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Climatic Effects on School Buildings

Methods of Optimising the Energy Performance of School Buildings in the Different Climatic Regions of Iran

Thesis Submitted for the Degree of Doctor of Philosophy in Architecture

By

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Dedication:

This thesis is dedication to the following:

- The almighty God
- My father and my mother
- My wife, Souzan and my son, Shahab

Acknowledgement

I am forever indebted to the almighty God, who has given me the wisdom, health and fortitude to attain this height in my educational and career pursuit.

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Abstract

Since the 1970s, over a thirty-year period, awareness of the limitation in fossil fuel reserves has been increased steadily and international attention has been given to an energy conservative way of life.

Like many developing countries, today Iran is beset with serious energy supply difficulties. The main issues are the rapid increase in energy demand/cost, air pollution caused by over use of fossil fuels (usually used in buildings for heating purposes), the limitation of fossil fuel resources and the difficulties in the transportation and distribution of fossil fuel especially in winter around the country. Therefore, it is crucial to adopt a new strategy for sustainable energy use and to consider the application of renewable energy technologies in the design of buildings. Solar energy is one of the most significant and technically exploitable renewable energy resources available in Iran. This needs to be taken into account seriously, regarding both economical and environmental problems in that country.

Since school buildings in Iran are one of the major consumes of energy for heating, cooling and lighting purposes and according to their inappropriate current design from the energy efficiency point of view, this study has been performed with the aim of developing methods of optimising the energy performance of school buildings in Iran and promoting low energy architecture in the design of these buildings in different climatic regions of Iran.

For this purpose, first the Iranian climatic has been reviewed and appropriate classification was presented. Since solar radiation data have not been calculated in Iran so far, there was a need for a precise calculation of solar radiation for each and every city in order to better exploit the benefits of solar energy for the future of this country. Therefore, the method of calculation of solar radiation in different cities of Iran based on European Solar Atlas and Islamic Republic of Iran Meteorological Organisation's statistics was presented and a spreadsheet excel program was developed for the calculation of solar radiation data of 152 cities of Iran. A comparison has been made between the excel program and Meteonorm. The result showed that the excel program data were more useful in that they were more precise and much more reliable compared to Meteonorm data for Iran. Also, based on solar radiation data another excel program (based on the admittance method) was developed for the calculation of heating, cooling and lighting energy use of buildings in Iran. By using this program the effect of window design on the thermal performance of school buildings and the response of walls and roofs to solar radiation was investigated in hot climates. Substantial saving in the annual running cost of school buildings as much as 14% was achieved under appropriate window arrangement.

In order to explore the problems of existing design, a case study has been performed on current schools design in Iran and the energy use of these schools was analysed.

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Chapter 1

Introduction

1_1 * Background

Before 1973, little action was taken toward a conservative use of energy. With the rapid escalation of energy prices beginning in 1973, and the continuous increase since then, international attention has been given to an energy conservative way of life. The problem of energy use and availability is common to a greater or lesser extent throughout the world. While the industrialized nations depend heavily upon fossil fuels for their industrial processes, the developing nations also desire to increase their technological capabilities and thus the use of energy in its various forms. The last 50 years have seen a fivefold increase in world energy use partly as a result of the availability of easily extractable fossil fuels (coal, gas and oil) and awareness of the limited nature of these reserves has existed since the 1970s. Although it is unlikely that the world will completely run out of fossil fuels in the this millennium, the majority of easily extractable reserves are located in a small part of the world and the price of fuels will therefore increase.

Depending on the level of industrial activity, a country uses about 30 to 35 percent of its total energy consumption in buildings. Of this amount, about 60 percent is used for heating and air conditioning. This means that of the total energy consumption, about 20 percent is used in building space heating and air conditioning. Burning fossil fuel is the most important source of providing energy in a building. One of the most serious complications of burning fossil fuel is the release of CO_2. The last 70 years have seen a 10% rise in atmospheric levels of CO_2 and at the same time global temperatures have risen by 0.2° C. The burning the fossil fuels is thought to account for half the global warming in the world through the greenhouse effect.

Fossil fuels are too precious to burn; they should be used wisely and not wastefully and not for the purpose of cooling or heating, etc. it must be stressed that the world's fossil fuel energy is limited by geological conditions. We are living in period where energy demands must be reduced through any means available. These should include; conservation of energy, employment of renewable energy, energy-conscious planning and design of buildings. Therefore the renewable energies should be the primary 21st Century energy source because it is free and exists all around us waiting to be exploited.

Solar energy is a renewable resource, which can make a useful contribution to the heating and lighting of buildings, and has an important role to play for sustainable development. We get a lot of sunshine, which if properly controlled, can help to reduce a buildings energy bills. Solar energy is also a non-polluting source of energy. Thus its effective utilisation helps to reduce emissions of carbon dioxide and other gases resulting from the use of fossil fuels.

Every building has some of its heating requirements met by solar energy. Sunlight passing through windows is a source of heat; but most buildings are not specifically designed to utilise solar energy. The value of passive solar heating is enhanced by proper building insulation. A well insulated building requires less energy for heating; and thus much of the heating load can be met by passive solar features. Insulation, like passive solar features, can often be incorporated into new building designs with little increase in construction costs.

Actions to improve building thermal efficiency could result in great energy savings, both for cooling and especially for heating, are through building envelope components (i.e., ceilings, walls, floors and glazing). Therefore, among all efforts to improve building thermal efficiency, application of thermal insulation in opaque components of building envelopes is the most effective and important one. By the installation of thermal insulation in building envelope components, in addition to a reduction of space heating and cooling costs on a long-term basis, other benefits such as occupant comfort and smaller capacity requirements for heating and cooling systems would be realised. Because of the considerable savings in the operating costs of a system and savings in initial costs, insulation pays back its investment in a short period of time.

The total number of school buildings in Iran in the year 2001 is almost 133,210. Since fossil fuels are cheap and plentiful in Iran, the energy consumption for heating, cooling and lighting of school building is dependent on these fuels and renewable energy has not yet been used. As a result of air pollution in Iran and with the aim of reducing the energy consumption of school buildings, the Iranian government has adopted a new strategy for sustainable energy use. They identified solar energy as an important non-polluting and renewable energy source. By making effective use of this we can limit environmental damage, conserve our fossil fuel reserves and save money.

This study describes the methods of optimising the energy performance of school buildings in the different climatic regions of Iran. It is largely aimed at the architects and engineers involved in the design of school buildings. It will also be of interest to building managers because it gives some idea of the various remodelling options.

1_2 * Scope of the Problem

The current designs of school buildings in Iran are not energy efficient. One of the reasons for this could be the use of inappropriate glazing-ratios and the materials used in the construction of walls and roofs have little or no thermal insulation.

One of the major problems of the developing countries such as Iran is the lack of knowledge about new technologies in using renewable energy. Therefore, the keys to improved building energy efficiency in the future are to learn and apply these efficient technologies.

One of the simplest methods of doing this is to make use of solar energy as a supplement to the heating and lighting requirements of buildings. This aspect forms a major part of this study.

The transportation and distribution of fossil fuels especially during winter is one of the other problems that the government is now facing in Iran. This also supports the use of renewable sources of energy such as solar energy.

1_3 * Hypothesis

Solar energy can be used to contribute to the energy requirement in educational buildings in different climatic regions of Iran.

1_4 * Aims and Objectives

This study aims to promote low energy architecture in order to improve the design and construction of new and existing school buildings in Iran. It also aims to develop methods of optimising the energy performance of school buildings in the different climatic regions of Iran.

The objectives of this study are as follow:

1) Reducing the use of fossil fuels as a heating resource. This will also affect the following:

- Reducing air pollution due to the consumption of fossil fuels.
- Controlling the current rising of global warming and reducing the adverse environmental impacts of burning fossil fuels as a main source of energy in the world.
- Conservation of energy, employment of renewable energies and environmental sustainability.
- Implementation of solar energy as a natural, cheap and clean source.

2) Suggesting an energy-conscious design for school buildings with the aim of reducing the energy costs of heating, cooling and lighting.

3) To develop a computer program for calculation of solar radiation in Iran.

4) To develop a computer program that facilitates the mathematical computations of heating, cooling and lighting and performs economic analyses.

5) Providing new design guidelines for energy efficient school design in Iran.

1$_5$ * Methodology

Firstly, a review has been performed on the Iranian climate. Secondly, the history of energy use in the world as well as Iran has been analysed and renewable energy technologies reviewed. By using Islamic Republic of Iran Meteorological Organisation statistics, a solar radiation computation for different cities of Iran has been carried out and an Excel spreadsheet program was designed with the aim of calculating solar radiation for Iranian cities. Then another excel program was developed for the calculation of heating, cooling and lighting energy consumption of buildings in Iran. By using this program the effect of window design on the thermal performance of the buildings has been studied. Also, the response of other building elements (walls, roofs and etc.) to solar radiation was investigated. Finally, a case study has been performed on current schools design in Iran and the energy use of these schools was analysed.

1.6 * Thesis Structure

This section provides a guide to this thesis. This thesis consists of ten chapters and appendices, which can be summarised as follows:

Chapter One: Chapter one contains the introduction. It gives a background to the issues. It also includes a descriptive introduction to the scope of the problem, rational, aims, objectives, methodology, and the thesis structure.

Chapter Two: The climatic characteristics of a region have an important impact on different aspects of a building. In many regions of Iran we obtain a lot of sunshine, which if properly used, will help to save a considerable amount of energy. This chapter contains general information about the geography of Iran. Also the climate of Iran is classified into 8 main groups. Then, the characteristics of each climatic group and its subgroups are described in detail.

Chapter Three: The analysis of the history of energy use in the world as well as Iran and a review of renewable energy technologies is dealt with in chapter three. This chapter reviews the potential of some of the major mature renewable energy technologies.

Chapter Four: Solar energy is one of the most important renewable energy sources in the world. Solar radiation data are the best source of information that is related to solar energy besides other meteorological measurements. These data have not been calculated in Iran so far. Therefore, this chapter contains the method of calculation for solar radiation in different cities of Iran and a designed excel sheet program for Iran.

Chapter Five: This chapter reviews the requirements for lighting in schools with the aim of suggesting appropriate levels and glazing ratios for natural lighting.

Chapter Six: In order to calculate the energy requirements of school buildings in Iran for heating, cooling and lighting it is necessary to use a thermal simulation programme. This chapter considers the development of a simulation programme based on the admittance method and the development of a daylighting/ artificial lighting programme. These programmes use the climatic information outlined in chapter 2 along solar radiation outlined in chapter 4 and lighting outlined in chapter 5 in an integrated excel spreadsheet.

Chapter Seven: The choice of fenestration for a building can significantly affect its thermal performance. The energy performance dependence of the reference school on its fenestration design is analysed in chapter seven. The accuracy of simple graphical methods, e.g. the Olgyay method, for estimating the size of fixed external shading devices is also investigated.

Chapter Eight: This chapter reviews the history of educational system and the structure of education in Iran. A case study is performed on the current school design in different climatic regions of Iran with the aim of exploring the problems of current designs and suggesting some advice on how to solve these problems.

Chapter Nine: Chapter nine contains the summary of the work carried out in the research, the contribution the research has made to knowledge and the conclusions derived from this research, including the limitations, recommendation and suggestions for future research.

Appendices: The last section of this thesis contains additional information relevant to this research. It is deemed that this research will not only serve the research and development fraternities, but also make such a factual and valuable knowledge accessible to all members of the construction profession and architecture.

Chapter 2

Climate of Iran

2 * Climate of Iran

2_1 * Introduction

The climatic characteristics of a region have an important impact on different aspects of a building. In order to increase the life expectancy of building, to have a better quality of comfort and life in the indoor spaces and to save more energy it is crucial to consider these characteristics in the design of buildings, especially in the 21^{st} century using solar energy as a renewable resource and decreasing the fossil fuel consumption and air pollution are really crucial for a clean environment.

The main reasons of the wide variability in different regions of Iran are as follow:

- The difference of latitude between the northest areas and southest one is about 15°.
- More than 2500metres difference between the highest and lowest altitude in these areas.
- The high mountains of Alborz in the north and Zagros extending from north-west to south-east of Iran.
- The Caspian Sea located in the north limit and Oman Sea and Persian Golf in the south limit of Iran.

According to the wide variation of climate in Iran, it is necessary to predict a specific type of building and landscape in every climatic region. This type of buildings will benefit from the natural source energy (solar energy, wind and etc.) in their environment. Also, these buildings located in some region of Iran, will be comfortable to live without using fossil fuels and mechanical heating and cooling systems.

2_2 * Climate and Building

Of all the factors and elements affecting the built environment in any part of the world, climate seems to be the most significant. Depending on the location, buildings either need to be heated or cooled to maintain comfortable indoor conditions. In the tropical zone, which is the hottest climatic belt in the world, the main problem is how to maintain comfortable indoor climate by cooling, either passively or mechanically. In the hot dry and semiarid climates the heat is even more intense and therefore there is an even greater need for evolving an architectural philosophy that can effectively cope with the stress of the climate.

Responsiveness to climate has almost become synonymous with responsiveness to the sun, which is quite understandable in some respects since the sun is the source of the prime energy that shapes the climatic belts and life therein. The sun is the ultimate source of energy on which the life force of the earth and it's inhabitants is dependent, and whose movement across the sky gives Man a perception of rhythm, having a strong bearing on time, climate and the seasons. As stated by Knowles (Knowles, 1981).

> "The sun is fundamental to all life. It is the source of our vision, our warmth, our energy, and the rhythm of our lives. Its movements inform our perceptions of time and space and our scale in the universe".

Generally places on the earth surface closer to the sun have hot/warm climates because of the high intensity of solar radiation, while places relatively further away towards the poles receive less radiation and therefore have temperate/cold climates. Higher solar radiation levels are not simply because zone is 'closer' to the sun but it is also affected by other factors such as atmospheric depletion by Ozone, vapours and dust particles and duration of sunshine (Koenigsberger, et al. 1980).

The power of the sun to sustain life on earth is so fundamental and dependable that man cannot conceive of life without energy from the sun (Cook, 1977). The benefit of this solar energy with respect to buildings is not only subjective but also function of the location on the earth surface and consequently the climate. Solar radiation is "magnanimous" in cold/temperate climates where heat is not only needed for comfort but also vital for survival. In warm/hot climates solar radiation is a source of discomfort and every effort is made to cool the building to a comfortable level.

2₃ * General Geography Information of Iran

2₃.₁ * Location

Iran is situated in south-western Asia and borders the three CIS states, the Republic of Armenia, the Republic of Azerbaijan, and the Republic of Turkmenistan, as well as the Caspian Seas to the north, Turkey and Iraq to the west, the Persian Gulf and the Gulf of Oman to the south and Pakistan and Afghanistan to the east.

23.2 * Landscape

A series of massive, heavily eroded mountain ranges surround Iran's high interior basin. Most of the country is above 460 metres, one-sixth of it over 1980 metres. In sharp contrast are the coastal regions outside the mountain ring. In the north, the 643.72 kilometres strip along the Caspian Sea, never more than 112.65 kilometres wide and frequently narrowing to 16, falls sharply from the 3048 metres summit to 27.4 metres below sea level. In the south, the land drops away from a 610 metres plateau, backed by a rugged escarpment three times as high, to meet the Persian Gulf and the Gulf of Oman.

23.2.1 * Mountains: The Zagros range stretches from the border with the Republic of Armenia in the northwest to the Persian Gulf, and then eastward into Baluchistan. As it moves southward, it broadens into a 200 kilometres-wide band of parallel, alternating mountains lying between the plains of Mesopotamia and the great central plateau of Iran. It is drained on the west by streams that cut deep, narrow gorges and water fertile valleys. The land is extremely hard, difficult to access, and populated largely by pastoral nomads.

The Alborz mountain range, narrower than the Zagros but equally forbidding, runs along the southern shore of the Caspian to meet the border ranges of Khorassan to the east. The highest of its volcanic peaks is 5569 metres, snow-covered mountain Damavand. On the border of Afghanistan, the mountains fall away, to be replaced by barren sand dunes.

The arid interior plateau, which extends into Central Asia, is cut by two smaller mountain ranges. Parts of this desert region, known as dasht, are covered by loose stones and sand, gradually merging into fertile soil on the hillsides. Where fresh water can be held, oases have existed from time immemorial, marking the ancient caravan routes. The most remarkable feature of the plateau is a salt waste 322 kilometres long and half as wide, knows as the kavir (deserts). It remains unexplored, since its treacherous crust has been formed by large, sharp-edged salt masses which cover mud. Cut by deep ravines, it is virtually impenetrable.

$2_{3.2.2}$ * Deserts: The vast deserts of Iran stretch across the plateau from the northwest, close to Tehran and Qom, for a distance of about 644 kilometres to the southeast and beyond the frontier. Approximately one-sixth of the total area of Iran is barren desert.

The two largest desert areas are known as the Kavir-e-Lut and the Dasht-e-Kavir. Third in size of these deserts is the Jazmurian. It is often said that the Kavir-e-Lut and Dasht-e-Kavir are impossible to cross except by the single road which runs from Yazd to Ferdows, but in recent years, heavy trucks and other vehicles have travelled over long stretches of these deserts which contain extensive mineral deposits -chlorides, sulphates and carbonates - and it is only a matter of time before they are exploited.

$2_{3.3}$ * Lakes and Seas

$2_{3.3.1}$ * The Persian Gulf: The Persian Gulf is the shallow marginal part of the Indian Ocean that lies between the Arabian Peninsula and southeast Iran. The sea has an area of 240,000 square kilometres. Its length is 990 kilometres, and its width varies from a maximum of 338 kilometres to a minimum of 55 kilometres in the Strait of Hormuz. It is bordered on the north, north-east and east by Iran, on the north-west by Iraq and Kuwait, on the west and south-west by Saudi Arabia, Bahrain and Qatar, and on the south and south-east by the United Arab Emirates and partly Oman. The term Persian Gulf is often used to refer not only proper to the Persian Gulf but also to its outlets, the Strait of Hormuz and the Gulf of Oman, which open into the Arabian Sea.

The most important islands of the Persian Gulf on the Iranian side are: Minoo, Kharg, Sheikh Saas, Sheikh Sho'ayb, Hendurabi, Kish, Farur, Sirri, Abu-Mussa, the Greater and Lesser Tunb Qeshm, Hengam, Larak, Farsi, Hormuz and Lavan. The notable ports on the Persian Gulf coast are: Abadan, Khorramshahr, Bandar Iman Khomeini, Mahshahr, Deilam, Gonaveh, Rig, Bushehr, Bandar Lengeh, Bandar Abbas.

The Iranian shore is mountainous, and there are often cliffs; elsewhere a narrow coastal plain with beaches, intertidal flats, and small estuaries borders the gulf. The coastal plain widens north of Bushehr on the eastern shore of the gulf and passes into the broad deltaic plain of the Tigris, Euphrates and Karun rivers. It is noticeably asymmetrical in profile, with the deepest water occurring along the Iranian coast and a broad shallow area, which is usually less than 37 metres deep, along the Arabian coast.

There are some ephemeral streams on the Iranian coast south of Bushehr, but virtually no fresh water flows into the gulf on its south-west side. Large quantities of fine dust are, however, blown into the sea by predominant north-west winds from the desert areas of the surrounding lands. The deeper parts of the Persian Gulf adjacent to the Iranian coast and the are around the Tigris-Euphrates Delta are mainly floored with grey-green muds rich in calcium carbonate.

The Persian Gulf has a notoriously bad climate. Temperatures are high, though winters may be quite cool at the north-western extremities. The sparse rainfall occurs mainly as sharp down pours between November and April and is heavier in the north-east. Humidity is high. The little cloud cover is more prevalent in winter than in summer. Thunderstorms and fog are rare, but dust storms and haze occur frequently in summer.

Until the discovery of oil in Iran in 1908, the Persian Gulf area was important mainly for fishing, pearling, the building of dhows, sailcloth making, camel breeding, reed mat making, date cultivating, and the production of other minor products, such as red ochre from the islands in the south. Today these traditional industries have declined, and the economy of the region is dominated by the production of oil.

The Persian Gulf and the surrounding countries produce approximately 31 per cent of the world's total oil production and have 63 per cent of the world's proven reserves. The Persian Gulf area will probably remain and important source of world oil for a long period.

$2_{3.3.2}$ * The Caspian Sea: The Caspian Sea, which is the largest landlocked body of water in the world (424,240 sq. km.), lies some 26 metres below the sea level. It is comparatively shallow, and for some centuries has been slowly shrinking in size. Its salt content is considerably less than that of the oceans and though it abounds with fish, its shelly coasts do not offer any good natural harbours, and sudden and violent storms make it dangerous for small boats. The important ports on the Caspian coast are: Bandar-Anzali, Noshahr, and Bandar-Turkman.

$2_{3.3.3}$ * **Lakes**: Along the frontier between Iran and Afghanistan there are several marshy lakes, which expand, and contract according to the season of the year. The largest of these, the Sistan (Hamun-Sabari), in the north of the Sistan & Baluchistan province, is alive with wild fowl.

Real fresh water lakes are exceedingly rare in Iran. There probably are no more than 10 lakes in the whole country, most of them brackish and small in size. The largest are: Lake Urmia (area: 3,900-6,000 sq. km. depending on season) in Western Azerbaijan, Namak (1,806 sq. km.) in the Central province, Bakhtegan (750 sq. km.) in Fars province, Tasht (442 sq. km.) in fars province, Moharloo (208 sq. km.) in Fars province, Howz Soltan (106.5 sq. km.) in Central province.

$2_{3.4}$ * Climate

Iran has a complex climate, ranging from subtropical to subpolar. In winter, a high-pressure belt, centered in Siberia, slashes west and south to the interior of the Iranian Plateau, while low pressure systems develop over the warm waters of the Caspian, the Persian Gulf, and the Mediterranean. In summer, one of the lowest pressure centres in the world prevails in the south.

Low pressure patterns in Pakistan generate two regular wind patterns: the Shamal, which blows from February to October north-westerly through the Tigris-Euphrates Valley, and the 120-day summer wind, which sometimes reaches velocities of 70 miles per hour in the Seestan region near the Pakistan frontier. Warm Arabian winds bring heavy moisture from the Persian Gulf. The gulf area, where the heat and humidity are unbearable, stands in sharp contrast to the Caspian coastal region, where moist air from the sea mingles with the dry air currants from the Alborz to create a soft nightly breeze.

In the summer, temperatures vary from a high of 50° C in Khuzistan at the head of the Persian Gulf to a low of 1° C in Azerbaijan in the north-west. Precipitation also varies greatly, ranging from less than two inches in the south-east to about 25.5 in the Caspian region.

The annual average rain is about 356 millimetres. Winter is normally the rainy season for the whole country. Frequent spring thunderstorms occur, especially in the mountains, where destructive hailstones also fall. The coastal region presents a sharp contrast to the rest of the country.

The high Alborz mountains, which seal off the narrow Caspian Plain, wring moisture from the clouds, trap humidity from the air, and crete a fertile densely populated semitropical region with think forests, swamps, and rice paddies. Temperatures may soar to 38° C, the humidity to 98 per cent. Frost is rare. The monthly average temperature of some cities in Iran has been shown in table 2.1. The climatic data of all cities and stations of Iran are mentioned in appendix A.

Table 2.1: Monthly average temperature of some cities in Iran (National Meteorology Organization)

City	Average Max. °C	Average Min. °C	Absolute Max. °C	Absolute Min. °C	Average Temp. °C
Ahwaz	30.8	19.2	51.0	0.0	25.0
Arak	18.0	5.5	39.5	-30.5	11.8
Bandar-e-Abbas	30.4	21.9	45.0	4.8	26.2
Hamedan	18.2	-0.9	37.0	-29.6	9.6
Isfahan	19.9	13.6	40.0	-8.6	19.8
Kerman	29.8	-0.4	40.4	-14.0	16.1
Mashhad	20.6	8.0	41.0	-15.4	14.3
Rasht	25.5	7.4	35.2	-8.2	16.5
Shiraz	26.1	10.4	42.0	-6.2	18.2
Tabriz	16.7	5.7	38.6	-17.6	11.2
Tehran	22.3	12.4	40.4	-10.0	17.3
Urmia	15.6	4.0	34.6	-16.4	9.8
Zahedan	26.6	10.4	42.6	-9.8	18.5
Zanjan	23.6	-4.2	37.6	-27.6	9.3

In Iran, the change from one season to the next is fairly abrupt. By 21 March, the beginning of the Iranian year (Norooz), the fruit trees are in full bud and fresh green wheat covers the fields. Later, while the orchards are in bloom, wild flowers carpet the stony hills. Later, the summer heat burns and kills the flowers, and autumn is not marked by a display of bright colours and the soft haze of Indian summer; instead, there is a rapid transition from summer to winter.

2_4 * Climatic Classification in Iran

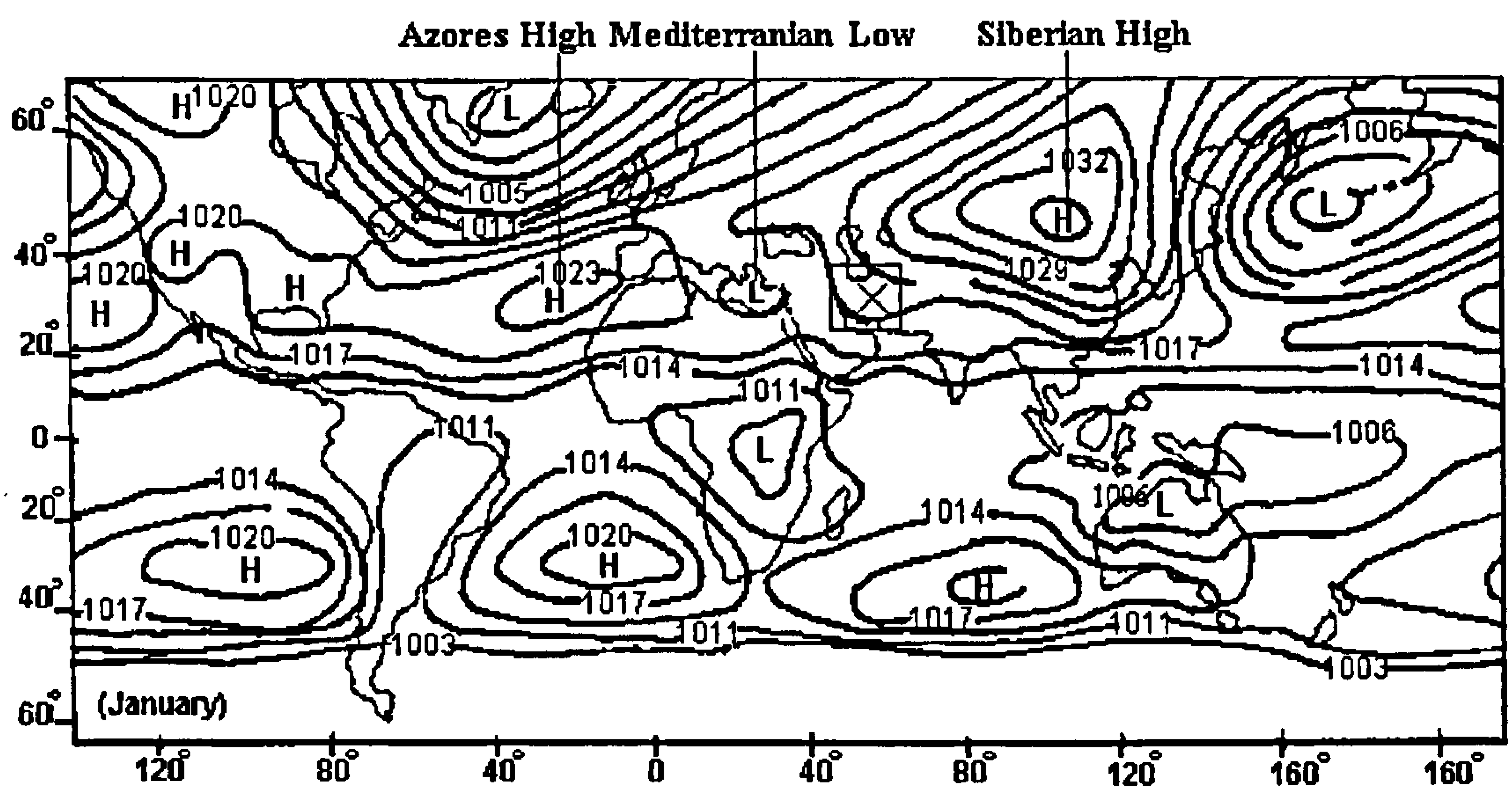
$2_{4.1}$ * Present Day Climate of Iran

This section describes those weather systems, which have important effects on the climatic classification in Iran. The climate conditions of Iran show a distinct seasonal pattern, which will be described in this section.

$2_{4.1.1}$ * Conditions in the Cold Season

The major pressure systems that affect Iran in late autumn, winter, and early spring are the Siberian High Pressure (SHP) and Mediterranean Low Pressure (Ganji, 1968; Khalili, 1992; see Fig. 2.1) in winter, SHP is the dominant system in north and central Asia with a strong centre above Baikal Lake (105°-110°E and 50°-55°N), which can send a tongue of very cold-dry weather towards central Iran (Alijani, 1990). The mean pressure in the centre of the SHP is usually higher than 1035 hPa, which can increase to over 1070 hPa. The SHP is a low level system and its thickness is less than 3,000 m and usually works below 2,500 m height. Although the SHP is an important winter system, the overall dominant system is from the westerly sector (Alijani, 1990; Khalili, 1992).

