of Serramanna were now urbanised. Consequently, and also because of the legal impossibility of quarrying in the fields around the village, the soil was purchased from a local building site. The source was the soil dug for the construction of a cellar, and this was assessed to be adequate after test bricks were made. The matching of the colours of the two bricks is excellent and this was also confirmed after both were defined through the *Munsell® Soil Colour Chart* (Anon. 2000) as very pale brown (Table 7.2). However, the identification of the two different soils can be difficult by the naked eye. This is the reason why the replacement *làdiri* were made detectable from the historic ones through the addition of the date and signature of the manufacturer which was impressed on their surface during the moulding stage.

The first elements to be repaired after dismantling the roof were the top parts of the walls. Cracks, erosion, and bulging were the most common symptoms of decay of the upper areas of the *làdiri* walls. Portions of walls suspected of concealing serious problems behind the render were scraped of all protective coats, and eventual damage was investigated and assessed. In most cases the replacement of the last courses of bricks with new ones was sufficient to create a sound wall end on which to lay the new roof structure.

Timber

The roof was not repaired as a whole, but by rather using single rooms as modules. After the roofing of one room was completed, the next one was tackled, and so on until completion. The several symptoms of decay caused by bad craftsmanship and the general state of decay of most of the roof skeleton inclined the architects to replace all roofing elements completely. Timber, cane sarking, and roof tiles were not selected and reused, but instead replaced with new ones. This decision is the main criticism of the whole conservation project of Casa Cadoni-Arcais. In addition to this, inspection carried out by the author showed that several historic fir timbers which were demolished and stocked at the site in fact appeared to be sound. It was also observed that a good number of historic roof tiles could have been recycled and that this operation could have been economically sustainable (Fig. 6.4). Replacement timbers were nonetheless made of fir, as with their historic counterparts. In order to do so, trusses and other timber elements were drawn on a scale of 1:1 and drawings were used as templates in the timber workshop where the cutting of details was carried out. After the assembly procedure of timber elements was concluded at the site, some of the timbers showed several cracks caused by their artificial drying. This is a characteristic phenomenon, typical of contemporary practice. Until the 1950s air-dried timber was traditionally imported to Sardinia from Sweden or Corsica. However, the more recent technique of kiln drying can produce separation of the fibres (Ridout 2000, 124). These stresses are nonetheless accepted by practitioners as the high cost of air-dried timber would compromise the conservation of the building.

Trusses were anchored to the wall structure by means of steel ties bedded in cement mortar. The justification for using cement was that on-site trials were carried out with both lime and with mud mortars, and in both cases the steel rusted. The use of stainless steel ties was not considered as an option because of its high coefficient of expansion and contraction and also because it would not be economically viable. The use of cementitious mortars for the connection of steel ties to *làdiri* walls is a traditional device in Campidano and examples dating from the 1930s were discovered in Serramanna (Ortu, pers. comm.). This device was considered to be the best solution for tying the walls to the timber roof as the other option was to build a tie beam around the perimeter of the building.

The repair of floors followed the general pattern used for roofs and was carried out in modules of one room at the time. This method was employed in order to avoid subjecting the building to severe stress.

Plinth

The only repair carried out on the stone plinths was the reconstruction of the sections affected by serious problems of rising damp or cracks. In order to prevent further damage caused by rising moisture, it was decided that the perimeter of the building should be surrounded by a French drain. This allowed rain water to be directed away from the building. Another problem connected to the capillary rise of damp was the presence of salt efflorescence. This may be caused by a construction fault, as salts may derive from the soil. This soil, rich in organic matter, was used for flattening the floor area before laying the floor tiles. This soil was therefore removed and a stone hardcore was instead laid before the historic tiles were re-layed with lime mortar.

Render

The building features not only various patches, but also several types of lime renders containing different aggregates and of different thickness. All sound coats were maintained whilst loose ones were scraped off and re-rendered with the following mix: ½ part of lime putty, ½ part of hydraulic lime, and 3 parts of aggregate. The sand was quarried from the local river and used as excavated. This aggregate had already been successfully tested by Lucio Ortu in several other buildings. The finishing layers were based on the evidence found in every room, and pigments were selected accordingly.

Other

Doors were conserved and reused in most cases. Approximately 60% were repaired and re-mounted into their original position. Windows were replaced by new double-glazed timber windows which have a similar design to that of the historic ones. All electrical wires were passed through the floor in order to interfere as little as possible with the historic fabric of *làdiri* walls.

6.3 Case Study B (Caserma Carabinieri, Quartu Sant'Elena)

This building was recently purchased by the Commune of Quartu Sant'Elena. When conservation is completed, the building will be dedicated to mixed uses: the upper floor will be converted into council flats, whilst the ground floor will host cultural and social activities for the benefit of the villagers.

The information concerning this section was gathered with the help of Fabrizio Cadeddu, the engineer in charge of the conservation of the building. He shared several site visits with the author during which numerous questions were raised and answered (15 March 2000, August 2000, and January 2001). Another important source of information was the conservation report written by Cadeddu, together with the archival research both he and the author carried out in the Archivio Storico Comunale of Quartu Sant'Elena. The latter was particularly important for tracing the history of the building and for understanding its archaeology.

6.3.1 The building

The date of construction of the existing building is uncertain, but archival research shows that that project planning was underway in 1868 and it can therefore be assumed that its construction was started soon after this date (ASQ 1868a). The building was designed by Agostino Loi who was the *Misuratore Assistente del Genio Civile.* The structure was built as Carabinieri barracks, and was described by the nineteenth-century historian Rossi Vitelli (1878) as one of the best barracks of the province of Cagliari. He also mentions that the building and the stables were intended for an overall number of 15 men and 15 horses. Archival records revealed the evolutionary history of the site under examination:

(1) An older building that existed on site prior to 1868 was a single-storey structure which had a mixed use. It was occupied partially as headquarters of the local municipality and partially as Carabinieri Barracks;

(2) in 1868 a project was carried out in order to enlarge the barracks and to create a separate unit for hosting the headquarters of the local municipality. The previous building was entirely demolished in order to allow the construction of the completely new

barracks (ASQ 1868a). The new building was built on new and sound foundations and was increased by one floor and one staircase. The latter was incorporated in the wing facing Via Caserma. The barracks were located in that portion of building stretching along Via Caserma, whilst the Commune was located in the wing facing Via Roma. The facade was designed with symmetrical windows and with other Neo Classical details such as floor lines and cornices. In this respect Cadeddu (pers. comm.) explains that the analysis of the fenestrations reveals the changes to which the building was subjected. Differences in dimensions and types of windows, and the distance from one window to another give important evidence for the evolution of the building. The analysis of the plan reveals in many ways the public function served by the building. It can be described as a line of offices to which access is guaranteed by two loggias. On the first floor the loggia is replaced by a long and wide corridor;

(3) in the 1970s the portion of building traditionally used as the headquarters of the Commune was demolished and replaced by a concrete construction. As a result, two separate parts can be now easily identified in terms of building materials. The concrete construction was used in the last decade as headquarters of an association of voluntary aid organization;

(4) in January 1997 the walls of the first floor were in a perilous state of decay due to lack of inspection of its gutters. Water penetration into the *làdiri* walls caused bulging in the walls, detachment of lime renders, erosion of walls, and other severe damage. This influenced the decision taken by the local authority to demolish those parts of the building that were prone to collapse (Figs. 6.11 and 6.14). The Commune decided to conserve the building soon after this enormous loss of original fabric.

Site inspection showed that, probably because of its function, the quality of construction of the barracks was of higher standard than that of the traditional architecture of Quartu Sant'Elena. A detailed description of the materials employed in the construction of the barracks was revealed through the 1868 project documents which are kept in the local archives (ASQ 1868a). The 'materials specifications' section carefully defines every material together with the method employed. The archival document was employed by Fabrizio Cadeddu as an important reference for writing the condition report of the building and for specifying what building materials were necessary for its conservation (Fabrizio Cadeddu, pers. comm.). The raison d'être for the document is related to the public function of the building and to the fact that its design was carried out by a professional. In this sense both the building and the document can be considered as exceptional in the frame of time between nineteenth and twentieth century Campidano. However, the craftsmanship employed in the construction of the building follows the traditional codes of vernacular Campidano, even though at a higher level. The next sub-sections consist of a list of the most important building materials as illustrated in the archival document which in some cases gives also an indication of where the materials were purchased from.

Limestone

Limestone and *làdiri* are the main building materials used in the structure. Limestone was mainly used for the construction of ground floor walls. Rubble limestone was bonded with lime mortar to form a solid underpin course, with a height varying from 0.60 to 4 metres. The archival records note that Agostino Loi specified that the courses of rubble limestone were not to be higher than 50 cm (ASQ 1868a) and it seems likely that this was necessary in order to avoid collapse of the courses before the drying of lime mortar was complete. The excellent craftsmanship embodied in the construction of these masonry walls is revealed by their lack of decay symptoms. The appearance of the rubble wall is that of a conglomerate of limestone and lime mortar, a typical system often employed in the construction of partitions in the neighbouring capital. Another application of the limestone conglomerate was discovered on the top courses of *làdiri* walls. In order to avoid resting the roof structure on the bare mud brick, a course of 50 cm of limestone conglomerate was built on top of the *làdiri* walls so that a sound layer was achieved. This device is carefully explained in the archival document in the section called *Ordine e Modo a Seguirsi nell'Eseguimento dei Lavori* (Specifications and Methods for the Completion of Works) which explains what building techniques were adopted on the site (ASQ 1868a). The type of limestone employed in the building is locally known as *tramezzario*, and its name derives from its geological distribution. The stone is in fact found between the two formations called *pietra forte* and *pietra cantone* (Cara and Sistu 1995, 223). The *tramezzario* stone is classified as yellow-whitish in colour, with a weak binding agent, and with a macro fauna of molluscs such as bivalvia, echinoid, and red algae (Cara and Sistu 1995, 226). The stone was traditionally quarried in the following areas located in the then outskirts of the capital: San Michele, Sant'Ignazio, Tuvixeddu, Calamosca, Sant'Elia and Buoncammino (Cara and Sistu 1995, 229). It seems likely therefore that the stone was quarried in Cagliari. The assumption here is that the stone might have been then shipped either by sea or through the canal systems of the saltworks located between Cagliari and Quartu Sant'Elena. However, no evidence was found to directly support this theory. The *tramezzario* limestone was used in the building under examination for the construction of doors and other openings, for the arches and pillars of the two loggias, and for the construction of wall corners (ASQ 1868a). These details were typically made of ashlar, showing the calibre of craftsmanship accomplished by the local stone masons. Ashlar stonework was bonded with lime mortar which was specified by Agostino Loi to have a ratio of 1/3 lime putty and 2/3 sand (ASQ 1868a).

Làdiri

The walls of the first floor were mainly constructed of *làdiri* bonded with a mix of lime and soil (ASQ 1968a) of unknown ratio. The walling structure was built with alternative courses of stretchers and headers or *con mattoni alternati in lungo ed in traverso* (ASQ 1868a), which is the Italian equivalent to English bond.

The construction technique for *làdiri* has already been discussed in detail in Chapter 3. The *làdiri* employed in the building under examination do not seem to differ from those in use in the same period and later in Campidano. However, the peculiarity of the Barracks lies the mixed use of limestone rubble and of *làdiri* - hence the need for the detailed discussion on the rubble limestone walls in the previous section.

Timber

Agostino Loi specifies in his 1868 document that the pine timber employed in the construction of floors was to be imported from Sweden or Corsica (Fig. 6.24). Floor joist ends were to be treated with vegetable tar before being embedded into the masonry for a depth of 40 cm (ASQ 1868a). Roof trusses were required in the same document to be made of well-seasoned chestnut timber measuring 18x20 cm (ASQ 1868a). Rafters and purlins were specified to be made of chestnut or juniper. Many of these timbers were clearly recycled from the demolished older building, something which was cross-checked through archival records (ASQ 1868a). The latter note that those timbers saved from the demolition of the previous building were carefully stacked and reused (ASQ 1868a). The construction of the roof was well documented by Agostino Loi who specified that canes for the construction of sarking were to be of two centimetres in diameter, over which a lime screed of three centimetres of thickness was to be applied. He then explained that roof tiles were to be laid on the lime screed by means of lime mortar and with an overlapping of 1/3 between two neighbouring tiles (ASQ 1868a). It should be noted briefly that the above archival documents were employed by Fabrizio Cadeddu as techniques of investigations to precede the techniques of conservation and repair.

6.3.2 General condition of the building

The aim of this section is to illustrate the main symptoms of decay in the building. The Barracks were found to be in an advanced state of decay, partly because of the recent demolition of a section of the first floor, and partly because of lack of maintenance. The top course of limestone conglomerate was missing in several areas, whilst in other areas it was found in a state of decay due to lack of cohesion between limestone and lime mortar.

Complete exposure to rain water due to demolition of the roof (Fig. 6.24) had caused serious damage to the floor and to the top courses of the *làdiri* walls, which were heavily eroded. Interior renders were also affected by rain water from above at the top level, and also by rising damp at plinth level. To some extent, a strip of sound render was found in the middle portions of walls and it was hoped that their conservation in situ might have been accomplished. However, both external and internal renders were scraped off in order partly to reveal the wall structure and partly to carry out further investigations about the state of decay of the mud brick walls.

6.3.3 Repair

The aim of this section is to give a description of the conservation and repair work carried out in the building under examination by separately analysing the different building materials (Figs. 6.11-6.18). The conservation of the building was carried out with the aim of restoring it to its state prior to occurrence of partial demolition (Figs. 6.25-6.29). The concrete wing was altered to suit the new public function and it was also provided with a lift to facilitate access for disabled people. An explanation of the repairs carried out to the building will follow in chronological order.

Limestone

The repair work of limestone was influenced by the impossibility of quarrying the same type of stone. Fired bricks of a colour matching the stone were used instead. Stone plinths were protected from rising damp through French drains and through ventilated drainage under the floor. Furthermore, hydraulic lime mortar was used at plinth level as this has the property of setting in damp conditions.

Làdiri

The soil used by manufacturer Stefano Cogodi for the moulding of mud bricks was quarried in the site called Is Argiddas (Serramanna). Employing a soil dug 30 km away from the site of the present building was a problematic decision from a sustainability point of view, but it was undoubtedly viable from the financial point of view. Lack of competent *làdiri* manufacturers in the vicinity of Quartu Sant'Elena influenced this choice and bricks were therefore produced in Serramanna and then transported to Quartu Sant'Elena. This choice was also dictated by the fact that the local traditional quarries mentioned in the documents consulted in the archive were not available anymore. The selection of the soil was carried out by Cogodi mainly through personal empirical experience in previous work. The original soil sites were located in Su Paris (Pizzu de Serra), Sa Serriscedda, and Santa Lucia (ASQ 1935), which are heavily urbanised today. In this respect, the replacement *làdiri* do not visually match the colour of the historic soil. This is demonstrated by the comparison of the two soils with the *Munsell® Soil Colour*

Chart (Anon. 2000) which shows that the historic *làdiri* were light-brownish grey, whilst the replacement *làdiri* were pale brown (Table 7.2). Because the difference in colour is so evident, and because the identification of the new *làdiri* was recognizable to the naked eye, it was felt that further identification was unnecessary (Fig. 6.17).

Structural cracks in the *làdiri* wall were repaired by extracting the damaged bricks and by replacing them with new ones. Serious cracks were repaired by inserting steel ties which were protected from rusting by coating them with an anti-corrosive paint and then bedding them with cementitious mortar.

Timber

The inspection of the historic roof structure revealed that timber was not meant to be exposed, but was instead to be concealed by the ceiling. The lack of fine craftsmanship involved in the making of the historic trusses, rafters, and purlins confirmed this conjecture. Furthermore, a closer inspection of rafters showed that they appeared to be salvaged elements from other buildings (Fabrizio Cadeddu, pers. comm.). As was seen for Case Study A, an entirely new roof structure was employed to replace the historic one. Salvaging and reusing timber elements was not considered a priority from the financial point of view. But it should be noted here that most of the historic roof had in any case collapsed during the demolition of the first floor. The remaining timbers were thus not in a state which allowed recycling (Figs. 6.23-6.24). This was also true of the historic roof tiles which could not be salvaged because they were missing or broken. The design of the new roof was based on archival evidence and also on what was found on-site. Floor joists were originally made of fir, but they have now been replaced by the more durable larch. After the *làdiri* walls were repaired or reconstructed, the top end of the walls were tied together with ring beams made of fired bricks, iron rods, and lime mortar.

Plinth

Missing parts of the rubble limestone conglomerate were repaired by inserting fragments of the same geological stone and with lime mortar (*rincocciatura*). The mortar was also mixed to crushed limestone in order to form a coarse binder to be used for bonding the rubble stones. The aim of this repair technique was to reproduce what was found on site and it was particularly useful close to the joint between the last course of the stone underpin course, and the first course of the *làdiri* wall. In this context, inspection was necessarily prompt in order to guarantee the stability of the *làdiri* wall. Rising damp at plinth level was reduced through injections of damp-proof chemicals.

Staircase

The staircase is made of fired bricks and its steps were originally made of slate. It is now made of a terrazzo-like mix of red stone and of white cement, probably a turn of the last century replacement. Some of the terrazzo steps were damaged after the collapse of the roof and were repaired in situ by specialist craftsmen.

Render

Several documents kept in the Archivio Comunale di Quartu Sant'Elena refer to the quarrying activity for sand which took place on the beach of Margine Rosso and to the fact that it was traditionally washed of soil impurities (ASQ 1889, ASQ 1937). The impossibility of purchasing such sand made the architect choose the option of quarrying the aggregate in proximity of Gianní. This sand was washed and sieved. Both replacement renders and mortars were made of a mix of hydraulic lime and of Gianní sand. Limewash finishing for the external facade was carried out with a mix of lime and ochre pigments, whilst it was decided to leave the internal limewashing white.

Other

Orosei limestone tiles were finished with a bush hammer and employed for replacing the original ones. Doors and windows were replaced with new ones, and were exact replicas of their historic counterparts in terms of both design and materials.

6.4 Conclusion

The main outcomes embodied in the conservation of the two buildings are briefly discussed in this section.

Issues of investigation

The most important lesson learnt in both cases is that the techniques of survey and scholarly research which preceded the techniques of conservation and repair were invaluable in providing background and context for the conservation work. In both cases the architects drew from their own experiences with past Master Craftsmen, and in the case of Quartu Sant'Elena extensive archival research was carried out by Fabrizio Cadeddu before undertaking the conservation work. However, no laboratory work was undertaken prior to the author contacting the architects for the two case studies. After samples were collected and analysed by the author, results were given to the architects to be used as an additional reference point for planned conservation work. In particular, the analysis of the two different types of mud bricks (historic and replacement) will be included by both architects in their final reports on the buildings. Use of experimental data was also made by both architects when reporting the work in specialised conferences.

Issues of conservation

A certain amount of training of craftsmen was carried out in Serramanna, whilst no training was carried out in Quartu Sant'Elena. In both cases the architects stressed the difficulty of finding skilled craftsmen, because traditional techniques are still considered by the craftsmen themselves as labourious, time-consuming, and transient. In Sardinia it is still common that contractors who bid for conservation projects are neither specialised, nor skilled. This was also the case for both case studies considered in this chapter. The solution found by both architects was to control and monitor the repair work carried out in the site on a daily basis.

The final point to stress before moving on to the next chapter is that the conservation of earthen buildings is a complex endeavour that requires the consideration of several materials, not just earth. Case Study B showed that *làdiri,* for example, can be found in juxtaposition with stone as a walling material.

Chapter 7

THE EXPERIMENTAL PROCESS

7.1 Introduction

This chapter discusses the experimental laboratory analyses carried out to test and complement the information provided by the traditional craftsmen. While the data given by the traditional craftsmen was vital for this thesis, it was nonetheless incomplete. For example, the craftsmen were unable to provide the specific mixes used for internal and external skim and scratch coats. Additional information through laboratory analysis was clearly necessary. It is also held that the experimental analysis in this chapter will prove to be a useful tool for the assessment of replacement materials in the repair work of the two case studies outlined in Chapter 6.

The specific materials analysed for this chapter were soil and lime. These are important materials in twentieth-century vernacular architecture of Campidano: *làdiri* is the most widespread walling material and lime the most popular rendering material. The analyses in this chapter were restricted to those materials for practical and time reasons, but future research will be able to use this data to provide a solid base for further analysis.

It is important to stress the extent to which the experimental analysis in this chapter and the information provided by the craftsmen (as discussed in earlier chapters) are complementary rather than one type of information being superior to the other. Just as the information provided by the craftsmen was often incomplete, laboratory analysis does not provide the necessary data on the craftsmanship involved in traditional construction (Fadli 1995,74; Shekede 2000,169). Chiari (2000) stresses that the scientific investigation of craftsmanship and traditional skills involved in the manufacturing of building materials is complementary to simplified experimental analysis, while Torraca argues that "conservation analysts need to consider historic data in carrying out their daily jobs. They should become, little by little, expert also in the techniques used in that domain ... and should acquire a broad view of culture, including social and political history and the history of technology" (Torraca 1999, 6). An interdisciplinary approach is therefore clearly necessary for this type of research.

The present chapter is divided into three main sections:

(1) section 7.3 deals with the experimental analysis of nine soil samples collected in Campidano. These form a soil atlas whose aim is to provide a reference for the area under examination;

(2) section 7.4 deals with the experimental analysis of 27 samples of lime render collected in Campidano. These are considered as forming an atlas whose aim is to provide a reference for the area under examination;

(3) section 7.5 deals with the experimental analysis of four soil samples and of 12 samples of lime render which were collected in the two case studies. The aim of this section is to study lime and soil as replacement materials in the context of the two case studies.

It should be noted here that the experimental data was not analysed in statistical terms because the population size (in both cases for lime and mud) is too small for statistical analysis.

7.2 The scope of laboratory analysis

Experimental tests were carried out by the author in the Mary Cudworth Laboratory of the Centre for Conservation (at the King's Manor, University of York). During the first year of research primary guidance on the experimental analysis of lime and loam samples was given to the author by John Hurd in the form of practical lectures and demonstrations which took place in the laboratory itself. This guidance was indispensable, and further encouraged more complex experiments based on the main literature on the topic: *Methods for Characterising Adobe Building Materials* (Clifton and Wencil Brown 1978), *International Conservation Course Laboratory Manual* (Teutonico 1985), *Protection de Mur de Terre non Stabilisée, Cas des Enduits en Terre* (Fadli 1995), and *ARC Laboratory Handbook* (Borelli and Urland 1999).

It is impossible to follow a single 'standard' practice for the experimental analysis of soil. This is due partially to the confusion in today's literature (Chiari 1983, 31; Houben and Guillaud 1994, 131; Alva et al 2001, 16) and partially to the fact that sophisticated testing was sometimes not possible due to the limited equipment available in the laboratory of the Centre for Conservation. The issue of lack of standardised methods for soil testing is also recognised by Hartzler (1996, 25) who explains that physical tests such as wetting/drying and freezing/thawing employ modified standards for soil cement. Houben and Guillaud (1994, 133) further explain that: 'At present very few countries have developed standard analyses and tests specifically suited to soil. Use is thus often made of tests originating in other disciplines such as concrete construction materials, road pavements, etc. These standards are not necessarily suited to earth'. This is confirmed by Chiari (1983, 31) who recognises that by comparison with other materials, the discipline of the conservation of mud brick buildings is fairly recent. This may be considered as a reason for the confusion over testing procedures that is still present in today's literature. Moreover, the structural behaviour (resistance to compression, tension and shear) of *làdiri* was not explored for this chapter because the laboratory lacked appropriate instruments.

It should be noted here that in order to allow repeatability, tests have been meticulously described by defining their scopes, by explaining the methods in straight chronological order, and by explaining results and conclusions. Even if the methodology can be found in the standard textbooks on soil analysis, only a brief description is provided, along with the appropriate citation. The lack of relevant previously-published work on Campidano makes the analysis in this chapter all the more important, but also unfortunately means that further comparative study beyond the scope of this thesis is currently impossible. All numerical results have been assembled into data-sheets, charts, and diagrams which can be found in the second volume of the thesis.

7.3 Analysis of *làdiri*

7.3.1 Introduction

The methodology adopted in this study for the analysis of soil samples falls into two categories: soil characterization (section 7.3.4) and physical tests (section 7.3.5). The first is necessary for understanding the nature of soil, whilst the second is useful for assessing the performance and behaviour of soil when subjected to stress tests. Soil characterisation is the basis on which to compare the results of the analyses of samples forming the atlas with those of the case studies. Then a similar comparison will be carried out with the results of the physical tests. The methods with which physical tests were undertaken do not follow standardised criteria, but a more simplified one. However, keeping the tests as simple as possible was justified by the fact that the results will be analysed through internal comparative criteria.

6.3.2 Selection of samples

The *làdiri* samples selected for this study can be subdivided into three categories:

(1) Nine samples were collected by the author from eight different villages of Campidano. Sampling was carried out by choosing typical, extreme, and marginal cases (a definition of 'typical', 'extreme' and 'marginal' is given in section 1.4.5 of Chapter 1): Gonnesa 3 (marginal), Samassi 8 (typical), Samassi A2 (typical), Serramanna 2 (typical), Serrenti 2 (extreme), Sinnai 3 (typical), Uras 3 (typical), Villamassargia 4 (extreme), and Villasor 2 (typical). In the context of this study the author will refer to the totality of these samples as 'atlas';

(2) two samples taken from the case study located in Serramanna: Case Study A3 (historic *làdiri*), and Case Study A4 (new *làdiri*);

(3) two samples taken from the case study located in Quartu Sant'Elena: Case Study B5 (historic *làdiri*), and Case Study B6 (new *làdiri*).

The atlas samples were selected so as to date from between 1900 and 1960, to ensure a reasonable geographical distribution, and finally to be representative of the region under examination (Fig. 1.17). In this respect they were conceptualised as forming an ideal atlas whose intention is to be used as a reference. This classification will be particularly useful when comparing the case study samples, of both old and new *làdiri*. The presentation of the data and their discussion will be therefore carried out into two distinct sections. The present section will show any correlations or exceptions amongst results of the atlas samples. The second section (7.5.1) will show how the results of the two case studies compare or contrast with the results of the atlas samples. The latter section will also show any theoretical or practical implications.

It should here be noted that the feasibility of sample-taking influenced the collection. Obtaining the material was a complicated task, especially when this intention was explained to building users. It is therefore probable that collection could have been simplified if unoccupied buildings had also been included. All specimens were collected in accordance with the guidelines explained by the literature (Clifton and Wencil Brown 1978, 2; Teutonico 1985, 53). A sample mass between 200 and 300 grams was considered to be adequate. Storage was carried out immediately in air-tight sample bags and labelled with name of the village, address, and orientation of the building. A small amount of destruction caused to the wall fabric during the sampling procedure was inevitable but acceptable (Garrison 1990, 7; Shekede 2000, 171).

Collection was always done at a height of 1.2 metres from ground level, often corresponding to 20-30 cm from the top of the stone plinth. The sampling procedure was undertaken in such a fashion that experiments were reproducible and therefore comparable. It may be necessary in the near future to reproduce a certain amount of experiments with samples collected from the same sites. In this case, the village and the address provided on every data sheet (page 445) will provide the necessary information to locate the original sample location. Further information is given about the height from ground level, whilst the samples were always collected in the middle portion of the wall (if not otherwise stated).

The content of straw in the samples is an aspect which deserves some particular attention. Several samples show some presence of straw, but others do not. It is possible that straw in some cases was not employed in the mix. But it is also likely that, because samples were scraped off the wall surface, a lack of straw is probably due to penetration of water on the surface with consequential decomposition of the fibres.

7.3.3 Soil evaluation through empirical tests

Several authors (Norton 1986, 10; Houben and Guillaud 1994, 48; Warren 1999, 99; Minke 2000, 22) and practitioners (John Hurd and Rob Ley, pers. comm.) recognise the importance of on-site empirical tests before any sophisticated analysis is conducted in the laboratory. It is claimed that field testing can often be considered to be an efficient tool, especially if carried out by expert craftsmen, for selecting and evaluating the right soil to use in repair.

When approaching a building in need of repair, the first thing to be accomplished before undertaking any work is a visual analysis in order to understand its fabric. Buildings are all different because of their peculiar construction techniques and therefore no building construction should be considered as a standard artifact. The colour of mud, its particle size, and its content and type of straw should be evaluated by sight.

The next stage is the assessment of building materials by feel (Warren 1999, 99). Samples ought to be taken from various parts of the building, as they could vary. Crushing the sample helps to determine the texture, to assess the amount of straw, its particle size, and the colour.

Wet analysis should then be employed. The sample is dampened and rubbed with both hands in order to understand the clay content: soil with a high clay content is smooth, whilst a gravelly soil is coarse. The sample is then soaked overnight so that it can be reworked and assessed the next day. In so doing, one should have a fair idea of what soil to use for repairing the building under examination. Locating the right subsoil for repair work can be simplified when neighbours and traditional craftsmen are involved, but as a general rule the topsoil should be avoided, whilst a good mix of clayey loam can be usually found fairly close to the surface.

After the soil has been found, its particle size is observed when dry, then it is soaked overnight and re-assessed. Straw and necessary sand are added and mixed to the loam. Some buildings are characterised by a small amount of straw in the mix and this depends on the characteristics of the available material. Clayey soil for instance can have its risk of shrinkage reduced by adding sand and straw to it.

A sample of only three tests to be reviewed here are:

Tap test: a lump is put in the hands, and is then tapped four times in order to check its brightness. If the moisture comes through the surface after four taps, then means the sand content is too high. If the moisture comes out after 15 taps, it means it is a good loam for building.

Ribbon test: a loam sausage is made into a thin ribbon which is hanged from one extremity. If the ribbon breaks after four inches, this means its clay content is too high. But if it breaks before four inches, this also means it is a good loam for building.

Chew test: a small sample is rubbed in the teeth in order to feel how smooth the loam is, together with its sand content. This test is also useful for having an idea about the granulometry of the soil. If the sample lacks intermediate material between gravel and clay for instance, the mouth (being such a sensitive tool) will be able to investigate this. These and other simple tests were carried out by the author on only a few samples. However, it was felt that laboratory tests would have been more satisfactory for the aim of this thesis.

7.3.4 Soil characterisation

The scope of the soil characterisation test is to provide a preliminary study before physical tests are carried out, thus allowing the identification of soils. All nine samples forming the atlas were characterised through the following criteria: colour, pH, particle size and size distribution, acid-soluble carbonate content, and the Atterberg limits (liquid limit, plastic limit, and plasticity index).

SOIL COLOUR

Introduction

The aim of this investigation is the determination of the colour of air-dried soil samples.

Materials and methods

Soil colour was measured by comparing the colour of the dry samples with the revised edition of the *Munsell® Soil Colour Chart* (Anon. 2000) under north light, late morning. This standard measurement system defines soil colour in function of three dimensions: hue, value, and chroma. The chart explains that 'The hue notation of a colour indicates its relation to red, yellow, green, blue, and purple; the value notation indicates its lightness; and the chroma notation indicates its strength (or departure from a neutral of the same lightness)' (Anon. 2000, 1). Following this method, samples were classified according to their colour characteristics.

The description of particles with a diameter larger than 90 microns was carried out with the help of a MEIJI stereo microscope under reflected light source. Particles were described in terms of their colour, size, and shape (Tables 7.1 and 7.2). The latter characteristic was studied after comparing the grains shapes with the chart described in the volume *Atlas of Sedimentary Rocks Under the Microscope* (Adams 1984, 3). A brief description of the organic material was also carried out as part of this visual assessment, chopped straw often being the only present fibre.

Results and discussion

The descriptions on Table 7.1 show that all atlas samples are characterised by the notation YR which stands for yellow-red, and by the preceding numerical range (value notation) 10. The latter value shows that samples are characterised by an absolute white value. The only element which was found to be different in several samples was the value/chroma notation. Samples were found to have a value notation varying between six and four and by a chroma notation varying between four and two. This particular combination of notations can be visualised as the central area of the 10YR sheet of the *Munsell® Soil Colour Chart.* This even distribution of colours denotes a strong homogeneity of the analysed samples, and possibly of the area under examination.

To conclude, the main finding of this investigation was: the determination of the soil colour is an important area of information, especially for comparing the historic mud bricks with those used for replacement. This will be particualrly significant and useful in the context of the case studies (section 7.5.1).

MEASUREMENT OF pH

Introduction

The aim of this experiment is the determination of the pH level of soil samples in their wet state. Silver (1987, 71) explains that research on the relationship between the pH level and the behaviour of soil as a building material is not yet complete, but it is certain that durability is affected by it. Some scholars have argued that another aspect in need of quantified study is the influence of salts on the pH and on the colloidal properties of soils (Alva et al 2001, 17). In addition to this, some discussion on wet clays is given by Clifton and Wencil Brown who point out that 'the behaviour of clay particles when wet is largely controlled by the exchangeable cations of the clay and the pH of the clay- water system. For example, a low pH promotes flocculation of the clay particles from suspension, while a high pH can lead to the formation of a stable suspension or dispersion of clay particles' (Clifton and Wencil Brown 1978, 10). As a conclusion, in both cases the important resulting characteristic seems to be the weakening of the strength of the material.

Materials and methods

The pH of soil samples was measured through the procedure outlined by Clifton and Wencil Brown (1978, 10-11). The soil was sieved with the 0.42 mm sieve and a sample of 20 gr of passing material was oven-dried at 100°C for 24 hours. Then after weighing, the sample was added to 40 ml of distilled water and mixed with a glass rod. After one hour of standing, a pH metre was used to take readings. The pH metre used for this test was a pocket-sized instrument (pHep®3) ranging from 0.0 to 14.0 pH, with a resolution of 0.1 pH, and an accuracy of ±0.1 pH.

Results and discussion

Mori (1972, 50) explains that Campidano's soils can have an acid reaction if originating from the decomposition of granite, trachyte or schist, a neutral reaction if deriving from basalt, and a slightly alkaline reaction if deriving from calcareous rocks. Acid soils (the majority of Campidano's soils) do not absorb water easily, and this is important in conservation terms. Aru (1989) defines pH according to the reaction of soils:

- basic ($pH<5.6$);
- mildly acid ($5.6<pH<6.5$);
- neutral ($6.6<pH<7.3$);
- mildly alkaline ($7.4<pH<7.8$);
- alkaline ($pH>7.8$).

The comparison of this classification with the data on Table 7.3 shows that the average pH value of the nine atlas samples is neutral. The trend shown here is that three out of nine samples have mildly acid reaction, one out of nine has mildly alkaline reaction, and five out of nine have neutral reaction. It can therefore be speculated that the influence of the calculated pH levels on the decay of earthen buildings is generally speaking minimal, at least within the range of the considered population (the influence of pH on the decay of soil was debated also in section 4.2 of Chapter 4).

To conclude, the main finding of this experiment was: the pH does not seem to influence negatively the overall performance of the atlas samples. The study of pH will be particularly significant and useful in the case studies context (section 7.5.1).

SOIL PARTICLE SIZE AND SIZE DISTRIBUTION

Introduction

The scope of this test is the calculation of the range of particle sizes of the samples, together with the determination of their particle size distribution curve. These are important tools for the conservation of earthen structures. In fact when a particle size distribution curve is continuous from the gravel range to the clays fractions, it reveals that the soil is well graded as the spaces between larger particles are filled by smaller ones. In so doing, particles are in contact with one another and therefore the void ratio is reduced. This characteristic impacts both soil durability (Clifton and Wencil Brown 1978, 12; Chiari 2000, 110), and mechanical strength (Houben and Guillaud 1994, 80).
It is important at this stage to give a definition of the four main components of soils:
- gravel: particles larger than 2000 microns;
- sand: particles varying from 2000 to 20 microns;
- silt: particles varying from 2 to 20 microns;
- clay: particles smaller than 2 microns.

This particle size definition is universally accepted by the literature (ASTM 1979; Teutonico 1985, 52). A more complete definition of the latter two components is given in the glossary.

Materials and methods

The method used for the determination of the particle size distribution can be divided into two separate parts: sieving for the coarser material (gravel and sand), and sedimentometry for the fines (silt and clay). The method is universally accepted by several textbooks on soil analysis (Teutonico 1985, 52-74; Houben and Guillaud 1994, 54; Minke 2000, 21).

In order to avoid clay flocculation, a 4% distilled water solution of a dispersing agent known as Calgon (sodium hexametaphosphate) was used. Samples were soaked in this solution and wet-sieved through a 75 microns sieve. In so doing, the retained material was oven-dried and sieved with an Octagon Digital mechanical sieve shaker, for a set time of 20 minutes, with amplitude 3. The stack of sieves employed for this experiment was (in microns): 2000, 1180, 600, 300, 150, and 90. The fraction which passed the wet-sieving was put in a 1000 ml glass cylinder, and agitated. Thermometer and hydrometer readings were then taken at elapsed times. The conversion of the sedimentation readings was carried out with the following constant values: unit weight of soil solids = Gs = 2.70 g/cm^3, correction factor (a) = 0.99, dispersing agent correction = zero correction = +3.0. With these values, the formula for the percent finer became: %finer = 99 (Ra-3+Ct)/Wsoil.

Results and discussion

The first relevant finding of this analysis is given in the datasheets (page 446). From these, the average percent values for the nine samples composing the atlas were calculated: gravel 7%, sand 58.5%, silt 15%, and clay 19.5%. The comparison of these ideal proportions with those read in the literature shows that they fit perfectly within the proportions provided by:

(1) Clifton and Wencil Brown (1978, 12) who explains that 'A good adobe will consist of between 60 and 80 percent sand, 20 to 40 percent silt and clay, with little or no gravel present';

(2) Norton (1986, 12) who points out that 'A typical soil suitable for use in mud bricks could have the following proportions: sand 40-75%, silt 10-30% and clay 15-30%'.

Chiari (2000, 109) proposed that: '...the amount of "true clay" in earth material is much less than we presently suspect, and that the best soils for construction are those that contain hardly any clay (clay by mineralogical definition)'. In fact, a more complete calculation of the percent content of pure clay can be accomplished by means of the Rietvelt method (Chiari 2000, 109), but this is neither within the scope of this study nor within the capabilities of the laboratory of the Centre for Conservation.

Another important finding was identified by classifying the soil samples according to the fraction prevailing in their composition (gravel, sand, silt, or clay). Chart 7.1 shows that in all cases the prevailing fraction was found to be sand. This was due either to similarities in the pedological characteristics of the different tested areas of Campidano, or to the fact that craftsmen traditionally selected sand-prevailing loams for building purposes. Furthermore, the conjecture that sand was traditionally added to the mix during the manufacturing process of *làdiri* was not confirmed during the interviews with traditional craftsmen. It seems that *làdiri* moulders employed the locally available soil as dug, to which vegetal fibres only were added. This high content of sand reveals that when the *làdiri* bricks are damp, the cohesiveness of the binder (clays) might be quickly reduced because of the low percentage of clays. Sand and gravel might tend to settle down and therefore to disrupt the matrix (Clifton and Wencil Brown 1978, 18). Moreover, the high content of sand also shows that water erosion was generally facilitated because of the small percentage of binding agents and this was also directly observed by the author on several buildings of Campidano.

The third major finding derives from the study of the granulometry curves of the nine samples forming the atlas. An effective methodology for the study of the grain size distribution curves of a population of soil samples is provided by Fadli (1995, 29-32) and is adopted here in this study. It consists in the grouping of all curves of the atlas in order to create an S-shaped *hysteresis* (Fig 7.1). This is the term that the author will tend to use when referring to the area delimited by two S-shaped curves. The two curves deriving from the perimeter of the hysteresis are defined by Fadli (1995, 29) as: *minimum curve*, or the entirety of the recorded minimum values; and *maximum curve*, or the entirety of the recorded maximum values (Fig. 7.2). The average of the entirety of values is defined as the *ideal curve*. As Fadli (1995, 31) explains further, the hysteresis under consideration, being asymmetric, can be corrected in order to allow the same of variation from both sides of the ideal curve. Another hysteresis, called *theoretical hysteresis*, as the zone with a high concentration of curves (Fig. 7.3), of which the average curve is the ideal one (Fadli 1995, 31). The representation of the theoretical hysteresis was undertaken after calculating the following divergence values for every grain diameter:

D max = %max - %med

D min = %med - %min

D = inf (D max; D min)

The correction of the minimum and maximum values is then carried out through the following formulas:

% max limit = D + %med

% min limit = %med - D

These values are plotted in the semilogarithmic graph in the shape of two symmetric curves which delimit the theoretical hysteresis (Fig. 7.3). Fadli (1995, 32) explains that the two new curves represent the limit values of the theoretical hysteresis. They demarcate an area that can be considered as a grading reference zone. The employment of this guidance zone is of great use especially for comparing the granulometry curves of the samples belonging to the atlas and also of those of the case studies (section 7.5.2). It should here be noted that the recommended zone, being the product of the analysis of a limited number of nine samples, is approximate and not rigid. It is in fact possible that soils which do not behave within the parameters of the zone are actually satisfactory in practice. The usefulness of a recommended zone derives from the fact that those soils which comply with it are more likely to behave satisfactorily than those which do not (Houben and Guillaud 1994, 127). The area on Fig. 7.3 has the limitation of being the result of the study of a limited population size. A more representative population size should be investigated in future research in order to allow a more precise plotting of the recommended zone for the specific area of Campidano.

To conclude, the main findings of this investigation were:

(1) the ideal proportions between gravel, sand, silt and clay were calculated for the nine atlas samples. This gave an indication about the average values for the area under examination, and of the fact that all samples had a sand-prevailing composition;

(2) the ideal recommended zone for the grain size distribution of the atlas samples was calculated. This will be an especially useful tool for future reference when comparing the granulometry curves of the case studies with the recommended zone (section 7.5.2).

DETERMINATION OF CARBONATES CONTENT

<u>Introduction</u>

The aim of this test is the determination of the percentage of carbonates (limestone and chalk) in the mineralogical composition of soils. It has been proposed that natural-occurring calcite can act as a cementing agent if present in a particle size close to that of clays, whilst its behaviour is more similar to that of aggregate if found in a particle size between sand and gravel (Hartzler 1996, 22). The reason for not separately dissolving clays and the totality of silt+sand+gravel in hydrochloric acid was due to the difficulty in isolating clays from the other three components. Research on the exact mechanisms by which carbonates act as 'natural stabilizing agents' and by which they contribute to stabilisation has not yet been carried out (Alva et al 2001, 4).

<u>Materials and methods</u>

The carbonates (limestone and chalk) content of soil was determined by crushing the samples, followed by oven-drying, weighing and dissolving into a 50% solution of hydrochloric acid. After complete dissolution was accomplished, samples were filtered, oven-dried at 100°C for 24 hours and weighed with a 0.1 gr sensitive balance.

<u>Results and discussion</u>

The results on Table 7.5 show the percentage of carbonates in each soil. Furthermore, carbonates were found in 88.9% of the tested samples. The conjecture is that the predominant acid-soluble element of the tested samples is calcium carbonate, but this is not supported by experimental analysis.