Figure 2.1: Major pressure systems during winter (January). After Khalili (1992). Location of Iran is distinguished by a cross.



The location and strength of the SHP were traditionally believed to be the result of very low energy and vegetation-free surfaces of the Siberian Plateau in the winter.

However, new research shows that it is much controlled by the characteristics of the Subtropical Jet Stream (SJS) in Asia (Alijani, 1990).

Another high-pressure system, which can affect Iran, is the Azores High Pressure system, which is centred basically on the Azores islands, North Atlantic Ocean, with a central pressure of 1025 hPa. This system can push wet weather currents towards the Western Europe and Asia (Beaumont et al., 1988).

A low-pressure system develops above the Mediterranean Sea between these two high pressures, which can migrate towards the western part of Asia, and Middle East. This system is also an important source of moisture for southwest Asia (Beaumont et al., 1988; Khalili, 1992).

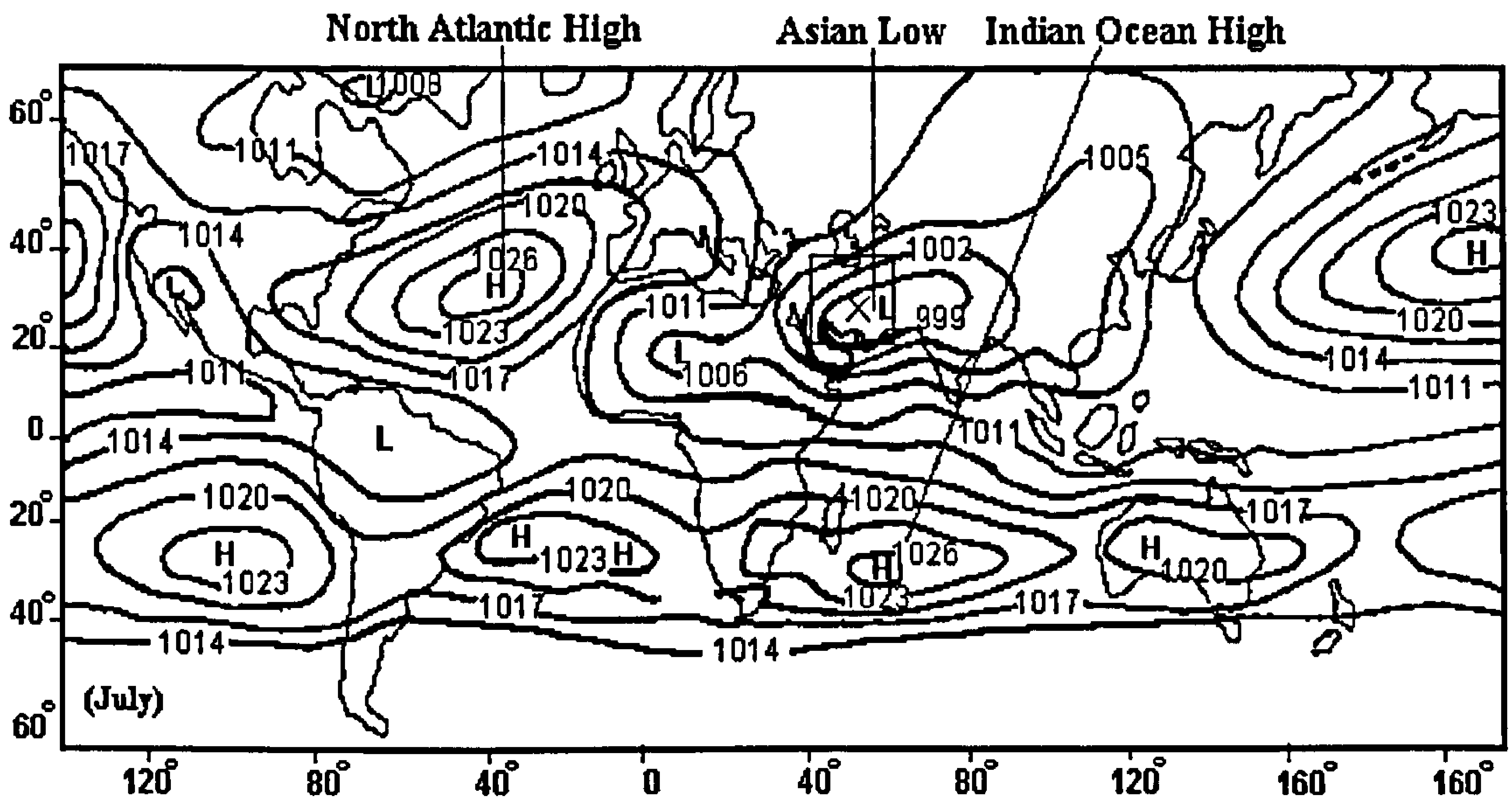
2.4.1.2 * Conditions in the Warm Seasons

During warmer periods of the year, usually between May and September, the Subtropical High Pressure (STHP) is generally the dominant system over Iran except for the southern margin of the Caspian Sea (Ganji, 1968). The STHP creates stable, hot and dry conditions, particularly in southern and central Iran, sometimes for more than half the year. Although the STHP is the dominant climatic agent of the high atmosphere, the prevailing system on the ground is an extensive hot area of low pressure, which is very unstable, and results in upward movement of the air. This regional low-level system is the major source of dust- and sandstorms in central Iran, particularly when it is amplified by a strong continental tropical current from the northwest (e.g. from Eastern Europe and Scandinavia; Khalili, 1992).

In summer four major systems, namely the STHP, North Atlantic High Pressure (NAHP), Asia Low Pressure, and Indian Ocean High Pressure (monsoon) systems interact over Iran. However, during different periods their effects are highly variable (Khalili, 1992; Fig. 2.2). The NAHP is the summer version of the winter Azores High Pressure, after bringing wet currents towards Western Europe; loose most of its moisture before reaching the Middle East area. This system during its movement towards Iran can absorb moisture from the Black Sea and the Caspian Sea and consequently lead to local precipitation along the northern border of Iran and in Azerbaijan (Khalili, 1992). This system occasionally penetrates into the western part of central Iran and lead to torrential rains during April and early May in the some areas (YMO reports, 1968-1993).

The Asian Low Pressure or Iran-Pakistan Low is centred on western Pakistan and east-central Iran in the summer. This "Low" extends into most of Central Asia as well as the Arabian Desert and can pull weather currents from adjacent high systems. The occurrence of this low-pressure system is an important factor in bringing monsoonal rains into the Indian Subcontinent (Alijani, 1981).

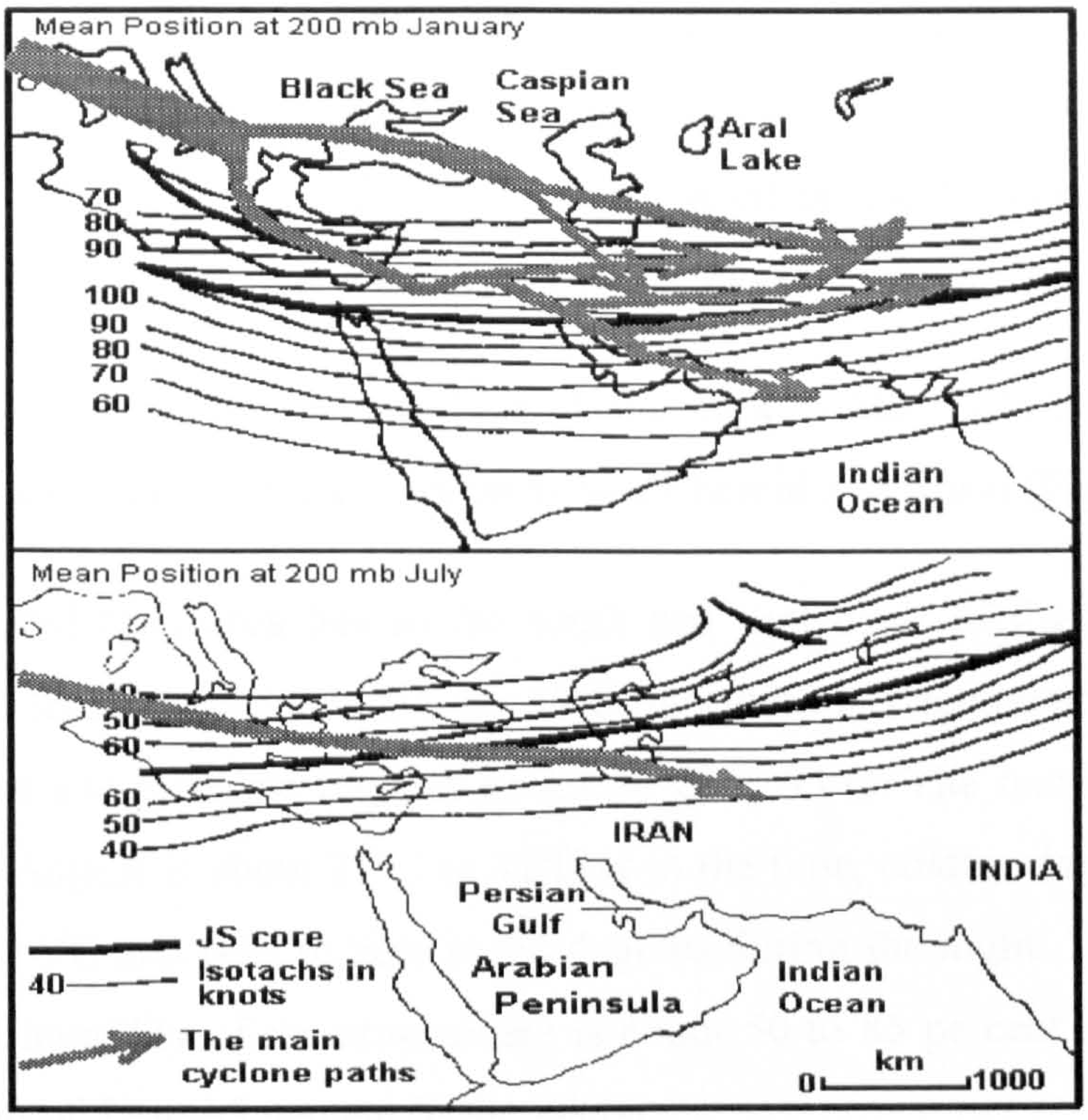
Figure 2.2: Major pressure systems during summer (July). After Khalili (1992). Approximate locations of Iran and central Iran are indicated by a quadrangle and a cross, respectively.



The Indian Ocean High has a central location between Australia and South Africa and can bring a highly moist weather system into the Indian Subcontinent. In its extensive activity it can bring torrential rains into South-eastern part of Iran (Sistan and Baluchistan). The monsoonal precipitation of Southeast Asia depends highly on this system (Ganji, 1968).

As well as these different pressure systems, there is a belt of strong westerly winds, known as the Subtropical Jet Stream (SJS), which is an upper atmospheric feature in the Middle East in general and in Iran in particular (Fig. 2.3). The position of the core of the SJS varies over 15 degrees of latitude from summer to winter in Iran. In July it is centred over the Caspian Sea, while by January it has moved southward to rest above the Persian Gulf (Beaumont et al., 1988). The position and characteristics of the SJS are believed to be the main factor for climatic conditions of central Iran (Alijani, 1981).

Figure 2.3: Position of the subtropical jet stream and cyclone tracks in winter and summer (from the Iranian Meteorological Organisation; after Beaumont et al., 1989).



The moisture pattern of the Middle East in general, and of Iran in particular, can best be explained by a succession of cyclones from the North Atlantic and the Mediterranean Sea (Fig. 2.3). During the summer the cyclone paths tend to pass over the northern part of Turkey and the northern side of the Alborz Mountains, and therefore, they cannot effect the climate of central Iran (Beaumont et al., 1988). During winter, cyclone tracks over the Middle East change towards the south due to southward shift of the SJS core (Alijani, 1981). The cyclonic precipitation during the winter is most important source of moisture for Lebanon, Jordan, Syria, Iraq, and Iran (Alijani, 1981; Beaumont et al., 1988).

The location of Iran, between 25° 3′-39° 47′ N and 44°-63° 18′ E, makes the climate of this area sensitive to the seasonal changes of the SJS and the polar front locations. Furthermore, the high mountain ranges of the northern, western, and central Iran can modify the regional pattern of the climate and environmental changes over Iran.

2.4.2 *Iran Climatic Zoning Map

Several climatic classification methods have been used in Iran, such as W. Koeppen's method which is based on the botanical and plant environmental conditions, the bio-climatical chart based on the Olgyay methods. A similar chart based on the Ashrea method and finally the Givoni approach which divided Iran into eight main weather categories with 36 sub-categories (Ministry of Housing and Urban Development, 1993). There are five main areas based on the temperature zones of Iran presented in the Cambridge History of Iran (Cambridge university 1975).

The five classified regions are: 1- Humid and mild 2- Very cold due to the high altitude 3- Dry and mild 4- Dry and warm 5- Semi-humid and warm (Figure 2.4).

The humid and mild area lies to the south and east coast of Caspian Sea. The average annual temperature is 14.5°C to 18°C and there is a temperature difference between coldest and warmest days of about 25°C to 35°C. The maximum average temperature in August is about 26°C to 32°C at in the time, coldest day in January is about 12°C to 16°C and falls to zero to +4 degrees during the night. There is a high amount of and humidity of the atmosphere is about 50 to 85 percent in the summer and a maximum of 75 to 95 percent in the winter.

The mountainous region with a relatively high altitude has a very cold winter and moderate and cool summer. The average annual temperature is only about 11°C to 14°C, the average difference between annual temperatures is about 35°C to 45°C. In August the maximum temperature rises to 28°C to 35°C in the daytime and a minimum of 10°C to 15°C is recorded for night-time. In the winter, particularly in January and February, daily temperatures reach only two to five degrees and fall to -9 degrees during night. A temperature below freezing occurs for four to five months during in the year. Snow is more common and there is less rain than elsewhere. The humidity is about 20 to 40 percent in summer and 70 to 85 percent in winter.

Figure 2.4: Iran climatic classification (Source: The Cambridge History of Iran)

I- Humid and mild region II - Very cold region due to the high altitude
III- Dry and mild IV- Dry and warm V- Semi-humid and warm region

The essentially dry and mild region is an area of lower altitude. There is a relatively cold winter and a relatively warm and dry summer. The annual average temperature is about 13°C to 17°C. The warmest day temperature in August reach to 31°C to 38°C and in contrast reaches 8°C to 18°C during the night. In winter the temperature is about seven to seventeen degrees in the daytime and from -2 to -6 degrees in the night. This climate is very dry humidity moist for almost three months and there is plenty of sunshine during all seasons.

The dry and warm area is located in the central, often desert parts of the country. There is cold weather in the winter but it is a very warm and dry in the summer. The average temperature is about 16°C to 19°C with 36°C to 42°C of difference between coldest and hottest days of the year. The daytime temperature in summer goes up to 35°C to 39°C. In contrast it falls to 12°C to 23°C during the night. The temperature goes up to 16 degrees in the winter day and falls to zero to -3 degrees during the night. Freezing temperatures during the one-month night occur for about per year.

The annual rainfall can be as low as 70mm to 800mm and the humidity reaches a maximum of 65 percent.

The semi-humid and warm climate is located in the south Iran, along the northern part of Persian Gulf. It extends from Khozistan province in the west to the province of Sistan and Baluchistan in the East. There is moderate weather in the winter and very hot and semi-dry weather in the summer. The annual average temperature is about 23°C to 27°C and there is a 35°C to 41°C difference between the hottest and coldest days. The temperature reaches 42°C to 46°C in the summer, though only 18°C to 28°C in the same season at night. In February the temperature falls to 16°C to 24°C during in the day and reaches only 3°C to 9°C at night. Freezing weather is very rare and the annual rainfall is about 100mm to 470mm with humidity from about 10 to 90 percent. There are around four to five months of hot weather during which the temperature reaches 38°C at mid-day, and there is little or no need for a heating system for the winter or spring seasons.

The Ministry of Housing and Urban Development of Iran has classified the climate into 8 main groups with 36 subgroups (Figure 2.5):

2.4.2.1 * The First Climatic Group: This group is composed of one subgroup, which is called strongly cold in winter and suitable in summer. It is located in high altitude regions with over 35° N of latitude and lies more than 2000 metres above the sea level (Figure 2.6). Abali, Lighvan and Polour are the main cities.

Since there is no hot weather in this climatic group, there is no need for a cooling system in the summer season. Therefore the most important factor in the design of building in this region is to prevent the loss of heat. The use of solar energy in the heating system of building should be considered.

The geographic characteristics of the cities located in this climate have been shown in table 2.2.

2.4.2.2 * The Second Climatic Group: This group is the largest climatic region and has the greatest number of climatic subgroups. It consists of 8 subgroups and 89 meteorological stations. There are large variations in latitude and altitude (Height) of different regions located in this group. As it can be seen from the figure 2.7, this climate is located in the north, east north and west north (except the coasts of Caspian Sea) of Iran. Also it includes the high altitude regions that stretch from northwest to southeast and some high altitude areas in the east.

There are some regions of altitude less than 1000 metres in northern areas of Iran with higher latitude, for example Mashhad over 985 metres high and Joulfa 704 metres high. However, in the southern limit of this climate including areas of lower latitude some regions of more than 2000 metres high can be seen (for example Baft with 29° N of latitude and 2250 metres high). The combination of these two climatic factors i.e., latitude and height from the sea level, is the reason why the temperature of high altitude regions in the south is similar to the temperature of low altitude areas in the north.

The climatic circumstances in this group are strongly to relatively cold in the winter and temperate to semi hot- arid in the summer.

Despite the wide range of temperature in this climate the heating need of building must be achieved through mechanical heating and solar energy. Since the temperature and humidity are relatively low in almost all subgroups, there is no need for a cooling system. However, in the following subgroups it is necessary to use a cooling system (for a very limited time) in the summer because of the rise of temperature in this season:

- Very cold - semi hot.
- Very cold - semi hot and arid.
- Cold -semi hot and arid.

The main aims of the climatic design are as follow:

1. Reduction of the heat loss.
2. Reduction of the effect of wind on the heat loss of buildings.
3. Using the solar energy as a heating system.
4. Protection of buildings against solar radiation.
5. To benefit from the daily variations of air temperature.

The geographic characteristics of the cities located in this climate have been shown in table 2.3.

$2_{4.2.3}$ * **The Third Climatic Group:** This group is Limited to the southern coasts of Caspian Sea and a narrow region around Urmia Lake (Figure 2.8).

It consists of 25 meteorological stations and 3 subgroups. There are three important factors in this climate, which are the causes of relatively cool weather in the winter and humidity in the summer:

- High latitude.
- Low altitude.
- Location near by the sea.

Regarding the cloudy sky and lack of solar radiation in the winter, the most important system needed in the buildings during a year is mechanical heating. One of the most important characteristics of this climate is the humidity of weather during summer season. The high level of humidity in the summer causes the lack of thermal comfort. Therefore it seems reasonable that creating a good circulation by wind flow make living more comfortable in buildings during summer season. Also, the U value of the external wall's materials must be low.

Consequently the consumption of energy in the mechanical cooling system will be reduced.

In the relatively cold and cool subgroup the amount of annual rainfall is high. Therefore, it is necessary to protect the buildings against the detrimental effects of rain.

The geographic characteristics of the cities located in this climate have been shown in table 2.4.

$2_{4.2.4}$ * **The Fourth Climatic Group:** This climate consists of 3 subgroups, however according to the number of meteorological stations and geographic area is smaller than the third climatic group (Figure 2.9).

It is located along the group 3 in two separated regions with higher altitude and in a long distance far from Caspian Coasts. Therefore, in comparison with group 3, the weather is colder in the winter and warmer in the summer.

The climatic characteristics of this region are very to relatively cold in the winter and hot and humid in the summer season. In these situations, the heating requirements of buildings will be achieved by firstly mechanical and then solar energy. For cooling purpose the natural system is the best method.

For decreasing the amount of heat transmission during winter, it is necessary to use materials with lower U value in the external walls of buildings.

The geographic characteristics of the cities located in this climate have been shown in table 2.5.

$2_{4.2.5}$ * **The Fifth Climatic Group:** This climate is composed of 7 subgroups and 37 meteorological stations (Figure 2.10).

This region is surrounded by the groups 1 and 6 and located in the central part of Iran. Also it is extended as a narrow band in the southwest of Zagros Mountain. The variation of latitude and altitude is very wide in this group.

The weather is relatively cold in the winter and semi to very hot in summer season. Since there is plenty of sunshine during all seasons, the solar energy can be used as a heating system in the winter.

During the summer season the air humidity is low. For this reason, in some part of warm season using suitable materials in the external walls of buildings will be helpful in the establishment of thermal comfort. However, during the warmest months of summer it is necessary to use mechanical cooling. The main aims of climatic design in this group are as follow:

1 – using the solar energy.

2 – Reducing the loss of heat of buildings.

3 – Preventing the effects of the high temperature on buildings.

The geographic characteristics of the cities located in this climate have been shown in table 2.6.

$2_{4.2.6}$ * **The Sixth Climatic Group:** It is composed of 16 subgroups and 11 meteorological stations and mainly consists of the low altitude regions and the deserts located in the central parts and southeast of Iran (Figure 2.11).

The height in the northern part of this climate is around 1000 metres and more than 1300 metres in the southern areas.

The lowest altitude is in Tabas with 33° 30' N altitude and 690 metres height and the highest one is in Gorgin-khobr with 29° latitude and 1835 metres height.

The weather is relatively cold, or cold during the winter and semi hot to very hot and arid in the summer. Because there is plenty of sunshine in the winter, there is no need for mechanical heating during this season. Since the air humidity is low a part of cooling requirements of building will be met by natural ventilation and the remaining by mechanical cooling. The main purposes of climatic design in this group are using solar energy during the winter and shading and natural ventilation (Badgir and etc.) in the summer.

The geographic characteristics of the cities located in this climate have been shown in table 2.7.

$2_{4.2.7}$ * **The Seventh Climatic Group:** This group is divided to 5 subgroups and 31 meteorological stations. It consists of areas with low latitude and is extended as a narrow band from west to south and south east of Iran (Figure 2.12).

Two important climatic factors, i.e., low altitude and low latitude are the causes of high temperature in this climate.

The weather is cool to temperate during winter and very hot and arid to strongly hot and semi humid in the summer. Therefore, the use of cooling system is extremely important in this group and there is no need for a heating system.

It is necessary to protect buildings against strong and dusty hot wind in this climate.

The main aims in the climatic design of this group are to protect the building against the hot temperature and strong solar radiation.

The geographic characteristics of the cities located in this climate have been shown in table 2.8.

$2_{4.2.8}$ * **The Eighth Climatic Group:** This group is composed of 3 subgroups and 12 meteorological stations and is located in the north coasts of Persian Golf and Oman Sea (Figure 2.13).

The variation in the latitude and altitude of the meteorological stations located in this group is very small. Khark is situated in the lowest altitude of this climate with 29° latitude and 3 metres height. Gheshm is located in the highest altitude with 26° 57' latitude and 31 metres height.

The weather during winter is temperate and suitable and in the summer very hot and arid.

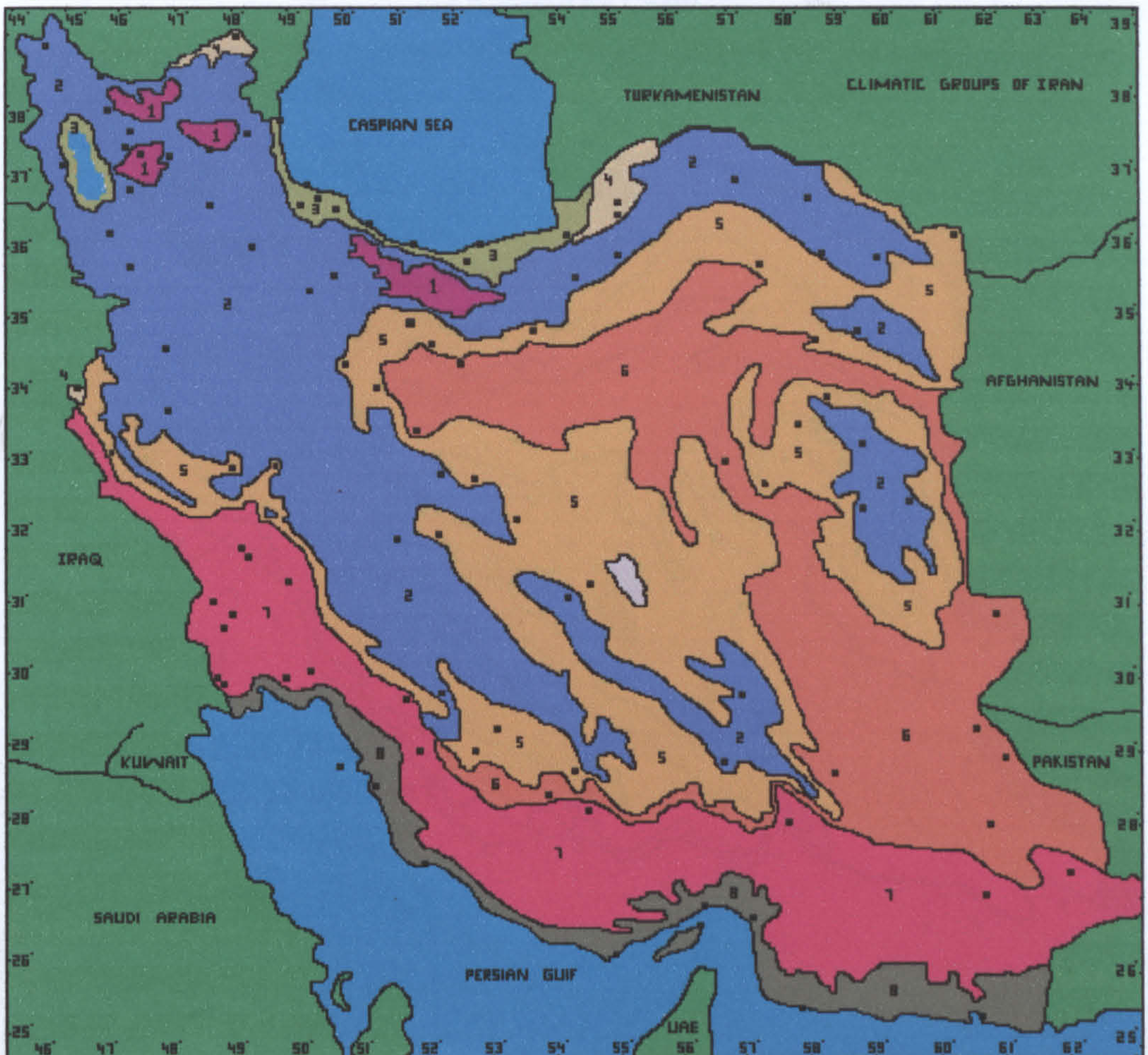
There are three main climatic factors that made this group the worst climatic group in Iran. These factors include very low altitude, low latitude and the location by the sea.

The high temperature and humidity in this climate are the main reasons why it is extremely necessary to use mechanical cooling system with high efficiency in buildings. However, there is no need for heating system during summer season (specially in the subgroup 8-3).

The main purposes of climatic design are to protect the buildings against the exterior high temperature and solar radiation, shading and establishment of a good air circulation in the interior part of the building.

The geographic characteristics of the cities located in this climate have been shown in table 2.9.

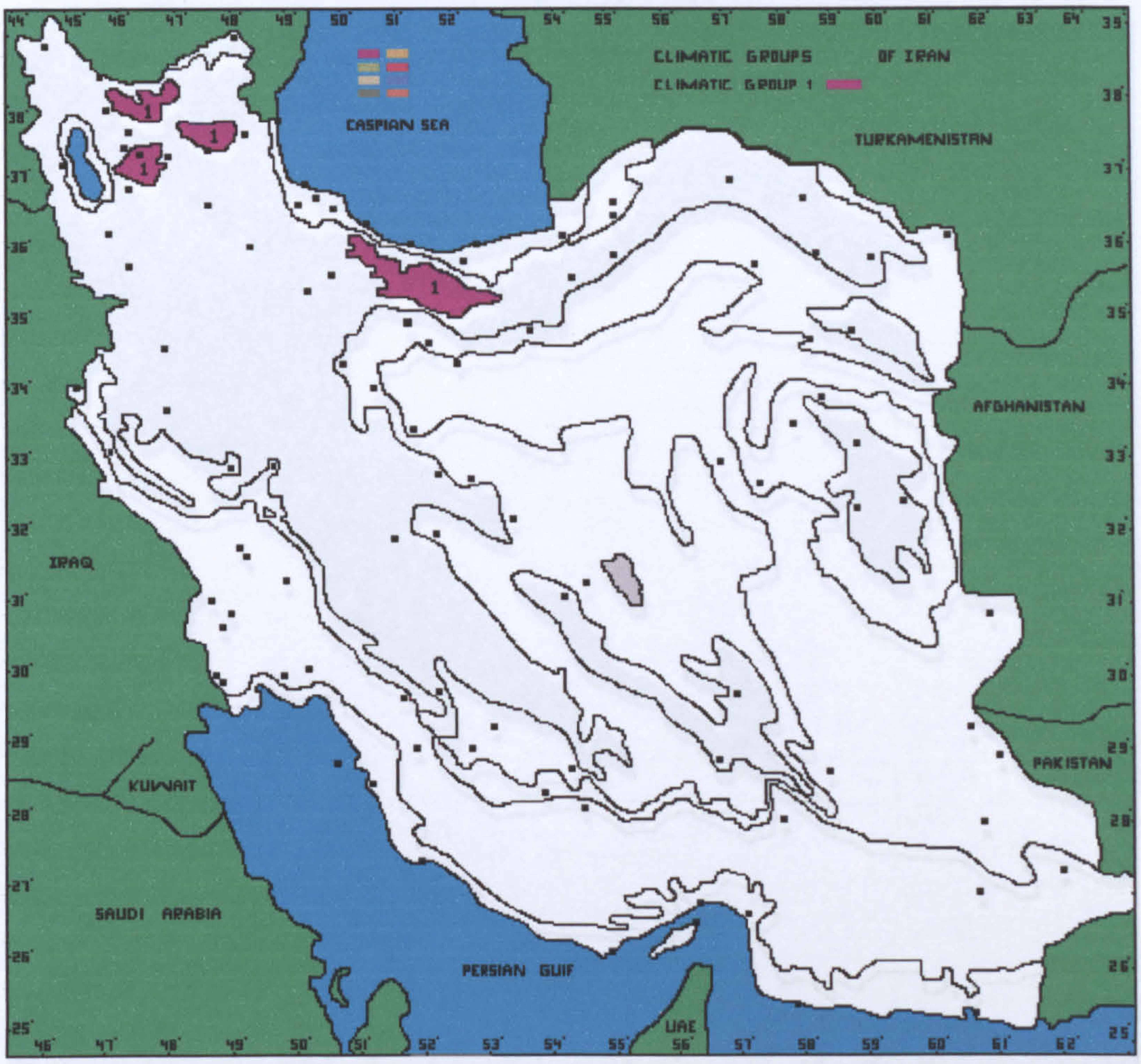
Figure 2.5: Iran climatic classification (Source: The Ministry of Housing and Urban Development, Iran)



Map: Designed by Gorji

Climatic conditions in two critical seasons in Iran					
Climatic Subgroup	Winter	Summer	Climatic Subgroup	Winter	Summer
Climatic Group 1			**Climatic Group 5**		
1-1	Strongly Cold	Suitable	5-1	Relatively Cold	Semi Hot
			5-2	Relatively Cold	Semi Hot and Arid
			5-3	Relatively Cold	Hot
			5-4	Relatively Cold	Hot and Arid
			5-5	Relatively Cold	Very Hot
			5-6	Relatively Cold	Very Hot and Humid
			5-7	Cold	Very Hot
Climatic Group 2			**Climatic Group 6**		
2-1	Strongly Cold	Temperate	6-1	Relatively Cold	Very Hot and Arid
2-2	Very Cold	Temperate	6-2	Semi Cold	Semi Hot
2-3	Very Cold	Semi Hot	6-3	Semi Cold	Very Hot
2-4	Very Cold	Semi Hot and Arid	6-4	Semi Cold	Hot and Arid
2-5	Cold	Temperate	6-5	Semi Cold	Very Hot and Arid
2-6	Cold	Semi Hot	6-6	Cold	Hot and Arid
2-7	Cold	Semi Hot and Arid			
2-8	Relatively Cold	Temperate			
Climatic Group 3			**Climatic Group 7**		
3-1	Very Cold	Humid	7-1	Cold	Very Hot and Arid
3-2	Relatively Cold	Humid	7-2	Cold	Strongly Hot and Arid
3-3	Cold	Humid	7-3	Cold	Strongly Hot and Semi Humid
			7-4	Temperate	Strongly Hot and Arid
			7-5	Temperate	Strongly Hot and Semi Humid
Climatic Group 4			**Climatic Group 8**		
4-1	Very Cold	Hot and Humid	8-1	Cold	Very Hot and Humid
4-2	Cold	Hot and Humid	8-2	Temperate	Very Hot and Humid
4-3	Relatively Cold	Hot and Humid	8-3	Suitable	Very Hot and Humid

Figure 2.6: The map of climatic group 1 of Iran climatic classification (Source: Kasmaei 1993 and designed by Gorji)

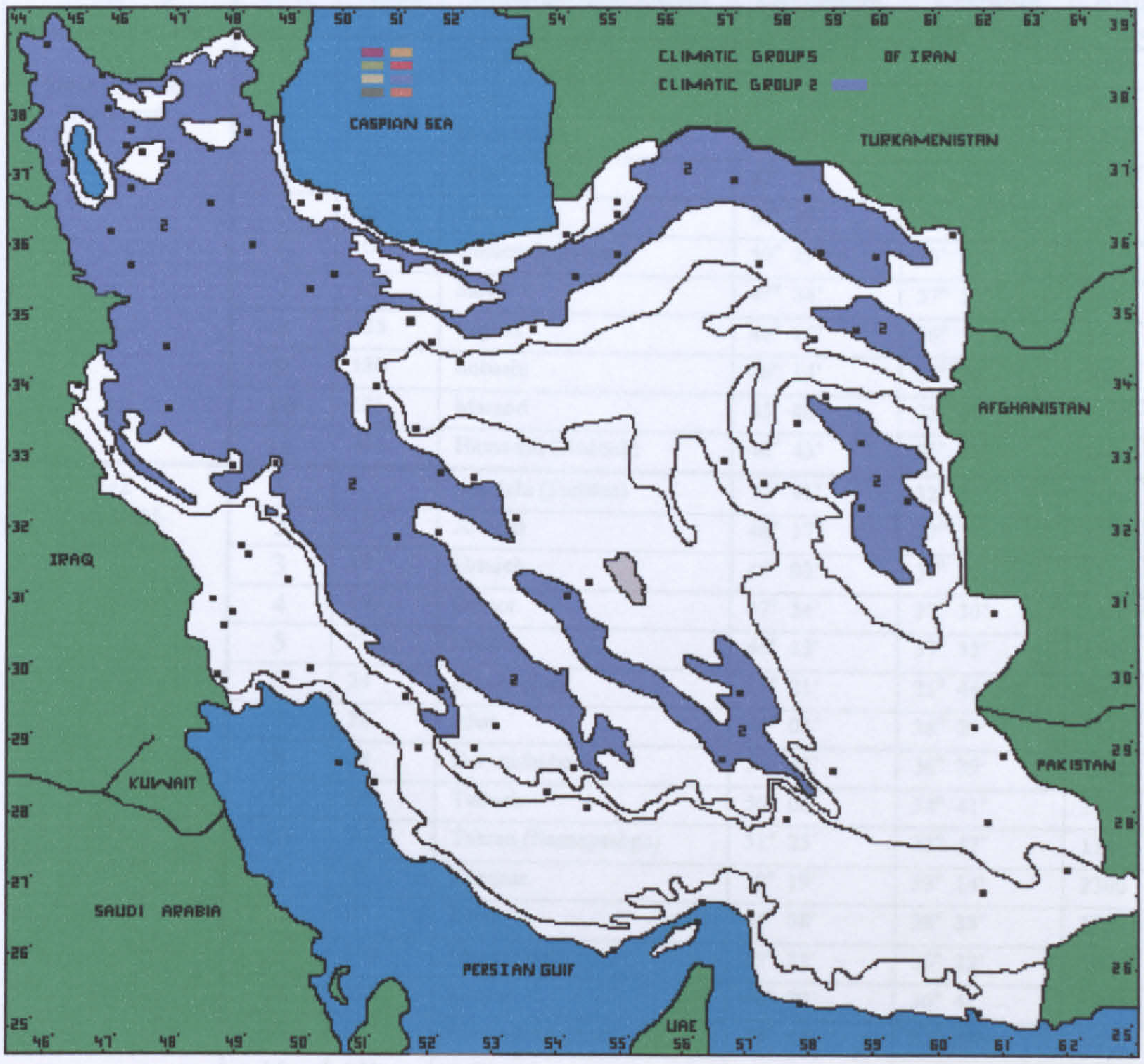


Climatic conditions in two critical seasons in Iran		
Climatic Group 1		
Climatic Subgroup	**Winter**	**Summer**
1-1	**Strongly Cold**	**Suitable**

Table 2.2: The geographic specifications of the meteorological stations in the climatic group 1

Subgroup	Row	Code	Stations and Cities	Longitude Degrees (E)	Latitude Degrees (N)	Altitude Metres
1-1 **Strongly Cold-Suitable**	1	4	Abali	51° 59'	35° 46'	2450
	2	177	Lar-Polour	52° 05'	35° 50'	2400
	3	182	Lighvan	46° 26'	37° 50'	2100

Figure 2.7: The map of climatic group 2 of Iran climatic classification (Source: Kasmaei 1993 and designed by Gorji)



Climatic conditions in two critical seasons in Iran		
Climatic Group 2		
Climatic Subgroup	**Winter**	**Summer**
2-1	Strongly Cold	Temperate
2-2	Very Cold	Temperate
2-3	Very Cold	Semi Hot
2-4	Very Cold	Semi Hot and Arid
2-5	Cold	Temperate
2-6	Cold	Semi Hot
2-7	Cold	Semi Hot and Arid
2-8	Relatively Cold	Temperate

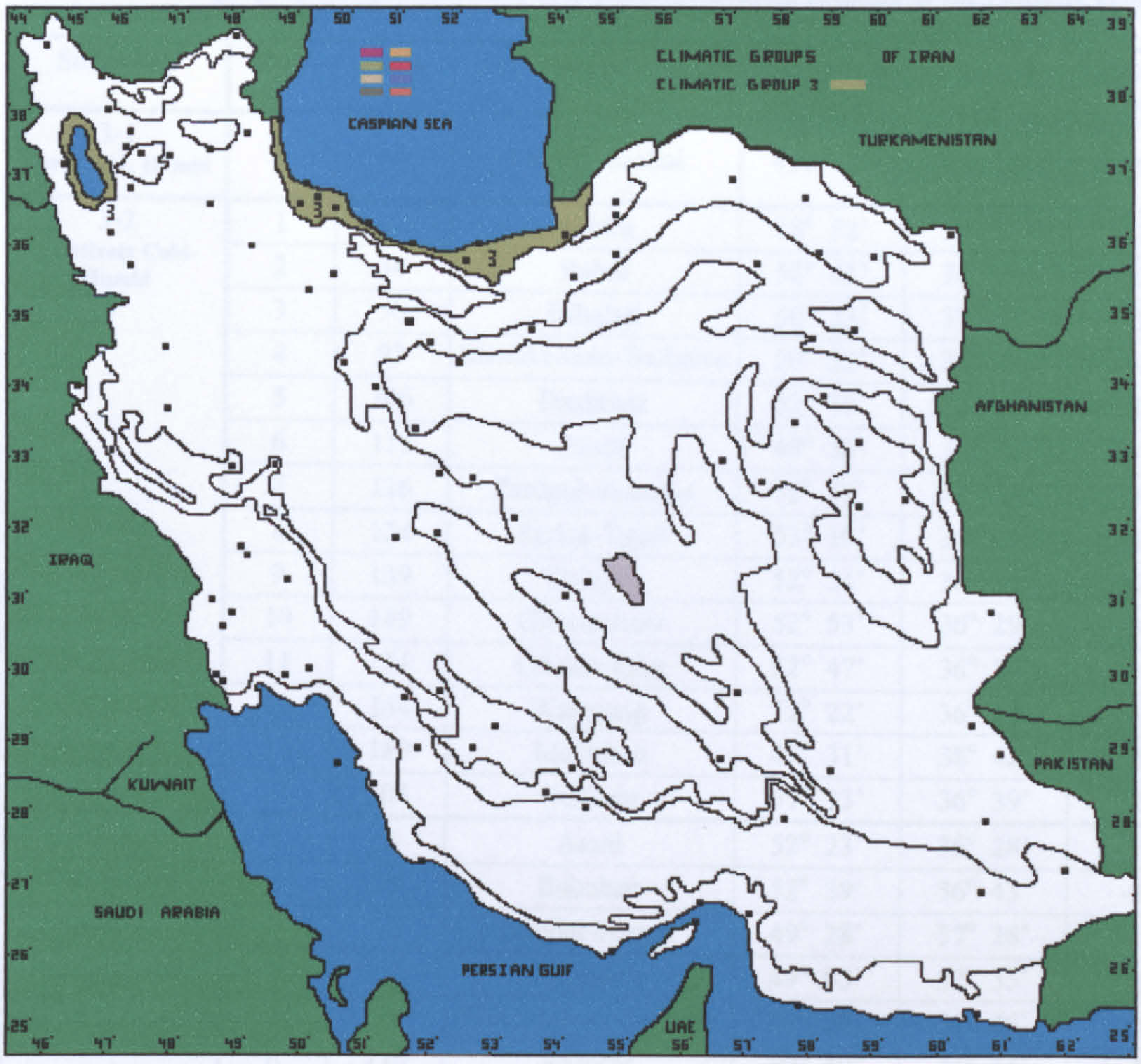
Table 2.3: The geographic specifications of the meteorological stations in the climatic group 2

Subgroup	Row	Code	Stations and Cities	Longitude Degrees (E)	Latitude Degrees (N)	Altitude Metres
2-1 Strongly Cold-Temperate	1	5	Ajichaie	46° 24'	38° 07'	1400
	2	10	Avaj	49° 13'	35° 38'	1894
	3	43	Bostanabad	46° 50'	37° 50'	1720
	4	58	Bijar	47° 37'	35° 52'	1940
	5	66	Tabriz	46° 17'	38° 05'	1361
	6	101	Dameneh (Fridan)	50° 29'	33° 01'	2300
	7	121	Sarab	47° 34'	37° 59'	1650
	8	125	Saghez	46° 16'	36° 15'	1494
	9	130	Sobashi	48° 14'	35° 10'	2039
	10	185	Marand	45° 46'	38° 46'	1305
	11	211	Hamadan (Nozheh)	48° 43'	35° 12'	1644
2-2 Very Cold-Temperate	1	2	Abadchi (Faridan)	50° 41'	32° 43'	2100
	2	15	Ardabil	48° 17'	37° 32'	1372
	3	18	Urmieh	45° 05'	37° 32'	1312
	4	19	Ostoor	47° 54'	37° 30'	1200
	5	21	Oskoo	46° 13'	37° 55'	1500
	6	24	Emam-ghais	51° 21'	31° 44'	2400
	7	28	Ahar	47° 03'	38° 29'	1157
	8	38	Bar -nishaboor	58° 42'	36° 29'	1520
	9	69	Tafresh	50° 02'	34° 41'	1878
	10	76	Tehran (Namayeshga)	51° 25'	35° 47'	1541
	11	95	Khansar	50° 19'	33° 14'	2300
	12	97	Khoy	44° 58'	38° 33'	1357
	13	102	Darehtakht	49° 22'	33° 22'	2000
	14	117	Zanjan	48° 29'	36° 41'	1663
	15	133	Shamsabad (Arak)	49° 44'	33° 49'	2400
	16	144	Adl	51° 03'	32° 04'	2280
	17	148	Firozabad (Khalkhal)	48° 13'	37° 35'	1090
	18	152	Ghareh-aghaj	47° 42'	39° 02'	700
	19	158	Ghochan	58° 30'	37° 06'	1282
	20	170	Garakan (Ashtiyan)	49° 58'	34° 33'	1791
	21	172	Golmakan	59° 11'	36° 28'	1300
	22	183	Makoo	44° 31'	39° 18'	1634
	23	191	Moochan	49° 39'	33° 50'	1786
	24	192	Mahabad	45° 55'	36° 50'	1300
	25	193	Mehrgerd	51° 31'	31° 33'	2600
	26	194	Miandoab	46° 06'	36° 58'	1314
	27	197	Meimeh	51° 10'	33° 26'	1980
	28	203	Nozhian	48° 32'	33° 15'	1984
	29	209	Valadabad	49° 58'	35° 56'	1210
	30	213	Hamand Absard	52° 05'	35° 39'	1800
2-3 Very Cold-Semi Hot	1	99	Dashband (Bokan)	46° 10'	36° 38'	1336
	2	150	Ghayen	59° 12'	33° 44'	1471
	3	195	Mianeh	47° 42'	37° 20'	1094
	4	184	Maragheh	46° 14'	37° 24'	1419
2-4 Very Cold-Semi Hot And Arid	1	14	Arak	49° 42'	34° 06'	1754
	2	140	Shirvan (Brojerd)	48° 48'	33° 46'	1392

Continue 2.3: The geographic specifications of the meteorological stations in the climatic group 2

2-5 Cold-Temperate	1	13	Golpayegan	50° 05'	33° 24'	2000
	2	42	Bojnord	57° 20'	37° 28'	1074
	3	54	Boeinzahra	50° 04'	35° 46'	1282
	4	65	Takestan	49° 42'	36° 04'	1361
	5	68	Torbat heydarieh	59° 13'	35° 16'	1333
	6	73	Tehran-Sadabad	51° 25'	35° 50'	1700
	7	84	Chenaran	59° 07'	36° 38'	1350
	8	88	Hanna	51° 44'	31° 13'	2350
	9	100	Damghan	54° 22'	36° 13'	1170
	10	128	Sangsorakh	58° 45'	37° 38'	1100
	11	131	Shahrod	55° 02'	36° 25'	1345
	12	137	Shahrkord	50° 51'	32° 19'	2066
	13	142	Torogh kertian	59° 33'	36° 10'	1300
	14	153	Ghazvin	50° 00'	36° 15'	1377
	15	180	Latian	51° 41'	35° 46'	1600
	16	188	Mashhad	59° 38'	36° 16'	985
	17	190	Malayer	48° 49'	34° 17'	1740
2-6 Cold- Semi Hot	1	80	Jolfa	45° 38'	38° 56'	704
	2	155	Ghotourchai	45° 15'	38° 51'	950
2-7 Cold- Semi Hot and Arid	1	36	Kermanshah	47° 07'	34° 19'	1322
	2	176	Goshehnahavand	48° 14'	34° 17'	1520
	3	129	Sanandaj	47° 00'	35° 14'	1373
2-8 Relatively Cold-Temperate	1	3	Abadeh	52° 40'	31° 11'	2004
	2	12	Ahmadvand	47° 03'	34° 28'	1400
	3	17	Ardakan (fars)	51° 59'	30° 16'	2200
	4	20	Asadabad(Birjand)	60° 01'	32° 55'	1500
	5	32	Ilam	46° 26'	33° 38'	1319
	6	40	Baft	56° 38'	29° 15'	2250
	7	57	Birjand	59° 12'	32° 52'	1456
	8	60	Polzamankhan	50° 54'	32° 29'	1860
	9	75	Tehran(Narmak)	51° 31'	34° 45'	1290
	10	86	Hojjatabad(Pishkoh)	54° 02'	31° 42'	1500
	11	107	Deh-someh	50° 50'	35° 57'	1500
	12	109	Zobahan(Isfahan)	51° 18'	32° 24'	1768
	13	157	Ghomshe(Shahreza)	51° 51'	32° 01'	1700
	14	162	Kerman	56° 58'	30° 15'	1749
	15	163	Karand	46° 15'	34° 17'	1500
	16	200	Najafabad	51° 22'	32° 38'	1350
	17	201	Natanz	51° 56'	33° 32'	1800
	18	206	Nishabor	58° 48'	36° 12'	1350
	19	212	Hamgin	51° 27'	31° 55'	2150
	20	61	Polkaleh	51° 14'	32° 23'	1800

Figure 2.8: The map of climatic group 3 of Iran climatic classification (Source: Kasmaei 1993 and designed by Gorji)

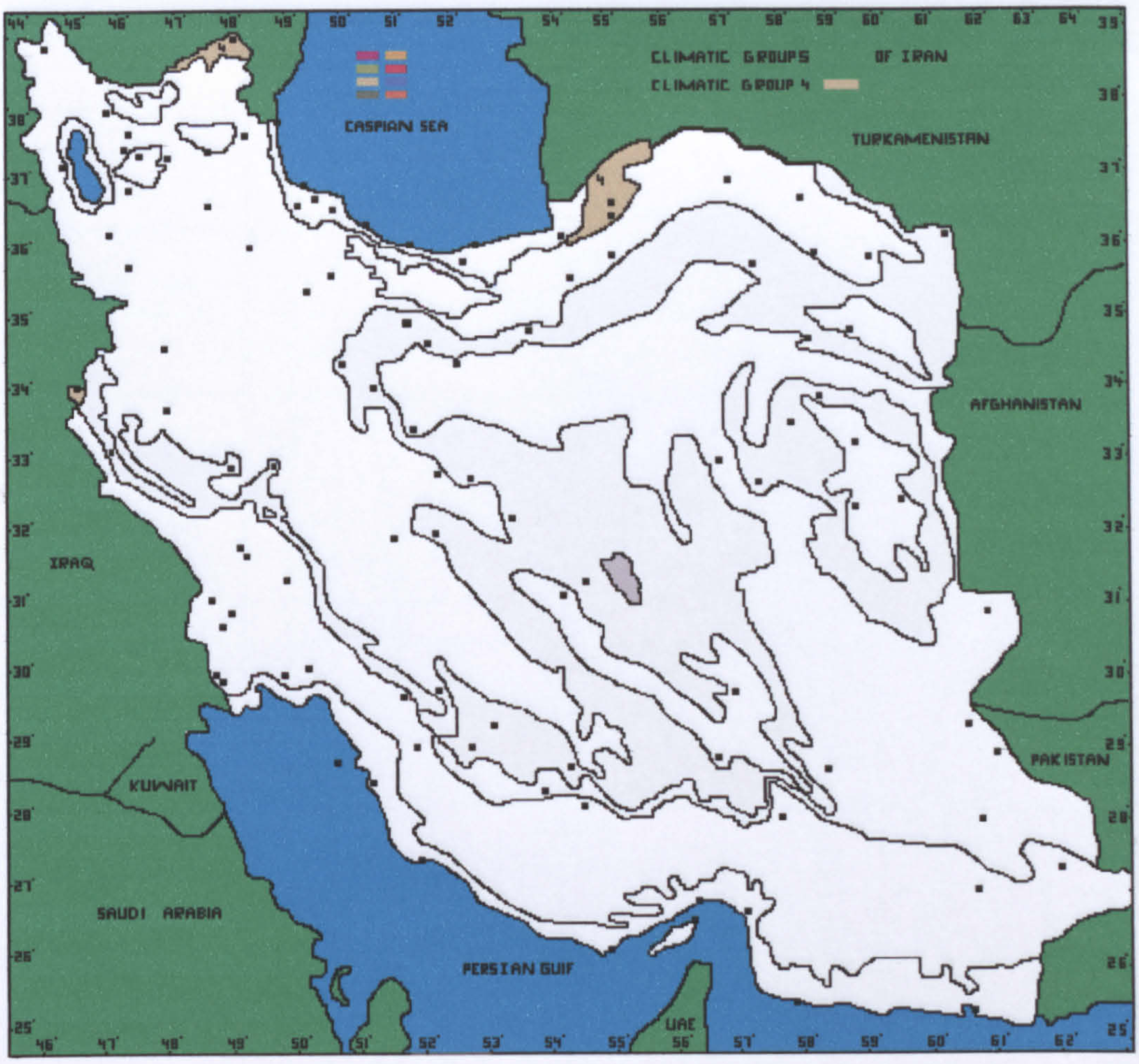


Climatic conditions in two critical seasons in Iran		
Climatic Group 3		
Climatic Subgroup	Winter	Summer
3-1	Very Cold	Humid
3-2	Relatively Cold	Humid
3-3	Cold	Humid

Table 2.4: The geographic specifications of the meteorological stations in the climatic group 3

Subgroup	Row	Code	Stations and Cities	Longitude Degrees (E)	Latitude Degrees (N)	Altitude Metres
3-1 Very Cold- Humid	1	37	Barandoozchai	45o 14'	37o 23'	1300
3-2 Relatively Cold-Humid	1	7	Astara	48° 52'	38° 26'	-25
	2	34	Babol	52° 41'	36° 33'	2
	3	56	Bibalan	50° 23'	37° 02'	-10
	4	93	Khoshkedaran-Tonkabon	50° 52'	36° 48'	-2
	5	106	Dashtnaz	53° 10'	36° 41'	28
	6	112	Rasht	49° 36'	37° 15'	-7
	7	116	Zardgol-Sorkhabad	52° 59'	35° 55'	1500
	8	124	Sarkat-Tajan	53° 10'	36° 24'	300
	9	139	Shirgah	52° 54'	36° 17'	223
	10	149	Ghaemshahr	52° 53'	36° 29'	50
	11	151	Ghoran-talar	52° 47'	36° 29'	90
	12	164	Karesang	52° 22'	36° 19'	500
	13	189	Moshiran	47° 31'	38° 42'	653
	14	204	Noshahr	51° 33'	36° 39'	-20
3-3 Cold- Humid	1	9	Amol	52° 23'	36° 28'	29
	2	35	Babolsar	52° 39'	36° 43'	-21
	3	46	Bandar-Anzali	49° 28'	37° 28'	-15
	4	62	Pilimbira	49° 05'	37° 35'	6
	5	91	Khorramabad(Tonkabon)	50° 59'	36° 46'	50
	6	110	Ramsar	50° 40'	36° 54'	-20
	7	113	Rodbar(Kilan)	49° 24'	36° 48'	280
	8	147	Foman	49° 19'	37° 12'	-10
	9	169	Gorgan	54° 28'	36° 49'	155
	10	179	Lahijan	50° 00'	37° 11'	-2

Figure 2.9: The map of climatic group 4 of Iran climatic classification (Source: Kasmaei 1993 and designed by Gorji)

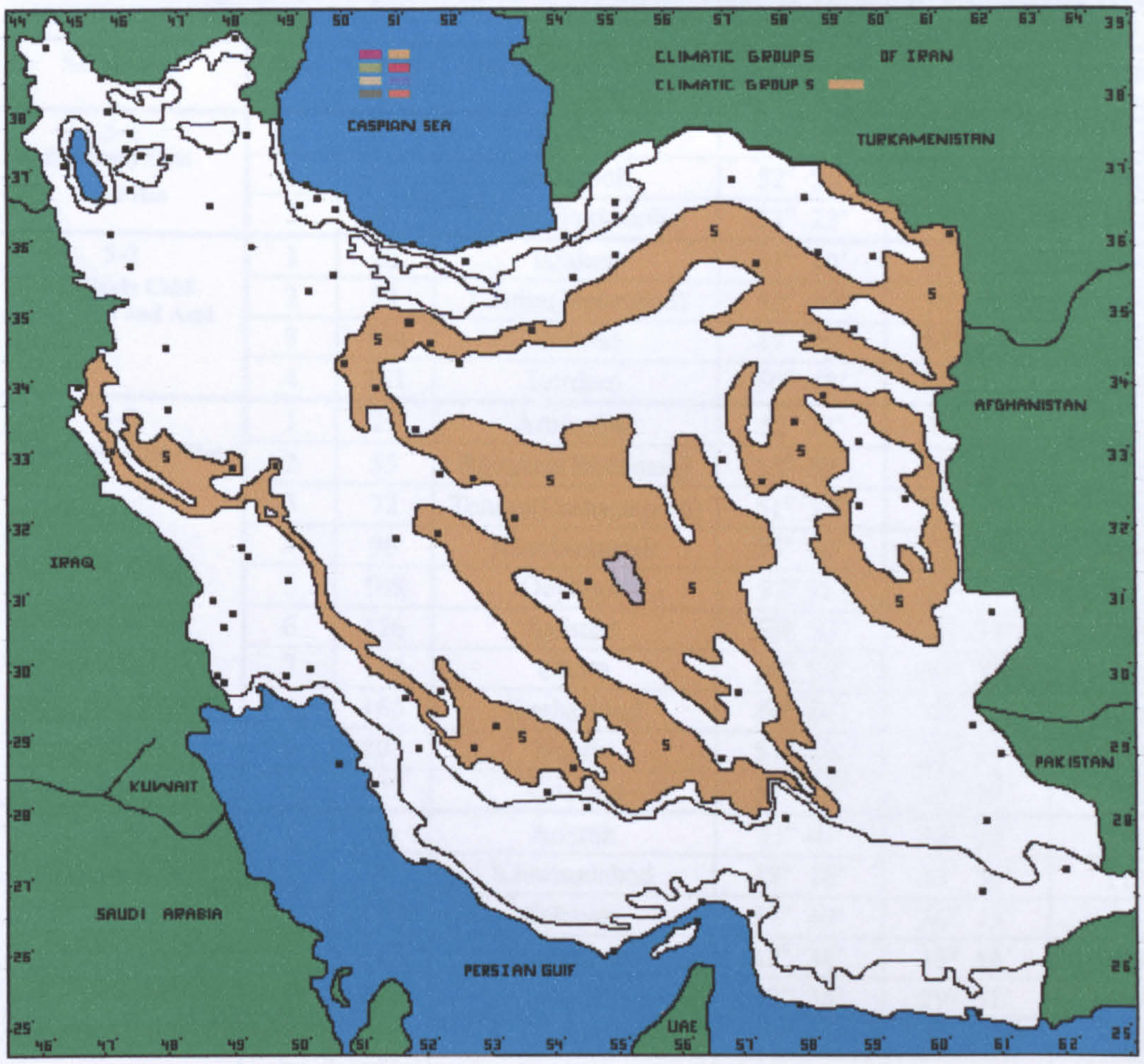


Climatic conditions in two critical seasons in Iran		
Climatic Group 4		
Climatic Subgroup	**Winter**	**Summer**
4-1	Very Cold	Hot and Humid
4-2	Cold	Hot and Humid
4-3	Relatively Cold	Hot and Humid

Table 2.5: The geographic specifications of the meteorological stations in the climatic group 4