To conclude, the main finding of this test was: a certain degree of cementation in the selected mud bricks may be due to the carbonate content, but a quantification in terms of strength was not carried out.

PLASTIC LIMIT, LIQUID LIMIT, AND PLASTICITY INDEX (ATTERBERG LIMITS)

Introduction

The aim of these tests is the determination of the *rheological* behaviour of soils in their wet state. Experience shows that different soils behave differently despite having the same water content (Clifton and Wencil Brown 1978, 19), and this is usually due to their specific mineralogical composition. In this framework, the Atterberg limits are considered as essential tools for the determination of the rheological behaviour of soil (definitions of the plastic limit, liquid limit and of the plasticity index are given in the glossary). Most importantly, the determination of the Atterberg limits has a direct applicability to conservation. Crosby (1987, 35) explains that 'The effects of free moisture which result in a failure can probably be simply stated as the reduction of frictional quality of soil particles that resist movement of one particle in relationship to another. This occurs when the space between clay wafers is increased as moisture gains access.' Such a phenomenon characteristically takes place when the liquid limit of the soil is reached. In addition to this, some scholars (Chen 1985, 492; Burt 1995, 13) argue that the moisture content of mud brick walls can increase until complete saturation and, if the liquid limit is reached, dilapidation and further serious damage can result. The plasticity index gives useful indications about the behaviour of wet soils and these characteristics can be qualified through the diagrammes of the Atterberg limits (Houben and Guillaud 1994, 59).

Materials and methods

Before both experiments were carried out, samples were crushed with a rubble pestle, dried in the oven for twenty-four hours at 100°C, and then passed through a 0.42 mm sieve. A hand-operated Casagrande apparatus and grooving tool were employed for the determination of the liquid limit. The calculation of the Atterberg limits is a standard procedure which can be found in several textbooks on soil analysis. The method used for the calculation of the liquid limit and of the plastic limit follows that outlined by Teutonico (1985, 75-88).

The Atterberg limits provide important information about the loam's behaviour. For instance, the activity coefficient (Ca) gives an idea about the swelling and shrinkage of a soil. It is the ratio between the plasticity index (Ip) and the percentage of grains smaller than 2 microns (clay). The formula employed in this study is: Ca = Ip/%clays. Following this procedure, the soil samples can be classified according to their degree of activity:

- inactive (Ca<0.75);
- medium activity (0.75<Ca<1.25);
- active (1.25<Ca<2);
- very active (Ca>2).

The limits can also be useful for characterising the cohesivity and the expansion of a soil which are both relevant to predicting the loam's behaviour before it is used in the building. Another application of the determination of the Atterberg limits is explained by Hughes: 'The density of the soil determines its dry compressive strength, permeability and durability. The density that can be achieved is a product of the soil's physical and index properties (Atterberg limits) and also the soil moisture related to the available compactive effort' (Hughes 1987, 60).

Results and discussion

Table 7.9 shows that none of the atlas samples were 'active' or 'very active'. The results provided on the same table also suggest that whilst all atlas samples are characterised by a low expansion and by no activity, their cohesion varies. It should be noted here that all non-cohesive samples are well within the reference zone (Fig. 7.5 and 7.6), whilst sample Villamassargia 4 is partly outside the hysteresis (Fig. 7.7), which probably explains its slight cohesion. The same figure shows that Samassi A2 seems to be very close to the border of the recommended area.

To conclude, the main category of results of these tests were:

(1) the strength of soils - the lighter the index, the higher the clay content and the stronger the soils (Clifton and Wencil Brown 1978, 20);

(2) the definition of soils in terms of their activity, cohesion, and expansion;

(3) the behaviour of soils in their wet (expansion) or dry (shrinkage) state (Clifton and Wencil Brown 1978, 26).

7.3.5 Physical tests

The scope of the physical tests is the study of the behaviour of soil samples when subjected to severe conditions of stress. The tests explained in this section were conducted in order to submit the samples to standardized criteria when possible. The analysis of experiments was studied following the self-referring system explained by Fadli (1995) with the intention of submitting the samples to as minimum a number of tests as possible. It should be noted here that the freeze-thaw test was not carried out because the annual temperature rarely falls below zero in Campidano.

PREPARATION OF LADIRI *SAMPLES*

Soil prisms (Fig. 7.10) were manufactured in order to test their behaviour against erosion, abrasion, shrinkage, and wetting and drying. They were cast from a timber mould (measuring 5x5x2 cm) and subjected to physical tests. The choice of these dimensions was dictated by the amount of available soil. The dry soil was passed through the one- centimetre sieve in order to avoid erosion caused by larger pebbles (Fadli 1995, 47). Because different soils show different workability when mixed with the same amount of water, and because different samples show a different optimum water content for maximum performance (Clifton 1977, 4), the mix for moulding the specimens was carried out by adding the amount of water necessary to reach a state between the plastic limit and liquid limit of every soil sample. Some samples attained their workability when their plastic limit was reached, whilst some others needed more water. As a consequence of this, the workability of soil was defined as the level of water that would allow the mix to be packed in the corners and edges of the mould with the help of a spatula (Hartzler 1996, 28). After the soil was worked into the edges and corners, the mould was filled in with more material and the top surface was smoothed by means of wet fingers. The mould was lubricated with oil in order to allow easy removal of the samples. Then specimens were put to dry at room temperature on evaporating dishes, and turned on their sides after one day. Samples dried in laboratory room conditions, which was calculated to be a temperature of 17°C and 39% relative humidity. Weighing was carried out daily and it was concluded that tests could be started only after a minimum of seven days of air-drying. It was demonstrated that after this drying period specimens did not in fact show any weight change. This again was important as the moisture content was considered as a constant of the tests.

EROSION TEST (DROP TEST)

Introduction

The aim of the erosion test, also known as drop test or perforation test, is the understanding of the behaviour of soil prisms when submitted to physical abrasion and fluid erosion, both occurring naturally due to heavy rain water. Erosion is intended in this study as the result of an accumulation of mechanical energy which is directly proportional to the intensity and height of drops (Didier and Ghomari 1990, 397).

Materials and methods

The aim of the experimental design is to create a controlled artificial rain with the aim of eliminating two main variables: intensity of drops and height of source of drops. This type of weathering simulation is an important test in conservation terms because it gives an indication of the behaviour of mud bricks when exposed to the repeated impact of drops of rain. However, the ideal system which simulates rain is certainly more aggressive than the naturally occurring causes of erosion. The method followed here is similar to what explained by Fadli (1995, 47). It does not need a sophisticated apparatus, but it was found to be an effective method for the testing of soil prisms. It should be noted here that the experiment was designed to force the drop to impact perpendicularly the horizontal surface of the sample. The author is aware that this is not a realistic situation in *làdiri* buildings because their horizontal earthen surfaces are traditionally protected by overhanging eaves or by other architectural elements. The method used in this experiment is therefore an idealised system. Cubes were put to rest on a timber railing following the scheme explained on Fig 7.11. A key burette with a straight stopcock was used to produce one drop of distilled water per second. This simulated rain was dropped from a height of one metre from the smooth surface of the samples. The depth of the cavity was measured at elapsed times (Table 7.10) so that the diagramme of the velocity of perforation could be designed (Fig. 7.13). Measuring the diameters of the holes was found to be a complicated task because the cavity was often not well defined, and therefore this data was not recorded. As some samples needed a long period for complete perforation to be accomplished, a maximum of six hours was considered to be an adequate limit to be imposed to the readings. The reason for choosing this limit is due to the experimental design itself. This type of investigation necessitates the continuous presence of the experimenter in the laboratory until complete perforation is achieved, which obviously limits the maximum timespan available.

Results and discussion

The results on Chart 7.3 give an idea of the final perforation time of every sample. Some samples were quickly perforated, whilst others needed more time. Another way of visualising these results is given by the velocity of perforation curves plotted on Fig. 7.13, where the depth of perforation is given in function of the perforation time. In order to draw complete perforation curves, a certain number of readings at elapsed times was taken (Table 7.11). As soil is characterised by particles of different sizes and constitution, and is therefore not an isotropic material, the flat sections derive from the fact that the drops in that time frame might have encountered an obstacle (such as a larger sand particle) during the perforation process.

The schematic results on Table 7.12 show that the perforation time of the atlas samples was variable, but a trend can be found when correlated to the clays content. Correlation was carried out in this study by classifying samples according to their perforation time in numerical order and by checking that the same order is followed by the percent values of the clay content. Exceptions in the numerical order of the clay content column were those with a tolerance greater than 10% (this value was arbitrarily chosen). Seven out of nine of the atlas samples feature a perforation time directly proportional to the clay content. The two exceptions to this were:

- Samassi A2: good resistance to water erosion probably due to its extremely high clay content (not cohesive);
- Sinnai 3: comparatively poor resistance to water erosion even if clay content is not too low (not cohesive).

The behaviour of these peculiar samples can be studied further by comparing their granulometry curves with the recommended zone (theoretical hysteresis). This comparison is visualised on Fig. 7.7 which shows that the Samassi A2 sample fits entirely within the recommended zone. This sample is characterised by almost no gravel and by a very high percentage of clay. Fig. 7.6 shows that Sinnai 3 sample fits almost entirely within the recommended zone. This sample is characterised by a good mix of gravel, sand, silt and clay. It is also visible from Table 7.12 that the amount of straw does not seem to be a relative factor in the durability of the samples subjected to the drop test. Samples were also classified according to their complete perforation time (Table 7.10):

- very slow (>180 min);
- slow (90-180 min);
- medium (45-90 min);
- fast (15-45 min);
- very fast (0-15 min).

This classification will be particularly useful in section 7.3.6 where comments will be made on the overall performance of the atlas samples.

To conclude, the main finding of this test was: the perforation speed of soil prisms is for 78% of the cases directly proportional to the amount of clay in their mix.

WETTING AND DRYING TEST

Introduction

The scope of this test is the determination of the behaviour of soil prisms when subjected to wetting and drying cycles. The experimental design is again a more aggressive simulation than the naturally-occurring causes of weathering of mud bricks. In this respect this type of test is not a precise repetition of the field conditions of earthen buildings where the process occurs more slowly (Hartzler 1996, 39). Crosby explains that wetting and drying cycles

> *'...have been recognised as an important factor in adobe as well as in stone deterioration. The same mechanisms are at work in mud brick, but probably to a much greater extent. This is probably true of mud bricks that have a significant amount of expansive clays. The results of the wetting and drying actions are most dramatic during drying conditions when the most significant amounts of surface material becomes friable and falls from the walls at the slightest touch. The actual stresses resulting from wetting and drying cycles, as well as other internal forces, are certainly more obvious on the exposed surface of the mud brick material. For most practical purposes, when not in the presence of excessive moisture, the deterioration caused by such factors as wetting and drying cycles are limited to the surface or to the material near the surface'*
> (Crosby 1987, 38)

Materials and methods

In order to facilitate their manipulation, samples were positioned horizontally onto a stone slab. Then they were totally immersed in ambient-temperature tap water for thirty minutes, after which they were dried for 24 hours in the oven at 50°C. After drying, samples were removed from the slab and weighed. Comments on their decay condition were also recorded. This completed one cycle of the test. For these samples the problem was at first what to consider as prism and what to consider as loss material. The method used here consisted in considering as prism the material included in the 5x5 cm perimeter. The calculation of the data was carried out in the following way: after the failed prism was dry-weighed, the resulting figure was subtracted from that of the dry weight of the prism before the cycle of wetting and drying was started. The resulting number was the weight loss of the soil prisms after the first cycle.

It was decided that because some samples nearly failed completely, the test would be interrupted after the first cycle. As this was such an aggressive test, further repetition would have only caused further and unquantifiable disintegration of the samples. The employment of several cycles is a standard procedure for the testing of more durable earthen material such as that stabilised with cement, acrylic, or lime. In the case of unstabilised soil samples the continuation of the test to more cycles is not easily applicable. Another reason for not undertaking more cycles is related to the comparative nature of the methodology employed in this chapter. It was felt that useful data would be secured anyway if the samples underwent just one single cycle.

Results and discussion

The results of the wetting and drying test are gathered together on Table 7.14 where information on the presence of cracks, contour scaling, and of flaking is also given. Prior to the description of the extent of the decay, it is important to define some parameters:
- very large failure, with weight loss from 100% to 80% (no samples);
- large failure, with weight loss from 80% to 60% (no samples);
- medium failure, with weight loss from 60% to 40% (Serramanna 2);
- slight failure, with weight loss from 40% to 20% (Samassi 8, Sinnai 3, and Villasor 2).
- very slight failure, with weight loss from 20% to 0% (Gonnesa 3, Samassi A2, Serrenti 2, Uras 3, and Villamassargia 4).

This classification of the samples according to their weight loss is a reliable method for measuring their performance and the percent expression is the only means of comparing the results. The employment of the above classification shows that five samples out of nine are characterised by a very slight failure. Table 7.16 shows that six of the nine atlas samples are characterised by a weight loss which is directly proportional to the clay content. This calculation was carried out similarly to what was done for the erosion test (10% tolerance). The three samples which do not respect the tolerance of 10% are: Gonnesa 3, Uras 3, and Villasor 2. Of all three, only the latter granulometry curve does not fit entirely in the recommended zone. The above classification will be particularly useful in section 7.3.6 where comments will be made on the overall performance of the nine atlas samples.

To conclude, the main finding of this test was: the decay of soil prisms subjected to one wetting and drying cycle is for the majority of cases inversely proportional to the amount of clay in their mix.

SHRINKAGE TEST

Introduction

The aim of this test is to study the behaviour of loam samples to shrinkage. This has important implications for conservation and will be especially useful with reference to the case studies samples.

Materials and methods

Shrinkage was calculated by employing the same moulds used for the making of the test prisms. The amount of water added to the soil was that which was necessary to reach a state between the plastic limit and the liquid limit of every soil sample, similarly to what was explained for the preparation of soil prisms. The calculated shrinkage was neither linear nor volumetric, but superficial, and the formula used for its determination was $(S_1\text{-}S_2)\text{x}100/S_1$, where S_1 is the area of the mould (25 square centimetres) and S_2 is the area of the shrunk sample. It should be noted here that this method is not a standard procedure and that its use was dictated by the limited amount of available soil.

Results and discussion

The results collected on Table 7.18 give a clear idea that the shrinkage of seven of the nine atlas samples is directly proportional to the clay content. This calculation was carried out similarly to what was done for the erosion test (10% tolerance). The only two samples which do not follow this trend are: Villasor 2 and Serramanna 2. In both cases the granulometry curves do not perfectly fit within the recommended zone (Figs. 7.6 and 7.5).

Samples displayed great variation to shrinkage test and were also classified (Table 7.24) according to the following system:

- very low (0-3 %);
- low (3-6 %);
- medium (6-9 %);
- high (9-12 %);
- very high (>12 %).

The above classification will be particularly useful in section 7.3.6 where comments will be made on the overall performance of the nine atlas samples.

To conclude, the main finding of this test was: the shrinkage of soil prisms is for the majority of cases directly proportional to the amount of clay in their mix.

ABRASION TEST

Introduction

The aim of this test is the study of the behaviour of soil prisms to mechanical abrasion and 'wear and tear'. Abrasion is an important issue in conservation terms as it can be caused by a combination of wind and sand, by animals stroking themselves on the bare wall, or it can also be accidentally man-made.

Materials and methods

The device used for this test consisted of a pallet weighing one kilogram and characterised by two retaining strips with the function of avoiding sliding of the sample (Fig. 7.17). General purpose sand paper with the following characteristics was employed: coarse, grade S2, dimension of strips 28x8 cm. Abrasion was conducted on the smooth face of the sample (top face), and one new sheet of sandpaper was used for every sample.

A single back and forth motion constituted one cycle, and twenty-five cycles for every sample were felt to be representative of the mechanical abrasion test. In order to accomplish results that are independent of the shape and the size of the sample, the dry weight of abraded material was recorded per square centimetre of the abraded area (Houben and Guillaud 1994, 135). The formula used for this calculation is: coefficient of abrasion = (weight of abraded material)/(abraded area). The coefficient of abrasion was calculated for every sample and expressed in gr/cm^2.

Results and discussion

The results on Table 7.22 demonstrate that five out of nine atlas samples have a coefficient of abrasion which is inversely proportional to the clay content. This calcuation was carried out using a similar procedure as for the erosion test (10% tolerance). The four exceptions to this finding were: Sinnai 3, Samassi A2, Serrenti 2, and Uras 3. The peculiar behaviour of these samples can be explained further by comparing their granulometry curves with the recommended zone for the atlas samples. This comparison is visualised on Figs 7.5, 7.6, and 7.7 which show that samples Samassi A2, Serrenti 2, and Uras 3 are all well within the recommended zone, whilst the grain size distribution curve of Sinnai 3 is entirely outside the zone in proximity of the sand grain size distribution. Samples were also classified (Table 7.24) according to their coefficient of abrasion:

- very low (0-0.2 gr/cm^2);
- low (0.2-0.4 gr/cm^2);
- medium (0.4-0.6 gr/cm^2);
- high (0.6-0.8 gr/cm^2);
- very high (>0.8 gr/cm^2).

The above classification will be particularly useful in section 7.3.6 and 7.5.1.

To conclude, the main finding of this test was: the coefficient of abrasion of soil prisms is for the majority of cases inversely proportional to the amount of clay in their mix.

7.3.6 Conclusions from the analysis of the atlas of *làdiri* samples

Table 7.24 contains a summary of all the results of the physical tests undertaken on soil prisms. The samples are classified according to their test performances. The table shows that the best performing sample appears to be Serrenti 2, whilst the worse performing one seems to be Serramanna 2. In order to simplify the interpretation of the results for the atlas samples, a further summation of the figures on Table 7.24 is necessary:

(1) the samples that are resistant to physical tests are those between one and five: Serrenti 2, Uras 3, Villamassargia 4, Gonnesa 3, and Samassi A2 (Table 7.24). All granulometry curves of this category of samples are well included inside the recommended zone, with the exception of that of Villamassargia 4. Sample Uras 3 is an exception of sorts, but its curve fits almost entirely in the recommended zone (Fig. 7.6);

(2) the samples that are less resistant to physical tests are those between six and ten: Villasor 2, Samassi 8, Sinnai 3, and Serramanna 2 (Table 7.24). All granulometry curves of the second category of samples are partially not included inside the recommended zone, with the only exception of that of Samassi 8 which is well inside it (Fig. 7.5).

These were the major conclusions of the physical tests. Furthermore, the study shows that there is a correlation between the behaviour of soil to physical tests and the vicinity of the grain size distribution curve to the ideal curve. This also demonstrates the validity of the recommended zone. These are important conclusions especially with reference to the comparison that will be carried out between the case studies samples and the recommended zone (section 7.5.1).

The comparison of the last column of Table 7.24 (results) with the penultimate column of Table 7.3 (clay content) shows that six out of the nine samples are characterised by a positive behaviour which is directly proportional to the clay content. These samples are: Serrenti 2, Villamassargia 4, Gonnesa 3, Villasor 2, Sinnai 3, and Serramanna 2. These can be identified as the soils with 'normal' behaviour, in other words, those whose behaviour was predicted by their clay content. In contrast, the soils which did not conform to expectations were: Samassi 8, Samassi A2, and Uras 3. Amongst these, Uras 3 was the only sample whose behaviour to physical tests and the proximity of its curve to the ideal one was found to be considerably positive. Two possibilities exist for this: the low amount of clay found in its composition might result from a miscalculation during the sedimentometry analysis or perhaps the type of clay is of such good quality that the performance of the soil benefits from even very small amounts.

To conclude, the design of the recommended zone derived from the experimental analysis of the atlas samples provides a useful comparison and evaluation tool for future reference. This also confirms the usefulness of the methodology which will be particularly valuable and applicable when dealing with the samples taken from sites of the two case studies (section 7.5.1).

7.4 Analysis of lime render

7.4.1 Introduction

The aim of this section is to describe the results of the experimental analysis of interior and exterior lime renders. Lime increased in popularity between 1900 and 1960 and is thus a far better material for study than comparatively uncommon mud. Mud coats were also usually the product of the screening of the same soil employed for mud brick making. It would therefore have been redundant to repeat the tests used for mud brick. Lime is no longer used as a coating material, but is still found in several buildings of Campidano as it is seldom replaced or maintained. This is confirmed by the analysis of the questionnaire (Table 4.10), which shows that 42.7% of the buildings visited were still plastered with lime (historic plaster), 39.9% were plastered with cementitious coats, whilst only 6.6% were plastered with mud (historic plaster).

The analysis of lime renders was taught to the author by John Hurd during a session (10 March 1999) in the laboratory of The King's Manor (Mary Cudworth Laboratory). Further guidance was given by the textbook *International Architectural Conservation Course Laboratory Manual* (Teutonico 1985), which illustrates the same method used by Hurd. The chief aim of the analysis of lime render was the determination of its components: the content of calcium carbonate and of aggregate.

It is important at this stage to define aggregate: in the context of lime renders the author refers to aggregate as the totality of gravel, sand, silt, and clay. In particular, the totality of silt, clay, and eventual organic matter is referred to in this study as 'impurities'.

7.4.2 Selection of samples

The selection of the samples of lime render was carried out with the intention of choosing specimens dating between 1900 and 1960, that were geographically distributed from across Campidano, and which were representative of the region under examination (Fig. 1.17). Lime renders were sampled and classified as follows:

(1) Twenty-seven samples were collected by the author from 16 different villages of Campidano. Sampling was undertaken by choosing typical, extreme, and marginal cases (a definition of 'typical', 'extreme' and 'marginal' is given in section 1.4.5 of Chapter 1). Samples were then classified into four categories forming what the author refers to in this section as the 'atlas':
- internal scratch coats (5 samples);
- internal skim coats (7 samples);
- external scratch coats (5 samples);
- external skim coats (10 samples).