Subgroup	Row	Code	Stations and Cities	Longitude Degrees (E)	Latitude Degrees (N)	Altitude Metres
4-1 Very Cold- Hot and Humid	1	63	Tazehkand	47° 58'	37° 04'	63
4-2 Cold- Hot and Humid	1	59	Parsabad-moghan	47° 54'	39° 39'	59
	2	67	Tajrish (Dezashib)	51° 27'	35° 48'	67
4-3 Relatively Cold- Hot and Humid	1	6	Azadshahr	55° 10'	37° 05'	6
	2	23	Afrachal	53° 15'	36° 14'	23
	3	174	Gonbadghabos	55° 10'	37° 15'	174
	4	214	Hotan(chat)	55° 16'	37° 59'	214

Figure 2.10: The map of climatic group 5 of Iran climatic classification (Source: Kasmaei 1993 and designed by Gorji)

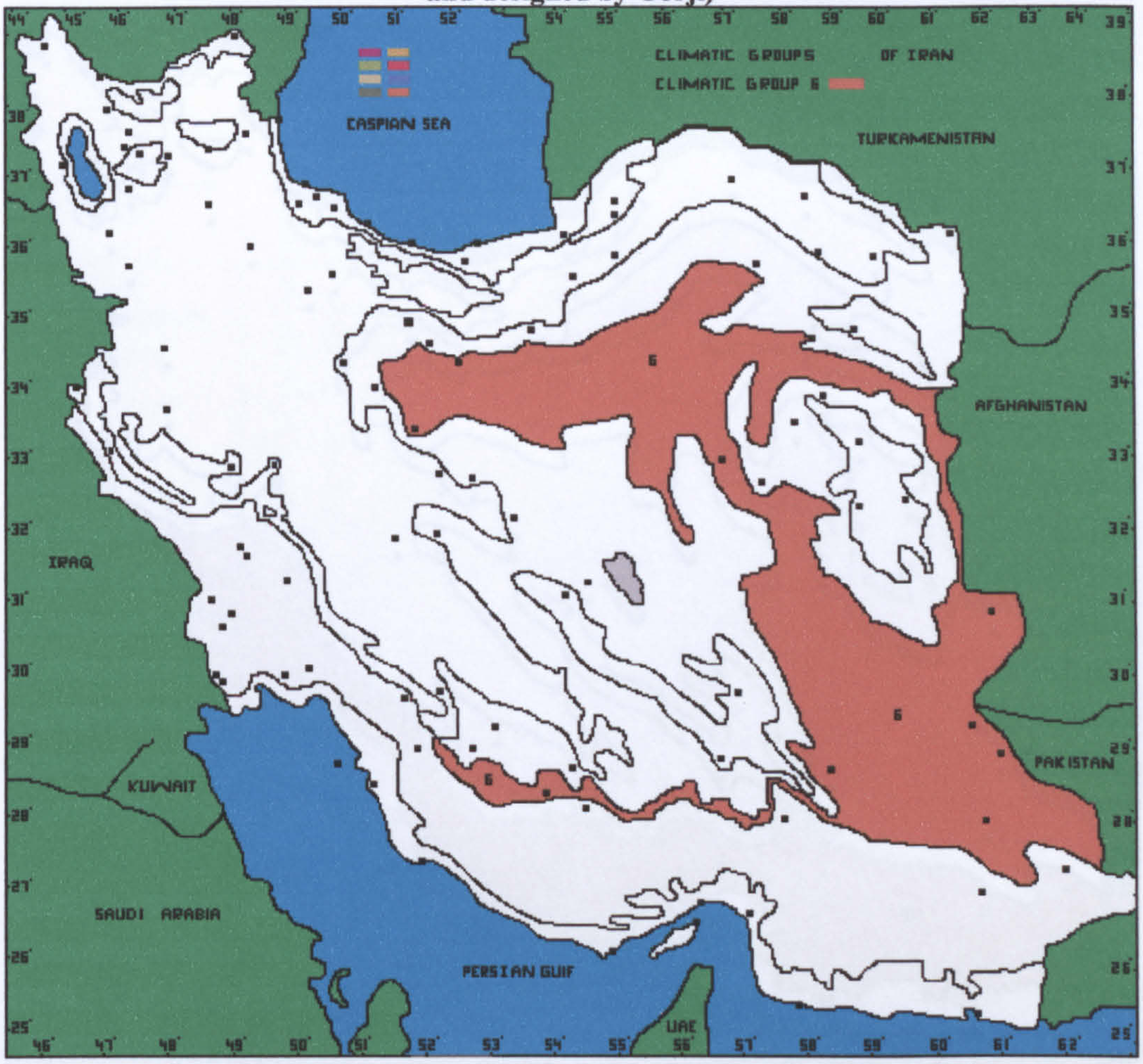


Climatic conditions in two critical seasons in Iran		
Climatic Group 5		
Climatic Subgroup	**Winter**	**Summer**
5-1	Relatively Cold	Semi Hot
5-2	Relatively Cold	Semi Hot and Arid
5-3	Relatively Cold	Hot
5-4	Relatively Cold	Hot and Arid
5-5	Relatively Cold	Very Hot
5-6	Relatively Cold	Very Hot and Humid
5-7	Cold	Very Hot

Table 2.6: The geographic specifications of the meteorological stations in the climatic group 5

Subgroup	Row	Code	Stations and Cities	Longitude Degrees (E)	Latitude Degrees (N)	Altitude Metres
5-1 Relatively Cold-Semi Hot	1	41	Bejestan	58° 11'	34° 31'	1370
	2	52	Bonkooh	52° 26'	35° 18'	1006
	3	71	Tehran(Parkshahr)	51° 23'	35° 41'	1210
5-2 Relatively Cold-Semi Hot and Arid	1	22	Isfahan	51° 40'	32° 37'	1590
	2	74	Tehran(Mehrabad)	51° 19'	35° 41'	1191
	3	104	Doroud	49° 09'	33° 29'	1402
	4	181	Lordjan	50° 48'	31° 31'	1700
5-3 Relatively Cold- Hot	1	25	Aminabad	51° 28'	35° 35	1000
	2	55	Bayazeh(Biabanak)	55° 02'	33° 20'	1450
	3	72	Tehran(Doshantappeh)	51° 25'	35° 42'	1232
	4	96	Khorbiabanak	55° 02'	33° 47'	850
	5	108	Deyhook	57° 31'	33° 17'	1600
	6	126	Semnan	52° 23'	35° 33'	1138
	7	156	Ghom	50° 53'	34° 38'	928
	8	165	Kashafroud	60° 50'	35° 59'	580
	9	205	Neyriz	54° 19'	29° 11'	2100
	10	207	Varamin	51° 39'	35° 19'	1000
5-4 Relatively Cold-Hot and Arid	1	26	Anarak	53° 40'	33° 20'	1416
	2	90	Khorramabad	48° 18'	33° 30'	1134
	3	119	Sabzvar	57° 40'	36° 13'	941
	4	127	Sangtrash	48° 34'	33° 14'	1584
	5	138	Shiraz	52° 35'	29° 32'	1491
	6	145	Ferdos	58° 09'	34° 01'	1290
	7	161	Kashmar	58° 28'	35° 12'	1060
	8	186	Marvdasht	52° 48'	29° 59'	1603
	9	208	Varzaneh	52° 37'	32° 24'	1450
	10	216	Yazd	54° 24'	31° 54'	1230
5-5 Relatively Cold-Very Hot	1	11	Ahmadabad-Doroudzan	52° 27'	30° 12'	1800
	2	16	Ardestan	52° 24'	33° 22'	1381
	3	103	Dargaz	59° 06'	37° 26'	500
	4	118	Saveh	50° 21'	35° 01'	1167
	5	120	Sepiddasht	48° 53'	33° 13'	1100
	6	123	Serakhs	61° 10'	36° 32'	225
	7	171	Garmsar	52° 20'	35° 15'	856
	8	173	Gonabad	58° 42'	34° 21'	1150
	9	199	Naein	53° 05'	32° 52'	1600
5-6 Relatively Cold-Very Hot and Humid	1	33	Evanekey	52° 04'	35° 21'	1400
5-7 Cold- Very Hot	1	143	Abbasabad-Ghom	50° 38'	34° 04'	1445

Figure 2.11: The map of climatic group 6 of Iran climatic classification (Source: Kasmaei 1993 and designed by Gorji)

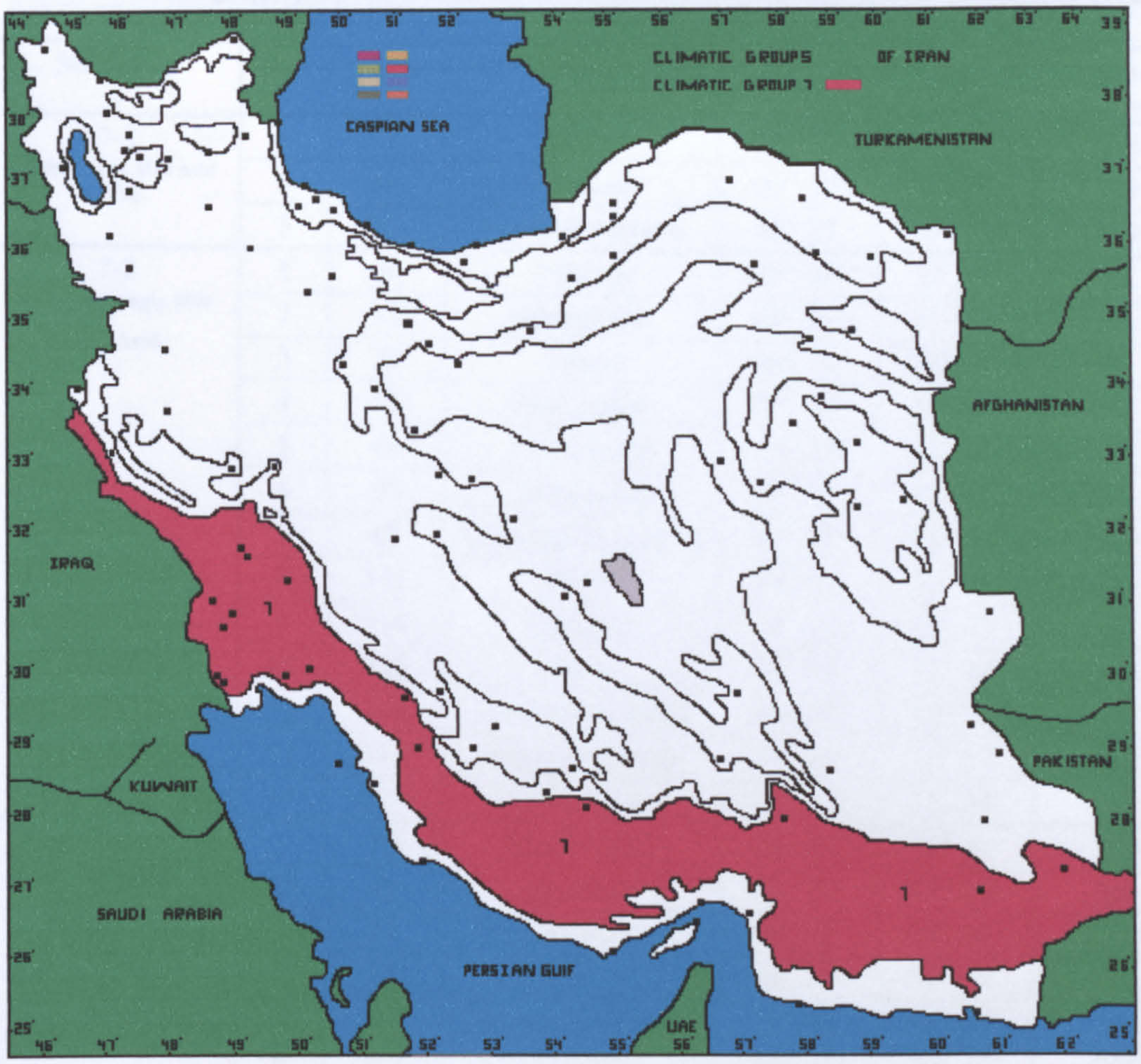


Climatic conditions in two critical seasons in Iran		
Climatic Group 6		
Climatic Subgroup	Winter	Summer
6-1	Relatively Cold	Very Hot and Arid
6-2	Semi Cold	Semi Hot
6-3	Semi Cold	Very Hot
6-4	Semi Cold	Hot and Arid
6-5	Semi Cold	Very Hot and Arid
6-6	Cold	Hot and Arid

Table 2.7: The geographic specifications of the meteorological stations in the climatic group 6

Subgroup	Row	Code	Stations and Cities	Longitude Degrees (E)	Latitude Degrees (N)	Altitude Metres
6-1 Relatively Cold-Very Hot and Arid	1	94	Khafr	53° 12'	28° 58'	1300
	2	141	Tabas	56° 54'	33° 36'	690
	3	160	Kashan	51° 27'	33° 59'	975
6-2 Semi Cold- Semi Hot	1	175	Gorgin-Khobr	56° 13'	28° 50'	1825
6-3 Semi Cold-Very Hot	1	89	Khash	61° 14'	28° 13'	1430
6-4 Semi Cold-Hot and Arid	1	115	Zahedan	60° 53'	29° 28'	1370
	2	146	Fasa	53° 41'	28° 58'	1383
6-5 Semi Cold-Very Hot and Arid	1	114	Zabol	61° 29'	31° 01'	487
	2	196	Mirjaveh	61° 27'	29° 01'	900
	3	83	Choghart	55° 28'	31° 40'	1340
6-6 Cold- Hot and Arid	1	44	Bam	58° 24'	29° 09'	1055

Figure 2.12: The map of climatic group 7 of Iran climatic classification (Source: Kasmaei 1993 and designed by Gorji)

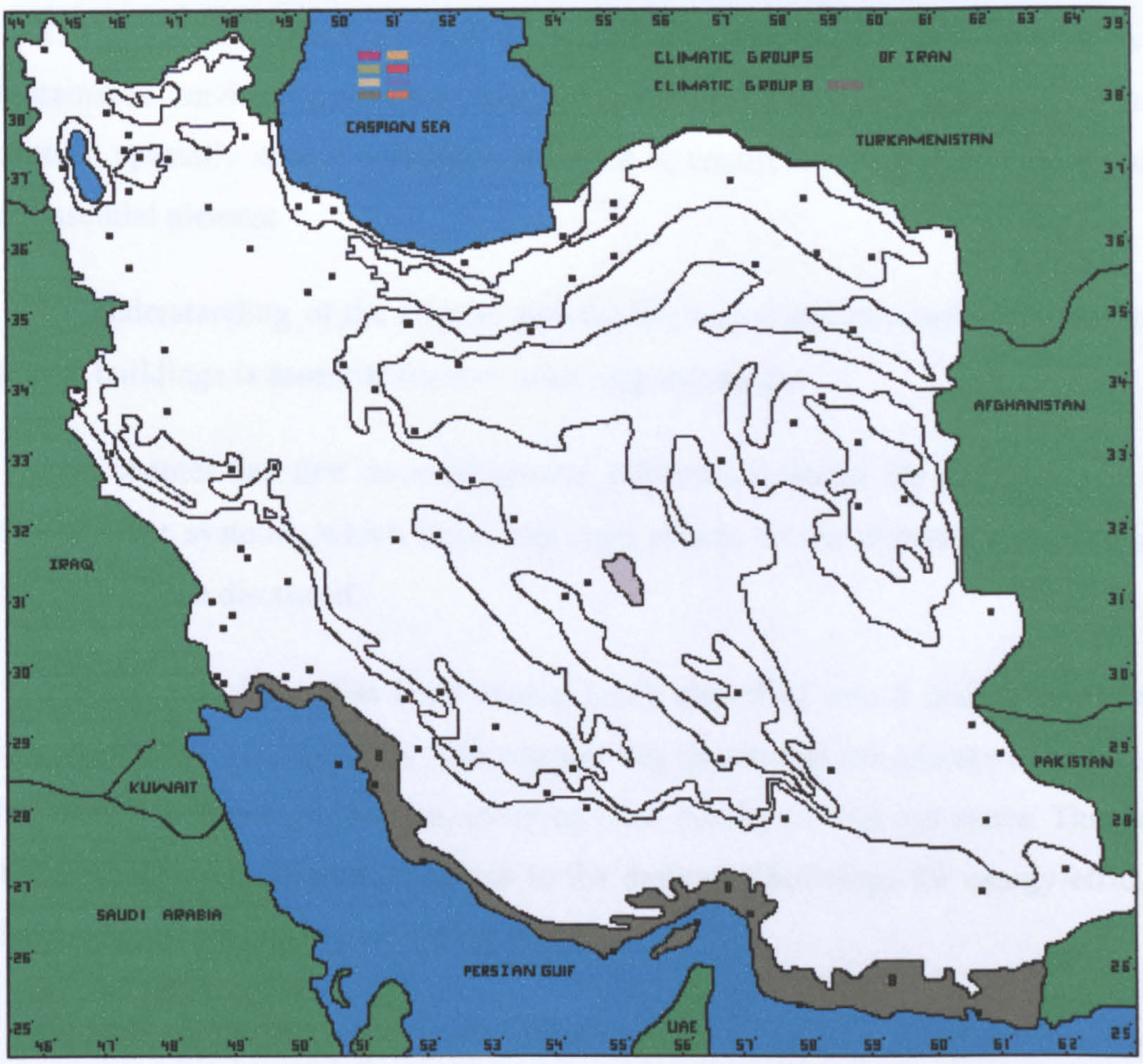


Climatic conditions in two critical seasons in Iran		
Climatic Group 7		
Climatic Subgroup	**Winter**	**Summer**
7-1	Cold	Very Hot and Arid
7-2	Cold	Strongly Hot and Arid
7-3	Cold	Strongly Hot and Semi Humid
7-4	Temperate	Strongly Hot and Arid
7-5	Temperate	Strongly Hot and Semi Humid

Table 2.8: The geographic specifications of the meteorological stations in the climatic group 7

Subgroup	Row	Code	Stations and Cities	Longitude Degrees (E)	Latitude Degrees (N)	Altitude Metres
7-1 Cold- Very Hot and Arid	1	98	Darab	54° 32'	28° 45'	1150
	2	168	Gachsaran	50° 50'	30° 20'	709
	3	202	Norabad-mamasani	51° 32'	30° 13'	900
7-2 Cold- Strongly Hot and Arid	1	8	Aghajari	49° 48'	30° 42'	29
	2	27	Andimeshk	48° 21'	32° 27'	85
	3	29	Ahwaz	48° 40'	31° 20'	22
	4	51	Boneseydan	48° 30'	32° 11'	5
	5	64	Tashkouiyeh	55° 33'	28° 04'	750
	6	70	Tang-pang	48° 45'	32° 56'	641
	7	85	Hajiabad(Bandarabbas)	55° 55'	28° 19'	900
	8	105	Dezfol	48° 23'	32° 24'	143
	9	134	Shamoun	48° 21'	32° 23'	60
	10	135	Shosh	48° 15'	32° 12'	180
	11	166	Goutiyan-safiabad	48° 26'	32° 16'	52
	12	187	Masjed-soliman	49° 16'	31° 59'	362
	13	210	Haft-tapeh	48° 21'	32° 05'	80
7-3 Cold - Strongly Hot and Semi Humid	1	39	Bagh-malak	49° 53'	31° 31'	900
	2	45	Bampoor	60° 27'	27° 12'	360
	3	81	Jiroft	57° 46'	28° 37'	668
	4	87	Hamidiyeh	48° 26'	31° 29'	53
	5	111	Ramhormoz	49° 36'	31° 16'	200
	6	159	Kazeron	51° 40'	29° 36'	766
	7	167	Gotvand	48° 48'	32° 14'	150
	8	178	Lar-fars	54° 20'	27° 41'	900
	9	215	Hovayzeh	48° 04'	31° 26'	32
7-4 Temperate- Strongly Hot and Arid	1	1	Abadan	48° 15'	30° 22'	11
	2	31	Iranshahr	60° 42'	27° 12'	566
	3	136	Shoshtar	48° 50'	32° 03'	150
7-5 Temperate- Strongly Hot and Semi Humid	1	50	Bandar mahshahr	49° 12'	30° 30'	3
	2	92	Khorramshahr	48° 11'	30° 25'	5
	3	132	Shabankareh	51° 06'	29° 20'	120

Figure 2.13: The map of climatic group 8 of Iran climatic classification (Source: Kasmaei 1993 and designed by Gorji)



Climatic conditions in two critical seasons in Iran		
Climatic Group 8		
Climatic Subgroup	Winter	Summer
8-1	Cold	Very Hot and Humid
8-2	Temperate	Very Hot and Humid
8-3	Suitable	Very Hot and Humid

Table 2.9: The geographic specifications of the meteorological stations in the climatic group 8

Subgroup	Row	Code	Stations and Cities	Longitude Degrees (E)	Latitude Degrees (N)	Altitude Metres
8-1 Cold - Very Hot and Humid	1	30	Ahwaz (mollasani)	48° 53'	31° 36'	50
	2	122	Saravan	62° 21'	27° 21'	1100
	3	154	Ghasreshirin	45° 34'	34° 31'	300
8-2 Temperate - Very Hot and Humid	1	47	Bandar Dayer	51° 56'	27° 50'	12
	2	48	Bandar Abbas	56° 22'	27° 13'	10
	3	49	Bandar Lengeh	54° 50'	26° 35'	13
	4	53	Boshehr	50° 50'	28° 59'	19
	5	78	Jazireh-Khark	50° 16'	29° 16'	3
	6	198	Minab	57° 04'	27° 09'	30
8-3 Suitable - Very Hot and Humid	1	77	Jask	57° 46'	25° 38'	4
	2	79	Jazireh-Gheshm	56° 15'	26° 57'	31
	3	82	Chabahar	60° 22'	25° 26'	10

2_5 * Summary

The impact of climate on different aspects of a building is very important. A total sustainable environment must involve optimum energy-consuming educational centres, specially school buildings, in which optimum climatic orientation would be an essential element.

An understanding of the climate and the biological and psychological comfort of school buildings is essential for their planning and design.

This chapter has first covered general information about the geography of Iran. The weather systems, which have important effects on the climatic classification in Iran, have been discussed.

The climate of Iran has been appropriately classified into 8 main groups with a total number of 36 subgroups. This chapter has shown that the climate of Iran is very variable with respect to location, covering from hot dry to cold wet zones. This means that there may be different solutions to the design of buildings for energy efficiency depending on the locality within the country.

The data of 216 meteorology stations and cities of Iran have also been described in appendix A.

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Chapter 3

History of Energy Use in the World and Iran

3 * History of Energy Use in the World and Iran

3_1 * Introduction

The prospect of producing clean, sustainable power in substantial quantities from renewable energy sources is now arousing interest worldwide. This is partly simulated by recent technological developments, which have improved the cost-effectiveness of many of the 'renewable', and increasing concerns over the environmental consequences of conventional fossil and nuclear fuel uses.

In this chapter first the history of energy use in the world will be reviewed. Then, it will look on the world energy supply and the world consumption of all forms of primary energies, which will introduce the magnitude of the energy problem in the future. Also, this chapter will outline the resources of energy in Iran, the role of this country in the global energy market, the contribution of Iranian oil and gas to the world supply and the pattern of consumption of oil and gas products in different sectors. The environmental problems, which are associated with large-scale fuel use will be discussed in detail, in order to highlight the danger of burning fossil fuels and to examine the possibility of using renewable energy sources as a partial or perhaps even complete solution to these problems.

One of the global renewable energy resources is solar energy. It is abundant in Iran and can make a significant contribution to the energy needs of buildings. Therefore, at the end of this chapter we will concentrate on the use of passive solar energy as a clean and cheap source of energy in buildings.

3_2 * World Energy Use

The dominant aspect of industrial societies is the large-scale use of fossil and to a lesser amount, nuclear fuels. The growing, distribution and preparation of foods is based on the use of energy. Also it is essential for construction, fabrication and the organisation of many other activities (Johansson, 1993). A brief review of world energy use is necessary because it will introduce modern uses of energy. In order to provide light, to cook food and to keep warm wood burning has been used for almost half a million years by mankind. Far more later fire was a useful way to obtain metals, such as iron, copper and etc, and to burn bricks and clay pots.

Near ten or twelve thousand years ago, animals have been used for the purpose of traction. Also for between five and six thousand years the power of wind has been used for the transportation of mankind by ships in the Mediterranean (Goulding, et al 1992).

Near three thousand years ago, the power of wind and water were the source of energy used in mills. Therefore, for many centuries natural forces, such as wind and water, have been the main source of providing energy for transportation and production (Johansson, 1993).

A considerable number of sophisticated civilisations have used only the energy of animals, human bodies, wind, water and other renewable energies, World Commission for Environment and Development (WCED, 1993). These types of energy sources are still dominantly used in many less industrialised countries (Harland, 1993).

The industrial revolution had important impact on changes to the present intensive use of fuels. This revolution led to an increase in the dependence of fossil fuels. It is divided into three periods. At the earliest stages watermills were introduced. Coke and coal were used once the steam engine was invented. Therefore, fuels replaced running water as the source of power production. During the nineteenth century coal and iron ores were plentiful and provided the main source of fuel and materials. Ineffective methods of energy use were employed in industrial procedures and resulted in adverse environmental impacts (Laughton, 1990).

During the end of the nineteenth and the beginning of twentieth century the electricity and the internal combustion engine, gas and oil as additional fuels were developed. Also the industry of chemistry creating new materials improved. At that time the availability of more complex materials (mixture of metals, etc.), good transport and cheap fuels resulted in the progress of industrialisation (Boyle, 1996).

In the mid-twentieth century the widespread distribution networks of electricity, began and progressed rapidly to the point at which it was available almost universally in industrialised countries. Industrial culture became totally dependent on fossil fuel with the opening of major oil fields of the Middle East and North Africa. After the

Second World War the nuclear sources of electricity were introduced as an additional power source and fuels were seen as cheap and plentiful. The consumption of those fuels was mostly inefficient, whilst their adverse environmental impacts were still ignored (Bevan, 1994).

In the late twentieth century, manufacturing is still increasing continuously, but is no longer the largest sector of the economy. Services (especially communications and information processing) are dominant activities, associated with progress in support technologies. The development of scientific and technical knowledge has also been very considerable (Evans, 1990).

There has been a progressive awareness of the environmental effect of industrial societies (especially burning of fossil fuels) since the late 1960's (Houghton, 1992). The occurrence of oil crises in the 1970's-provoked a growth in new techniques for making more efficient use of energy and using renewable sources. It is now technically possible to reduce the use of fuel, simply by giving attention to the energy aspects of the design of buildings, equipment, industrial and biological procedures, low energy materials and many other ways (Gyoh, 1993).

In the 1990's, this understanding of energy efficiency is only beginning to be applied, however, economic restrictions have held it back (World Energy Council Statistics, 1993).

The energy crisis of the early 1970's brought in it's wake a much increased attention to the possibility of using alternative energy technologies (Wozniak, 1979). These energy supply systems are fuelled from a source whose continued existence is actually insured.

During the past twenty years concern about using renewable energy has been growing steadily. Recent studies show that renewable energy will make a considerable contribution to global energy supplies in the longer term, (Alexander, 1996). Concern in renewable energy has been heightened by a number of interests over the use of fossil fuel energy technologies and their adverse effects on the earth's ecological system (Harland, 1993). The impacts of conventional energy systems on global warming has revitalised concern in renewable energy technologies. The environmental impact of renewable energy is little. Almost none of the renewable energy sources releases gaseous or liquid pollutants during operation. Therefore, they are widely seen as part of the solution (Boyles, 1996).

The increasing concern over non-conventional energy sources (new and renewable energy) arises from the understanding that the commercial forms of energy in popular use such as solid forms of fossil fuels and liquid and gaseous hydrocarbons are limited and ultimately exhaustible sources of energy (Boyle, ed 1996). Some observers fear that conventional sources of energy may not be able to fulfil the demands of future generations (Gyoh, 1996).

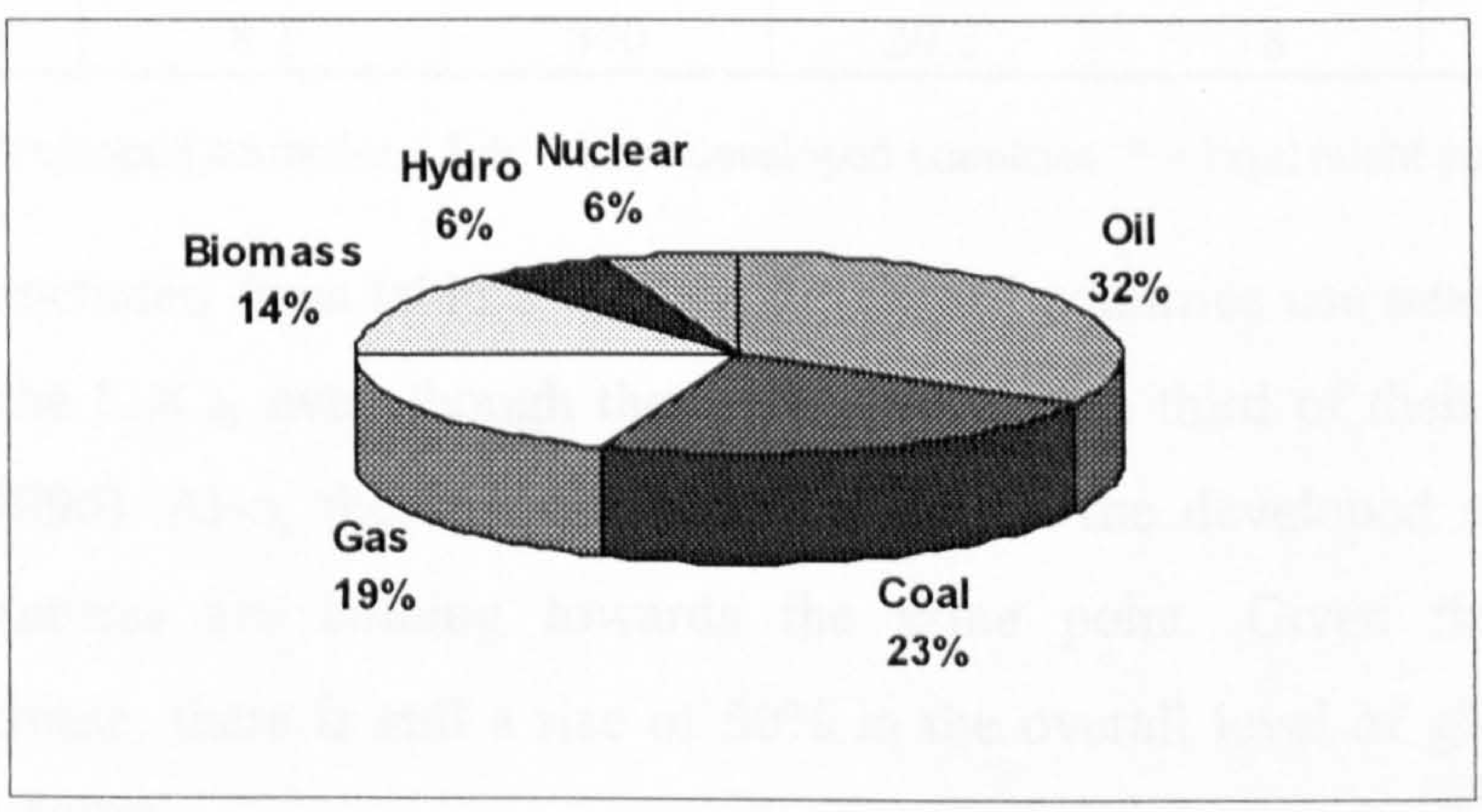
3₃ * World Energy Supply

Modern societies, are now largely dependent on the use of large amount of energy, most of it in the from of fossil fuels, for virtually all aspects of life (Houghton, 1992).

In 1992, the estimated total world consumption of primary energy (in all forms) was approximately 400EJ per year, equivalent to some 9500 million tonnes of oil (mtoe) per year (table and figure 3.1). Assuming, that the world population was about 5300 million, in 1992 the annual average world-fuel-use for every body is equivalent to about 1.8 tonnes of oil. This is equivalent to about 470 imperial gallons of oil per person per year (Boyle, 1996).

Table and figure 3.1: Estimated annual energy consumption 1992 (Source: Boyle, 1996)

Oil	Coal	Gas	Biomass	Hydro	Nuclear
33%	22.8%	18.8%	13.8%	5.9%	5.7%



It can be seen from figure and table 3.1 (by source in 1992) that oil is the dominant fuel (33%), followed by coal at about 23%. Coal was once the dominant fuel in the world, however is now losing ground rapidly to oil and to gas (around 19% share). Hydro electricity and nuclear are used at around 6% each (DTI, 1995and Boyle, 1996).

These figure also include fuels used by commerce, industry, etc. and large amount of wood and other biological fuels mainly used in the third world. The consumption of these traditional fuels accounts for around 14% to the overall total (Hall, 1991)

The magnitude of the energy problem facing future generations can be illustrated by the following calculation: In 1990, the world's population was about 5 billion people. The best United Nations (UN) estimates of population tendency indicate that it is will increase to around 8 billion by 2025, but stabilising towards the end of the next century at somewhere between 10 and 12 billion people. Most of that rise will be in the less developed countries (LDCs). Fuels are used at an average rate in the developed countries, which is more than six times that in the LDCs. The summary is presented in table 3.2.

Table 3.2: Increase in energy use expected as a result of population increases (Source: Adapted from Holdren, 1990)

Year	Population	Total energy use		Energy use per person	
	(Billion)	(EJ/y)	(TW)*	(GJ/y)	(KW)
1990 (Dev)	1.2	284	9.0	237	7.5
1990 (Ldc)	4.1	142	4.5	35	1.1
1990 (world)	5.3	426	13.5	80	2.5
2025 (Dev)	1.4	167	5.3	120	3.8
2025 (Ldc)	6.8	473	15.0	69	2.2
2025 (world)	8.2	640	20.3	78	2.5

Dev = Developed countries. Ldc = Less developed countries. * = Equivalent power.

It can be concluded from table 2 that the developed countries use nearly twice as much fuel as the LDCs, even though they have less than a third of their population (Greenpeace 1996). Also, the energy use per person in the developed and the less developed countries are coming towards the same point. Given the expected population increase, there is still a rise of 50% in the overall level of global energy use (Boyle, ed 1996).

3_4 * Iran Energy Sector

The medium to long-term development of the Iranian oil and gas sectors may play a crucial role in the long-term stability of global energy markets. The macro economic performance of the Iranian economy, as the economic foundation determining future domestic demand for oil and gas, together with the level of investment for the expansion of production capacity in the oil and gas sectors will affect the volume of Iranian oil and gas contributions to the world supply. Any under-estimation of the strategic importance and economic significance of Iranian oil and gas from the Caspian basin and the Persian Gulf, for the stability of future supply to major consuming nations may prove to be hazardous. Regional political and economic developments will undoubtedly affect the expansion in production of Iranian oil and gas, and hence influence Iran's export capabilities in the future. Iran's future oil and gas demand population growth, the rapid rate of urbanization, agricultural and industrial developments as well as the economic dislocation and low investment caused by the eight-year imposed war with Iraq have resulted in an increasing domestic demand for energy in order to rehabilitate the war damaged industries and fuel economic reconstruction. Iran's population in 1996 was estimated at some 60 million. Population growth in Iran was among the highest in the world during the 1980's, during which period it reached a peak of 3.6 percent a year, high enough to double the population in less than twenty years. The resulting pressure on public finance for education, housing, employment, health services and food and energy subsidies, forced the government to introduce strict measures on population control. Following the successful implementation of these policies, the rate of population growth, according to the 1996-97 censuses, fell to an estimated 1.4 percent, with approximately 55 percent of the population being currently under the age of 20. Such a young population necessarily implies a tendency towards higher rates of population growth, as well as a rapid rate of urbanization. This will increase the pressure on the government not only to create employment opportunities but also to accommodate the residential and commercial demand for energy, particularly in the urban transportation sector. The consumption of oil products in the household and commercial sectors has risen from 80.4 million barrels of oil equivalent in 1990 to over 116.5 million barrels of oil equivalent in 1995, showing an increase of 50 percent. Over the same period, the transportation sector has increased its consumption from 96.2 million barrels of oil equivalent, to 137.2 million barrels of oil equivalent, an equivalent growth rate of 43 percent. The consumption of natural gas has similarly registered a sharp increase. The total consumption of gas in the residential sector in 1996-97 was 10,984 million cubic meters, which accounts for 26 percent of total domestic consumption. In the same year, the industrial sector consumed 10,259 million cubic meters; equivalent to 24.3 percent of total domestic consumption. The major end-users in industry are the iron and steel industries. However, power generation plants are the biggest domestic gas consumers in Iran, consuming about 33 percent of the total domestic gas consumption. In summary, it can be said that the transport, household and commercial sectors are the main users of oil products, equivalent to 24 percent and 20 percent of the total energy consumed in 1995, while industry, household and commercial sectors, with 14.3 percent and 12 percent of the total energy consumed respectively, constitute the main users of natural gas in 1995.

The historical trends in oil and gas consumption, as depicted in tables 3 and 4, clearly demonstrate the increasing pattern of oil and gas consumption in Iran. An extrapolation from these figures suggests that population growth, the rapid rate of urbanization and industrial expansion will lead to increased demand for oil products and natural gas in the medium and longer terms. It is expected that the gas consumption of households will increase to 14,988 million cubic meters in 1999-2000 (1378). Similarly, the total gas consumption demanded by industry is estimated to increase to 15,190 million cubic meters in 1999-2000 (1378). Power generation will also increase gas consumption to 17,338 million cubic meters in 1999-2000.

A forecast of petroleum and gas consumption in Iran, 1996-2026, is given in table 3.5. Production Capacity Expansion: The increasing level of domestic energy demand on the one hand, and the dependency of the Iranian economy on the export revenues derived from petroleum, on the other hand, implies that the expansion of production capacity is, and will remain, a policy imperative in the foreseeable future. An examination of historical trends in oil and gas production illustrates this point. Iran needs to produce more oil and gas in order to increase its contribution to the incremental world demand and to obtain more hard currency for the financing of its future economic growth and development, as well as to satisfy growing domestic demand. Gaining access to domestic and foreign capital for investment in the oil and gas sectors and effectively managing energy demand while achieving efficiency in energy use, are the main two policy options open to Iranian policy-makers.

While it is true that higher levels of energy consumption are basically essential to fuel higher rates of industrial development and economic growth, the rationalization of domestic energy consumption is a prerequisite to the mobilization of resources for investment to expand production capacity. Adjusting the price of domestic petroleum, from the economic point of view, is the key to domestic energy demand management. Even after doubling the price in March 1995 and maintaining upward price shifts annually, oil product prices have remained the lowest in the world. This clearly encourages waste, inefficiency and the smuggling of petroleum products to neighbouring countries.

Despite the relative success of energy policy-maker's efforts to correct the disparity between domestic and international petroleum product prices, there are limits, within the Iranian macro economic setting, to upward price shifts. It should be noted that the transportation sector accounts for about 40 percent of the demand for oil products in Iran, followed by the household and commercial sectors, which account for nearly 33 percent. Again, household and commercial sectors consumed about 40 percent of the natural gas, and over 53 percent of the electricity produced in Iran in 1996-97.

Any significant upward shift in household and transportation energy prices may produce adverse social and economic side effects under the prevailing conditions of severe income disparity between different income groups as well as between rural and urban sectors. The rapid expansion of the service sector in conjunction with an increased inclination to use market forces in economic planning, signals the likelihood of a widening inequality gap. It follows that substantial petroleum product price adjustments towards international levels will become increasingly difficult in the foreseeable future.

This argument holds equally true for industry. While this sector consumes nearly 14 percent of total oil products, it demands about 30 percent of total natural gas produced in Iran. Industrial demand for gas and the consumption of natural gas by power plants, account for more than 70 percent of the total production of natural gas.

Although the projects to replace the use of petroleum products with natural gas have resulted in an annual saving of about 750 million dollars over the past few years, any significant price rise in the energy consumed in industry and power plants may hinder the process of industrialization. In fact, although many of the dynamic economics of Asia enjoyed cheap energy at the earlier stages of industrialization, cheap energy may encourage industrial inefficiency. Hence, the optimal setting of energy prices for industrial use should be carefully formulated. The successful implementation of energy price adjustment would also release substantial financial resources by reducing the amount of subsidies in the energy sector. Despite technical difficulties in accurate estimation, it can be said that subsidies in the energy sector amounted to some 11 billion dollars last year. Such considerable financial resources could be used to enhance the industrialization process and economic growth in Iran.

Taking into account the above mentioned complexities in domestic energy demand management through petroleum product price manipulations, it is estimated that, given a successful scenario of higher energy price implementation, domestic demand for oil products will reach some 2 million barrels per day by the year 2010, a doubling of consumption in less than 15 years. This signifies, once again, the necessity for the expansion of production capacity in order to maintain and/or increase oil exports as a primary energy-policy option. Needless to say, the expansion of refining capacity as an effective response to domestic incremental demand is another vital energy policy issue facing the Iranian petroleum industry. Further participation in oil and gas activities in the region especially in the Caspian basin, as well as the achievement of increased foreign investment in the Iranian oil and gas industries, are two other key issues in the fulfilment of energy policy objectives. Extended role in Caspian oil and gas development despite U.S. pressure to by-pass Iran, the mere economic fundamentals of pipeline construction and oil and gas marketing imply that Iran, with its unique geographical position, will eventually gain its historic opportunity as the best possible pipeline route for the export of hydrocarbons from the Caspian basin to international markets.

It is of critical importance to note the substantial economic and political background for closer cooperation between the energy sectors of Iran and the Central Asian republics. Iran has worked hard to develop trade ties with the new republics of the former Soviet Union following their independence in 1991 and Iran's unique strategic position and its cultural ties with these countries has played a critical role in the success of this endeavour. The 700 km railway link from Bandar-Abbas, a coastal town in the Persian Gulf, to the Iranian national railway network at Bafq, together with the national network extension to Sarakhs free zone on the Turkmenistan border, which opened in 1996, provide ample opportunity for the flow of goods from the Persian Gulf to Central Asia. In fact, the joint construction of highways, railroads, seaport links and pipelines is the main focus of Iran's policy towards Central Asia, since this facilitates Iran's role in trade and transportation within the region. The Central Asian independent states provide important exports markets, albeit small, for Iranian goods, while the Central Asian countries have benefited considerably from trade and closer economic ties with Iran. This is particularly true of Turkmenistan, which has been adversely affected by non-payment for its gas exports to some countries.

Iran's cooperation in the oil and gas industries of the Caspian basin and Central Asian republics of central importance. The combined efforts of Iran, Kazakhstan and Turkmenistan in oil and gas exploration and marketing would offer these states not only greater economic independence, but enable them to reach new markets in the Asia Pacific via the Persian Gulf. The swap deal with Kazakhstan represents an innovation in promoting economic links with Central Asia. Under the terms of this deal, Iran delivers oil for Kazakhstan from its southern terminals in the Persian Gulf, in return for receiving the same amount of Kazakh oil in its northern ports. Under the original deal, during the initial phase of the project, deliveries will amount to 40,000 barrels per day, rising to 120,000 barrels.

In another development, the feasibility studies for the construction of a pipeline between Turkmenistan and Turkey through Iran are under way. It is envisaged that this pipeline will run into eastern Iran through Shahroud, Semnan and south of Tehran towards Tabriz and the Turkish border and will transport about 28 billion cubic meters of Turkmen natural gas per year. Moreover, Iran has financed 80 percent of a 200-km pipeline, which transmits about 4 billion cubic meters annually of Turkmenistan's gas to Kurd-Kuy in northern Iran. It is planned that Iran will increase its gas imports through this pipeline up to 8 billion cubic meters annually for 25 years. Iran, Kazakhstan and Turkmenistan have also reached an agreement on trilateral cooperation for the transfer of Kazakh and Turkmen crude oil through Turkmenistan and Iran to international markets (Ghanimifard, 1998)

The consolidation of the above-mentioned economic and commercial ties between Iran and the energy-rich countries of the Caspian basin suggests that the mutual economic benefit of such cooperation will ultimately defuse adverse external political pressure. This will, in turn, pave the way for more substantial participation in the oil and gas industries of the region. As mentioned earlier, foreign investment is being sought by Iran for oil exploration offshore and onshore, and also for developing major gas fields.

With over 93 billion barrels of proved oil reserves, equivalent to over 9 percent of the world's total, and with over 21 trillion cubic meters of proved gas reserves, equivalent to over 15 percent of the world's total, Iran offers a great prospect for foreign investment in the oil and gas industries. The current levels of oil and gas production indicate that Iran's shares in the world's total production of oil and gas are 5.5 percent and 1.7 percent, respectively. This clearly suggests a long-term comparative advantage for foreign investment, especially in the gas sector. This factor, in addition to the geographical accessibility of Iran to world markets has attracted the interest of a number of major companies in investing in the Iranian oil and gas industries. Total, Gas prom and Petronas were among the serious contenders who have succeeded in signing contracts.

In summary then, the considerable volume of oil and gas reserves, direct accessibility to world markets via the Persian Gulf, its geographical position as a bridge linking the Caspian basin to the Persian Gulf, the growing domestic consumer and investment markets, and last but not least, political stability, have made Iran an attractive market for foreign capital. In fact, it is the working principles of open economies that will, in the longer-term, determine the functioning of international oil and gas markets. Short and medium-terms intervention in the international energy markets for the attainment of short-sighted domestic political gains can only disturb the market.

Table 3.3: Crude oil Consumption (Thousand barrels per day)

1980	1981	1982	1983	1984	1985	1986	1987	1988
511.7	518.1	719.1	871.4	723.0	735.0	711.5	751.0	766.0
1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
773.6	853.8	592.6	940.7	960.2	920.0	945.0	984.1	1076.6*

Table 3.4: Natural Gas Consumption (Marketed) (Billion cubic meters)

1980	1981	1982	1983	1984	1985	1986	1987	1988
7.1	6.0	7.2	11.0	13.5	14.6	15.2	16.0	20.0
1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
22.2	24.2	32.2	35.1	36.9	40.4	36.6	40.4	46.6*

Table 3.5: Forecast of Petroleum and Gas Consumption in Iran, 1996-2026
(Million barrels per day of oil equivalent)

	1996	2001	2006	2011	2016	2021	2026
Petroleum	1,361	1,466	1,579	1,701	1,833	1,974	2,127
Gas	0.750	1,195	1,906	2,433	3,105	3,962	5,057
Assumed Population Growth Rate 1.2% Population (mns)	60	63.6	67.6	71.6	76.1	80.7	85.7

Table 3.6: Crude Oil Production (Thousand barrels per day)

1980	1981	1982	1983	1984	1985	1986	1987	1988
1,817	1,565	2,421	2,442	2,032	2,192	2,037	2,296	2,476
1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
2,814	3,135	3,399	3,432	3,425	3,596	3,595	3,595	3,601*

Table 3.7: Natural Gas Production (Billion cubic meters)

1980	1981	1982	1983	1984	1985	1986	1987	1988
20.1	16.3	24.5	29.2	30.5	31.6	33.4	36.7	40.5
1989	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
43.4	54.5	66.1	71.3	74.4	81.8	79.6	85.0	88.1*

Source: N.I.G.C. * Estimated by N.I.G.C.

The extent of solar energy received by Iran is 8 times more than its total oil and gas reserves, total oil and gas reserves in Iran are equivalent to some 100 billion barrels of oil and 600 trillion cubic feet of gas. The official made the remarks at the seminar during the international solar energy conference and Islamic states, the first of its kind and which is currently ongoing in Shahryar. The total energy received by Iran amounts yearly to around 10,827 kilo-joules, or 1,000 times the total consumption and export of energy in the country, by utilizing one percent of the country's land area, Iran's energy needs can be met through the utilization of solar energy (Mo'tamedi, 1995)

3₅ * Environmental Problems

At present the world population is faced with various environmental problems. Many of these are the consequence of burning fossil fuels (IEA, 1992). There are widespread concerns about global warming, acidification, climate changes and oil pollution of the seas, which will be discussed in the next part of this chapter.

3.5.1 * Global Warming

The issue of global warming needs the most critical attention. It is described as a gradual increase in the global average air temperature at the earth's surface (Boyle, 1996). The average surface temperature of Earth is about 15°C. Over the last century, this average has risen by about 0.6 Celsius degree. Scientists predict further warming of 1.4 to 5.8 Celsius degrees by the year 2100 (Kyoto, 1997). Global warming is the consequence of increases in the concentration of greenhouse gases in the atmosphere. Carbon dioxide (CO_2) released by the consumption of fossil fuels is the most significant element of these greenhouse gas emissions (Houghton et al., 1990 and 1992). In addition to CO_2, water (H_2O), methane (CH_4) and chlorofluorocarbons (CFCs) are also called greenhouse gases. Even in very small (trace) quantities, they can have considerable effects on average temperatures (Boyle, 1996).

At present, the rate of world-wide greenhouse gas emissions is increasing every year. In order to minimize the magnitude of future warming these emissions must begin to decrease. Reducing the consumption of fossil fuels such as coal, oil and natural gas, especially in the industrialized world, is the single most important factor in controlling global warming (ICLEI, 1993).

The effects of global warming on agriculture would be also significant. The most serious effect is an increase in the risk of long spell of dry weather. The other side effects could be a rise in the sea level, a decrease in the sea ice and reduction of seasonal snow cover (Boyle, 1996).

$3_{5.2}$ * Acid Rain

Another side effect of burning fossil fuels is acid rain. Acid rain is a term, which is used to describe a variety of processes, which might more accurately be referred to as acidic deposition. Natural rainfall is slightly acidic due to dissolved carbon dioxide, picked up in the atmosphere. Organisms and ecosystems all over the planet have adapted to the slightly acidic nature of normal rain, and thus it poses no environmental problems. It is an increase in the acidity of rain, caused by human activities such as the combustion of fossil fuels that has turned acid rain into a problem. Highly acidic rain can damage or destroy aquatic life, forests, crops and buildings, as well as posing a threat to human health.

The magnitude of the impact of acid rain on environment and health is very dependant upon the type of bedrock and soil in a specific region. Regions where the bedrock and/or soil contain carbonates such as limestone and dolomite are less susceptible to damage by acid rain than areas with igneous bedrock. This is because the carbonate material acts to neutralize the acidity of the precipitation. Carbonates act as a "buffer"; they tend to keep both surface and groundwater at a constant pH.

There are basically two ways of reducing acid rain. Emission control technologies can be attached to smokestacks at power plants and other industries, removing the acid gases before they are emitted into the atmosphere.

The other alternative is to burn less high sulphur fossil fuel. This can be accomplished by switching to alternative sources of energy, or improving the efficiency of our energy consuming technologies. Ultimately, the most effective methods of reducing acid rain are renewable energy and energy efficiency. Renewable energy technologies such as solar and wind energy can produce electricity without any emissions of sulphur dioxide (SO_2) or nitrous oxides (Nox). Both renewable energy and energy efficiency have the added benefit that they also result in reduced emissions of carbon dioxide, the greenhouse gas most responsible for global warming (Houghton, ed 1992, ICLEI, 1993).

$3_{5.3}$ * Oil Pollution of the Seas

The transport of oil can cause serious damage to the seas. During the twentieth century the amount of oil production has increased. Therefore, the quantity of oil transported around the world, especially by sea, has also increased. The size of oil tankers has increased to the point where they are by far the largest commercial ships and this results in large amount of oil being released into the seas.

Although the transport of oil is a safe industry, when accidents happen they have a great net effect. Although the frequency of accidents is small in comparison to the number of tanker journeys, many minor incidents such as oil spills from tankers and oil storage facilities occur every year, causing significant environmental damage.

At present, the extent of oil pollution is such that clusters of floating oil are common in almost all oceans (Boyle, 1996).

3.5.4 * Environmental Sustainability and Climate Changes

The continual man-made emissions of "Greenhouse gases" are resulting in global atmospheric warming, local climate changes, and sea-level rise, with the prospect of consequent serious environmental, social and economic impacts.

The most comprehensive scientific assessment of climate change was conducted by Working Group I of the Intergovernmental Panel on Climate Change (IPCC), which is organized jointly by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). The results (Houghton et al., 1990, 1992) are the most authoritative and strongly supported statement on climate change that has ever been made by the international scientific community.

When the atmospheric CO_2 concentration is increased at the rate of 1 percent per year, the globally averaged surface temperature increase realized in the model is about 60 percent of the warming expected in the equilibrium state under the given concentration of CO_2 (Stouffer, et al., 1989; Murphy, 1992).

Concluded that uncertainties in predicting possible future climate changes exist in our inadequate understanding and thus inadequate treatment of the following processes (Houghton, et al., 1992):

- Clouds (particularly their feedback effect on warming induced by greenhouse gases, as well as the effect of aerosols on clouds and their radiative properties) and other elements of the atmospheric water budget, including the processes controlling upper-level water vapour;

- Oceans, which, through their thermal inertia and possible changes in circulation, influence the timing and pattern of climate change;

- Land surface processes that link regional and global climates;

- Sources and sinks of greenhouse gases and aerosols and their atmospheric concentrations (including their indirect effects on global warming);

- Polar ice sheets (whose response to climate change also affects predictions of sea-level rise).

3_6 * Renewable Energy

The renewable energy is described as a repeatedly occurring energy flow in the environment that can be controlled and used for the benefit of human beings (HGA, 1992).

The assessment of the potential contribution of renewable energies concluded that, with adequate support, renewable energy technologies could provide much of the growing demand at prices lower than those usually predicted for conventional energies (Johansson et al. 1993).

Renewable energy could supply three-fifths of the world's electricity market (Figure 3.1) and two-fifths of the market for fuels used directly (Figure 3.2) by the middle of the twenty-first century.

Some of the benefits of transition to a renewable energy economy, which are not captured in standard economic accounts are social and economic development, land restoration, reduced air pollution, decrease in the intensity of global warming, fuel supply diversity and etc (Kaya and Yokobori, 1997).

Johansson (1997) has shown that by 2050 the emissions of global CO_2 would be reduced to 75 percent of their 1985 levels assuming that renewable energies and energy efficiency are both pursued (Figures 3.3 and 3.4).

Figure 3.1: The renewable-intensive global energy scenario, 1985-2050 Electricity generation (Source: Johansson et al., 1993)

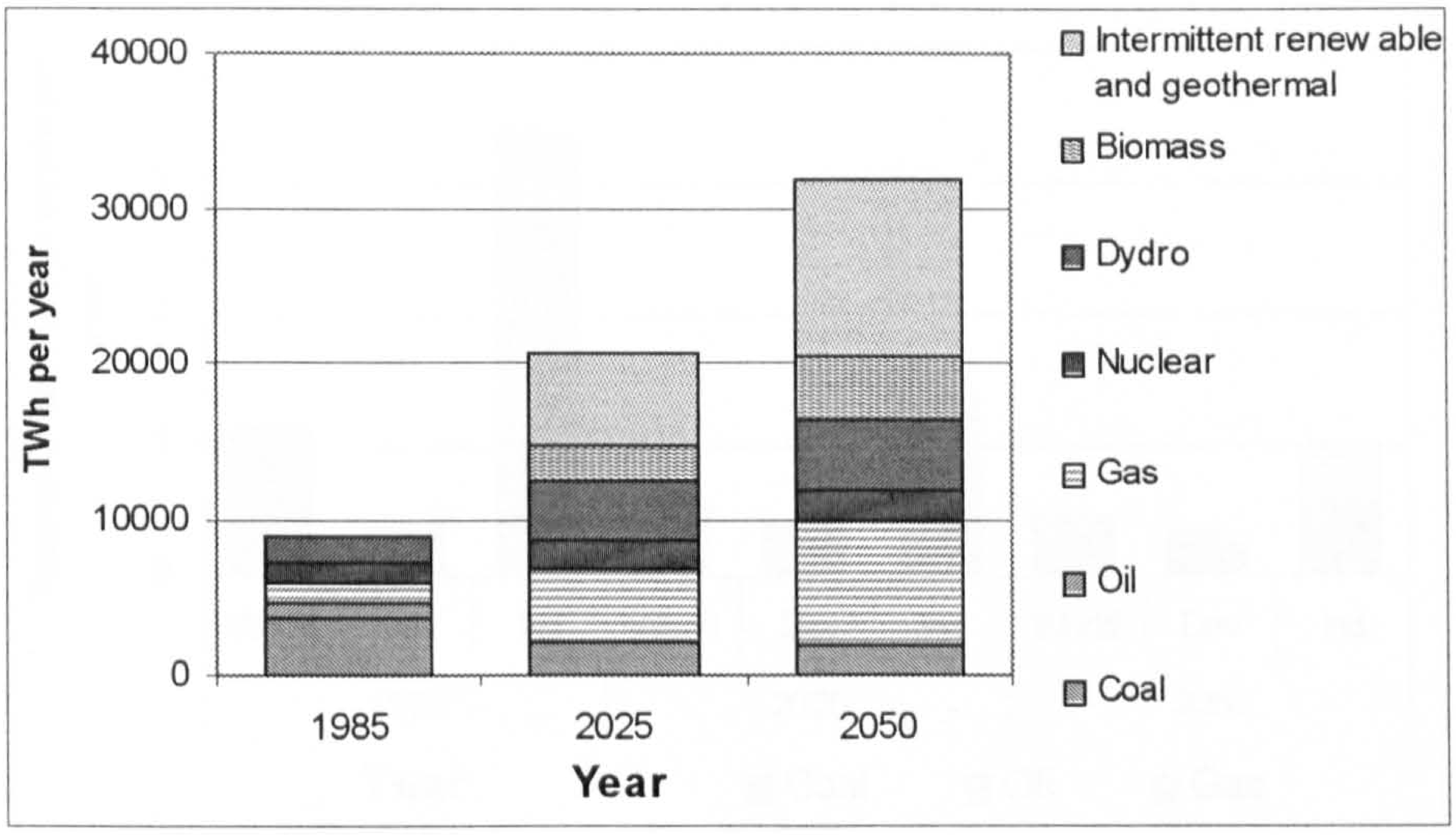


Figure 3.2: The renewable-intensive global energy scenario, 1985-2050 Direct fuel use (Source: Johansson et al., 1993)