(2) Three lime kilns were also visited and three natural samples of local limestone were also collected.

(3) The collection of samples of lime renders from the case studies was accomplished following this classification:
- Internal skim coat: 1 historic coat and 1 replacement coat (Case Study A);
- External skim coat: 1 historic coat and 1 replacement coat (Case Study A);
- Interior skim coat: 2 historic coats and 1 replacement coat (Case Study B);
- Exterior skim coat: 2 historic coats and 1 replacement coat (Case Study B).
It should be here noted that in both case studies the mixes for the replacement coats were the same for external and internal walls. In addition to this, two samples of fine and coarse sand used for the new lime render mix were also collected in the site of Case Study B for comparison purposes.

Five samples was considered to be the minimum representative for the atlas sub-groups (John Hurd, pers. comm.). Selecting sets of four of such samples (interior skim, interior scratch, exterior scratch, and exterior skim) from one single building was often found to be impractical. Convincing owners to allow the sampling of their interior renders was also a complicated task. The author also found that detecting ideal buildings with both interior and exterior renders made of lime as a binder was a complicated task because hybrid types with inclusions of mud are quite common in Campidano. Furthermore, it is common to find interior and exterior lime renders made of single coats only. As a consequence of this, independent samples were collected. The author found that unoccupied buildings were by and large the easiest target for sampling interior renders, as it would have been otherwise difficult to convince the occupiers to permit the taking of specimens from the inside of their dwellings. A minimum of 100 gr for every coat was collected with the help of a scalpel. The author is aware of the damage caused to buildings during sampling. As a consequence of this, priority was given to loose sections and the collection was carried out without causing further damage to the surrounding fabric. Collection was always tackled at a height of 1.2 metres from ground level, often corresponding to 20-30 cm from the top of the stone plinth. Samples were immediately stored in individual air-tight plastic bags. Labelling was then carried out to indicate the type of coat, the name of the village, the location in the building, the date, weather condition, and orientation. Repeatability of sample collecting is guaranteed if the same procedure explained in section 7.3.2 for *làdiri* is followed.

7.4.3 Analysis

DETERMINATION OF CARBONATES CONTENT AND ANALYSIS OF AGGREGATE

Introduction

This test has a double purpose. The first aim is the calculation of the ratios between carbonate and aggregate; the second is the analysis of the aggregate in terms of its mineralogical composition, and also in terms of its grain size distribution.

Materials and methods

Before the experimental analysis was conducted, detailed documentation on the samples was recorded. This included physical evidence on the number of coats, on their thickness, and on the colour of sand (see datasheets). The number of limewash layers and their colour was analysed by naked eye when possible, otherwise micrographs were taken under incidental light. Scratch coats were detached from skim coats by using a pen knife, then they were weighed and set aside. If limewash layers were also present, they were detached from the skim coat and also set aside as these would have compromised the results. Eventual small amounts of soil produced when detaching samples from the earthen wall was brushed off the sample. After weighing, samples were dried in the oven in order to eliminate moisture. After drying, weighing was again carried out and moisture content calculated by subtraction. A rubber pestle then was used for crushing the lime samples without crushing the sand. The crushed product was put into a cold two-molar solution of hydrochloric acid and left until dissolution of the binder was complete. The chemical reaction for the dissolution of calcium carbonate is: $CaCO_3 + HCl \Rightarrow CO_2 + CaOCl$ (that is: calcium carbonate + hydrochloric acid $\Rightarrow$ carbon dioxide + calcium chloride). The reaction is such that carbon dioxide evaporates, while calcium chloride is a soluble salt. Eventual presence of dolomite (magnesium carbonate, $CaMg(CO_3)_2$) was not calculated because it reacts less readily with cold hydrocloric acid. After dissolution was completed, filter paper (185 mm diameter, qualitative wet-strengthened fast, for coarse precipitates) was used together with a funnel for separating the aggregate from the hydrochloric acid solution. The aggregate was then dried in the oven for 30 minutes, at 100°C. When the aggregate was stuck to the filter paper, detachment was carried out with the help of a metal scraper. Weighing was then carried out and the percentage amount of binder calculated. After weighing, eventual lumps of aggregate were loosened by pressing gently with a rubber pestle. Dry sieving was undertaken with the help of a shaking machine (Octagon Digital type) for 20 minutes, with amplitude three. Sieve stacks used with the shaking machine are (in microns): 2000, 1180, 600, 300, 150, 90, 63 and 20. Every mesh was brushed off from all sand or soil which was found stuck between the laths and the material was collected and weighed. Weighing was conducted with a triple beam balance, to an accuracy of 0.1 grams.

A data sheet was designed by the author in order to keep a systematic recording of the process. The data sheet is composed of three sections: the first gives the physical description and the location of every sample, the second gives the data derived after the dissolution in hydrochloric acid and sieving, and the third section is a diagrammatic version of the particle size distribution. After the retained weights were marked, their correspondent percent values were calculated (percent retained). The percentage passing was obtained with the formula %passing = %arriving - %retained (Teutonico 1985, 56). The percent passing was then translated into a semilogaritmic diagram with grain size in the abscissa and percent finer in the ordinate. The granulometry curve is an essential tool for understanding the grading of the aggregate. It is in fact possible to affirm that to a wide curve corresponds a well-graded aggregate suitable for mortar, whilst to a steep and narrow curve corresponds a poorly-graded sand unsuitable for mortar.

Aggregate was classified into sub-groups (gravel, sand, silt and clay) after particle size was defined, following what specified by ASTM (1979) and by Teutonico (1985, 52), as already seen in the section on soil analysis. This classification allowed the calculation of the percent amount of gravel, sand, and of silt and clay of every sample. The latter two figure as a single unit to which the author refers as 'impurities', this definition being applied only in the context of lime render analysis. In fact, for the purpose of this study it was found unnecessary to separate both silt and clay after dissolution of lime renders.

Once the 27 data sheets were filled in and the diagrams completed, a set of four tables (Tables 7.27, 7.28, 7.29, 7.30) was used to illustrate the percent amount of moisture, calcium carbonate, gravel, sand, and impurities (silt and clay). Average values for the four tables were calculated and this allowed the designing of the percent values of the ratios for every category.

It should be noted here that the dissolution method has two principal limitations. The first is due to the dissolution of eventual calcareous aggregates and to the consequential misleading ratio between lime and aggregate (Ashurst 1983, 20; Teutonico 1985, 93). The second limitation is due to the fact that the apparent grain size analysis does not correspond to the actual one if calcareous aggregate is present in the mix. This is supported by Pearson (1992, 162) who explains that:

> *A sample of the render weighing at least 100 grams may be sent to a laboratory for analysis and report for use as a guide to matching the original. However, analysis will only identify the constituent materials and may be misleading, as aggregates containing chalk or limestone will be included with the lime content to produce figures that indicate a high percentage of binder. The figures are thrown further into confusion if old, crushed mortar has been included in the mix. The analysis will not identify whether the lime was prepared from chalk or limestone or whether it was site-fired in a clamp or factory-made.*
> (Pearson 1992, 162)

A similar observation on the limitations of lime render analysis is also made by Ashurst (1983, 20) who explains that the presence of a misleading binder is a notorious problem. Another limitation, which implies the dissolution of lime renders in hydrochloric acid, is that the binder-to-aggregate ratios were traditionally calculated by *volume*, whilst laboratory experiments were conducted by *weight*.

Vianello (1987, 253) studied a method for the calculation of the carbonatic aggregate by soaking the sample into acetone, thus allowing the separation of the grains from the cementing agent. The matter is then wet-sieved through a 0.063 mm sieve. According to Vianello, the sieving allows the elimination of the finer particles which are considered to be made of only disaggregated binder. The dried aggregate is then sieved through a stack of sieves and its granulometry curve calculated. The method proposed by Vianello proved effective for his research on the historic mortars of the region around Venice (where aggregate was traditionally washed of all impurities), but is not applicable for the specific case of Sardinia (where aggregate was traditionally employed as quarried). In fact the wet-sieved matter would not only contain the disgregated filler, but also the finer impurities such as clay and silt which would definitively influence the granulometry curve and the performance of the filler.

The granulometry curves of aggregates were derived through similar methods to those used for soil in section 7.3.4. Recommended zones were calculated for the four categories of samples: internal scratch coats, internal skim coats, external scratch coats, external skim coats (Figs 7.18-7.29). The methodology was precisely the same as that carried out in section 7.3.4 for soil samples.

Results and discussion

Laboratory analysis of lime renders was found to be extremely valuable, the most important results being the following:

a) Hydraulic properties of lime

The first main finding is related to the use of natural and artificial hydraulic limes in Campidano. Three representative limestone samples of about 200 gr were collected from the vicinity of lime kilns whose use was documented until the 1950s. After dissolution of the stone samples in hydrochloric acid, the average percentage of impurities of the three samples was calculated to be:

(1) 3.3% (sample from shaft kiln located in Via Roma, Nuraminis);

(2) 1.3% (sample from hillside kiln located between Monte Pireddu and Su Benatzu, Santadi);

(3) 3.7% (sample from shaft kiln located in the north outskirts of Aquacadda).

This kind of analysis does not give any certainty about how limestone performed after firing (Wingate 1985, 37), but the figures above are indispensable for classifying the resulting limes as *fat* or *pure*, with *high calcium*, white in colour, with very fast setting, with considerable expansion, and characterised by no setting in water [classification based on Teutonico (1997, 6)]. This small survey has another important outcome. It confirms the Mamuta's conclusion (1933a, 14) that natural hydraulic lime was seldom intentionally produced in the island, but was rather imported from the peninsula. Furthermore, after the analysis of all samples of lime coats, external and internal, only one case showed the presence of artificial pozzolanic aggregate. A mix of sand and crushed roof tiles was found in one sample collected from Gonnesa village. The sample name is Gonnesa 2 (exterior scratch coat) and a micograph of it can be seen in Fig. 7.30. The analysis of the sample gave a percentage proportion of lime:sand:crushed tiles of 25.4:28.4:46.1. This ratio is extremely close to 1:1:2, which is the traditional mix of three parts aggregate and one part lime. This is also confirmed by the comparison of the proportion 1:3 with the average percent value on Table 7.33 (the exact ratio for exterior scratch coats being 1:3.1).

b) Eventual presence of chalk

During the initial stages of the experimental analysis it was assumed that the calcium carbonate contained in lime renders could derive from either limestone and chalk. In order to understand this, some fractions of white limewash layers were analysed with the microscope to identify their structure. Calcium carbonate has an obvious shape because of the nature of its irregular agglomerates, while chalk is harder. After samples were analysed under the microscope, it could therefore be immediately ascertained that the samples under analysis had no gypsum content. This was also cross-checked through reading the geological maps of the area from where samples were collected. It was decided that limewash need not to be analysed chemically, especially when visual analysis showed that its only constituent was pure calcium carbonate. Laboratory research cannot produce the percent proportion between lime and water used in the making of limewash, but it seems likely that it could range from 1:2 (Schofield 1994, 16) to 1:4 (Uvina Contreras 1998, 12). Some authors (Holmes and Wingate 1997, 50) tend to give a more empirical explanation illustrating that water is usually added to lime until consistency of a milk is conferred.

c) Lime renders as a complex porous system

Several important findings from the analysis of lime renders derive from the comparison of Tables 7.27, 7.28, 7.29, and 7.30. Before discussing the results, a definition of 'softness' of lime render is necessary. As a general rule, the softer the render, the higher the amount of sand and gravel and the lower the amount of lime. The simplified formula which explains this is: softness $\propto$ %aggregate / %calcium carbonate. The comparison between Tables 7.27 and 7.28 reveals that interior wall surfaces were rendered with increasing hardness from the interior mud-brick wall face to the inside of the building. This is demonstrated by the fact that interior scratch coats have a lower content of sand and gravel than interior skim coats, whilst their calcium carbonate content is higher than that of skim coats. In comparison between Tables 7.29 and 7.30 demonstrate that exterior lime surfaces were rendered with decreasing hardness from the external mud-brick wall face to the outside of the building. This is demonstrated by the fact that exterior scratch coats have a slightly higher content of sand and gravel than exterior skim coats, whilst their calcium carbonate content is lower than that of skim coats. The main conclusion drawn from this is that the traditional device for the protection of earthen buildings of Campidano seems to have been the use of two exterior coats with increasing softness from inside to outside and of two interior coats with decreasing softness from outside to inside (Fig. 7.51). The theory proposed here is that the peculiarity of such a device is that it allows condensation to migrate outside the wall. Soft surfaces are usually more porous than hard coats and the more porous the render, the higher the managing of moisture through evaporation (Hughes 1986, 1). This is relevant in conservation terms because condensation in proximity of the internal coats can be five times higher than that in proximity of external coats (Massari 1993, 45). It is important to stress here that this experimental finding was confirmed by Master Craftsman Elvio Murgia of Serramanna as already mentioned in section 3.8 of Chapter 3.

It was also calculated that, on average, interior scratch coats double in thickness the skim coats:

- the average thickness for the scratch coat is 1.8 cm;
- the average thickness for the skim coat is 0.91 cm.

Furthermore, exterior lime coats were found to be characterised by the following average thicknesses:

- the average thickness for the scratch coat is 1.24 cm;
- the average thickness for the skim coat is 0.54 cm.

Some samples contained soluble salts, probably due to employment of unwashed sand quarried from local beaches. Salt content analysis was carried out only on a limited number of samples by separating the water in which the sand was left to sediment. The solution of water was then left to evaporate. Salts were found in an average concentration of 1.5%.

d) Mixes for interior and exterior coats

The analysis of lime renders gave further useful information about the average ratios between lime and unwashed aggregate for the four categories (Tables 7.27, 7.28, 7.29, and 7.30): these are used as a reference point, especially when comparing the results of the analysis of the renders of the two case studies (section 7.5.2).

Lime renders are rarely specified in historic documents, but what was unveiled by the author in archival records shows some disagreement. If in Quartu Sant'Elena the volumetric proportions of lime to aggregate for mortars and renders was found to be of 1:2 (ASQ 1868a and ASQ 1900a), in Iglesias it was specified as 1:3 for the mortar and of 1:2.25 for lime render (ASI 1906a). Furthermore, other records shows that the proportion between lime and pozzolanic additive was specified as 1:2.3 (ASQ 1900a). The average ratios for the data read in the archival records of Quartu Sant'Elena and Iglesias is 32%:67.4%. This can be compared to the average ratio of the four categories on Tables 7.27-7.30 which is 26.7%:70.1%. Archival documents did not specify two different ratios for skim and scratch coats, but only a single ratio for both cases. This is the reason why the overall average value for the four cases of Tables 7.27-7.30 was used for comparison here. This slight difference between the average archival ratio and that calculated with the 27 samples analysed by the author can be explained as:

(1) A certain degree of arbitrariness by Master Craftsmen when preparing lime mortar

mixes;

(2) A too-limited number of archival documents which do not properly represent the area under examination;

(3) Disagreement between 'official' records and what was actually carried out in the site;

(4) Disagreement between 'official' records and what was actually carried out by Master Craftsmen in more rural settings than those of Quartu Sant'Elena and Iglesias.

e) Presence of impurities

Another important outcome can be revealed by the analysis of the aggregate obtained after dissolution. It is clear from its analysis that the aggregate was generally mixed to the binder 'as quarried'. Washing all impurities such as clay and silt was not a common practice in traditional Campidano. The reason for this may be due to the fact that aggregate was dug from rivers and streams, and never made from crushed rock. Its nature was therefore low in fines and impurities, and washing was not considered necessary. When referring to impurities, Ellis (2000, 31) explains that 'many of these materials had a positive or beneficial physical and chemical effect on the performance and durability of traditional mortars'. This view is strongly supported by John Hurd (pers. comm.) who explains that unwashed aggregate should be preferred to the washed sharp sand typical of cementitious mortars when making the mix for lime renders. However, this contradicts what was directly observed by the author in modern conservation practices in Sardinia. After the advent of cement, aggregate was agreed to be washed of all impurities with a consequential lack of finer matter in the granulometry curve.

To conclude, the main findings of this test were:

(1) natural hydraulic lime does not seem to have been used in twentieth-century Campidano, whilst it seems evident that artificial hydraulic lime might have had a small degree of popularity;

(2) no chalk was found in the population of analysed renders and this is also confirmed through a cross checking with the geological map of Campidano;

(3) ideal binder/aggregate ratios were calculated for skim and scratch coats of both internal and external surfaces;

(4) the recommended zone for skim and scratch coats of both exterior and interior surfaces were calculated;

(5) lime renders were traditionally applied to both internal and external sides of *làdiri* walls in order to form a complex porous system of coats which allows condensation to be driven off from the interior of the building (Fig. 7.51);

(6) sand was traditionally employed as quarried because impurities were found in the majority of the analysed samples.

VOID RATIO AND OPEN POROSITY TESTS

Introduction

The void ratio analysis reveals the percent of space between the particles of dry aggregate. More specifically, void ratio can be defined as 'the proportion of space between particles in a dry aggregate, and is expressed as a percentage of the aggregate' (Leslie and Gibbons 1999, 15). The aim of this test is to confirm or question the data obtained after the dissolution test. The hypothesis here is that the void ratio of the aggregate obtained through dissolution of the lime render should be very close to the calcium carbonate content of the sample itself. Thus the accuracy of the analysis of the carbonate content can also be tested.

Materials and methods

This test was limited to the samples of the 'exterior scratch coats' category, and thus only confirmed the calculation of the percent amount of calcium carbonate in this category. Dry sand was put in a calibrated glass cylinder and its volume was measured. Water was put into another calibrated cylinder and its volume was also measured. Then water was added to the sand until the spaces between grains were filled. As Leslie and Gibbons (1999, 15) explain, the void ratio is the ideal ratio of binder to use in a mix for that specific sand, and it is usually around 33% (one part binder for three parts of aggregate). These figures were calculated using water as a binder. But this ideal ratio should consider the fact that, when lime putty, for example, is used as a binder, the density of lime is higher than that of water. It is therefore more difficult for lime to fill in all the spaces between particles in an aggregate. This is the reason why lime mortars have a certain amount of voids or porosity. It was therefore necessary to calculate the porosity of lime renders in order to be able to prove the following hypothesis: [calcium carbonate content from dissolution] = [porosity] + [void ratio]. The porosity was calculated by following precisely the standard procedure explained by Teutonico (1985, 39).

Results and discussion

The comparison of the three columns of data on Table 7.34 shows that the sum of the sand's void ratio and of porosity does not total the percent of carbonates. This does not agree with the test hypothesis. While it is possible that the hypothesis is simply wrong, this lack of correlation between results might also show that the methodology adopted for studying this particular problem was inadequate. The calculation of the void ratio, of the porosity and of the carbonates content was carried out by using weight as a dimension, whilst traditionally lime and sand were measured by volume. It may be therefore possible that the method used here, together with the correspondent sets of readings, is not applicable to the case of lime renders. Further research on this point is necessary before a definitive conclusion can be made either way.

EMBEDDING A SAMPLE IN RESIN

Introduction

The aim of this test is the study of limewash layers of interior and exterior skim coats, together with the mineralogical analysis of the aggregate.

Materials and methods

This method was explained to the author by John Hurd, and further guidance was taken from the textbook *Atlas of Sedimentary Rocks Under the Microscope* (Adams 1984). Product Araldite 2020 was used for imbedding the samples. The transparent resin was used together with the hardener for creating a solid bonding between the limewash layers and the skim coats to which they were applied, in order to allow the cutting of cross sections (Figs. 7.30-7.34). Prior to embedding, the samples to be bonded were cleaned, dried and roughly cut in order to fit into the mould. After the mixing of resin and hardener was carried out with a pallet knife, a layer of solution was poured into the mould. Then the sample was positioned on top of this layer and then more resin was poured in the mould. After a curing time of 24 hours, the sample was removed from the mould. Polishing of cross sections was achieved with the help of emery paper with grades 240, 320, 400, 600, 1000 and 1200. Only one face was polished. The sample was then mounted on a microscope slide by gluing its polished side with a thin layer of resin. Observation of the sample was carried out with a MEIJI stereo microscope under reflected light. The sequence of layers, colour, and distribution of particles was observed and recorded. Some embedded samples were ground to standard thickness of 0.03 mm. This allowed the observation of micrographs under polarising light, and was also useful for the analysis of the geological nature of the aggregate (Fig. 7.32).

Results and discussion

The observation of micrographs shows that the most popular pigments for the limewashing of renders were: azurite, yellow (*terra gialla*), ochre (iron oxide), umber (*terra umbra*), vermillion (*terra rossa*, sulphide of mercury), and green (copper salt). The study of the aggregate found that the traditional sand used for lime renders is of siliceous origin, excellent for building purposes. Results revealed almost no traces of those stones which should usually be avoided as aggregate, such as mica, soapstone and slate. Further analysis of the mineralogy of sand was conducted through examination of the dry aggregate obtained after the dissolution of samples of lime renders in hydrochloric acid. A binocular microscope was used, following the method explained by Leslie and Gibbons (1999, 20). The results of this analysis demonstrate that aggregates present in the samples may be classified into six main mineralogical components:

- quartz, clear and glassy crystals;
- feldspar, pink and opaque;
- mica and soapstone, dark grey or black in colour;
- rock fragments;
- pozzolanas (crushed fired clay, as found in the Gonnesa 2 sample);
- impurities (clay, silt, salts, timber, coal, nails, fibres).