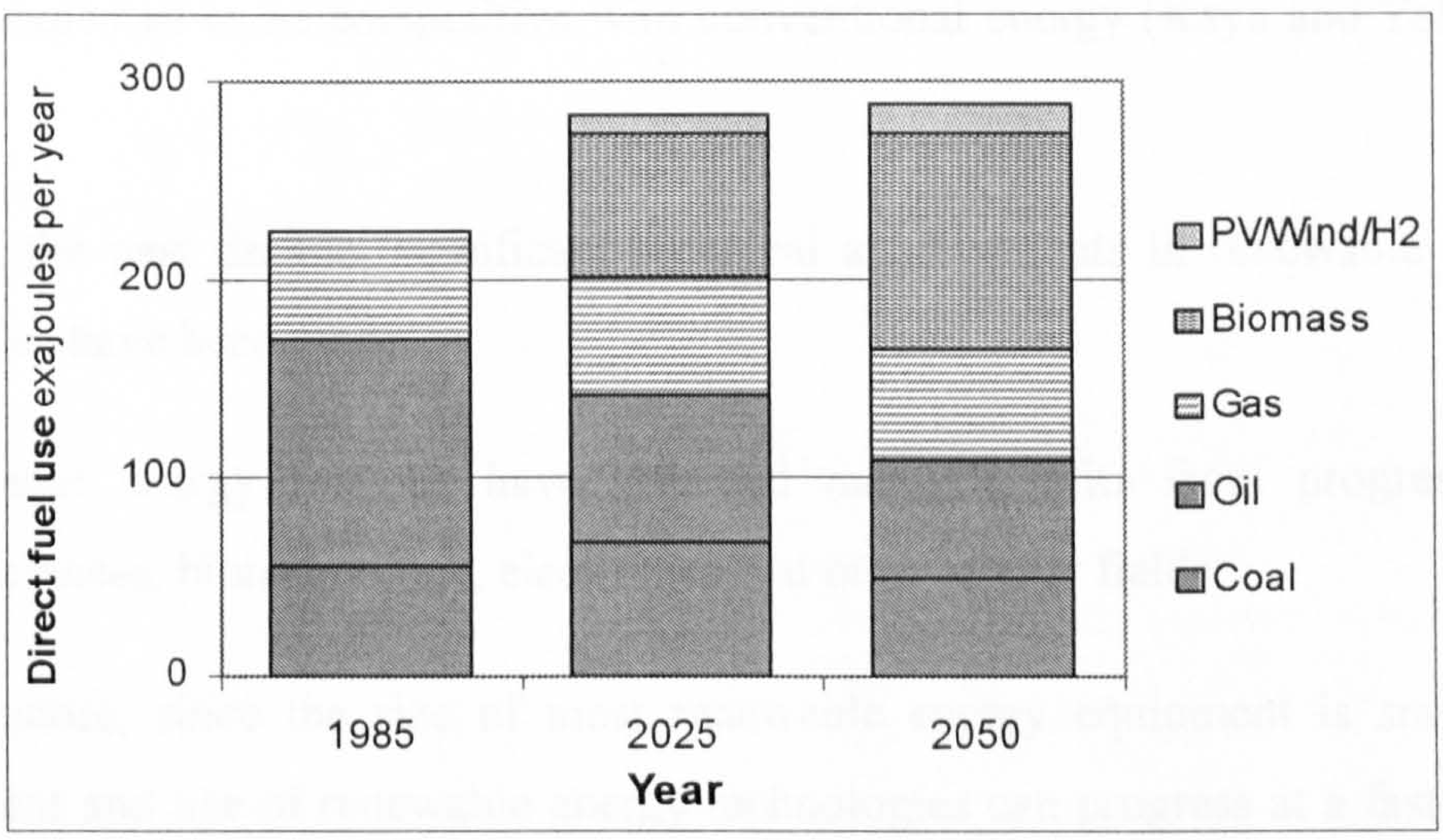


Figure 3.3: The renewable-intensive global energy scenario, 1985-2050 Emission of CO_2 (Source: Johansson et al., 1993)

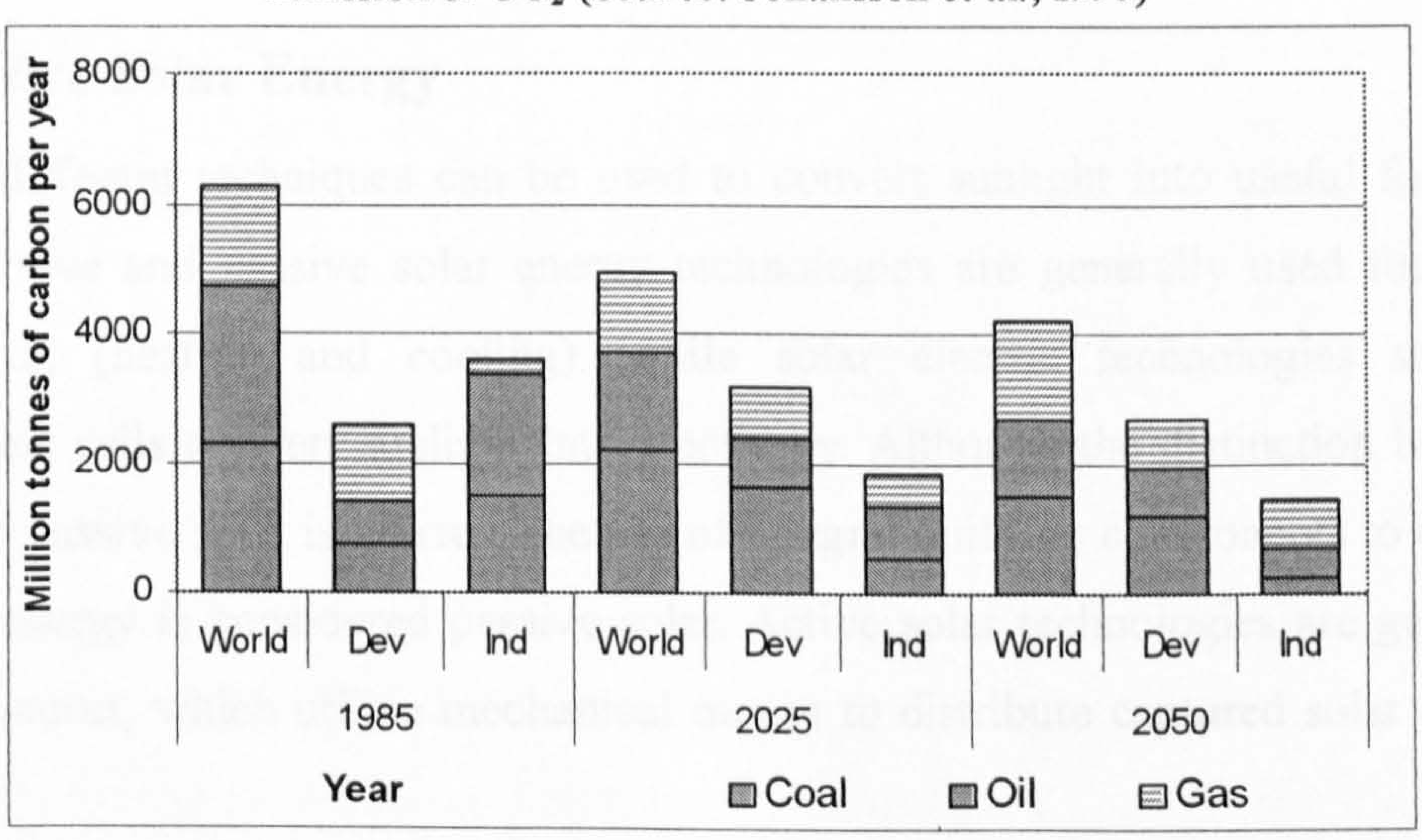
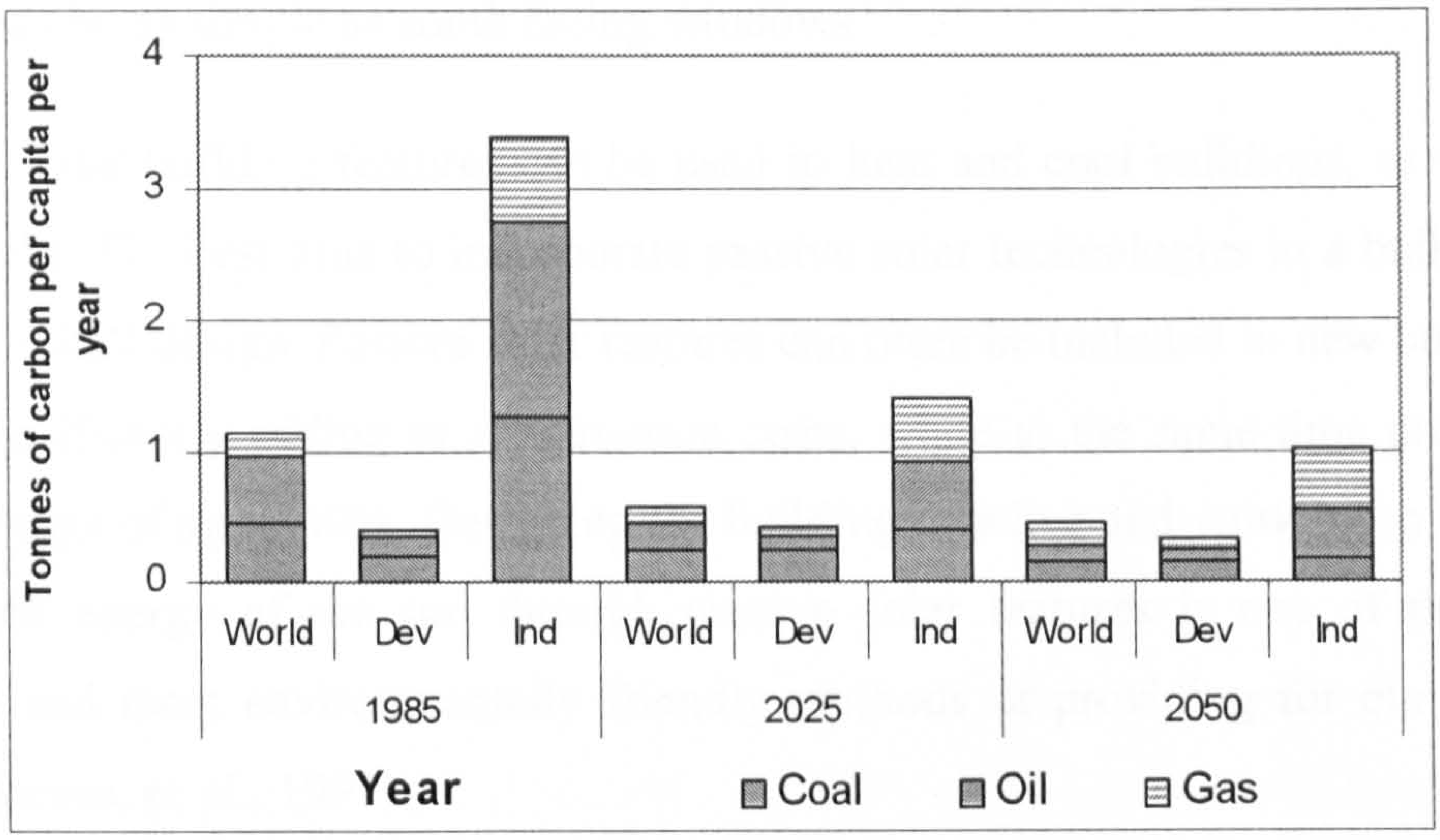


Figure 3.4: The renewable-intensive global energy scenario, 1985-2050 Per capita emissions of CO_2 (Source: Johansson et al., 1993)



These benefits could be accomplished at no additional cost, because renewable energy is expected to be competitive with conventional energy (Kaya and Yokobori, 1997).

During the past decade, significant technical achievements in renewable energy technologies have been made.

Renewable energy systems have obtained many benefits from progresses in material sciences, biotechnology, electronics and other energy fields.

Furthermore, since the size of most renewable energy equipment is small, the development and use of renewable energy technologies can progress at a faster pace than conventional technologies (Kaya and Yokobori, 1997).

3₇ * Passive Solar Energy

Many different techniques can be used to convert sunlight into useful forms of energy. Active and passive solar energy technologies are generally used for space conditioning (heating and cooling), while solar electric technologies such as photovoltaic cells convert sunlight into electricity. Although the distinction between active and passive solar is blurred, the use of integral building components to capture the sun's energy is considered passive solar. Active solar technologies are generally add-on features, which utilize mechanical means to distribute captured solar energy.

An example of active solar energy is a solar hot water heater, while passive solar features may be as simple as south facing windows.

Passive solar building features can be used to heat and cool buildings, as well as provide light. The best time to incorporate passive solar technologies in a building is during the initial design. Passive solar features can often be included in new buildings without significantly adding to construction costs, while at the same time providing energy savings of up to 40%. Designing the buildings we live and work in, to capture the ambient energy of the sun through passive solar features is one of the least expensive and most environmentally friendly methods of providing for our energy needs (Jefferson, et. al., 1991).

The capture of solar energy by passive solar technologies has almost no negative impact on the environment. Passive solar energy gives off no air or water emissions and therefore does not contribute to any of the environmental problems such as acid rain and global warming, which are associated with other source of energy.

There is nothing new about using the sun's energy to heat our living spaces; humankind has used passive solar techniques for thousands of years. In many countries in the world including Iran, cheap and abundant fossil fuels have led to the abandonment of passive solar building design. Rediscovering passive solar energy and incorporating technological advances can go a long way towards creating a more sustainable energy future.

Every building has some of its heating requirements met by solar energy. Sunlight passing through windows is a source of heat; but most buildings are not specifically designed to utilize solar energy. The value of passive solar heating is enhanced by proper building insulation. A well insulated building requires less energy for heating; and thus much of the heating load can be met by passive solar features. Insulation, like passive solar features, can often be incorporated into new building designs with little increase in construction costs (Energy Mines & Resources Canada, 1990).

Optimum passive solar design begins with the layout of a building plot or subdivision. Buildings must be oriented so that they can take full advantage of available solar energy and subdivisions must be designed in such a way that all buildings have equal access to sunlight. In the northern hemisphere, it is best to situate buildings with their long axis in an East-West direction. This configuration maximizes solar gain in the winter, when the sun is to the south, and minimizes it in summer afternoons when the sun is in the west.

Direct solar gain, increased thermal mass and attached sunspaces are the most common features of passive solar heating. Many other features exist, but are basically variations on the above. Direct solar gain, the main source of passive solar heat, is accomplished by capturing the sun's energy through large areas of south facing windows. Window glass is virtually transparent to incoming solar radiation. When sunlight strikes the interior of a building, it is converted into heat which is not as readily transmitted back through the glass, thus resulting in a heat gain inside the house. Window glass, however, is generally not a good insulator, and increased solar heat gain during the day can be offset by loss of heat through windows at night. New high efficiency, triple glazed windows with special coatings have recently been developed that have such a high insulation value that they are net producers of heat even when facing north in the winter (Howes, R.; Fainberg, 1991).

Careful attention to the placement of windows which open and interior partitions can greatly increase the natural flow of air through a building, by capturing the prevailing winds. In climates with hot days and cool nights, night-time ventilation can be used to cool the thermal mass of a building. A building with good insulation and a high thermal mass may then stay cool during the day. As with passive solar heating, fans may be used to encourage this ventilation.

Daylighting is the use of sunlight to replace electric lighting in a building. There is no technology at the current time capable of storing sunlight for release at a later time. Daylighting is therefore most valuable in applications such as school buildings where most of the lighting demand occurs during the day. Windows provide light for the perimeter of buildings while atria, light-shelves and light-pipes, can transmit daylight into the interior of buildings. In combination with electronic "photo-sensor" controls which adjust electric lights according to light levels, daylighting features can drastically reduce the amount of electricity required to light a building.

The use of daylighting has often been seen as contradictory to the need for keeping a building cool in the summer. Sunshine streaming through a window provides daylight, but is also a source of heat. While this heat is valuable in the winter, it can make buildings unbearably hot in the summer. New window technologies such as films which let in light but not heat, and "smart windows" whose transparency can be adjusted by an electric current, have helped to reconcile the needs for both light, and heat in buildings.

Passive solar energy has the potential to supply a large proportion of the energy needs for a properly designed building such as school. The best opportunity for using passive solar is in new construction. Before the proliferation of fossil fuels, architects routinely designed buildings to utilize available solar energy for heating, cooling and lighting. Recent advances in technology and building materials have greatly expanded the tools for architects to work with, and thus the potential for passive solar energy. Passive solar energy, while often seen as "low-technology", represents in many cases, the cleanest, and least expensive possible source of useful energy for buildings (ICLEI, 1993).

3_8 * Conclusion

This chapter has looked at the historical development of energy use and detected that whilst it was a basic element of the creation of an advanced society, it also took place with little attention for the efficiency of use and environmental concerns.

This chapter has demonstrated that the supply of fossil based fuels is limited and will not meet the medium to long-term needs of countries. There is also a growing awareness internationally that the world must adjust its consumption of energy and limit the emission of harmful global warming gases. This means that in the future the world community must make serious efforts to:

a) Reduce dependence on fossil fuels.

b) Increase the use of renewable less polluting sources of energy.

c) Improve the energy efficiency of countries and in particular the energy efficiency of buildings.

The energy efficiency of buildings can be improved through better design and utilising solar energy as a renewable source of energy to supplement the use of fossil fuels.

Since the amount of solar radiation in Iran is great enough to meet a part of the heating, cooling and lighting needs, therefore it seems that using passive solar energy in the design of new schools will help us to:

- Create a more sustainable environment in the future.
- Reduce the consumption of fossil fuels.
- Provide the cleanest and least expensive possible source of useful energy in schools.
- Save a considerable amount of energy
- Introduce the advantages of this technology to architects in order to be incorporated in the design of buildings.

The next chapter reviews the calculation of solar energy as a resource of renewable energy. This is believed, will set the framework for a better understanding of Solar Radiation Computation In Iranian Cities.

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Chapter 4

Solar Radiation Computation in Iranian Cities

4 * Solar Radiation Computation in Iranian Cities

4_1 * Introduction

In Chapter 3 it was shown that solar radiation could be used to supplement the use of fossil fuels in the drive to reduce the dependence on fossil fuels. However in order to do so it is necessary to be able to estimate the solar radiation values for surfaces of buildings.

This thesis aims to produce a methodology for optimising the energy performance of school buildings in Iran and therefore it is necessary that solar radiation values for building surfaces in the selected cities in Iran can be calculated.

Comprehensive hourly solar radiation data for Iran was not available from the Islamic Republic of Iran's Meteorological Office and therefore it is necessary to develop algorithms for calculating such values and to evaluate them against the limited published data for Iran.

When solar radiation reaches the earth's surface, its intensity is little more than half the value at the top of the atmosphere. Prediction of the value at a particular location is difficult and will depend on local conditions such as pollution; the amount of cloud cover and the length of the path the solar radiation takes through the atmosphere. The final value differs with the time of day, season of the year and position on the earth's surface.

The intensity of solar radiation at a particular location will have two components – the direct radiation and diffuse radiation. Direct radiation (beam radiation) is the solar radiation received from the sun without any change of direction. Diffuse radiation is the solar radiation received from the sun after its direction has been changed by reflection and scattering by the atmosphere.

This chapter discusses the method of calculation of solar radiation for cities, such as Tehran, Esfahan, etc. by using the algorithms developed in the European Solar Atlas modified by information from the Islamic Republic of Iran Meteorological Organisation (IRIMO). The equations developed in the European Solar Atlas after modification have been used to develop a spreadsheet programme to enable calculations of solar intensities to be carried out. The Excel spreadsheet was then used as part of the overall calculation programme for predicting energy usage, which is described in this chapter.

The equations used to calculate both direct and diffuse solar radiation are the ones used in the SERC Meteorological Data Base Handbook and The University of Sheffield Building Science Internal Reports BS 28, 30, 44, 46 and BS 66. It was decided to use this work (although old) as there is a lack of reliable solar data or correction factors for Iran, and it was felt that the basic equations relating to solar radiation would be robust enough for the work in this thesis.

Finally in order to ensure that the values calculated by the following procedures were suitable to be used in the energy estimation part of this work, the results had to be checked against available data. This was carried out by comparing the results with those produced by the Swiss programme Meteonorm Version 3.

However in some of the equations the values given are specific for the European situation and are not appropriate for Iran. In such cases modifications have been made to ensure that the calculated values are appropriate.

The Chapter is split into three sections, the first dealing with the calculation of direct solar radiation, the second with diffuse solar radiation and the third with the validation of the calculated results.

Section 1 – Calculation of Direct Solar Radiation

4_2 * Calculation of Direct Solar Radiation on a surface

The basic equation adopted for estimating the value of the direct solar radiation on a surface was that adopted by Page (Page and Sharples, 1988) and is shown below. This equation requires a knowledge of other modifying factors and these are explained in the following sections. However before this equation can be solved it is necessary to have an understanding of the basic geometry of the relationship between the position of the sun and the receiving surface. These relationships are also outlined.

$I_c = I_{oj} \exp(-m\, \delta_R\, T_L)$ Wm^{-2} Algorithm 4.1

In order to calculate clear sky direct irradiance on a horizontal or inclined surface **$I_c(\beta,\alpha)$** is calculated by:

$I_c(\beta,\alpha) = I_c \cos v(\beta,\alpha)$ Wm^{-2} Algorithm 4.2

Where, **I_c** is the intensity of solar radiation measured normal to the solar beam and **$\cos v(\beta,\alpha)$** is the cosine of angle of incidence.

For a horizontal surface:

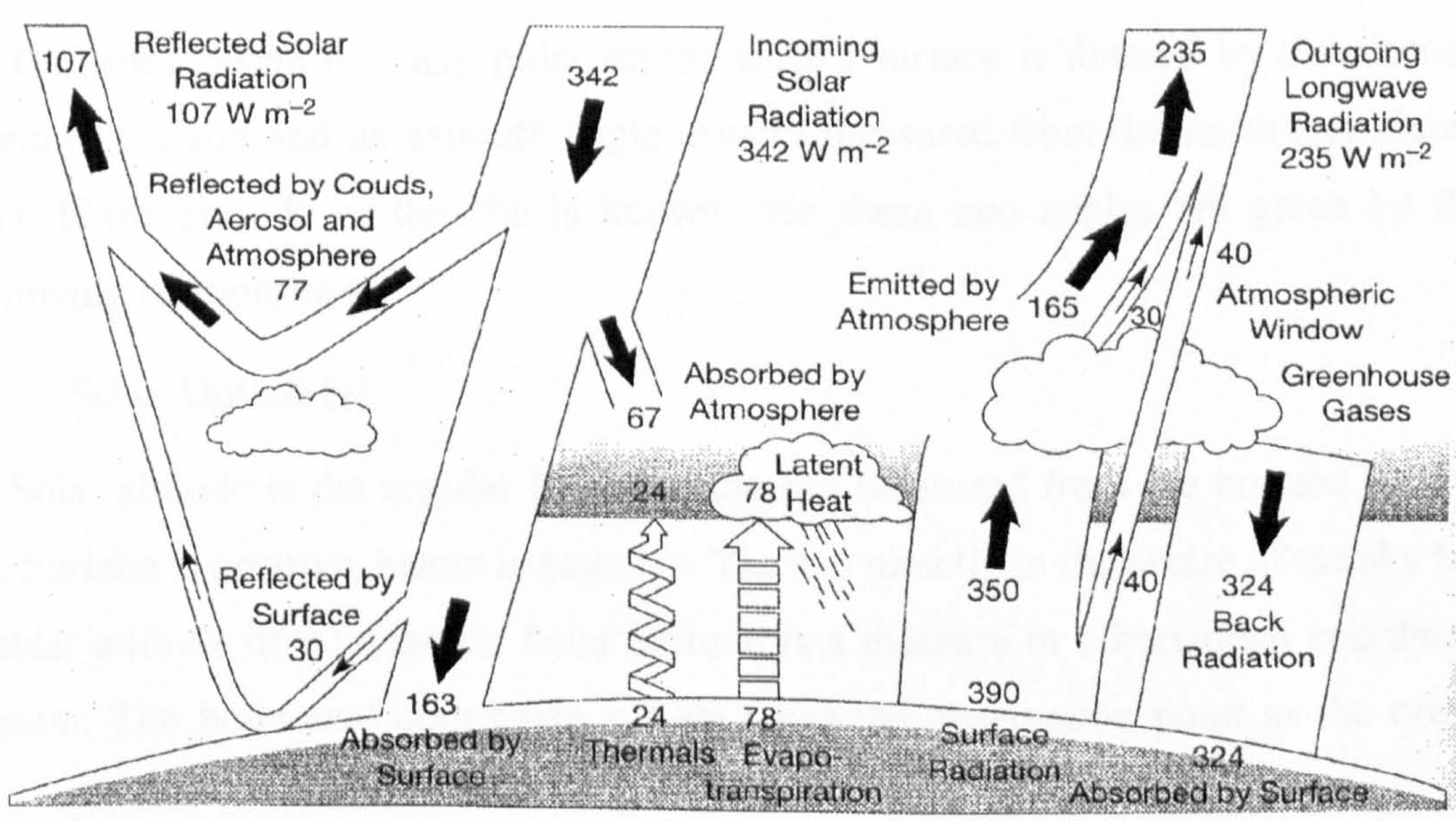
$I_c(0.0) = I_{oJ} \exp(-m\, \delta_R\, T_L) \sin\gamma$ Wm^{-2} Algorithm 4.3

Where, **I_{oJ}** is the extraterrestrial irradiance at normal incidence on day J (Wm^{-2}), **m** is the relative air mass, δ_R is the rayleigh optical thickness at given air mass and **T_L** is the linke turbidity factor.

4_3 * Factors Affecting the Value of Solar Radiation Reaching a Building Surface

In order to estimate the value of solar radiation at a surface it is necessary to be able to estimate the reduction from the value at the boundary of the Earth's atmosphere. These reductions are caused by absorption of radiation by the atmosphere, water vapour and other pollutants. Finally at the surface the value of radiation is a function of the angle the surface makes with the direct beam. Figure 4.1 shows how the extraterrestrial value is modified by passage through the atmosphere

Figure 4.1: Global mean energy flows between the surface and atmosphere, Reproduced from Trenberth et al 1996 (Harvey, 2000)



The earth revolves not only around its own axis but also around the sun. The latter movement takes place in an elliptical path so that the earth is at a varying distance from the sun at different times of the year. The shortest sun-earth distance happens around first of January when the earth is $147.1*10^6$ Km away from the sun while the longest is around first of July being $152.1*10^6$ Kilometres. The earth's axis is tilted at an angle of 66.5° to its plane of movement around the sun. This inclination is responsible for the declination angle of the sun and different duration of sunshine at a given point on the earth's surface. All the above factors affect the availability of solar radiation reaching the earth's surface. The intensity of solar radiation normal to the sun's rays at the outer limits of the earth's atmosphere at mean sun-earth distance is known as solar constant (I_O), Its most accepted value is 1367 Wm^{-2}. The variation in the intensity of solar radiation at the earth's atmosphere outer limit due to the change in sun- earth distance is related to the solar constant in the following algorithm as suggested by Gruter (1984).

$$I_{OJ} = I_O * [1.0 + 0.03344 \cos (J' - 2.80^\circ)] \quad Wm^{-2} \quad \text{Algorithm 4.4}$$

Where: **J'** is day angle and we can calculate by that formula ($J' = J/ 365.25 * 360$) and **J** is day number.

In order to calculate the values of solar radiation it is necessary to have information relating to the following parameters:

$4_{3.1}$ * Solar Altitude and Azimuth

The sun's position at any point on the earth's surface is defined by the altitude angle of the sun and its azimuth angle usually measured from the north (see figure 4.2). If the latitude of the site is known then these two angles are given by the following relationships:

$4_{3.1.1}$ * Solar Altitude (γ)

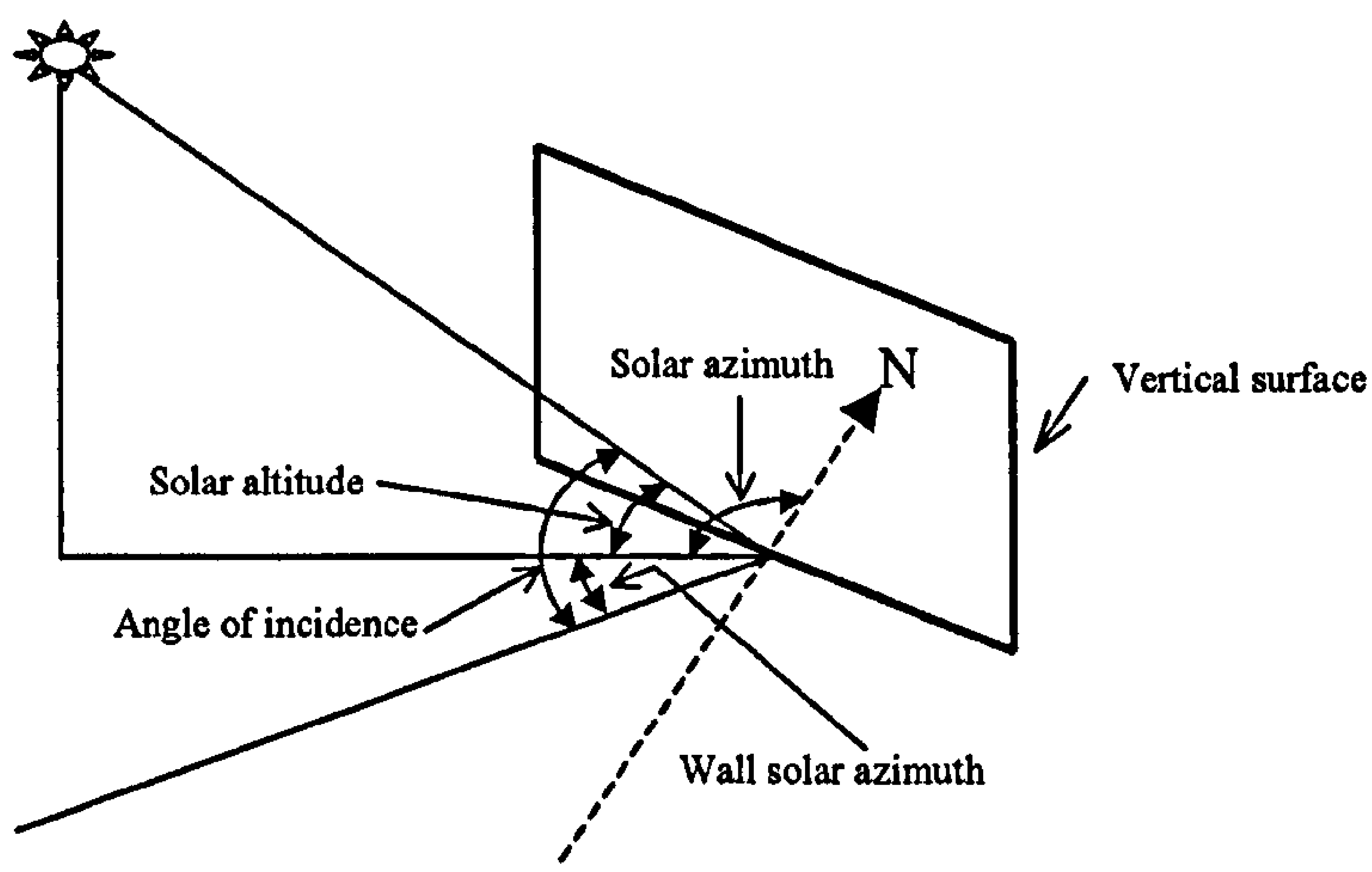
Solar altitude is the angular height of the sun measured from the horizon. Above the horizon is positive, below is negative. The sun directly in the centre of the sky has a solar altitude of 90 degrees. Solar altitude is a measure in a horizontal coordinate system. The horizontal coordinate system takes the observation point as the origin and fixes the sun's position by giving a compass direction (azimuth) and elevation above the horizon (altitude).

For computation at the hourly level it is economical to calculate daily values of ($\sin\phi \cos\delta$) first because their values remain constant for the day, and then to retain the values for consequent calculation hour at different values of ω.

$\sin\gamma = \sin\phi \sin\delta + \cos\phi \cos\delta \cos\omega$ degrees Algorithm 4.5

Where, ϕ is the latitude of the site (N +ve, S -ve), δ is the declination angle of the sun with respect to earth's equator and ω is the solar hour angle.

Figure 4.2: Sun's movement through the sky vault showing solar azimuth and altitude of sun



$4_{3.1.2}$ * Solar Azimuth (ψ)

Solar azimuth is the angular position of the sun measured around the horizon with north being 180 degrees, east -90 degrees, south 0 degrees and west +90 degrees. The solar azimuth angle in the northern hemisphere is between the vertical plane containing the direction of the sun, and the vertical plane running true north- south measured from south. The value of azimuth angle is positive when the sun is to the west of south i.e. during the afternoon in solar time. It has a negative value when the sun is east of south. For the southern hemisphere the reference direction is true north. The sun's position is often described as a bearing from true north, and this is sometimes incorrectly referred to as the solar azimuth angle. It is important to adopt the correct definition in using the algorithms below (Page and Sharples, 1988):

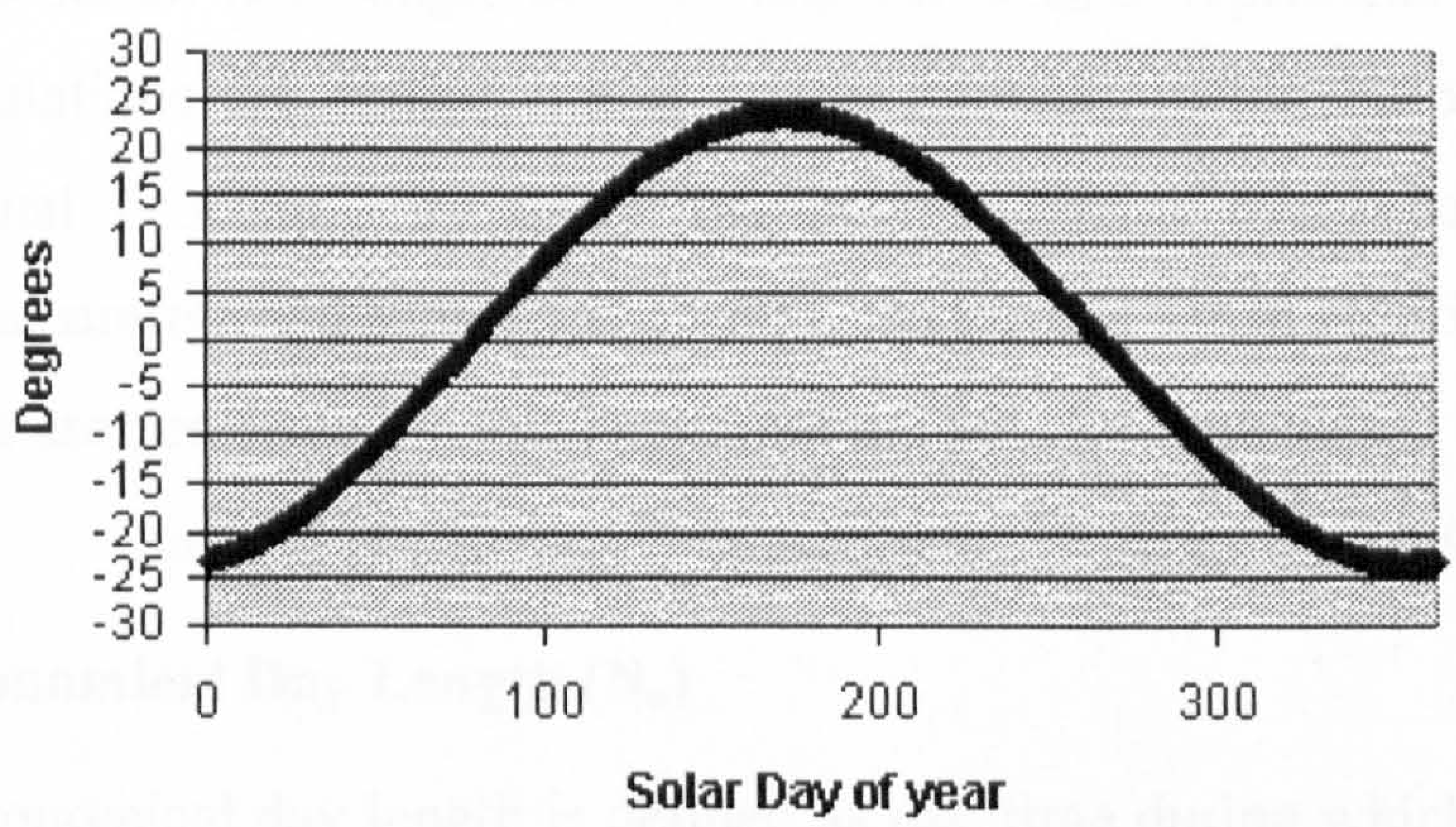
$\cos\psi = (\sin\phi \sin\gamma - \sin\delta) / \cos\phi \cos\gamma$ degrees Algorithm 4.6
$\sin\psi = \cos\delta \sin\omega / \cos\gamma$ degrees Algorithm 4.7

4.3.2 * Solar Declination (δ)

Solar declination is a measure of how many degrees north (positive) or south (negative) of the equator that the sun is when viewed from the centre of the earth. This varies from approximately +23.5 (North) in June to -23.5 (South) in December. The graph below (see figure 4.3) shows how solar declination varies throughout the year. Solar declination is described as the angle between the sun's rays and the earth's equatorial plane. Declination values are positive when the sun is north of the equator (March 21 to September 23) and negative when the sun is south of equator. Maximum and minimum values of δ are +23° 27' and –23° 27'. In order to estimate monthly mean levels of global, horizontal solar radiation it is necessary to establish the value of the solar declination δ. The values of δ were calculated from the following algorithms (Gruter, 1984):

$\delta = \sin^{-1}(0.3978 \sin[J' - 80.2 + 1.92 \sin(J' - 2.8)])$ degrees Algorithm 4.8

Figure 4.3: Solar Declination (Source: Web site



In table 4.1 the recommended values of day number (J) and solar declination for estimating monthly (for first day of each month of Iranian calendar) mean levels of solar radiation are presented having been calculated by the above Algorithm 4.8.

Table 4.1: The recommended values of day number J and solar declination δ for estimating monthly mean global solar radiation levels (Northern Hemisphere)

Recommended Date	Day No. J (365 days/ year)	Solar Declination (degrees)
21st Jan.	21	-19.92
20th Feb.	51	-10.95
21st Mar.	80	0.20
21st Apr.	111	11.84
22nd May	152	20.37
22nd Jun.	173	23.44
23rd Jul.	204	20.09
23rd Aug.	235	11.48
23rd Sep.	266	-0.04
23rd Oct.	296	-11.38
22nd Nov.	326	-20.12
22nd Dec.	356	-23.44

4.3.3 * Solar Hour Angle (ω)

The solar hour angle for a particular location on the earth is zero when the sun is directly overhead, negative before local noon and positive in the afternoon. In one 24-hour period, the solar hour angle changes by 360 degrees (i.e. one revolution). As the earth rotates 360° about its axis in 24 hours, in one hour the rotation is 15°. By convention the hour angle is negative before noon and positive after noon, i.e. 09.00 LAT represents an hour angle of –45° and 15.00 LAT represents an hour angle of +45°. Calculations are carried out at hourly intervals in the European Community computational procedure by using the hour angle at every half hour between astronomical sunrise and sunset, i.e. t_r and t_s. As we can see in algorithm 4.11, 4.12 all calculations are performed in local apparent time (Solar time = t).

$$\omega = 15\,(t - 12) \quad \text{degrees} \qquad \text{Algorithm 4.9}$$

4.3.4 * Astronomical Day Length (N_o)

The astronomical day length is defined as that time during which the centre of the solar disc is above the horizon and is given by:

$$N_o = (1/7.5)\cos^{-1}(-\tan\phi\,\tan\delta) \quad \text{hours} \qquad \text{Algorithm 4.10}$$

The times of sunrise, t_r, and sunset, t_s, in local apparent time (i.e. solar time) are found from:

$$t_r = 12 - (N_o/2) \quad \text{hours} \qquad \text{Algorithm 4.11}$$
$$t_s = 12 + (N_o/2) \quad \text{hours} \qquad \text{Algorithm 4.12}$$

Iran is located between latitudes 25° N and 39° N. The city of Yazd (latitude 32° N) is selected as an example and values of N_o, t_r and t_s are shown in tables 4.2, 4.3 and 4.4.

Tables 4.2: Values of N_o for latitude 32° N, for all days in Yazd-Iran, calculated by Gorji.

Day/MON	JAN.	FEB.	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	9.949	10.520	11.361	12.377	13.291	13.955	14.063	13.566	12.699	11.734	10.768	10.071
2	9.957	10.547	11.393	12.409	13.318	13.968	14.056	13.542	12.668	11.703	10.739	10.056
3	9.966	10.574	11.426	12.441	13.345	13.981	14.048	13.518	12.637	11.672	10.711	10.041
4	9.977	10.605	11.458	12.474	13.372	13.993	14.040	13.494	12.605	11.639	10.681	10.027
5	9.988	10.628	11.491	12.506	13.398	14.004	14.030	13.468	12.574	11.607	10.651	10.014
6	10.000	10.657	11.523	12.538	13.424	14.015	14.020	13.443	12.543	11.575	10.626	10.002
7	10.012	10.685	11.556	12.570	13.450	14.025	14.010	13.418	12.511	11.543	10.600	9.990
8	10.025	10.713	11.589	12.602	13.475	14.035	13.999	13.392	12.479	11.511	10.573	9.979
9	10.039	10.742	11.622	12.633	13.500	14.044	13.987	13.366	12.448	11.478	10.546	9.969
10	10.054	10.772	11.654	12.665	13.525	14.052	13.975	13.340	12.416	11.446	10.519	9.958
11	10.069	10.800	11.686	12.697	13.550	14.059	13.962	13.312	12.384	11.414	10.493	9.950
12	10.084	10.830	11.721	12.728	13.573	14.066	13.948	13.285	12.352	11.382	10.468	9.942
13	10.101	10.860	11.753	12.759	13.597	14.072	13.934	13.258	12.321	11.350	10.443	9.935
14	10.118	10.891	11.786	12.790	13.620	14.077	13.919	13.231	12.289	11.318	10.418	9.929
15	10.136	10.921	11.819	12.821	13.642	14.083	13.904	13.203	12.256	11.286	10.394	9.923
16	10.154	10.951	11.852	12.852	13.665	14.087	13.888	13.175	12.224	11.255	10.370	9.917
17	10.173	10.981	11.885	12.882	13.687	14.090	13.872	13.147	12.192	11.224	10.346	9.913
18	10.193	11.012	11.918	12.914	13.708	14.092	13.854	13.118	12.159	11.192	10.417	9.909
19	10.213	11.043	11.951	12.944	13.730	14.094	13.837	13.089	12.127	11.161	10.348	9.907
20	10.234	11.074	11.984	12.974	13.750	14.096	13.819	13.060	12.094	11.130	10.278	9.905
21	10.255	11.105	12.017	13.004	13.769	14.096	13.800	13.031	12.062	11.099	10.257	9.904
22	10.277	11.138	12.050	13.034	13.789	14.096	13.782	13.002	12.029	11.067	10.236	9.904
23	10.299	11.169	12.082	13.063	13.808	14.095	13.762	12.972	11.997	11.037	10.215	9.905
24	10.322	11.201	12.116	13.092	13.827	14.093	13.742	12.942	11.964	11.006	10.195	9.906
25	10.345	11.232	12.148	13.121	13.845	14.091	13.722	12.913	11.932	10.975	10.175	9.908
26	10.369	11.264	12.182	13.150	13.862	14.088	13.701	12.882	11.899	10.945	10.156	9.909
27	10.393	11.297	12.214	13.179	13.879	14.085	13.680	12.852	11.867	10.915	10.139	9.911
28	10.417	11.328	12.247	13.207	13.895	14.079	13.658	12.822	11.835	10.886	10.120	9.920
29	10.443	*	12.279	13.235	13.911	14.074	13.636	12.792	11.802	10.855	10.103	9.926
30	10.468	*	12.312	13.263	13.926	14.069	13.613	12.761	11.769	10.825	10.087	9.932
31	10.494	*	12.345	*	13.941	*	13.589	12.730	*	10.797	*	9.939

Tables 4.3: Values of " t_r " for latitude 32° N for all days in Yazd-Iran, calculated by Gorji.

Day/MON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	7.025	6.740	6.320	5.812	5.355	5.023	4.968	5.217	5.650	6.133	6.616	6.964
2	7.021	6.726	6.304	5.795	5.341	5.016	4.972	5.229	5.666	6.149	6.630	6.972
3	7.017	6.713	6.287	5.779	5.327	5.010	4.976	5.241	5.682	6.164	6.644	6.979
4	7.012	6.697	6.271	5.763	5.314	5.003	4.980	5.253	5.697	6.180	6.659	6.986
5	7.006	6.686	6.254	5.747	5.301	4.998	4.985	5.266	5.713	6.196	6.674	6.993
6	7.000	6.672	6.238	5.731	5.288	4.992	4.990	5.278	5.729	6.213	6.687	6.999
7	6.994	6.658	6.222	5.715	5.275	4.987	4.995	5.291	5.744	6.229	6.700	7.005
8	6.987	6.643	6.206	5.699	5.263	4.983	5.000	5.304	5.760	6.245	6.713	7.011
9	6.980	6.629	6.189	5.683	5.250	4.978	5.007	5.317	5.776	6.261	6.727	7.016
10	6.973	6.614	6.173	5.668	5.237	4.974	5.013	5.330	5.792	6.277	6.740	7.021
11	6.965	6.600	6.157	5.652	5.225	4.970	5.019	5.344	5.808	6.293	6.753	7.025
12	6.958	6.585	6.140	5.636	5.213	4.967	5.026	5.357	5.824	6.309	6.766	7.029
13	6.949	6.570	6.123	5.620	5.202	4.964	5.033	5.371	5.840	6.325	6.779	7.033
14	6.941	6.555	6.107	5.605	5.190	4.961	5.041	5.385	5.856	6.341	6.791	7.036
15	6.932	6.540	6.090	5.590	5.179	4.959	5.048	5.398	5.872	6.357	6.803	7.039
16	6.923	6.525	6.074	5.574	5.167	4.957	5.056	5.412	5.888	6.373	6.815	7.041
17	6.913	6.509	6.058	5.559	5.156	4.955	5.064	5.427	5.904	6.388	6.827	7.043
18	6.904	6.494	6.041	5.543	5.146	4.954	5.073	5.441	5.920	6.404	6.791	7.045
19	6.893	6.479	6.025	5.528	5.135	4.953	5.082	5.455	5.937	6.420	6.826	7.046
20	6.883	6.463	6.008	5.513	5.125	4.952	5.090	5.470	5.953	6.435	6.861	7.047
21	6.873	6.447	5.992	5.498	5.115	4.952	5.100	5.485	5.969	6.451	6.872	7.048
22	6.861	6.431	5.975	5.483	5.106	4.952	5.109	5.499	5.985	6.466	6.882	7.048
23	6.850	6.416	5.959	5.469	5.096	4.953	5.119	5.514	6.002	6.482	6.892	7.047
24	6.839	6.400	5.942	5.454	5.087	4.954	5.129	5.529	6.018	6.497	6.903	7.047
25	6.827	6.384	5.926	5.439	5.078	4.955	5.139	5.544	6.034	6.512	6.912	7.046
26	6.815	6.368	5.909	5.425	5.069	4.956	5.150	5.559	6.050	6.527	6.922	7.045
27	6.804	6.352	5.893	5.411	5.060	4.958	5.160	5.574	6.067	6.542	6.931	7.044
28	6.791	6.336	5.877	5.397	5.053	4.960	5.171	5.589	6.083	6.557	6.940	7.040
29	6.779		5.860	5.382	5.045	4.963	5.182	5.604	6.099	6.573	6.948	7.037
30	6.766		5.844	5.368	5.037	4.965	5.194	5.620	6.116	6.588	6.956	7.034
31	6.753		5.828		5.030		5.205	5.635		6.602		7.031

Table 4.4: Values of " t_s " for latitude 32° N for all days in Yazd-Iran, Calculated by Gorji.

Day/MON	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	16.975	17.260	17.680	18.188	18.645	18.977	19.032	18.783	18.350	17.867	17.384	17.036
2	16.979	17.274	17.696	18.205	18.659	18.984	19.028	18.771	18.334	17.851	17.370	17.028
3	16.983	17.287	17.713	18.221	18.673	18.990	19.024	18.759	18.318	17.836	17.356	17.021
4	16.988	17.303	17.729	18.237	18.686	18.997	19.020	18.747	18.303	17.820	17.341	17.014
5	16.994	17.314	17.746	18.253	18.699	19.002	19.015	18.734	18.287	17.804	17.326	17.007
6	17.000	17.328	17.762	18.269	18.712	19.008	19.010	18.722	18.271	17.787	17.313	17.001
7	17.006	17.342	17.778	18.285	18.725	19.013	19.005	18.709	18.256	17.771	17.300	16.995
8	17.013	17.357	17.794	18.301	18.737	19.017	19.000	18.696	18.240	17.755	17.287	16.989
9	17.020	17.371	17.811	18.317	18.750	19.022	18.993	18.683	18.224	17.739	17.273	16.984
10	17.027	17.386	17.827	18.332	18.763	19.026	18.987	18.670	18.208	17.723	17.260	16.979
11	17.035	17.400	17.843	18.348	18.775	19.030	18.981	18.656	18.192	17.707	17.247	16.975
12	17.042	17.415	17.860	18.364	18.787	19.033	18.974	18.643	18.176	17.691	17.234	16.971
13	17.051	17.430	17.877	18.380	18.798	19.036	18.967	18.629	18.160	17.675	17.221	16.967
14	17.059	17.445	17.893	18.395	18.810	19.039	18.959	18.615	18.144	17.659	17.209	16.964
15	17.068	17.460	17.910	18.410	18.821	19.041	18.952	18.602	18.128	17.643	17.197	16.961
16	17.077	17.475	17.926	18.426	18.833	19.043	18.944	18.588	18.112	17.627	17.185	16.959
17	17.087	17.491	17.942	18.441	18.844	19.045	18.936	18.573	18.096	17.612	17.173	16.957
18	17.096	17.506	17.959	18.457	18.854	19.046	18.927	18.559	18.080	17.596	17.209	16.955
19	17.107	17.521	17.975	18.472	18.865	19.047	18.918	18.545	18.063	17.580	17.174	16.954
20	17.117	17.537	17.992	18.487	18.875	19.048	18.910	18.530	18.047	17.565	17.139	16.953
21	17.127	17.553	18.008	18.502	18.885	19.048	18.900	18.515	18.031	17.549	17.128	16.952
22	17.139	17.569	18.025	18.517	18.894	19.048	18.891	18.501	18.015	17.534	17.118	16.952
23	17.150	17.584	18.041	18.531	18.904	19.047	18.881	18.486	17.998	17.518	17.108	16.953
24	17.161	17.600	18.058	18.546	18.913	19.046	18.871	18.471	17.982	17.503	17.097	16.953
25	17.173	17.616	18.074	18.561	18.922	19.045	18.861	18.456	17.966	17.488	17.088	16.954
26	17.185	17.632	18.091	18.575	18.931	19.044	18.850	18.441	17.950	17.473	17.078	16.955
27	17.196	17.648	18.107	18.589	18.940	19.042	18.840	18.426	17.933	17.458	17.069	16.956
28	17.209	17.664	18.123	18.603	18.947	19.040	18.829	18.411	17.917	17.443	17.060	16.960
29	17.221		18.140	18.618	18.955	19.037	18.818	18.396	17.901	17.427	17.052	16.963
30	17.234		18.156	18.632	18.963	19.035	18.806	18.380	17.884	17.412	17.044	16.966
31	17.247		18.172		18.970		18.795	18.365		17.398		16.969

43.5 * Conversion of Local Mean Time to Local Apparent Time

Our concepts of time are based on an earth centred (geocentric) view of the motion of the sun (solar time). True time is based on the motion of the physical sun around the earth. The movement of the sun around the earth is non-uniform. The sun's apparent (or true) motion varies due to:

- The elliptical nature of the earth's orbit,
- The inclination of the axis of the earth's rotation, and
- The perturbations of the moon and the other planets.

The difference between true time and mean time is called the equation of time. Mean time (which is the time that our watches try and keep) is time based on the average motion of a fictional sun, which moves at a uniform rate. There are many related mean time measures. The most well known are Greenwich Mean Time also from as Universal Time. The equation of time is a measure of the difference between mean time and true (or solar time). Since 1930 and a decision of the International Astronomical Union the equation of time has been measured with a positive maximum in November. The equation of time is measured in degrees, and may be converted to minutes by multiplying by 4 (i.e., 1 degree = 4 minutes of time) (Web site 2).

The computation effort is simplified by using local apparent time (solar time) in solar studies. A conversion procedure with two stages is used where data related to local mean time (clock time) are needed. The equation of time (ET), which allows for perturbations in the earth's rotation, is calculated in the first stage. The second stage deals with the difference between the longitude of the site under consideration and the reference time zone longitude for the site (Gruter, 1984).

$$ET = -0.128 \sin (J' - 2.8) - 0.165 \sin (2J' + 19.7) \quad \text{hours} \quad \text{Algorithm 4.13}$$

$$LAT = LMT + (\lambda - \lambda_R / 15) + ET - c \quad \text{hours} \quad \text{Algorithm 4.14}$$

Where, λ is the longitude of site, λ_R is the reference longitude of the time zone (positive to the east of Greenwich), c is the correction for summer time, if used (usually +1 in spring and summer, zero in autumn and winter) the dates of introduction of summer very from country to country, **LAT** is the local apparent time and **LMT** is the local mean time.

The value of λ_R for Iranian time zone was estimated as + 52.5 and Table 4.5 gives values of equation of time (ET) for all days based on this. Iran is located between longitudes 45° E and 63° E. The city of Yazd with longitude 54° E is selected as an example and values of LAT for this city are illustrated in table 4.6.

Table 4.5: The equation of time (ET) for all days calculated by Gorji (Units: Hours)

D/Mon	Jan.	Feb.	Mar	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	-0.057	-0.225	-0.217	-0.074	0.047	0.038	-0.060	-0.104	0.004	0.184	0.276	0.175
2	-0.064	-0.228	-0.214	-0.069	0.049	0.035	-0.063	-0.103	0.009	0.189	0.276	0.169
3	-0.072	-0.230	-0.211	-0.063	0.051	0.033	-0.066	-0.102	0.015	0.194	0.275	0.162
4	-0.079	-0.232	-0.207	-0.058	0.053	0.030	-0.069	-0.100	0.021	0.200	0.275	0.156
5	-0.086	-0.234	-0.204	-0.053	0.054	0.027	-0.072	-0.099	0.027	0.205	0.274	0.149
6	-0.093	-0.236	-0.200	-0.048	0.056	0.024	-0.075	-0.097	0.033	0.210	0.273	0.142
7	-0.100	-0.237	-0.196	-0.043	0.057	0.021	-0.078	-0.095	0.039	0.214	0.271	0.135
8	-0.107	-0.238	-0.192	-0.038	0.058	0.018	-0.080	-0.093	0.045	0.219	0.270	0.128
9	-0.114	-0.240	-0.188	-0.033	0.059	0.015	-0.083	-0.091	0.051	0.224	0.268	0.121
10	-0.120	-0.240	-0.184	-0.028	0.060	0.012	-0.085	-0.088	0.057	0.228	0.266	0.114
11	-0.127	-0.241	-0.180	-0.024	0.060	0.009	-0.088	-0.086	0.063	0.232	0.263	0.107
12	-0.133	-0.241	-0.175	-0.019	0.061	0.005	-0.090	-0.083	0.069	0.236	0.261	0.099
13	-0.140	-0.242	-0.171	-0.015	0.061	0.002	-0.092	-0.080	0.075	0.240	0.258	0.092
14	-0.146	-0.241	-0.166	-0.010	0.061	-0.001	-0.094	-0.077	0.082	0.244	0.255	0.084
15	-0.152	-0.241	-0.161	-0.006	0.061	-0.005	-0.096	-0.074	0.088	0.247	0.252	0.077
16	-0.157	-0.241	-0.157	-0.001	0.061	-0.008	-0.097	-0.070	0.094	0.250	0.249	0.069
17	-0.163	-0.240	-0.152	0.003	0.061	-0.012	-0.099	-0.067	0.100	0.254	0.245	0.061
18	-0.168	-0.239	-0.147	0.007	0.060	-0.015	-0.100	-0.063	0.107	0.257	0.241	0.053
19	-0.174	-0.238	-0.142	0.011	0.059	-0.019	-0.102	-0.059	0.113	0.259	0.237	0.046
20	-0.179	-0.237	-0.137	0.014	0.058	-0.022	-0.103	-0.055	0.119	0.262	0.233	0.038
21	-0.184	-0.235	-0.132	0.018	0.058	-0.026	-0.104	-0.051	0.125	0.264	0.229	0.030
22	-0.189	-0.234	-0.127	0.022	0.056	-0.029	-0.105	-0.047	0.131	0.266	0.224	0.022
23	-0.193	-0.232	-0.121	0.025	0.055	-0.033	-0.105	-0.042	0.137	0.268	0.219	0.014
24	-0.197	-0.230	-0.116	0.028	0.054	-0.036	-0.106	-0.038	0.144	0.270	0.214	0.007
25	-0.202	-0.228	-0.111	0.031	0.052	-0.040	-0.106	-0.033	0.149	0.272	0.209	-0.001
26	-0.206	-0.225	-0.106	0.034	0.051	-0.043	-0.106	-0.028	0.155	0.273	0.204	-0.009
27	-0.209	-0.223	-0.100	0.037	0.049	-0.047	-0.106	-0.023	0.161	0.274	0.199	-0.017
28	-0.213	-0.220	-0.095	0.040	0.047	-0.050	-0.106	-0.018	0.167	0.275	0.193	-0.025
29	-0.216		-0.090	0.042	0.045	-0.053	-0.106	-0.013	0.173	0.276	0.187	-0.032
30	-0.220		-0.084	0.045	0.043	-0.057	-0.105	-0.007	0.178	0.276	0.181	-0.040
31	-0.222		-0.079		0.040		-0.105	-0.002		0.276		-0.047

Table 4.6: Values of LAT with longitude 54° E for all days in Yazd-Iran, calculated by Gorji LMT=12.00