Aggregate shape was analysed through the microscope and by subsequent correlations with data taken from Adams (1984, 3). The comparison with Adams' table illustrates that, on the whole, grains can be classified as featuring 'high sphericity', and as 'subrounded'. The minimal amount of sharp grains indicates that, generally speaking, aggregates derive from river sand, as confirmed during the interviews with Master Craftsmen. This is probably purely practical as sharpness is not a desirable characteristic in aggregates because the mix is then less workable. This view is also shared by Ellis (2000, 32) who notes that when sharp aggregate is used, the water necessary to keep the mix workable decreases the mortar's strength and increases shrinkage.

To conclude, the main findings of this test were:

(1) the aggregate used for the making of lime renders of twentieth-century Campidano is river sand which for the majority of cases originated from the decomposition of granites. As a consequence of this, quartz and feldspars are mainly represented and mica, soapstone and slate are sparse;

(2) the micrographs gave also useful information about the most popular pigments used for the decoration of interior coats and for the limewashing of exterior coats.

7.4.4 Conclusions from the analysis of lime renders

The results of the analysis of lime renders have two practical implications. The first concerns the geological nature of the limestone, and the second regards the composition of lime renders.

The composition of the binder does not contain any chalk, and the percent of impurities is such that the lime can be classified as non-hydraulic, fat, pure or with high calcium. This type of lime is characterised by a very fast slaking time, considerable expansion, and by a white colour.

The dissolution of renders in hydrochloric acid shows that the skim and scratch coats of both internal and external surfaces are characterised by a variable lime:aggregate ratio which is a function of the type of coat. The experimental analysis therefore confirms that the typical 1:3 ratio is not standard in Campidano. The reason for this finding is that external and internal coats are designed to form a porous system. Internal coats are characterised by an increasing softness from the limewash to the scratch coat, whilst external coats are characterised by an increasing softness from the scratch coat to the limewash. It is proposed here that this porous system allows both the condensation present in the internal wall surface and the moisture present in the mud brick to be driven outside the building. Other useful findings are represented by the recommended zones for the granulometry curves of the aggregates of skim and scratch coats of both interior and exterior renders. These will be particularly useful in the context of the case studies in section 7.5.2. Furthermore, the presence of impurities in the aggregate demonstrates that the traditional craftsmen were correct: river sand was commonly employed and was rarely washed of all impurities before use. Information on the pigments traditionally added to limewashes for interior and exterior walls were also identified. With the discussion of the results of the *làdiri* and lime tests in place, it is now possible to consider the implications for the case study samples.

7.5 Experimental analysis of materials from the case studies: results and discussion

This section examines and evaluates the employment of soil and lime as repair materials at the two case studies discussed in Chapter 6. The analysis of the samples collected in these two buildings was carried out by precisely repeating the set of experiments undertaken on the atlas samples. This was necessary not only for correlating any repairs with historic materials, but also for allowing comparison of these with the results of the atlas samples.

The section is structured into two parts: analysis of soil samples and analysis of lime samples. It should be noted here that both *làdiri* and lime renders are often variable in composition in the same portion of wall. It is not uncommon in fact to find walls made of courses of *làdiri* of different colour and origin. Furthermore, historical patches characterised by different ratios between lime and sand can be also common in lime. A visual illustration of sample location is provided in Fig. 1.17.

7.5.1 *Làdiri*

The aim of this section is to compare and contrast the results of the experimental analysis of the historic mud brick with those of the replacement mud brick of the two case studies. The hypothesis is that the assessment of the loams chosen for the repair of the two buildings under examination can be carried out through this methodology. The idea behind the assessment of the replacement bricks is that their performance is considered positive if they behave sacrificially towards the historic bricks.

Case Study A (Casa Cadoni-Arcais, Serramanna)

The first important point provided by the analysis of soil samples derives from the visual comparison of the colour of the *làdiri* used for replacement with the colour of the historic mud brick. Table 7.2 shows that the match between the original and the repair *làdiri* is extremely close. This was also confirmed by the author's direct observation during several site visits. Furthermore, experimental analysis provided several other significant findings. The difference between the pH of the two soils is 0.3, which is an extremely low value (Table 7.4). This is confirmed by Clifton and Wencil Brown (1978, 10) who suggest that 'pH measurement can be used to determine if repair materials are compatible with the original adobe. It is suggested that the pH of a repair adobe should be within + or - 2 pH units of the original adobe.' It can also be seen on Table 7.4 that the historic soil can be classified as mildly alkaline, whilst the pH of the repair soil is neutral. This might have positive implications in philosophical and durability terms as the replacement soil might behave as slightly sacrificial towards the historic soil.

The study of grain size analysis of the two soil samples shows that they have similar clay content but different gravel, sand, and silt content (Table 7.4). This is also visible in Fig. 7.8 where it is also shown that the granulometry curve of Case Study A3 (historic mud brick) is entirely included within the recommended zone, whilst the curve of Case Study A4 (replacement mud brick) is slightly outside it. This might suggest that the soil used for repair might not be well graded. This might again have positive implications in philosophical and durability terms as the replacement soil might slightly behave as sacrificial towards the historic one.

Clifton and Wencil Brown (1978, 26) explain how the plasticity index influences the performance of soil in conservation terms: 'Higher plasticity indeces are accompanied by larger expansions upon wetting and larger shrinkage upon drying'. Case Study A3 and Case Study A4 are characterised by a plasticity index of respectively 7 and 4.2 (Table 7.8). This means that both soils may expand between 4 and 10% (by comparison with Table 7 in Wencil and Brown 1978, 26). But this also means that the replacement *làdiri* might expand slightly less than the historic ones. It seems that their dimensional responses to moisture, and therefore their durability, are nevertheless quite close because their match in terms of plasticity is also extremely close.

The response of the samples to physical tests will be explained here schematically:

(1) both samples behaved extremely well to erosion (Table 7.11);

(2) sample Case Study A4, the replacement *làdiri*, behaved slightly less well to wetting and drying than Case Study A3, the historic brick. This seems to be due to the difference in the clay content of the two samples (Table 7.15);

(3) Case Study A4 showed a much higher shrinkage than Case Study A3 because of the clay content (Table 7.19);

(4) Sample Case Study A4 behaved better to the abrasion test than Case Study A3 (Table 7.23).

These findings are extremely significant. The recapitulations on Table 7.26 show that only one of the result of the characterisation tests is negative and that only one of the results of the physical tests is negative. The table shows that the behaviour of the replacement soil cannot be considered unsatisfactory, and it confirms that Case Study A4, the replacement *làdiri*, behaves sacrificially towards the historic brick.

Case Study B (Ex Caserma dei Carabinieri, Quartu Sant'Elena)

The first important result of the analysis of the two samples Case Study B5 and Case Study B6 is derived from Table 7.2. The table shows that the colour of the soil employed for the moulding of replacement bricks of the Caserma dei Carabinieri of Quartu Sant'Elena is very close to that of the historic soil. This is also confirmed by the author's direct observation during several site visits. The two soils are characterised by neutral pH values, and the difference between the two was calculated to be only 0.1. As was the case for Case Study A, this has an implication on the durability because the new brick might be slightly sacrificial towards the historic one. Table 7.4 shows that the clay content of the replacement sample is more than double than that of the historic sample. Furthermore, Fig. 7.9 demonstrates that whilst the granulometry curve of the historic brick (Case Study B5) fits entirely well within the recommended zone, that of the replacement brick (Case Study B6) is slightly outside the minimum limit curve. It should be explained here that the idiosyncratic shape of the granulometry curve of Case Study B6 is probably related to the fact that, after quarrying, the manufacturer transported the soil to another area to soak and mix it. During the mixing stage, this soil is blended with the local loam of the mixing area, which is particularly rich in organic matter. Replacement *làdiri* were therefore moulded with a combination of two types of soil. This explains the idiosyncracies of the resulting diagramme. For the same reason sample Case Study B6 shows an *average* value of activity (Table 7.9). The organic matter might have influenced its composition and therefore its activity coefficient. This might have positive implications in philosophical and durability terms as the replacement soil might behave as slightly sacrificial towards the historic one.

As far as plasticity is concerned, Case Study B6 has an index of 23.6 (Table 7.8), which means that it may expand by 13% to 18% (by comparison with Table 7 in Wencil and Brown 1978, 26). Furthermore, Case Study B5 has a plasticity index of 7.5 (Table 7.8), which means that it may expand by 4-10% [by comparison with Table 7 in Wencil and Brown (1978, 26)]. This shows that there is quite a substantial difference between the percentage expansion of the replacement *làdiri* and that of the historic brick. This runs against the traditional advice which says that the closer the *làdiri* 'match in their plastic indeces, the more compatible are their dimensional responses to moisture' (Clifton and Wencil Brown 1978, 26). But it is also true that because replacement *làdiri* were employed mainly in the first floor walls, their exposure to rising damp was therefore reduced. The above results seem to be a function of the amount of clay in the samples (Table 7.4).

The behaviour of the samples to physical tests will be explained here schematically:

(1) sample Case Study B6, the replacement *làdiri*, displayed much better resistance to the erosion test than Case Study B5, the historic *làdiri* (Table 7.11). This seems to be caused by difference in the clay content of the two samples;

(2) Case Study B6, behaved far worse to wetting and drying than Case Study B5 (Table 7.15);

(3) Case Study B6 shrank 13.5 times more than the historic brick (Table 7.19);

(4) Case Study B6 resists abrasion more than Case Study B5 (Table 7.23).

The results on Table 7.25 and Table 7.26 show that the overall performance of Case Study B6 (replacement brick) to the characterisation and to physical tests is slightly more positive than that of Case Study B5 (historic brick). In other words, it seems that in the long term the replacement *làdiri* will not be sacrificial towards the historic one.

7.5.2 Lime render

The aim of this section is to study the results of the experimental analysis of lime renders collected from the case study sites in order to assess their repair. The discussion of the results is based on an elementary methodology. The general requirement when replacing lime renders is that they should match the original in terms of carbonate content and grain size distribution of the aggregate (Pearson 1992, 162). This is therefore the assumption through which the question of assessing historic and new lime renders was studied in the context of the two case studies. Further details of the suitability of a render are also provided through correlations with the atlas samples.

Case Study A

The collection of the historic renders of Casa Cadoni-Arcais was carried out under the supervision of architect Lucio Ortu. Only a few representative specimens were collected due to time and resource limitations. Evidence showed that the building was characterised by one single coat of interior lime render and by one single coat of exterior lime render. It was not therefore possible to define them as scratch or skim coats. The repair mix specified by the architect was the same for interior and exterior renders. The overall number of collected samples was three:

- Case Study A1: exterior coat (historic);
- Case Study A2: interior coat (historic);
- Case Study A5: replacement coat for both interior and exterior coats.

The author is aware of the too limited number of samples and of the possible discrepancies in the surface as a single wall that there can be with materials mixed by hand. After analysis was complete, it was noticed that the sample of historic interior lime render (Case Study A2) is a peculiar mix of lime, chopped wheat straw, and clay. The percentage of carbonate was found to be extremely high (65.3%), the residual matter being a combination of straw and clay. There is no evidence that this was a traditional solution for the rendering of interior surfaces of *làdiri* walls either in Serramanna or in Campidano. It is though possible that the employment of straw as aggregate might derive from its traditional use in mud renders. As the render contains such a peculiar mix, comparison with the atlas's interior renders is impossible due to the incompatibility of aggregates. However, the lack of correlation of this specific render with the atlas samples is extremely significant because it suggests that the traditional manufacturing process of lime renders was not codified, but was rather a procedure which evolved and adapted to specific cases.

The analysis of the external historic render (Case Study A1) shows that the ratio between lime and sand is exactly 1:3. Because this historic coating system was not made into two different coats, it was deemed appropriate to compare its granulometry curve with both recommended zones for scratch coats and skim coats. This comparison suggests that the distribution of the curve of Case Study A1 is well within the maximum and minimum curves of the external scratch coats (Fig. 7.35). The curve is exceptionally close to the ideal curve in proximity of the coarse sands, but it is less representative in the area of the fine sands where it slightly overlaps with the minimum curve (Fig. 7.35). The comparison of the curve of the aggregate of Case Study A1 with the recommended zone for external skim coats suggests that the distribution is almost overlapping, and partially outside, the minimum curve. The implication of these two comparisons is that the sample Case Study A1 can probably be considered as a scratch coat and that therefore the sample Case

Study A5 should be compared to it in these terms. The mix for the re-rendering of the interior and exterior surfaces (Case Study A5) was designed by the architect to be employed independently for both skim and scratch coats. It was therefore decided to compare the granulometry curve of Case Study A5 with the recommended areas of both interior and exterior scratch coats (Figs. 7.37 and 7.38). In the first case the curve is perfectly inside the recommended zone, whilst in the latter case the curve is only for a small fraction outside the minimum curve.

To conclude, it seems that the lime mix used for coating both internal and external surfaces at Casa Cadoni-Arcais satisfies the overall requirements dictated by the recommended areas of the atlas samples. The only exception is represented by the interior lime render which, because of its unusual nature, cannot be used for correlations.

Case Study B

The collection of samples of historic lime renders of the Caserma dei Carabinieri of Quartu Sant'Elena was designed to be representative of the building under examination. The collection was supervised by engineer Fabrizio Cadeddu who was in charge of the conservation of the building. The five samples collected were:

- Case Study B1: interior coat (historic);
- Case Study B2: exterior coat (historic);
- Case Study B3: interior coat (historic);
- Case Study B7: exterior coat (historic);
- Case Study B8: replacement coat for both interior and exterior coats, skim and scratch.

In addition to these, one sample of coarse sand (Case Study B9) and one sample of fine sand (Case Study B10) were also collected from the site. These two samples were made into a mix and used as aggregate for the new lime renders. Their granulometry curves have been calculated (data sheet section). The above definition of the historic coat intentionally does not provide any information about the type of coat (skim or scratch) because this was not clear on the site and also because they were in any case found to be single- coated.

An initial comparison between the historic renders shows that there is a similarity in terms of carbonate content between the two interior samples, whilst their comparison with the exterior samples differs in terms of their carbonate content. This provides an important finding: interior surfaces of both the first floor (Case Study B1) and the ground floor (Case Study B3) seem to have been rendered with similar mixes. This is also confirmed by the comparison of the granulometry curves of these two samples which seem to be very similar (in the data sheet section). Another important implication is that the average carbonate content of the two interior lime renders (Table 7.32) is very close to the average value of the correspondent atlas of interior skim coats (Table 7.28). The comparison of the granulometry curves of the aggregates of Case Study B1 and Case Study B3 (both interior lime renders) with the recommended areas for internal skim coats (Figs. 7.39 and 7.44) and internal scratch coats (Figs. 7.40 and 7.43) respectively was found to be successful. The curves in all cases fit into the areas and this shows that they are well graded.

It should be noted here that this type of similarity is not generally applicable to the case of the exterior lime renders. The percent carbonate content of Case Study B2 (Table 7.32) is not in fact close to the average value of the atlas samples. This seems to be valid for the external skim coats (Table 7.30), but also for the scratch coats (Table 7.29), whilst the study of the aggregate's curves contrasts with this finding. The curve of Case Study B2 is very much within both recommended zones for external skim coats and external scratch coats (Figs. 7.41 and 7.42). The same rationale can be applied to Case Study B7 (exterior coat) which contrasts significantly with any average value from the atlas samples (Tables 7.29 and 7.30). This is also true for the aggregate (Figs. 7.45 and 7.46). But it should also be noted that 23.35 is the average percentage value of carbonate content for the two samples (Case Study B2 and B7), and this figure agrees with the average result on Table 7.29, and also to a certain degree with that of Table 7.30.

As was the case for Case Study A, only one mix was employed for the re-coating of both interior and exterior surfaces. It is also worth mentioning that no difference was made between skim and scratch coats in terms of their mix. For this reason only one representative sample was collected from the building site - Case Study B8. The result from the experimental analysis of this sample (Table 7.32) shows that its carbonate content is extremely close to that of both Case Study B1 and Case Study B3 (Table 7.32). This means that the mix for the replacement coat matches that of the two interior historic renders. The suitability of grain size analysis of the aggregate is also well respected and this is confirmed after a comparison with the recommended areas for both skim and scratch coats. A similar comparison of the carbonate content of Case Study B8 with that of Case Study B2 (exterior scratch coat) or with that of Case Study B7 (exterior scratch coat) does not feature the same matching properties. Again, the recommended areas for both skim and scratch coats well contain the curve of the aggregate of Case Study B8.

7.5.3 Conclusion

It should be proposed here that a more complete and detailed study of the two buildings examined here might have been achieved if more samples had been analysed. The present study is therefore characterised by this limitation which however does not undermine the significance of the work. Another limitation of the present study is represented by the fact that the data gathered after the experimental analysis were not analysed in statistical terms. The conjectures proposed throughout the present chapter should anyhow be considered valuable because they show *trends*, even if these results are not generalisable in statistical terms to the area under examination.

The relatively high success of the Case Studies grain size analysis curves into the atlas's recommended areas seem to demonstrate the validity of both methodology and results. This is also true for the comparison of the carbonate content of lime renders.

Chapter 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

The aim of this final chapter is to summarise the findings of the previous chapters and to draw some conclusions in the form of final statements and recommendations. Two sets of recommendations are highlighted here: the first is specific to the case of Campidano, whilst the second attempts to provide a framework for a more international approach. The chapter ends with a section on suggestions for future research in the field of conservation of earthen buildings of Campidano.

8.2 General summary and conclusions

The aim of the present section is to give an overall summary of the main issues researched in the thesis. The final part of this section will return to the research questions from section 1.2.2 (Chapter 1) in order to assess if they have been answered throughout the thesis.

The topic of archaeometry and the conservation of twentieth-century earthen buildings of Campidano was studied in seven successive steps - one to every chapter - which are listed below.

The thesis began with both the background to the research and the methodology employed in the present work which were discussed in **Chapter 1**. The issues raised in this chapter were extremely useful for structuring the methods of data gathering. It showed that the thesis utilised four tools for the gathering of primary information for investigating specific aspects of the research: archival research, interviews, questionnaires, and experimental analysis.

Chapter 2 focussed on gaining an understanding of the evolution of building materials in Campidano in terms of their geology, pedology, archaeology, and of their historical employment. The sections on geology and pedology provided a useful overview of the variety of rock formations and of soil types of Campidano. The investigation on the archaeology of building materials demonstrated the evolution of their use in the region under examination. For example, it was shown that mud brick was employed as early as the XII century BC in Sardinia. The second part of Chapter 2 considered the social environment of earthen buildings of Campidano and the factors that influenced their development and the cessation of their construction. Furthermore, through a focus on the village of Quartu Sant'Elena, an overview was given on how conservation regulation contributed to the repair and maintenance of the vernacular heritage from 1850 up to recent times. The three primary findings of this section were:

(1) The conservation officer is no longer a relevant and authoritative figure in the villages of Campidano, and this has directly led to a lack of regular inspection and control over repair work;

(2) Between 1850 and 1960, owners of buildings in need of repair were forced by the local municipality to intervene on their own homes within a specific period of time. However, this procedure is no longer a feature of more recent policy;

(3) It can be concluded from the analysis of archival records that between 1850 and 1960, maintenance, building repair, and conservation were more embodied in the culture and in the daily life of the dwellers than is the case today. The lack of contemporary awareness and interest in repairing vernacular buildings is also due to the erroneous perception of conservation as a specialised and expensive discipline which relates largely to monuments.

Following the thesis framework, Chapter 2 ended by exploring why earthen buildings are so neglected today. Several reasons were identified through a small survey based on interviews with local professionals in the field of earthen building conservation (section 2.10 of Chapter 2).

Chapters 3, 4, and 5 consisted of data gathering from three separate but nonetheless inter-related themes. A wide survey based on interviews with 40 traditional craftsmen listed on Table 4.46 was used for studying the manufacturing processes of building materials of Campidano. The results were assembled in **Chapter 3**, where it was demonstrated that the construction of Campidano's buildings was a complex undertaking due to the number of materials which were traditionally employed. It was in this context that building materials were studied in detail, and this helped to understand their traditional use and conservation. However, before focussing specifically on the conservation aspect, a population of 288 earthen buildings was assembled and analysed with the aid of a structured questionnaire in order to study the symptoms of decay. In some cases the actual mechanisms of decay were also studied, and this survey forms the bulk of **Chapter 4**. Once the main decay symptoms were known, the next stage was the recording of the traditional repair techniques developed by traditional craftsmen of the last century (**Chapter 5**). This discussion demonstrated that the repair of earthen buildings was often a codified activity and that traditional craftsmen associated specific methods with specific decay symptoms. Another important outcome of the findings of Chapter 5 was that the methods explained therein were, for the majority of cases, evaluated in a positive light in terms of philosophy and ethics of conservation. The assessment was carried out through following these categories: minimum interference with the historic fabric, recycling of materials, and repairing like with like.

Chapter 6 was a description of the two case studies located in Quartu Sant'Elena and Serramanna, which were selected as examples of best conservation practice in Campidano. A brief introduction on the history of two buildings was followed by describing the conservation that was undertaken, and comments on the repair work were also made. This chapter is intended to be an introduction to the buildings from which the samples of lime renders and of *làdiri* were collected.

The analysis of the case studies and field samples was undertaken in depth in **Chapter 7**. This chapter was devoted entirely to the experimental analysis, and it started with a description of the methods through which samples were selected. While the number of analysed samples of lime renders was considered appropriate for this analysis, the *làdiri* samples were unavoidably limited by a combination of time and the available resources. Nonetheless, several important findings were made. The chapter was divided into three sections:

(1) the first section dealt with the experimental analysis of nine representative *làdiri* samples from Campidano. These were taken as a reference atlas for the comparison of the case study samples. Another outcome of the analysis of these samples was the information which derived therefrom. A detailed and comprehensive explanation of these findings can be read in the summary in section 7.3.6;

(2) the second section identified four atlases as references for lime renders. The four atlases were in detail: interior skim coat, interior scratch coat, exterior scratch coat, and exterior skim coat. A detailed and exhaustive explanation of these findings can be read in the summary in section 7.4.4;

(3) the third section dealt with the analysis of the *làdiri* and lime render samples collected in the two case studies. Results of the analysis of the historic samples were compared to their corresponding replacements. Once again, a detailed and exhaustive explanation of the findings can be read in the summary in section 7.5.1 and 7.5.2.

To conclude, the research questions of section 1.2.2 of Chapter 1 will be discussed here in order to assess if they have been answered throughout the thesis. The first set of research questions was structured into three parts. The first part was answered in section

2.10 of Chapter 2. It was concluded that Sardinia stopped building with earth in 1960 because of the overwhelming introduction of modern materials. The second part was answered partly in section 2.9 and 2.10 of Chapter 2, whilst the third part was answered fully in Chapter 4. It was concluded that traditional architecture is today neglected by its inhabitants because modern materials have more status and loam as a building material is considered as insanitary and something which reminds people of the poorer past. The second set of research questions was structured into two parts. The first part was answered in section 2.6 of Chapter 2 and in Chapter 3. It was concluded that the manufacturing processes of building materials of vernacular Campidano are several and complex. The second part was answered in Chapter 5, Chapter 6, and Chapter 7. The main conclusion that can be made for a more appropriate conservation of the Sardinian earthen heritage is to employ traditional repair methods as explained in Chapter 5, and to stop using modern materials and techniques.

8.3 Recommendations for the specific case of Campidano: the search for local awareness

> *The key to success lies perhaps with pride. If a community can feel pride in its buildings, particularly its humbler buildings, it will value them. So let the climate of good sense for the conservation of mud-brick buildings include economic and practical help, the use of traditional methods and a recognition that the quality of the environment which these structures represent is significant and should be a matter of pride.*
> (Warren 1980, 18)

The research found that the main obstacle against the acceptance and the conservation of the earthen buildings of Campidano is the lack of awareness and pride in the buildings on the part of their owners and users. This statement is based on the author's direct observation during several informal conversations with building users while undertaking the field work. It would have been poor research technique - and quite probably unethical as well - to have attempted to change people's attitudes while interviewing building users in the field. However, the experience gained during this research has aided in the formulation of several general suggestions on how perceptions and attitudes towards earthen building conservation can be improved, and these are summarised in this section. The suggestions derive from summarising the main conclusions of the previous chapters and especially of those in Chapter 3, Chapter 5, and Chapter 7. It is important to stress that it is not the aim of this section to provide solid practical proposals on these issues, but rather to highlight areas and make general suggestions as to how matters can be improved for the better. It is hoped that these recommendations can form the basis for the future formulation of relevant guidelines by those local authorities (e.g. town councils) involved in the conservation of the earthen built heritage of Sardinia. It should be explicitly acknowledged here that the author is not advocating specific 'practical' proposals, but simply a range of issues that need to be advanced. The practicalities require in this sense further discussion and development of the themes.

Based on the research in this thesis, a series of themes on how conservation and public awareness can be improved in Campidano have been identified, which are listed thereafter. These are by no means intended as firm practical proposals, but simply as an outline of where and how improvement can occur.

1) Reversibility and minimum intervention into the historic fabric

This thesis has demonstrated that the traditional repair methods explained in Chapter 5 were often guided by the themes of preservation of resources and minimum interference into the historic fabric. This was clearly because these were the most economic ways of carrying out the repair work. Furthermore, these traditional interventions were for the majority of cases reversible, as they were 'capable of being withdrawn leaving the fabric as it was' (Warren 1993, 7). These two aspects point to the acceptability of traditional methods from the ethical and philosophical point of view. In contrast, the use of modern stabilization techniques such as consolidation or grouting should not be considered because they are irreversible and do not usually allow for complete retreatment.

The author observed that, similar to the British experience, the skilled tradesmen of the past have been replaced by 'cowboy' builders who fill the gap in demand in the field of vernacular heritage conservation (Sühr 2001, 86). The suggestion here is firstly that practitioners and homeowners should be given appropriate advice on traditional repair methods by attending short courses, and secondly that young apprentices should be trained in terms of employment of traditional materials and methods. The issue of training is further studied in point 4 of this section.

2) Traditional, local, and recycled materials in repair

The first important suggestion on these points is that research should precede the selection of the repair material. Employing local materials in repair work has many advantages, not least of which is the fact that the sources for the original materials were traditionally close to the site. The recycling of building materials is especially applicable to the earthen buildings of Campidano. Soil was often traditionally recycled and reconstituted in the form of mud bricks for replacement purposes, but also in the form of mortar, dry packing, and less frequently in the form of mud render. Traditional, local, and recycled materials should be part of conservation philosophy in contemporary practice.

3) Repair 'like with like'

As the research progressed, it became clear that in Campidano, sympathetic repair methods using the same materials that compose the building were also the traditional methods. This was especially true for the repair of renders and of *làdiri* walls. Master Craftsmen explained that they tended to carry out a 'like with like' repair method, as this was traditionally said to be the best method. The 'like with like' repair process was traditionally employed amongst several building cultures, not only in Sardinia, but also in Argentina and England (Viñuales 1980, 54; Engeland 1988, 60). The suggestion here is that these methods should be part of the conservation philosophy in contemporary practice.

4) Repair guided by the tradition of the building and by past craftsmen: the role of training

The lack of specialised craftsmen in the repair of earthen buildings, together with the issue of training needs, is constantly deplored in what little literature does exist on the

Sardinian earthen heritage (Ingegno 1987, 24; Pilloni 1989, 71; Garau 1997, 81; Sanna 1992, 50; Sanna 1997, 64; Angioni 1998, 76; Fodde 2000a, 125). As a consequence of this, traditional buildings are conserved with inappropriate modern materials and methods. This is partly due to the fact that the workmanship necessary for using traditional materials (such as limewash) requires more skill, sensitivity and grounding in traditional culture than does that required for using modern materials (such as solvent-based paint).

The suggestion advanced here is that the role of the Master Craftsman and his knowledge of traditional repair methods should be re-instituted by training through the on-site training of young apprentices including the involvement of older craftsmen. It is felt that this could still be achievable in Campidano, as demonstrated by the interviews undertaken by the author (Chapter 3 and Chapter 5). This would be in keeping with traditional practice in Campidano, where young apprentices were trained at different levels before reaching the status of Master Craftsmen. However, this training should be accompanied by scientific study of relevant building materials. It should be also stressed that on-site training will be achievable only if financial assistance is available as otherwise training costs will prove prohibitive. This very point was recently experienced in Campidano by Vado (pers. comm.). In recent times, Vado and the Cooperativa Dedalo have undertaken the training of several craftsmen during the construction of the Centro Anziani in Sestu, this being the largest earthen structure constructed in Campidano since the 1960s. The financial problems found in relation to the training of new apprentices were many. For example, it was calculated that the cost of building (material and labour included) one square metre of *làdiri* wall was GBP 81.20, whilst one square metre of hollow brick and cement could have been built for GBP 25.00 (Agattau 1999, 115). An important influence on this difference was the cost of the training of craftsmen and of the research which was carried out throughout the construction process (Agattau 1999, 116). The recent experience of the Cooperativa Dedalo in this regard shows that the training of apprentices will only be sustainable in the long term if appropriate financial support is provided by grant-giving bodies, which has not been the case in the recent past in Sardinia.

5) Maintenance after repair

Annual maintenance and the renewal of sacrificial layers are essential tools for the conservation of earthen buildings. The keynote of maintenance is that if a fault is not repaired, instant failures will occur. Regular and cyclical maintenance was historically undertaken in Sardinia. This is demonstrated by archival research carried out by the author in Iglesias which brought to light a series of deeds promulgated between 1702 and 1759 between the Collegio de la Santissima Trinidad (Orden de Predicadores de Iglesias) and the local population. The documents show that sums of money were lent from the Collegio to those owners who needed to repair or maintain their dwellings. The six deeds largely apply to the repair of parts of dwellings such as walls (ASI 1702; ASI 1751; ASI 1754), but also involve the repair of entire houses (ASI 1710; ASI 1751; ASI 1759).

However, in today's world, building regulations never provide any recommendations on maintenance after building repair (i.e. inspection of gutters, roof tiles, renders, etc). This absurd lack of interest in maintenance is also shared by building users who have certain preconceptions against maintenance, often owing to the frequent work that its adoption usually implies. The suggestion here is that building regulations should be explicit about requiring the use of traditional materials and methods.

6) Need for experimental analysis of building materials before undertaking any repair work

Sardinia lacks specialised conservation laboratory facilities for the analysis of traditional building materials. The recommendation here is for the creation of a conservation laboratory to be hosted either by the University of Cagliari or by a civic body such as, for example, the local Soprintendenza.

7) The role of the conservation officer

The problems related to the lack of conservation of Campidano's earthen dwellings are twofold. First is the lack of inspection of the repair work carried out in historic centres, as the role of the conservation officer, a traditional figure between 1850 and 1950 in

Sardinia, is not as identifiable today as in the past. Second is the lack of general interest in vernacular architecture and its consequential neglection by building users (this issue will be expanded in point 8 of this section).

8) Aesthetics and the media

The aesthetics of vernacular buildings in Campidano do not correspond to the negative portrayals existing in today's media. It seems that there is a need to show that one does not have to live in a modern building to be able to enjoy the comforts of modern life. The association between earthen buildings and primitive living is still in the minds of many - not just Sardinians. The recommendation here is that media should be encouraged to play a role in reversing existing perceptions by presenting conservation as a sustainable and modern option to new construction.

9) Registration of the earthen architecture of Campidano as 'heritage at risk' by ICOMOS

This recommendation was given by the ICOMOS World Report (2000) on Monuments and Sites in Danger. If the earthen architecture of Campidano is registered as 'heritage at risk' - following the example of the Apulian vernacular architecture of the *trulli* - this would offer the local authorities a considerable help in conserving their earthen heritage (Bumbaru 2000, 222). It is felt here that this project would be an important contribution to the protection of the traditional architecture of Campidano.

8.4 Recommendations for the earthen architecture of the Mediterranean basin

The aim of this section is to give an explanation of which of the recommendations studied for the specific case of Campidano can be applicable and generalisable to the wider context of earthen building culture of the Mediterranean basin. The logical sequence starts from the local perspective of Campidano up to the regional or local level and to the national and Mediterranean level. This is an easily definable area characterised by consistency of climate and by similar earthen building cultures. For example, a comparison between Campidano's *làdiri* buildings and the *plintharia* (mud brick) architecture of the plains of Cyprus can be made by reading Loizides (1999, 13). Another similar comparison can be made between Campidano's traditional building culture and that of Spain. Furthermore the organic materials employed in the construction of earthen structures are similar due to the consistency in the Mediterranean flora. Regional cultures are also characterised by similar behaviour towards the issue of conservation of earthen buildings. As already mentioned in section 2.10 of Chapter 2, the trend in several countries of the southern Mediterranean is to neglect earthen dwellings in favour of modern construction.

The present section is structured after the guidelines given at *Terra 2000*, the most recent international conference on the study and conservation of earthen architecture, where the author acted as lead rappoprteur for the session titled Political, Legal, and Economic Context. One of the themes addressed by the guidelines given at *Terra 2000* was the articulation of the recurrent concepts concerning the theoretical framework behind the conservation of earthen buildings. It therefore seems legitimate for this internationally-valid perspective to be taken as a starting point for the international recommendations which will be given in this section. There are five are the main guidelines discussed here:

1) Regional identity

The keynote to the issues raised during *Terra 2000* was the increasing awareness of regional identity in many countries of the world, with special reference to conservation regulation and practice. The movement from globalization and the standardisation of codes and practices to a fragmentation and a recognition of the peculiarities of individual cases was noted as an increasingly important issue. In this respect the issue of repair methods should be understood as involving local, autochthonous techniques to be employed for specific and homogeneous areas or building types.

2) Regional inventories

The study of specific conservation strategies and the collection of information on building types and techniques is a crucial point, and can often be a basis for legal structures and for encouraging public acceptance of earth as a building material. The interesting point here is the idea of regional inventories with which to document building types and techniques, and of studies on methodology for the conservation of regional earthen architecture. In this context, the application of scientific methods and analyses (e.g. laboratory analysis of materials, mapping systems such as GIS) to the study of earthen buildings and culture can be effective for the designing of regional databases and regulations. It can be also suggested that, prior to the design of regional conservation regulations, a thorough investigation of the specific building types and needs of the area under examination should be initiated.

3) Traditional skills

The recording of past practices and traditional skills is another growing area of concern and this was noted by many contributors at Terra 2000. In his keynote contribution given to the theme Materials and Craftsmanship, the crystallographer Giacomo Chiari argued that the approach to earthen buildings should be twofold (Chiari 2000, 110): it should start with the study of archaeometry, and should end with their conservation. Chiari (2000, 110) also explained the importance of traditional Master Craftsmen and of traditional techniques: '...we really need to make an effort to document and preserve as much as possible the surviving techniques ... My impression is that we should ... start writing manuals on how things are done, by the few who still know how to do it. I strongly believe in this approach to the conservation of earthen architecture...'

The involvement of local traditional craftsmen in the teaching and transferring of knowledge and skills to younger generations can be considered as a turning point for good practice. This 'training needs' framework should be set in conjunction with the use of appropriate materials, especially when referring to conservation. Young enthusiastic apprentices could learn the skills and the craftsmanship necessary for the conservation and rehabilitation of earthen buildings by attending taught courses. This can be also advisable in the context of financial aid structures in post-disaster reconstruction. Aid and rehabilitation projects should be individually designed to suit local cultures and materials, and successfully incorporated if constructed and maintained by local people. In so doing, systems based on regional traditions would outlast imposed systems.

4) Sustainability

Another important area is long-term sustainability in relation to new building. The purchasing of building materials from local sites, the problem of global warming, and the reduction of carbon dioxide emission, are all important issues. Earth could be more easily accepted as a building material if there were norms and regulations that certify materials together with their manufacturing processes. The construction of a prominent new public building in earthen materials could start the process of awareness-raising and introduce the understanding of past traditions. This was also proposed by Vado (1999a, 517) for the specific case of Sardinia, with the intention that good new earthen architecture can be taken as a model by people. This may re-start the appreciation and emulation process which was typical in the first half of the twentieth century in Sardinia (Lucio Ortu, pers. comm.).

5) Local charters

The drafting of appropriate local Charters is a possible way forward. Charters available today are unsatisfactory as they are not considered compatible with earthen structures. Universally-considered conservation guidelines such as the Eurocentric Venice Charter and the Australian Burra Charter could be revised or re-designed to suit the requirements of specific regions and local communities. This should be applicable not only to areas of the Mediterranean basin where repair is based on the work of indigenous Master Craftsmen, but also to regions where this tradition has been forgotten. The unsuitability of the internationally-oriented charters has been previously denounced by Krishna Menon (1994, 37-44) with reference to the Indian context, and by Marconi (1988, 70) with reference to the specific case of the vernacular built heritage of Italy. International charters should therefore be adjusted to meet the local culture of the region under examination. Such a reorganisation necessitates a substructure for the production of local building materials (e.g. the reopening of local quarries and kilns) to envisage a future for the conservation and care of earthen buildings. The five recommendations discussed in this section could be easily employed for the better management, conservation and documentation of the earthen heritage of the Mediterranean basin.

8.5 Future research suggestions

This section was written with the awareness that the thesis is not an exhaustive study of the conservation of twentieth-century earthen buildings of Campidano. Some topics needing further research have therefore been identified and will be explained here in order of suggested priority:

1) Production of a 'Heritage at Risk' directory for the specific case of Campidano

There is an overwhelming need to identify and list earthen heritage at risk, including single earthen structures. This directory could list the earthen heritage at risk, such as single earthen structures or groups of buildings of historic cores of villages, in order to promote awareness amongst local institutions and building users.

2) Practical testing of the repair methods provided in Chapter 5

As this research progressed, it became clear that having documented the traditional repair methods for earthen buildings, there is now a need to test the applicability of the systems in a variety of buildings, initially in Campidano first, and then further afield in the Mediterranean basin. This should also be accompanied by a thorough experimental analysis of materials to be repaired in order to determine the type of intervention required to conserve the buildings.

3) Survey of the geographical distribution of the architectural heritage of Sardinia through the census

This proposal has already been submitted to the Central Bureau of Statistics by Orazi (1995, 228) without any success. It was suggested that the national census form could include some questions on the type of building materials used so that a detailed survey of the extent of earthen buildings of Campidano could be made. The suggestion here is that this proposal could be included in the next census.

4) Experimental analysis of building materials of Campidano

A wider and more systematic survey than that undertaken by the author could be part of a more comprehensive research programme which would involve scientists and professionals in conservation. A wider number of samples could be collected, including the collection of natural samples when possible, and the analysis could be preferably carried out using more a rigorous statistical methodology in order to form a more conprehensive study of lime and loam as building materias in Campidano.

5) Building archaeology

A more comprehensive study of the archaeological evolution of building techniques of Sardinia is yet to be assembled, and not only with reference to earthen structures. There is a strong need for research which could assemblie and review all of the scattered available information. The creation of a broad corpus of work on the archaeology of Sardinian construction would undoubtedly provide lessons for future conservation initiatives.

Clearly there is much work yet to be done, but this thesis has provided the invaluable beginning through which such future research can proceed. A solid framework for the analysis and conservation of the previously-neglected earthen architecture of Sardinia is now in place. This thesis has also conclusively proven the importance of this vernacular architecture to the broader cultural life of this unique Mediterranean island. Furthermore, it is clear that the implications of this research apply not only to Sardinia, but to the Mediterranean basin as a whole - and possibly beyond.

APPENDIX 1

The following unpublished document is dated 25 March 1773 and it was written in Iglesias during the Savoy domain by the Piedmontese engineer Daristo. This is the oldest known description of the process of brick making in Sardinia. Daristo explains why the construction of the Episcopal Palace and Seminary of Iglesias would have been more convenient if sound bricks had been employed instead of stone.

The document is kept in the Archivio dei Gesuiti, Seminario Arcivescovile, Iglesias (Sardinia). The author is grateful to Grazia Villani who sent him a copy of the document on 2 November 1999. The original document in Italian follows the author's translation of the manuscript.

The relevance of the document in the context of this thesis is due to the popularity of use of fired bricks in the construction of architectural elements such as arches and portals.

English text:

Construction of the Episcopal Palace and Seminary

Instructions by the Signor Capitano Ingegnere Daristo for the making of good quality bricks.

Clay stones such as bricks, tiles and square tiles are the most advantageous materials for the construction of civil and rural buildings, but only if these materials are characterised by good quality, solidity and by easy laying.

The best material for the making of bricks, tiles and square tiles is either white clay or reddish clay. In order to make perfect bricks, both clays ought to be of *fat* nature and with fine grains. Clay should be quarried in autumn and then put in a barn after all stones and organic matter are eliminated. Then the dug clay is left to ferment for the entire winter so that even the smallest lump can soak. During spring time the clay is again moistened and reduced in the form of a putty for three or four times, allowing the mix to dry before each session. The more the clay is mixed and uniform in consistency, the better the quality of bricks, tiles and square tiles.

Once the mix is ready, it is necessary to choose the wooden moulds which can vary in size: the rectangular mould with length double the width is the best and easiest to handle when making bricks. As bricks are employed also for the construction of corners, their length can be slightly bigger than their double breadth. In so doing, the extra space will be covered by lime mortar and the result is that corners will be always straight.

The easiest bricks to handle are similar in dimensions to those in use in Piedmont, measuring 6x3x1.5 ounces of the *piede lipandro* (12 ounces = 0.513766 metres = 1 piede lipandro = 1 piede di Piemonte). The process of brick making and tile making now will be explained in order to give a clear idea of the whole operation.

The mould is soaked in water and sprinkled with sand in order to prevent clay from sticking to the wooden faces. Clay is then put in the mould and compressed by hand and with the help of a wooden board. The moulded piece is then extracted and put to dry.

Before drying process is complete, brick corners are cleaned with a knife from all imperfections in order to achieve a crisp shape. Then bricks are moved to a dry area protected by eventual dampness and stored in groups of four or five rows following their long and thin side. Then they are stacked in layers to minimise the amount of connecting area between two bricks and in order to achieve even drying. Then the stacked bricks are covered with roof tiles in order to be sheltered from rain wash off. The sides of the volume of stacked bricks are protected with branches in order to avoid uneven drying caused by strong sun, and this allows the achievement of improved quality bricks.

In order to maximise the quality of bricks, one has to observe the following directions. The moulding process should take place between spring time and September in order to give bricks time to dry well before burning process.

Different are the ways for burning bricks, but the most adequate method foresees the use of a potter kiln. It is important to stress that kilns should be charged in such a way that the total volume of bricks is 2/3 inferior than that of the kiln. In so doing, if bricks are positioned skillfully, the flame should be able to find its way in the gaps between the bricks and the result could be an even firing of the charge. It is advised to leave a gap between the internal wall surface of the kiln and the charge itself in order to allow the insertion of wood or charcoal wedges.

The burning process should be increased gradually in temperature until bricks are well fired. In order to understand if bricks are satisfactorily burnt, two bricks are beaten one against the other. If the resulting sound is clear and strong, bricks are of good quality. Bricks which make a confused or deaf sound should be rejected.

Good quality bricks can be also tested in a more precise way. In autumn, bricks are put to rest on the bare ground in order to be exposed to the winter weather. Those bricks which in spring are found to have crumbled are considered of bad quality, but on the contrary those which are found to be integral are considered of good quality.

Brick quality cannot be assessed only by the analysis of the colour because this would be appropriate only for those bricks which are part of the same batch. Comparing bricks which have originated from different batches is not a correct method because clays are different, and of different colours. To be more strictly precise, colour is not useful at all for the identification of the quality of bricks, but it is only useful for assessing the quality of clays before burning. Brick makers today give little importance to the selection of the best clays because they are money-driven and therefore prefer to use the closest available clay to the kiln. Brick makers tend to save in transportation, in amount of mixing, and in cleaning of impurities. Furthermore, the firing process is today not always carried out correctly. The kiln is usually over-charged with tightly positioned bricks and this does not allow the flame to reach those on the top. In the latter case, the sand which covers those bricks positioned on the bottom can vitrify and tend to over burn. In so doing, the resulting bricks can be classified according to their location in the kiln:

1. The so-called *ferrioli* bricks, the closest to the source of heat. These are extremely useful in damp sites and for building foundations;
2. the so-called *albano,* the more distant bricks from the fire. No use is advised for these bricks. Their use should be avoided, especially for the building of walls facing midnight;
3. the third quality is called *mezzanella* and is represented by medium-positioned bricks. Their use is good for any exposure, as long as the clay is of good quality.

After this classification, it is important to stress that not all the bricks which are part of

the above categories are fired at the same temperature; their firing is inversely proportional to their distance from the fire.
Bricks are therefore sub-classified as follows: *ferrioli*, *mezzanella molto cotta* (high-fired mezzanella), *mezzanella sufficientemente cotta* (sufficiently-fired mezzanella), *mezzanella meno cotta* (low-fired mezzanella), and *albano*.
The Capitano Ingegnere will give further explanation after being transferred.

Iglesias, 25 March 1773

Original text in Italian:

Fabbrica del Palazzo Vescovile e Seminario
Instruzione del Signor Capitano Ingegniere Daristo circa la qualità, e maniera di formare i mattoni

(p. 1)
Le pietre fatizzie d'argilla, cioè mattoni, tegole e quadrelli, sono le più vantagiose, e spedienti cose, che adoperar si possono per la construzione degli edifici civili, e rurali, qualora però le medesime hanno quelle condizioni che richiegonsi per haverle in pieno grado di bontà, e configurazione confacente per la solidità, come anche la convenienza per la loro pronta posizione in opera.
La miglior argilla per formare li sud(dett)i mattoni, tegole e quadrelli, è la cretoia bianchiccia, ovvero rosseggiante; si l'una, che l'altra dovrà essere di sua natura sottile e grassiccia, affinché perfetti riescano gli anzi detti; fa di mestiere [che] venga essa scavata nell'autuno, e riposta in un'aia, facendone lo scernimento per toglier via li sassolini, e radici, qualor ve ne fossero; indi si ridurrà in pasta ben macerata, tanto che possa ella fare qualche effervescenza per dissolvere la crudezza delle di lei anche più minute parti e così si lascierà nel corso dell'Inverno. Nella Primavera poi, e per qualche tempo [a]vanti di far uso della materia monda; si ridurrà di nuovo in pasta, la qual cosa ripettasi per tre o

quattro volte, lasciando fra una volta e l'altra un tempo sufficiente per essicare l'argilla, osservando, che quanto sarà rimescolatta, e impastata, tanto

(p. 2)

migliori riusciranno li mattoni, tegole e quadrelli, e nell'atto di formargli si procurerà una perfetta ugualità di consistenza nei pastoni.

Terminato l'impasto dell'argilla nella quantità bisognevole, è necessario avere le forme, e modello di legno, le di cui misure sogliono essere diverse; la migliore, e la più comoda forma che si possa dare ai mattoni, si è quella d'un parallelepipede retangulo, la di cui lunghezza sia doppia della larghezza, con tanta inoltre di lei parte d'avantagio, quanta importarà ne può la comensura, affine che due di essi in larghezza insieme gionti colla necessaria calce tra loro, li laterali più corti dei medesimi constituischino un grado perfetto.

Riguardo alla grandezza, che meglio può convenire alli predetti mattoni per essere maneggevoli, è quella che si usa in Piemonte, in cui la lunghezza è onccie sei, abbondanti, la larghezza onccie tre, e la altezza onccie una e mezza del piede liprando, come si potrà scorgere dalla forma o modello di legno, che per tal'effetto verrà rimesso; per dare in seguito una sufficiente idea di quest'operazione si descriverà la maniera di costruire li mattoni, che sono quelli di cui si fa' maggior uso nelle fabriche, e quanto si dirà di questi servirà di lume bastevole per formare le tegole, e quadrelli.

Comincia per tanto l'operaio a bagnare

(p. 3)

internamente il modello del mattone, e tosto lo asperge con sabbia secca, tanto che basti affinché l'argilla non si attacchi al modello, il quale empio in seguito coll'argilla già impastata, la comprime fortamente colle mani, indi con un pezzo di legno termina di comprimerla uguagliandola nel modello, dopo del che cava fuori il mattone, e ponendolo in disparte esposto al sole, principia da capo, e forma un altro mattone, e così successivamente proseguisse.

Allorché questi mattoni sono secchi a metà, con un coltello si toglie tutto ciò che può rendere il regolare il loro contorno, indi sopra un suolo al quanto elevato, affinchè in caso di pioggia non siano inondati e si disfacciano di nuovo, si collocano di due in due, ciascheduno sul fianco più lungo e sotile se ne fa' una fila, e facciendo in seguito quatro o cinque file una sopra l'altra, si disponguino le cose in modo che i mattoni si tocchino fra' loro per la minore possibile quantità di superficcie aciočhé seguino più facilmente, poscia si coprono con tegole già cote per ripara[r]li dalle piogie, e nei fronti con ramicelle frondute si riparano dai forti ardori del sole, il quale attraendo con una tropa violenza l'umido dei detti mattoni, produrrebbe molte disgionzioni nelle parti argillose, contrarie alla bontà, che si ricerca nei mattoni.

Alle date notizie, si deve agiungere la seguente avvertenza

(p. 4)

affine di avere mattoni d'otima qualità.

Si darà principio nella Primavera, et in tempo confacente a convertire in mattoni l'argilla già per intiero preparata, e si procurerà, che in settembre al più sia terminata questa operazione, affinché i mattoni abbiamo tempo ad esiccarsi, ben, bene prima d'essere posti nella fornace, senza la quale avvertenza riescono d'inferiore qualità.

Fra le diverse maniere di far cuocere i mattoni nella fornace la migliore è quella di porgli entro una fornace a volta poi appresso consimile alle fornaci de pentolai, disponendo in essa i mattoni in modo, che ci sia fra l'uno e l'altro uno spazio tale che il totale volume dei mattoni non oltrepassi li due terzi della capacità della fornace, affinché la fiamma possa facilmente insinuarsi in questi vani e cuocere ugualmente tutti i mattoni a questo fine; si lascia anche un vano tutto d'intorno fra le pareti interne della fornace ed i mattoni, e tutti questi vani si empiano di piccoli pezzi di legna e di carbone.

Il fuoco si farà gradatamente, sin atanto che si conosca che i mattoni sono ben cotti, se poi il forno non sia a volta, fa di mestiere che i mattoni non si dispongano a troppa altezza affine riescano tutti ben cotti.

Per conoscere poi la qualità dei mattoni che ci si esibiscono vi sono alcune maniere.

Una di queste maniere consiste nel battergli l'uno contro l'altro, se il suono che producono sarà netto, e forte, il mattone sarà di buona qualità; e si dovrano rifiutare quelli che producono un suono confuso, o sordo.

(p. 5)

Un'altra maniera ancora più sicura per riconoscere i mattoni di buona qualità, è di distendergli per terra nell'autuno, e lasciargli esposti all'intemperie dell'inverno; quelli, che alla Primavera si troverano i[n]farinati, manifesteranno con ciò la loro pessima qualità, e per contrario sarano buoni quelli che non avrano sofferto alterazione alcuna; è di poca considerazione il pretendere di discernere la buona qualità dei mattoni dal solo colore, è cosa troppo sogetta all'errore, poiché il colore serve solamente a distinguere i mattoni più, o meno cotti nella medesima cotura; ma non si può ciò conoscere confrontando mattoni di diverse cotture, allorché le argille, colle quali sono costrutti i mattoni, sono diversamente colorite; a parlare con tutta precisione, il colore de' mattoni, a niente serve per riconoscere la qualità interna come abondevolmente si può dedurre dalle così dette intorno alle qualità delle argille, dalle quali la qualità dei mattoni necessariamente dipende.

(...) [Il] guadagno nei fabricatori dei mattoni, e la falza, ed apparente economia, che ben spesse volte si osserva in quelli che fano lavorare a proprie spese, sono il motivo, che ora si bada poco alla qualità dell'argilla, ora si preferisce un'argilla di qualità inferiore sulla sola considerazione che trovandosi questa più vicina al sito della fabrica, si fa con ciò un risparmio nelle condotte, ora si tralascia di separare l'argilla dalle materie eterogenee, e quasi da tutti s'impasta pochissimo l'argilla, e solamente tanto, che basta per poterla configurare in mattoni.

(p. 6)

La presentanea maniera poi di far cuocere i mattoni, è anche puoco buona; imperoché nel disporre i mattoni nella fornace, si lascia poco vano tra un mattone e l'altro, affine di collocarne un maggiore numero in ciascheduna cuocitura; e in altra si sobrappongono tanti mattoni gl'uni sopra gli altri, e si forma un'altezza tale, che le legna le quali ardono nella parte inferiore della fornace, hanno pochissima azione sopra li mattoni collocati superiormente, mentre chè pel grande fuoco si fetrica l'arena dei mattoni posti inferiormente, e si cuoce oltre modo l'argilla, quindi ne viene che da questa maniera di far cuocere i mattoni ne risultano in ciascheduna cuocitura qualità diferenti, che dalla sola azione del fuoco derivano, le quali qualità dai Pratici in corso di fabrica si riducano a tre, e sono

Prima. I mattoni denominati *ferrioli* e questi sono quelli che erano più vicini alla legna. Questa specie di mattoni solamente si adopera con vantaggio nei siti umidi, e nella fondamenta delle fabriche.

Secunda. I mattoni più lontani dal fuoco, si denominano *albano*, l'uso di questi è sempre cattivo in qualunque sito si adoperino; ma è poi pessimo nella parte esterna delle muraglie, e specialmente in quelle che sono esposte a mezzanotte.

La terza qualità, si denomina *mezzanella*, e sono i mattoni, che nella fornace erano tropo vicini ne troppo lontani dal fuoco, l'uso di questi è sempre buono in qualunque sito

(p. 7)

della fabrica s'impieghino, purché sia di buona qualità l'argilla con cui sono stati costruti. Nonostante la fatta distinzione dei mattoni, si dee osservare, che non tuti quelli della medesima qualità sono cotti al medesimo segno; impercioché, siccome i mattoni nella [fornace] sono disposti in grande altezza, e che il fuoco si fa solamente nella parte inferiore della fornace, la quale non ha per di sopra nessuna volta, che riverberà il fuoco d'alto in basso, e che i vani, che si lasciano frà i mattoni non sono sufficienti a lasciar la fiama comodamente, né questi vani sono empiuti di materie combustibili, così il grado di cuocitura nei mattoni, sminuisce a misura che questi si trovano più lontano dal sito inferiore della fornace, ove si fa il fuoco, chepperò i mattoni attigui al fuocò riescono molto ferrioli, lo sono meno li sucessivi, ed ancora meno gli altri, che sono posti superiormente, e che già si considerano per Mezzanella molto cotta. A questa sucede la Mezzanella sufficientamente cotta; gli altri mattoni immediati, si contano per Mezzanella meno cotta, e già confinante con l'*albano*, e finalmente il giungere all'Albano, in cui li mattoni d'infima qualità sono li più lontani dal fuoco, le quali tutte fano praticamente, e danno sufficientamente a dividere, che la detta presentanea maniera di far cuocere li mattoni è molto difetosa, e che debono adoperare quelle maniere, per cui si ottengono tutti i mattoni ugualmente ben cotti e conseguentemente idonei a prestare nelle fabriche qual vantaggio, che nell'uso loro pretendesi.

(p. 8)

Il sottoscritto Cap[ita]no Ingegnere si riserva di spiegare magiormente li suoi sensi qualora si trasferirà.

Iglesias, li 25 marzo anno 1773

APPENDIX 2

This text derives from an unpublished letter of Michael Wingate to Sir Bernard Feilden dated 6 March 1986. The document is kept in the Sir Bernard Feilden Papers, folder on Mortars and Plasters, King's Manor Library Archive, Centre for Conservation, University of York.

...The chemical industries may specify and get highly reactive limes, but the bagged hydrated limes offered to us are not really as reactive as they should be, particularly for conservation work without cement. Some of the best modern kilns produce material as good as that produced in the past by wood-fired kilns where the low temperatures were a great advantage. Hand picking improves quality since the severely overburnt and underburnt material is rejected.

You wondered about the chemical composition. Although the great majority of the quicklime will be calcium oxide, there are very considerable impurities. The underburnt material is still calcium carbonate and in bagged hydrated lime this is ground fine and put into the bag. In traditional work large underburnt cores were rejected on the sieve after slaking and the small pieces passing the sieve appear as 'aggregate' rather than as a dilution throughout the lime matrix of a mortar. The severely overburnt material would be a more or less cementitious (though very damaging) compound of calcium oxide and allumino-silicates. At the modern limeworks some of this is rejected by the cyclone, but the reminder is ground up small and popped in the bag.

This still leaves the invisible difference between a lump of pure calcium oxide which may be either reactive (= good) or less reactive down to the level of dead-burned lime which just will not slake at all. In its origin the kiln temperature is the deciding factor. At the higher temperatures I think the lump shrinks. Then the pores formed as the carbon dioxide is driven off close down, reducing the surface area available for reaction...

APPENDIX 3

SPECIMEN OF QUESTIONNAIRE

1. Year of construction
2. Name of the Master Mason
3. Profession of the Master Mason
4. Village
5. Conservation carried out with
   - ❑- Traditional materials
   - ❑- Modern materials
   - ❑- No conservation since it was built
6. Listed Building
   - Yes ❑
   - No ❑
7. Lavatory facilities
   - Yes ❑
   - No ❑
8. **Plinth**
   - ❑- stone
   - ❑- fired brick
   - ❑- concrete
9. Plinth: condition report
   - ❑- erosion
   - ❑- decomposition
   - ❑- cracks
   - ❑- stains
   - ❑- vegetation
   - ❑- changes of ground level
   - ❑- rising damp
10. **Walls: materials**
    - ❑- mud brick
    - ❑- stone and mud brick
    - ❑- cement brick and mud brick
    - ❑- fired brick and mud brick
    - ❑- concrete and mud brick
11. Walls: condition report
    - ❑- erosion
    - ❑- decomposition
    - ❑- cracks
    - ❑- stains
    - ❑- vegetation
    - ❑- collapse
    - ❑- leaning walls
    - ❑- rising damp
    - ❑- nests of rodents
12. Walls: renders
    - ❑- mud
    - ❑- lime
    - ❑- cement
    - ❑- no render
    - ❑- tiles
13. Walls: paint
    - ❑- limewash
    - ❑- modern paint
14. Renders
    - ❑- erosion
    - ❑- decomposition
    - ❑- cracks
    - ❑- stains
    - ❑- vegetation
    - ❑- no renders
    - ❑- detachments
15. Walls: corners
    - ❑- mud brick
    - ❑- fired brick
    - ❑- stone
    - ❑- cement brick
    - ❑- concrete
16. Corners: condition report
    - ❑- detachment
    - ❑- cracks
    - ❑- render missing
17. **Openings: doors**
    - ❑- mud bricks
    - ❑- fired bricks
    - ❑- with balcony
    - ❑- stone
    - ❑- cement bricks
    - ❑- concrete
18. Openings: condition report
    - ❑- good
    - ❑- to maintain
    - ❑- to be re-built
19. Openings: windows
    - ❑- mud brick
    - ❑- fired brick
    - ❑- with balcony
    - ❑- stone
    - ❑- cement brick
    - ❑- concrete
20. **Fenestrations**
    - ❑- aluminum
    - ❑- original timber
    - ❑- new timber
    - ❑- PVC
21. Fenestrations: condition report
    - ❑- good
    - ❑- to be maintained
    - ❑- to be re-built

22. Openings: portal
- ☐- round arch
- ☐- three-centred arch
- ☐- timber beam
- ☐- cement beam

23. Portal: filling above the arch
- ☐- mud brick
- ☐- fired brick
- ☐- stone
- ☐- cement brick
- ☐- concrete

24. Portal: jambs
- ☐- mud brick
- ☐- fired brick
- ☐- stone
- ☐- cement brick
- ☐- concrete

25. Portal arch
- ☐- mud brick
- ☐- fired brick
- ☐- stone
- ☐- cement brick
- ☐- concrete

26. Portal (fenestration):
- ☐- original timber
- ☐- new timber
- ☐- aluminum

27. **Decorations**
- ☐- cornices
- ☐- floor level decoration
- ☐- stucco-work
- ☐- flat columns
- ☐- terracotta

28. Decorations: condition report
- ☐- good
- ☐- to maintain
- ☐- to be re-built

29. **Loggias:**
- ☐- round arch
- ☐- three-centred arch
- ☐- pointed arch
- ☐- beam/flat arch

30. Loggias: filling above the arch
- ☐- mud brick
- ☐- fired brick
- ☐- with balcony
- ☐- stone
- ☐- cement brick
- ☐- concrete

31. Loggias: jambs
- ☐- fired brick
- ☐- mud brick
- ☐- stone
- ☐- cement brick
- ☐- concrete
- ☐- timber

32. Loggias: condition report
- ☐- good
- ☐- to maintain
- ☐- to be re-built

33. **Roof**
- ☐- double slope
- ☐- flat roof
- ☐- terraced

34. Roof: structure
- ☐- timber
- ☐- steel
- ☐- concrete

35. Roof tiles
- ☐- traditional tile
- ☐- industrial tile
- ☐- asbestos lumber

36. Roof: condition report
- ☐- water penetration
- ☐- dampness
- ☐- animal nests
- ☐- vegetation

37. Roof: gutters
- ☐- inside the wall
- ☐- outside the wall
- ☐- gargoyle

38. Gutters: condition report
- ☐- good
- ☐- to be maintained
- ☐- to be re-built

39. **Courtyard: paving** system
- ☐- cobbles
- ☐- fired bricks
- ☐- cement
- ☐- earth

GLOSSARY OF TECHNICAL OR FOREIGN TERMINOLOGY

The aim of the glossary is to define the terminology that could not be explained otherwise in the main text of the thesis. Italian and Sardinian terms are always in italics and the explanation of Sardinian words is often followed by the village or area where the word was recorded. If the term is widespread in the whole region of Campidano, provenance is not given. The glossary is structured into three sections: geological terms, technical terminology on conservation, and foreign terminology.

Abbreviations:

It = Italian

Fr = French

Sp = Spanish

Sr = Sardinian

Geological terms

Anthraccite = the general name given to stratified accumulations of carbonaceous material derived from vegetation

Basal conglomerate = a conglomerate formed at the beginning, i.e. the earliest portion, of a stratigraphical unit

Cambrian period = (Geology) from the Roman name of Wales, Cambria. The oldest system of rocks in which fossils can be used for dating and correlation. The period commenced at least 530 +/- 40 m.y. ago, and had a duration of at least 70 m.y.

Carboniferous period = the period between the Devonian and the Permian periods

Clastic rock = rock built of up of fragments of pre-existing rocks which have been produced by the processes of weathering and erosion, and in general transported to a point of deposition

Cretaceous period = from the Greek *creta*, chalk. The Cretaceous period had a duration of approximately 72 m.y., from 136 to 64 m.y.

Devonian = a period named from the county of Devon in south-west England. It extends from 395 to 345 m.y., having a duration of 50 m.y.

Eocene epoch = the epoch of the Tertiary period between the Palaeocene and Oligocene epochs

Epicontinental = situated within the limits of a continental mass

Gothlandian period = named after the Island of Gothland, Sweden. The period extended from 435 to 395 m.y., having a duration of 40 m.y.

Hercynian period = applied by and after the ancient writers to the wooded mountain-system of Middle Germany or to portions of it. The period extended from the Carboniferous to the end of the Permian periods

Jurassic period = name derives from the Jura Mountains of France. It is the period of time extending from 195 m.y., having a duration of 60 m.y.

Lithofacies = facies particularly characterised by its rock type

Miocene epoch = the epoch of the Tertiary period between the Oligocene and the Pliocene epochs

Oligocene = the epoch of the Tertiary period between the Eocene and Miocene epochs

Ordovician period = named from the Ordovices, an ancient Celtic tribe in Central Wales. The period extended from 500 to 435 m.y., a duration of 65 m.y.

Permian rock = named from the province of Perm in Russia. The period of time from 280 to 225 m.y., a duration of 55 m.y.

Pleistocene epoch = the epoch of the Tertiary period between the Pliocene and the Holocene epochs

Pliocene epoch = the epoch of the Tertiary period between the Miocene and the Pleistocene epochs

Porphyry = the term is used for any medium-grained rock containing large crystals or any mineral

Pyroclastic rock = pyroclastic rocks consist of fragmental volcanic material which had been blown into the atmosphere by explosive activity

Triassic period = the period extends from 225 to 195 m.y., with a duration of 30 m.y.

Schist = a regionally metamorphosed rock characterised by a parallel arrangement of the bulk of the constituent minerals

Technical terminology on conservation

Aggregate = the totality of gravel, sand, silt, clay, and organic matter in a lime mortar or render

Archaeometry = the discipline that studies how, when and where an object was manufactured, and if it had any later modification (Torraca 1999, 1). It can be also defined as the application of scientific methods and analyses to the study of culture in its archaeological context. Another definition is: 'how was an object made? when? where? was it modified later?' (Torraca 1999, 8).

Atterberg limits = see *plastic limit*, *liquid limit* and *plasticity index*

Clay = Alva and Teutonico (1983, 42) explain that 'to clay is attributed the property of cohesion in the soil composition, or better, that of "binder" of the mix', whilst the function of silt is not so well defined. Tests carried out on solid particles of silt characterise it as a material of poor plasticity, of marked dilatancy, of low cohesion, and that disgregates easily on contact with water' (Alva and Teutonico 1983, 42)

Clay-and-bool = traditional building technique of the Laigh O'Moray (Scotland). After shuttering is erected, big stone pebbles are put into the sides of the shuttering and earth is the tampered in order to form the core of the wall. When shuttering is removed, the sides of the wall will reveal stone patterns (Walker and McGregor 1997, 11)

Collapse = total or partial collapse of *làdiri* walls

Consolidation = a conservation treatment involving the application of a penetrating liquid designed to restore cohesive strength to friable or powdering materials such as plasters, adobe or paint (Matero 1995, 23)

Coving effect = (*làdiri* wall) basal erosion caused by a combination of causes: salt attack, splashing, loss of cohesion and animals abrading the wall

Cracks (*làdiri* and plaster) = 'fractures of variable length and orientation, ... and with or without associated planar displacement of the plaster' (Matero 1995, 25)

Decomposition (*làdiri* surface and mud plaster surface) = the superficial separation of the components of mud bricks into smaller elements

Decomposition (lime plaster) = the superficial separation of the components of lime plaster into smaller elements

Detachment (plaster) = complete or partial lacuna of plaster

Erosion (*làdiri* walls and mud renders) = water erosion is due to the fact that 'clay becomes impermeable to water and excess rain runs over the surface, carrying suspended matter and digging preferential channels which erode even faster because they are subjected to a larger water content' (Chiari and Alva 1984, 2; Chiari 1983, 35). Another cause of erosion is wind which 'can cause detachment of loose parts or be responsible for abrasion, especially if carrying suspended sand' (Chiari and Alva 1984, 3). It has also been proposed that the explanation of the mechanisms of erosion can be simplified as the sliding of horizontal clay wafers and their orientation over the vertical surface of the wall, causing consequential detachment (Torraca 1982, 96; Viñuales 1981, 44)

Erosion (lime plaster) = erosion of lime plaster is mainly due to the ability of calcium carbonate of being slowly converted in solution by water attack. Very porous lime plaster can be also eroded by the action of wind

Ethics = 'the term refers to rules of conduct; typically to conformity to a code or a set of principles. A distinction is sometimes made between ethics and morals. While both are concerned with what is good or bad, right or wrong, ethics are usually taken as referring to general principles of what one ought to do. Morals are usually concerned with whether or not a specific act is consistent with accepted notions of right or wrong' (Robson 1993, 29)

Flaking/scaling = (plaster) 'the lamellar loss of the plaster surface resulting in an uneven and irregular contoured surface of the exposed rough or finishing coat' (Matero 1995, 24)

Grouting = 'a conservation treatment involving the injection of fluid mortars or adhesives into blind or partially concealed voids to rehadere and/or fill detached layers and to re-establish structural continuity' (Matero 1995, 24)

Leaning walls (*làdiri* walls) = this expression includes those walls that are leaning because of design or constructional faults, and those that are leaning because of action of weather or of alterations to the building

Liquid limit = the liquid limit of a soil can be defined as 'the water content, expressed as a percentage of the oven-dried soil, at the boundary between the liquid and plastic states'(Teutonico 1985, 81)

Molarity = 'the number of moles of solute per litre or 1000 ml of solution. It is the most common system for calculating the concentration of solutions' (Teutonico 1985, 24)

Pathology = concerns with the cause, origin and nature of failure, and the changes that occur as a result of the failure. In a medical context 'the term *pathology* is defined as the systematic study of diseases with the aim of understanding their causes, symptoms and treatment' (Watt 1999, 1). In conservation terms the symptom is the effect

Plastic limit = the plastic limit of a soil can be defined as 'the water content, expressed as a percentage of the mass of oven-dried soil, at the boundary between the plastic and the semi-solid states' (Teutonico 1985, 75)

Plasticity index = the plasticity index of a soil is the difference between the *liquid limit* and the *plastic limit*

Pozzolan = 'a pozzolan is any material which contains constituents, generally allumina and reactive silica, which will combine with hydrated lime at normal temperatures in the presence of moisture to form stable insoluble compounds with binding properties. It may be used to give a hydraulic set to a mortar...' Broken roof tiles fired at low temperatures were preferred in Sardinia because of their porous nature. On the contrary, tiles fired at higher temperatures tend to decrease their pozzolanic properties (Leslie and Gibbons 1999, 32) especially if vitrification occurs

Rheology = the science of the deformation and flow of matter

Scratch coat = 'in three-coat plastering, the first or base coat, generally applied as a levelling coat and to prepare the surface for subsequent layers. This coat is often cross-raked lightly to present a roughened surface for a mechanical bond with the second coat' (skim coat) (Matero 1995, 24)

Silt = see *clay*

Stains = (plaster) patches of humidity over plinth level. This is therefore considered as a different symptom from rising damp

Symptom = see *pathology*

Technique = is the knowledge of how to make devices and other things out of raw materials. Technique is the knowledge which informs the activity of *workmanship*. It is what can be written about the methods of workmanship (Pye 1971, 21)

Technology = is the scientific study and extension of *technique*. In ordinary usage the word is used to cover not only this but invention, design and *workmanship* as well (Pye 1971, 21)

Workmanship = is the application of *technique* to making, by the exercise of care, judgement, and dexterity. As opposed to design, workmanship is what for practical purposes the designer cannot give effective instructions about by drawings or words, although he can envisage it perfectly well (Pye 1971, 21)

Foreign terminology

Adobe (Sp) = the Spanish word for mud brick. It is now used for referring to earthen building, especially in the USA and in Spanish-speaking countries. It can refer either to the building technique or to the building itself

Addu mùlli a unu a unu (Sr) = (literally: to work it one by one) rush had to soak (*ammoddiài*) for one or two days and to be flattened with the feet before using it for tying the cane sarking together (S.Giovanni di Sinis)

Aggiudu torràu (Sr) = the expression for *returned help*, a system that allowed the exchange of workmanship without circulating any money

Ammoddiài (Sr) = the overnight soaking of the loam before being used for *làdiri* making (Samassi); also used when referring to the soaking of rush, a procedure which made it softer before tying the cane sarkings with it (S.Giovanni di Sinis)

Ancrava (Sr) also found as *ancraba, encraba,* and *incraba* = wedges made of timber, broken roof tiles or stone, which were hammered in the vertical joints of mud bricks in order to make the layers of plaster grip

Anteas (Sr) = parallel arches of the kiln used for the firing of roof tiles and bricks, with the function of carrying the weight of the charge of the kiln (Silì)

Apprendista (It and Sr) = (craftsman) this was the stage of the apprenticeship after the *manorba*: at the age of eighteen the craftsman was a good brick and stone layer and, if skilled and experienced, could then become *maistru de muru*

Apprendisti pittori (It) = apprentices who had to execute the humbler works such as incorporating the pigments in the binder and cleaning the brushes (Monserrato)

Arriccio (It) = scratch coat

Arrisigadori (Sr) = iron scraper, used for cleaning the scrap from the bench during the process of tilemaking (Segariu)

Ascerai (Sr) = the process of fermentation of the soil when put to soak overnight (Assemini)

Barrilocca (Sr) = the afternoon nap as taken by the *làdiri* makers of Silì

Biacca (It and Sr) = white lead

Biga (Sr) = floor joist. The term originates from the Catalan word *biga*, or from the Spanish *viga* (Pastonesi 1998, 55)

Boiaca (Sr) = lime mortar used for fixing floor tiles

Bòvida (Sr) = term of Spanish origin meaning vault (Galdieri 1982, 198). It is still in use in Sardinia even though the Spanish colonization ended at the beginning of the eighteenth century, but the term is nowadays used for with the meaning of false ceiling. It was made of studs and a layer of canes (lathing) on which a screed of mud and straw (or lime and aggregate) was applied

Cagòdisi (Sr) = clay lumps which did not manage to soak during fermentation process (Silì)

Canna drommìa (Sr) = (literally: sleeping cane) this was the state of growth of the cane when it was ready to be cut

Canna maistra (Sr) = these two terms literally mean 'master cane', on which series of two horizontal layers of canes were tied with rush symmetrically when forming partitions (Villaurbana)

Cannas (Sr) = trapezoidal mould for roof tiles making (Sili)

Carrigài (Sr) = charging the kiln (Sili)

Chiaroscuro (It) = a fashionable interior decorative style characterised by two or three colours used for decorating the room and by the use of a heavy shading (Monserrato)

Chinzu è s'anea (Sr) = the second strata after the topsoil (*terra mozza*), it was not used in the making of tiles because too slim and sandy (Sil)

Ciappa (Sr) also found as *marra* = mattock (Samassi)

Ciniscíu (Sr) = typical mud mortar of the region known as Gerrei. There stone was bonded by using a mortar made of a mix of sieved soil, ashes and water. The mortar was known in the region for having a high bonding activity

Coccio pesto (It) = porous tiles were crushed and added to lime mortar. These could in the long term act as a pozzolanic additive and therefore give hydraulicity to the mortar

Concatenamento (It) = the system of juniper ties used against lateral bulging of walls (ASQ 1868b)

Contonara (Sr) = the fired brick dressing of corners in *làdiri* walls

Coxina (Sr) = kitchen

Crabiolas (Sr) = rafters, cut locally in Villamassargia and left to season for at least one year before use

Croimentu (Sr) = timber lintel for doors and windows

Cummussura (Sr) = (also found as 'commessura') see *trampabis*

Dama (Sr) = (or *mazzeranga*) wooden tool for beating stones on the ground when cobbling the courtyard (Villamassargia)

Dom'é sa mola (Sr) = the mill room

Domu (Sr) = from the Latin *domus* meaning house

Floriada (Sr) = best quality tiles, slightly whitey on the surface (Silì)

Fogheras (Sr) = the two sectors of the kiln for tile burning where faggots were placed to burn (Silì)

Forru (Sr) = kiln, oven (Silì). Villages such as Ghilarza often show areas named *Su Forr'e sa Teula* (The Tile Kiln), indicating the presence of a firing site (ASC 1847). Furthermore, in Ottana a *Nuraghe Furreteula* (Nuraghe Tile Kiln) exists

Fromma (Sr) = the splayer in roof tile making (Segariu)

Funtana (Sr) = fountain

Gravosa (Sr) as used in the expression *terra gravosa* = sandy soil, also known as *battisèi* (San Sperate)

Guatteddu (Sr) = special knife used by children and women for cleaning canes from all leaves before setting them to dry (S.Giovanni di Sinis); another tool used for cleaning canes was *sa pudazza* (Nuraminis, Assemini)

Imperdàra (Sr) = the finishing cobbled layer in walkways

Incambarai (Sr) = the act of cleaning *làdiri* bricks from all imperfections after drying (Assemini)

Intonaco (It) = skim coat

Imbianchino (It) = interior limewasher, also called *pintore de muru* (Monserrato)

Laccu (Sr) = (It. *trogolo*) monolithic stone manger, sometimes used as a tank for slaking lime (Villamassargia)

Ladireddu (Sr) = see *sestu pitticcu*

Làdiri (Sr) also found as *làdini, làdri, làdrini, làrdi* and *làrdini* = the Sardinian word for 'mud brick dried in the sun', the term has roots in the Latin *later* meaning mud brick. The word *làdiri* can be either singular or plural. Bertagnin (1999,.44) explains that there was in the Roman period a difference between mud bricks (*lateres*) and fired bricks (*lateres cocti*, or *testae*), and between mud brick walls (*opus latericium*) and fired brick walls (*opus testaceum*). See also definition of *Làdiraiu*

Ladiraiu (Sr) = *làdiri* maker by profession, the manufacturer of mud bricks was an important figure especially for those who wanted to build a house but did not have any good quality soil in their fields. Small-scale *làdiri* factories were not rare in Campidano, for example those located in Serramanna and Villaurbana: the last *ladiraiu* of Villaurbana was Terenzio Muroni who gave up producing bricks in 1958

Ludu (Sr) = mud, also used when referring to mud render

Ludu a pranta è manu (Sr) = (literally: mud render applied with bare hands) this activity was carried out by the women

Lùggiau (Sr) = pure clay (Silì)

Magazìu (Sr) = storage room

Maistru e linna (Sr) = the master of timber, whose main activity was the cutting and working of softwood for the making of windows, doors and portals

Maistru è muru (Sr) = (also found in the colloquial version 'Maistru') the master of the wall was the supervisor of the whole building; he was an essential figure of the building site because of his deep knowledge of different building materials

Manorba (Sr) = the second stage of apprenticeship after the *manovaleddu* in the craftsmen hierarchy: in this stage the craftsman was allowed to lift heavier building materials and to start working in the mixing of mortar

Manovaleddu (Sr) = the young unskilled worker who started from scrap by carrying out the lightest work

Marmorina (It) = a marbly compact stone, considered the best for burning lime (Villamassargia)

Mazz'è cani (Sr) = flat stones traditionally used in the repair of eroded walls (Vilamassargia)

Mazzeranga = see *dama*

Merd'è ferru (Sr) = literally 'iron dung'; the baking surfaces of ovens were usually made of an admixture of soil and *merd'è ferru,* consisting of impurities of coal derived from the hammering of iron which was provided to the craftsman by the local blacksmith

Mollus (Sr) = the splayer in roof tile making (Silì)

Murigai (Sr) = the first mixing of the mud used for tilemaking (Silì)

Murzai (Sr) = the mid-morning breakfast as had by the mud brick makers of Silì

Nuraghe (Sr) = megalithic circular forts made of stones sometimes laid without mud mortar. See *nuragic*

Nuragic = the Nuragic period spanned from 1500 BC to 230 AD and was named after the *nuraghe* construction

Obillùs (Sr) = blacksmith nails of various size for the construction and repair of trusses (Nuraminis)

Omu é sa palla (Sr) = straw barn

Omu manna (Sr) = the main room

Pàbia (Sr) = (*badile*) the shovel (Samassi)

Palanchinu (Sr) = lever used for moving heavy stone blocks

Palattu (Sr), Palazzo (It) = word used with reference to the transformation undertaken at the end of the nineteenth century by humbler vernacular earthen buildings which gradually assumed the shape of urban decorated palazzi

Pedra (Sr) = a terracotta element on which the tile-maker gave shape to the tiles (Sili)

Pei tremini (Sr) = (*a pei tremini*) is the expression for *rhomboid shape.* The *tremini* is the triangular grill traditionally used in the fireplace. The expression *a pei tremini* literally means 'as the print left by the feet of the grill'

Perda è arena (Sr) = sandstone

Perda è pibiri (Sr) = (literally: pepper stone) the most favourite stone for building plinths (Villamassargia)

Picapedreri (Sr) = term of Spanish origin meaning mason/craftsman, more recently used with reference to stonemasonry only

Pintore de muru (Sr) = (literally wall painters) the expression used for indicating those interior limewashers (also called *imbianchini*) who did not carry out any decorations, but just the basic limewash used as a background by the interior decorators (Monserrato)

Pisé de terre (Fr) = French expression for *rammed earth* originating from the Latin *pinsere*, to ram

Pittore (It) = interior decorator, in some cases considered as artist, also called *decoratore*. In mid twentieth-century Monserrato the following wall painters were active:

Giovannni Ariu, Giovanni Atzori, Francisco Cogoni, Antonino Lubrano, Paulleddu and Salvatore Porcu, the last one also known as Totore il Pittore (Monserrato)

Praza (Sr) = drying ground on which bricks and tiles were laid before burning process (Sili)

Prazixedda (Sr) = the open space where the kindle wood was stored

Pudazza (Sr) = a hooked tool used for the cleaning of *làdiri* from all imperfections in order to make them straight (Samassi)

Pudinga (Sr) = pebbles and unsoaked lumps of soil during mud brick manufacturing. Walls made of bricks with a high content of *pudinga* were strengthened against cracks by the insertion of juniper keys in the corners (Assemini)

Punciotto (Sr) = wedge used in stone splitting (Serrenti)

Purgatura (Sr) = the act of screening the clay from all impurities when making fired bricks (Quartu Sant'Elena)

Puzzu (Sr) = well

Quaddu armau (Sr) = naturally arched juniper timber used for the making of a basic truss: fixed on both ends on the walls, in its central curved part was concentrated the weight of the roof

Quadretti (It) = square floor tiles made of fired clay

Quartas (Sr) = the system through which four families joined together in a consortium in order to keep tile burning costs sustainable (Sili)

Rincasciu (Sr) also found as *arricasciu* = traditional repair method for plinths affected by rising damp or by salts (Campidano). In Villamassargia the word *rincasciu* was referred to the traditional repair methods for eroded *làdiri* walls

Rinzaffatura (Sr) = slurry coat of mud or lime applied to the wall before plastering

Saltus (Sr) = see *viddazone*

Scaffadura, Scaffai (Sr) = the second mixing of the mud used for tilemaking (Sili)

Scala è gattu (Sr) = timber staircase, characterised by a nail-free joinery (Villamassargia)

Scalladori (Sr) = timber tank for slaking lime (Villamassargia)

Scioffa (Sr) = the third mixing of the mud used for tilemaking (Sili). The name *scioffa* indicated also the mix of soil, water and straw used for the making of mud bricks (Samassi)

Sciorrài (Sr) = the unloading of the kiln (Silì)

Scivu (Sr) = also known as *sciffu*, the wooden trapezoidal container used for carrying the mix of mud and straw necessary for the making of two bricks (Villaurbana)

Scovitta (Sr) = floor brush, also used for limewashing (Villaurbana)

Scrostatura (Sr) = the act of scraping off the render from a mud wall (ASQ 1868b)

Seda (Sr) = the string used for detaching the clay from the frame (*cannas*). It was traditionally made of horse hair and more recently of plastic (Silì)

Serralia (Sr) = also called *serraglia*, the central keystone of portals and arches. The other quoins forming the arch were called *armeglias* (Serrenti, Samassi)

Sestu (Sr) = mould used for mud brick making; also used in Segariu for indicating the washing-off frame in tile making

Sestu pitticcu (Sr) = it is literally translated as small *sestu*, small mould. It is the truncated-pyramid mould used for the making of smaller *làdiri* (called *ladireddu*) used for the construction of emispherical ovens

Stabi é is bois (Sr) = cow shed

Strutturi (Sr) = bench used for tile making (Silì)

Stuccatore (It) = plasterer, stuccoworker (Monserrato)

Stuggiu (Sr) = area close to the *pedra* where the splayer was located (Sili')

Tegolaio (It) = roof-tile maker, one of the most popular tile-makers of twentieth-century Silì was Bernardo Manunza who could mould 700-800 tiles in a twelve-hour day (Silì)

Tabicu (Sr) = term deriving from the Spanish *tabique* (Mossa 1957a, 113 and Galdieri 1982, 198); the partitioning system made of timber posts and cane sarking covered with daub and then plastered

Tampico (It) = a vegetable fibre used for making brushes and extracted from the agave plant; *tampico* is more resistant and stronger than bristle

Terra dessu forraxi (Sr) = a clayey soil used for *làdiri* making. Strong in compression, it does not allow the render to grab and does not behave well during the wet season because it washes away easily (Assemini)

Terra d'ombra = it can be literally translated as 'shadow earth'. This was the pigment used for painting shadows and for the technique of pouncing: a cardboard sheet on which the pencil drawing was perforated was used in order to allow the *terra d'ombra* to penetrate through the holes and get fixed on the wall when brushed in (Monserrato)

Terra è anea (Sr) = this was considered to be the best soil for mud brick making, it was found in the alluvial lands close to streams (Villaurbana)

Terra mozza (Sr) = the topsoil that includes organic matter and stones, never used in roof tile making (Sili)

Terra niedda (Sr) = the third strata after the topsoil (*terra mozza*) and the mid strata (*chinzu è s'anea*), it was considered to be the best soil for tile making (Sili)

Tirare le cornici (It) = expression meaning 'to run mouldings'

Trambabis (Sr) = the round section iron bars (30 mm in diameter) fixed in the vertical joints of the mud brick wall (in the *cummussura*) in order to accept some timber boards on top of them. This was a cantilevered scaffolding and the iron bars had to be inclined upwards in order to avoid the boards to slip (Villamassargia)

Trappa (Sr) = the kiln's grid made of mud brick, built in order to carry the charge of tiles or bricks to burn (Sili); the same word was used for indicating the rough dome built at the bottom of the lime kilns with the function of carrying the weight of limestones to burn (Villamassargia)

Unghia (It and Sr) = dovetail joint cut in trusses, between king post and principal rafter

Viddazzone (Sr) = this was a system through which the agricultural land was organised in two halves: one half was cultivated and the other half was left to rest for one year in order to maintain crops of standard quality by rotating cultivated areas with uncultivated areas every year. The remaining land beyond the *viddazzone* was thinly populated and called *saltus*, mainly used for grazing

Xibireddu (Sr) = rush sieve especially made for sieving the sand used in tile-making extracted from the rivers (Sili)

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Abbreviations:

AGI = Archivio dei Gesuiti, Seminario Arcivescovile di Iglesias

ASC = Archivio di Stato di Cagliari

ASI = Archivio Storico di Iglesias

ASQ = Archivio Storico Comunale di Quartu Sant'Elena

AGI - Archivio dei Gesuiti, Seminario Arcivescovile di Iglesias

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