Day/Mon	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	12.043	11.875	11.883	12.026	12.147	12.138	12.040	11.996	12.104	12.284	12.376	12.275
2	12.036	11.872	11.886	12.031	12.149	12.135	12.037	11.997	12.109	12.289	12.376	12.269
3	12.028	11.870	11.889	12.037	12.151	12.133	12.034	11.998	12.115	12.294	12.375	12.262
4	12.021	11.868	11.893	12.042	12.153	12.130	12.031	12.000	12.121	12.300	12.375	12.256
5	12.014	11.866	11.896	12.047	12.154	12.127	12.028	12.001	12.127	12.305	12.374	12.249
6	12.007	11.864	11.900	12.052	12.156	12.124	12.025	12.003	12.133	12.310	12.373	12.242
7	12.000	11.863	11.904	12.057	12.157	12.121	12.022	12.005	12.139	12.314	12.371	12.235
8	11.993	11.862	11.908	12.062	12.158	12.118	12.020	12.007	12.145	12.319	12.370	12.228
9	11.986	11.860	11.912	12.067	12.159	12.115	12.017	12.009	12.151	12.324	12.368	12.221
10	11.980	11.860	11.916	12.072	12.160	12.112	12.015	12.012	12.157	12.328	12.366	12.214
11	11.973	11.859	11.920	12.076	12.160	12.109	12.012	12.014	12.163	12.332	12.363	12.207
12	11.967	11.859	11.925	12.081	12.161	12.105	12.010	12.017	12.169	12.336	12.361	12.199
13	11.960	11.858	11.929	12.085	12.161	12.102	12.008	12.020	12.175	12.340	12.358	12.192
14	11.954	11.859	11.934	12.090	12.161	12.099	12.006	12.023	12.182	12.344	12.355	12.184
15	11.948	11.859	11.939	12.094	12.161	12.095	12.004	12.026	12.188	12.347	12.352	12.177
16	11.943	11.859	11.943	12.099	12.161	12.092	12.003	12.030	12.194	12.350	12.349	12.169
17	11.937	11.860	11.948	12.103	12.161	12.088	12.001	12.033	12.200	12.354	12.345	12.161
18	11.932	11.861	11.953	12.107	12.160	12.085	12.000	12.037	12.207	12.357	12.341	12.153
19	11.926	11.862	11.958	12.111	12.159	12.081	11.998	12.041	12.213	12.359	12.337	12.146
20	11.921	11.863	11.963	12.114	12.158	12.078	11.997	12.045	12.219	12.362	12.333	12.138
21	11.916	11.865	11.968	12.118	12.158	12.074	11.996	12.049	12.225	12.364	12.329	12.130
22	11.911	11.866	11.973	12.122	12.156	12.071	11.995	12.053	12.231	12.366	12.324	12.122
23	11.907	11.868	11.979	12.125	12.155	12.067	11.995	12.058	12.237	12.368	12.319	12.114
24	11.903	11.870	11.984	12.128	12.154	12.064	11.994	12.062	12.244	12.370	12.314	12.107
25	11.898	11.872	11.989	12.131	12.152	12.060	11.994	12.067	12.249	12.372	12.309	12.099
26	11.894	11.875	11.994	12.134	12.151	12.057	11.994	12.072	12.255	12.373	12.304	12.091
27	11.891	11.877	12.000	12.137	12.149	12.053	11.994	12.077	12.261	12.374	12.299	12.083
28	11.887	11.880	12.005	12.140	12.147	12.050	11.994	12.082	12.267	12.375	12.293	12.075
29	11.884		12.010	12.142	12.145	12.047	11.994	12.087	12.273	12.376	12.287	12.068
30	11.880		12.016	12.145	12.143	12.043	11.995	12.093	12.278	12.376	12.281	12.060
31	11.878		12.021		12.140		11.995	12.098		12.376		12.053

4.3.6 * Wall Solar Azimuth

This is the angle which describes the sun's position in relation to a given plane on the earth's surface (see figure 4.4), and is calculated from the following formula:

$$\cos\nu = \cos\gamma \cos\alpha_f \sin\beta + \sin\gamma \cos\beta \quad \text{degrees} \qquad \text{Algorithm 4.15}$$

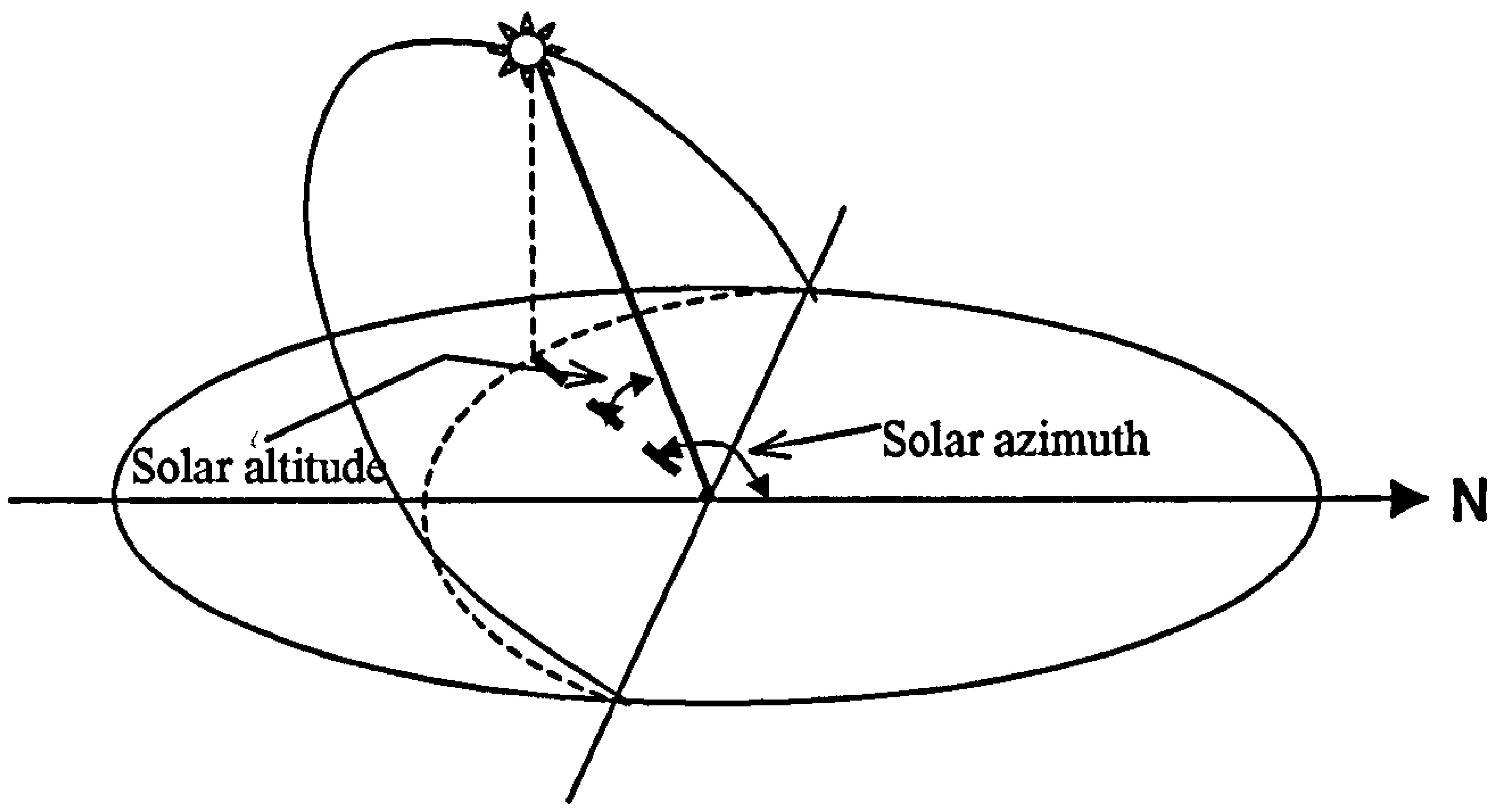
Where, ν is the angle of incidence of solar beam on surface, α_f is the wall- solar azimuth, which is the difference between the solar azimuth and the orientation of the surface and β is the inclination of the surface from the horizontal plane.

$$\alpha_f = \psi - \alpha \quad \text{degrees} \qquad \text{Algorithm 4.16}$$

The wall solar azimuth angle is the angle between the vertical plane containing the normal to the surface and the vertical plane passing through the centre of the solar disc, i.e. it is the resolved angle on the horizontal plane between the direction of the sun and the normal to the surface. The values are between –180° and +180°.

Where, α is the surface azimuth angle measured from due south in northern hemisphere and for due north in southern hemisphere (Easterly values -ve).

Figure 4.4: Sun's position with respect to the vertical surface showing wall-solar azimuth and angle of incidence designed by Gorji.



4$_{3.7}$ * **Air Mass** (The Path Length of the Sun's Rays Through the Earth's Atmosphere)

Normally a fixed amount of the scattering and absorbing gases such as ozone, oxygen and carbon dioxide is present in the atmosphere which are responsible for absorbing and reflecting a proportion of the solar radiation. The depletion in the intensity of direct solar beam will be a function of the path length through the earth's atmosphere. On the other hand, path length has a relationship with the solar altitude angle and in general is recognised as air mass denoted by m (Moon, 1940). Therefore:

$m = 1/\sin\gamma$ dimensionless Algorithm 4.17

According to algorithm 4.17 it will be observed that the value of m for altitude angles below 10° will be too large and erroneous. In order to avoid this discrepancy, Rodgers and Souster (1976) proposed the following relationship.

$m = \exp\,[a_o + \sum_{i=1}^{6} a_i\,(\sin\gamma)^i]$ (for $\gamma = 10°$) dimensionless Algorithm 4.18

Where constants a_i, i = 0,1,...,6 are given the following values:

$a_0 = 3.67985$ $a_1 = -24.4465$ $a_2 = 154.017$ $a_3 = -747.181$

$a_4 = 2263.36$ $a_5 = -3804.89$ $a_6 = 2661.05$

4$_{3.8}$ * **Turbidity**

Clear skies are important in predicting the peak solar irradiance and daylight illuminance levels for active solar energy utilisation and passive energy-efficient building designs. The clearness of the sky is affected by the clarity of the atmosphere, which is usually expressed in terms of a turbidity index. The sky contains air molecules, water vapour, dust and aerosols (Hussain, et al. 2000). The attenuation of solar energy through an atmosphere gives an indication of the atmospheric turbidity.

$4_{3.8.1}$ * Linke Turbidity Factor

In order to provide the basis for assessing the impacts of atmospheric turbidity on the direct beam irradiance at any site, the linke turbidity factor has been developed. There are two steps in calculating the turbidity factor.

Firstly the value of T_L is calculated, as shown in this algorithm 4.19, and then the corrected for solar altitude.

i) The Linke Turbidity factor is found from:

$$T_L = 22.76 + 0.0536\phi - 27.78\,ATI$$ dimensionless Algorithm 4.19

The atmospheric turbidity index (ATI) is chosen from table 4.7 regarding the type of atmosphere associated with the site.

Table 4.7: Classification of ATI with site (Dogniaux and Lemoine, 1983)

ATI	Turbidity type	Class of turbidity
< 0.72	Industrial atmosphere	4
0.72 - 0.76	Urban atmosphere	3
0.76 - 0.79	Clear atmosphere	2
> 0.79	Very clear atmosphere	1

ii) Corrections for Solar Altitude

The correction for Solar Altitude ware made in accordance with the recommendations of the WMO (1981).

-If $T_L < 2.5$ then:

$$T_L = T_L - (0.85 - 2.25\sin\gamma + 1.11\sin^2\gamma)(T_L - 1)/1.5$$ Algorithm 4.20

-Otherwise If $T_L >= 2.5$ then:

$$T_L = T_L - 0.85 + 2.25\sin\gamma - 1.11\sin^2\gamma$$ dimensionless Algorithm 4.21

$4_{3.8.2}$ * Atmospheric Transmittance Coefficient for Absorption by Air

The atmospheric transmittance per unit air mass q_a represents the proportion of extraterrestrial irradiance per unit air mass, which would be directly transmitted through the atmosphere as direct irradiance in the absence of any scattering by the atmosphere. The amount of absorption increases as the path length increases. The absorbed energy is, of course, not available for scattering. The function for q_a^m used by Valko has been used in these calculations and listed in table 4.8 (Valko, 1975 and Collman, 1971).

$$q_a^m = (\sum_{i=0}^{5} a_i\ \gamma^i).(0.506 * 0.010788\ T_L) \quad \text{dimensionless} \quad \text{Algorithm 4.22}$$

Where the values of a_i are given by:

$a_0 = 1.294$ $a_2 = -3.973 * 10^{-4}$ $a_4 = -2.2145 * 10^{-8}$

$a_1 = 2.4417 * 10^{-2}$ $a_3 = 3.8034 * 10^{-6}$ $a_5 = 5.8332 * 10^{-11}$

Table 4.8: Atmospheric transmittance after absorption alone q_a^m (dimensionless) (Valko, 1975)

Solar Altitude	Linke Turbidity Factor T_L							
	1	2	3	4	5	6	7	8
0°	0.641	0.627	0.613	0.599	0.585	0.571	0.557	0.543
2°	0.664	0.650	0.621	0.621	0.606	0.592	0.557	0.563
4°	0.686	0.671	0.656	0.641	0.626	0.611	0.596	0.582
6°	0.707	0.691	0.676	0.660	0.645	0.630	0.614	0.599
8°	0.726	0.710	0.694	0.678	0.663	0.647	0.631	0.615
10°	0.744	0.728	0.711	0.695	0.679	0.663	0.647	0.630
12°	0.761	0.744	0.727	0.711	0.694	0.678	0.661	0.645
14°	0.776	0.759	0.742	0.726	0.709	0.692	0.675	0.658
16°	0.791	0.774	0.756	0.739	0.722	0.707	0.688	0.670
18°	0.805	0.787	0.770	0.752	0.734	0.717	0.699	0.682
20°	0.817	0.800	0.782	0.764	0.746	0.728	0.711	0.693
22°	0.829	0.811	0.793	0.775	0.757	0.739	0.721	0.703
24°	0.840	0.822	0.804	0.785	0.764	0.749	0.730	0.712
26°	0.851	0.832	0.814	0.795	0.776	0.758	0.739	0.721
28°	0.860	0.841	0.823	0.804	0.785	0.767	0.748	0.729
30°	0.869	0.850	0.831	0.812	0.793	0.774	0.756	0.737
32°	0.877	0.858	0.839	0.820	0.801	0.782	0.763	0.744
34°	0.885	0.866	0.847	0.827	0.808	0.789	0.769	0.750
36°	0.892	0.873	0.853	0.834	0.815	0.795	0.776	0.756
38°	0.899	0.879	0.860	0.840	0.821	0.801	0.781	0.762
40°	0.905	0.885	0.866	0.846	0.826	0.807	0.787	0.767
42°	0.911	0.891	0.871	0.851	0.831	0.812	0.792	0.772
44°	0.916	0.896	0.876	0.856	0.836	0.816	0.796	0.776
46°	0.921	0.901	0.881	0.861	0.841	0.821	0.801	0.780
48°	0.925	0.905	0.885	0.865	0.845	0.825	0.804	0.784
50°	0.929	0.909	0.889	0.869	0.848	0.828	0.808	0.788
52°	0.933	0.913	0.893	0.872	0.852	0.832	0.811	0.791
54°	0.937	0.916	0.896	0.875	0.855	0.835	0.814	0.794
56°	0.940	0.919	0.899	0.878	0.858	0.837	0.817	0.796
58°	0.943	0.922	0.902	0.881	0.860	0.840	0.819	0.799
60°	0.945	0.925	0.904	0.883	0.863	0.842	0.822	0.801
62°	0.947	0.927	0.906	0.886	0.865	0.844	0.824	0.803
64°	0.950	0.929	0.908	0.888	0.867	0.846	0.825	0.805
66°	0.951	0.931	0.910	0.889	0.868	0.848	0.827	0.806
68°	0.953	0.932	0.911	0.891	0.870	0.849	0.828	0.808
70°	0.954	0.934	0.913	0.892	0.871	0.850	0.830	0.809
72°	0.956	0.935	0.914	0.893	0.872	0.852	0.831	0.810
74°	0.957	0.936	0.915	0.894	0.873	0.852	0.832	0.811
76°	0.958	0.937	0.916	0.895	0.874	0.853	0.832	0.812
78°	0.958	0.937	0.916	0.896	0.875	0.854	0.833	0.812
80°	0.959	0.938	0.917	0.896	0.875	0.854	0.833	0.813
82°	0.959	0.938	0.917	0.896	0.876	0.855	0.834	0.813
84°	0.959	0.939	0.918	0.897	0.876	0.855	0.834	0.813
86°	0.960	0.939	0.918	0.897	0.876	0.855	0.834	0.813
88°	0.960	0.939	0.918	0.897	0.876	0.855	0.834	0.813
90°	0.960	0.939	0.918	0.897	0.876	0.855	0.834	0.813

4.3.9 * Height above sea level

The height of the receiving surface relative to sea level will affect the amount of radiation received by that surface. It was suggested by Kasten, (1965) and Rodgers, Souster, and Page, (1978) that this could be established by using the ratio of atmospheric pressure differences between the receiving surface and sea level. The ratio (P/P_o) is used to correct the path length to take account of station height. This correction is especially important in mountainous areas. Z is the height site above sea level by metres.

If Height < 4000 metres: $P/P_o = 1.0 - (\frac{Z}{1000})$ dimensionless Algorithm 4.23

And if: 4000<Height<10000 metres:

$$P/P_o = \exp\left(\frac{Z}{1000}(-0.1174 - 0.0017 * \frac{Z}{1000})\right) \quad \text{Algorithm 4.24}$$

4.3.10 * Optical Thickness

The optical thickness of a pure rayleigh scattering atmosphere per unit air mass along a specified path length is described as the reyleigh optical thickness. The rayleigh optical thickness is dependent on the precise optical path and hence on relative air mass because solar radiation is not a monochromatic radiation (Kasten, 1980).

$\delta_R = 1/(0.9m + 9.4)$ per unit air mass dimensionless Algorithm 4.25

4.3.11 * Water Vapour

The water vapour content of the air over a given site is the other main atmospheric constituent, which is responsible for the further depletion of the solar beam. In general, it is referred to as precipitable water constituent of the atmosphere. The precipitable water constituent of the atmosphere is defined as the thickness (usually in mm) of the layer of liquid water resulting from condensing the water vapour present between the earth's surface and the upper limit of the atmosphere. According to Curtis and Lawrence (Curtis and Lawrence, 1972) the bulk of this water is present near the earth's surface and is nearly absent at a height of 10-12 Km.

Generally, this water constituent is composed of up to 4% of the atmosphere by volume and approximately 3% by weight. The absorption of the solar beam by the atmospheric water constituent is proportional to the depth of this content. Therefore, the transmission factor for water content is related to the air mass (Bannon and Steele, 1960).

The estimation of water content of the atmosphere has been the subject of many researchers all of whom have addressed the problem in a different way. Some of the work carried out by Hann (1901), Mirza (1971) and Robinson (1966) are simple in their approach (based on an understanding of vapour pressure) but are unable to deal with seasonal variations.

Monteith, (1961) has also written about the relationship between the precipitable water constituent and atmosphere derived from vapour pressure $W_{(mm)}$:

$$W_{mm} = \exp(0.295\sqrt{e} - 0.803 \qquad \text{units: mm} \qquad \text{Algorithm 4.26}$$

The analysis carried out in this thesis is based on the work of Smith (1966) in which he used a correction factor λ to calculate the water content as outlined below.

$$\mathrm{Ln}(W) = 0.1133 - \mathrm{Ln}(\lambda + 1) + 0.0393\, t_d \qquad \text{units: cm} \qquad \text{Algorithm 4.27}$$

Smith tabulated λ for a variety of situations, which are illustrated in table 4.9.

Table 4.9: Dependence of λ in algorithm 4.27 seasonal and latitudinal variations, calculated by Gorji.

Latitudinal zone (degrees N)	Seasons				Annual Mean
	Winter	Spring	Summer	Autumn	
0 - 10	3.37	2.85	2.80	2.64	2.91
10 - 20	2.99	3.02	2.70	2.93	2.91
20 - 30	3.66	3.00	2.98	2.93	3.12
30 -40	3.04	3.11	2.92	2.94	3.00
40 - 50	2.70	2.95	2.77	2.71	2.78
50 - 60	2.52	3.07	2.67	2.93	2.79
60 - 70	1.76	2.69	2.61	2.61	2.41
70 - 80	1.60	1.67	2.24	2.63	2.03
80 - 90	1.11	1.44	1.94	2.02	1.62
Northern Hemisphere Mean	2.52	2.64	2.62	2.70	2.61

4_4 * Present Analysis

It has been shown by Smith that λ varies with both season as well as latitude. Different seasons are marked by specific ranges of dew point temperatures so that λ can be expressed in terms of the dew point temperature t_d for a particular latitudinal band. By interpolating values of λ against different seasons a regression analysis can be performed to relate t_d with λ. When average values of t_d for Esfahan (32° 27' N) in

Iran were plotted against λ from table 4.9 a line of the following form was found to be fit the data (see figure 4.5).

$$t_d = -80.00\lambda + 280.1 \quad \text{Which gave: } \lambda = \frac{280.1 - t_d}{80.0}$$

Where: $\lambda = 3.00$ and $t_d = -0.5\ ^\circ C = 31.1\ ^\circ F$ (for Esfahan)

Using the above value of λ algorithm 4.27 can be rewritten as:

$$\text{Ln}\,(W) = [0.1133 - \text{Ln}\,(\frac{360.1 - t_d}{80.00}) + 0.0393\, t_d \qquad \text{Algorithm 4.28}$$

The above equation can be used to assess the atmospheric water content over Esfahan in terms of only one independent variable i.e. dew point temperature t_d. Table 4.9, however, shows that the variation of λ is more significant in terms of latitudes rather than seasons. Therefore a relationship between λ and latitudes can be of great importance for general prediction of water content for different sites.

For this purpose a quadratic regression was performed between average values of λ for different seasons as taken from table 4.9 and latitude (ϕ) and the following equation fitted the data:

$$\lambda = -0.0004005952\phi^2 + 0.020297 61\phi + 2.78110119$$

Therefore algorithm 4.27 can be rewritten to account for this latitudinal variation in λ in the following form:

$$\text{Ln}\,(W) = 0.1133 - \text{Ln}\,(a\phi^2 + b\phi + c) + 0.0393\, t_d \qquad \text{Algorithm 4.29}$$

Where: $a = -0.0004005952$ $b = 0.020297619$ $c = 2.783110119$

It may be noted that in all cases where the values of the dew point temperature t_d are assumed to be given in °F. Thus for t_d given in °C the above algorithm is written as:

$$\text{Ln}\,(W) = 0.1133 - \text{Ln}\,(a\phi^2 + b\phi + c) + 0.0393(1.8\, t_d + 32) \quad \text{units: cm} \qquad \text{Algorithm 4.30}$$

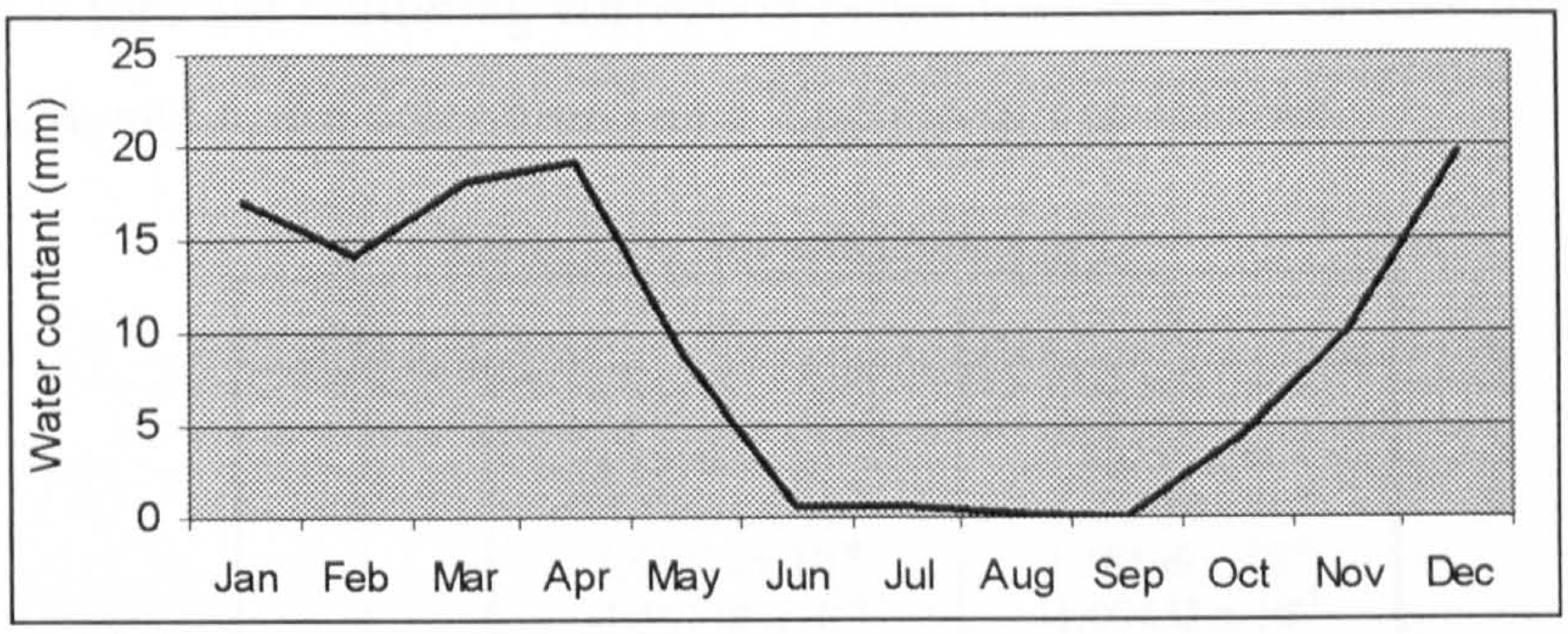
Where a, b and c are the same as before and t_d is given in °C.

Algorithm 4.30 was then applied to calculate water contents of the atmosphere over Esfahan region using dew point temperature data supplied by Iran Meteorological Organisation (IRIMO). Results are shown in table 4.10 and figure 4.5.

Table 4.10: Monthly mean water content of the atmosphere over Esfahan region given by Algorithm 4.30 calculated by Gorji (water content = amount of precipitation).

Month	Dew point temperature: °C	Water content: mm
January	- 5.3	17.1
February	-5.2	14.1
March	-3.3	18.2
April	-0.2	19.2
May	2.4	8.8
June	2.4	0.6
July	4.7	0.7
August	3.8	0.2
September	1.4	0.0
October	0.1	4.1
November	-1.9	9.9
December	-4.4	19.6
Annual	-0.5	112.5

Figure 4.5: Monthly mean water content of the atmosphere over Esfahan region



It should be observed that Esfahan has a semi-hot climate, the rainy season occurring during December, January, February, March and April. Therefore during these periods the average water content of the atmosphere should be higher than at other times of the year.

Section 2 – Calculation of Diffuse Radiation

4_5 * Calculation of Diffuse Radiation on Building Surfaces

The scattering of the direct solar beam by different atmospheric contents will result to the formation of diffuse solar radiation. When the sky condition is clear the amount of diffuse sky radiation is dependent on the quality of the atmospheric. The value of diffuse radiation on different surfaces does not show any geometric relationship because of its non-directional nature. Thus, often it may be desired to introduce particular relationships for surfaces of different slopes.

4$_{5.1}$ * Clear Sky Diffuse Irradiance on a Horizontal Surface (D_c)

In the first stage of the process, this algorithm mainly estimates the difference between the energy that could arrive with only absorption and without scattering and the direct beam energy that actually arrives on a horizontal plane and splits it into two equal parts. It is assumed that half the scattered energy passes towards the ground (forward scattering). By adding the pragmatic correction factor f_1, the basic algorithm developed was modified (Aydinli, 1981):

$$D_c = 0.5\,(I_{oj} * \sin\gamma * q_a^m - I_c(0,0))\, f_1 \qquad Wm^{-2} \quad \text{Algorithm 4.31}$$

$$f_1 = \sum_{i=0}^{5} a_i \gamma^i + (\sum_{i=0}^{5} b_i \gamma^i)*(T_L - 5) \qquad \text{Algorithm 4.32}$$

Where f_1 is forward scattering correction factor for clear sky diffuse irradiance and the values of a_i and b_i are determined as a function of i as follows:

Table 4.11: For calculation of f_1

i	a_i	b_i
0	9.27173 x 10^{-1}	-1.90432 x 10^{-1}
1	1.85002 x 10^{-2}	1.82259 x 10^{-2}
2	-5.37651 x 10^{-4}	-6.01334 x 10^{-4}
3	5.51224 x 10^{-6}	1.10146 x 10^{-5}
4	-1.50178 x 10^{-8}	-1.00432 x 10^{-7}
5	-3.81556 x 10^{-11}	3.53849 x 10^{-10}

4$_{5.2}$ * Ratio of Inclined Surface to Horizontal Surface Clear Sky Diffuse Irradiance f_2^* -Simple Two Component Model

In this method the clear sky irradiance is divided into two constituents: an isotropic background part and a circumsolar component which is treated as a point source located at the centre of the solar disc adding to the direct irradiance. These two constituents are calculated from the value of horizontal surface diffuse irradiance **D_c**. The first step is to calculate the ratio of horizontal background diffuse to total diffuse irradiance.

4$_{5.3}$ * Dividing the Diffuse Irradiance From the Sky Into a Background Component and a Clear Sky Component

$${}_bD_c / D_c = \sum_{i=0}^{2} (\sum_{j=0}^{2} a_{ij} T_L^j) \gamma^i \qquad \text{dimensionless} \qquad \text{Algorithm 4.33}$$

Table 4.12: Values of a_{ij} used in algorithm 4.33

j / i	i = 0	1	2
j = 0	9.502 x 10^{-1}	-1.340 x 10^{-3}	-1.907 x 10^{-5}
1	-2.458 x 10^{-2}	-1.817 x 10^{-3}	1.673 x 10^{-5}
2	9.574 x 10^{-4}	9.282 x 10^{-5}	-8.634 x 10^{-7}

This ratio may be used directly to calculate the horizontal surface background irradiance from the total horizontal surface diffuse irradiance. Then, the horizontal surface circumsolar constituent may be obtained as the difference.

$${}_{c}D_{c} = D_{c} - {}_{b}D_{c} \qquad Wm^{-2} \qquad \text{Algorithm 4.34}$$

Where ${}_{b}D_{c}$ is background diffuse irradiance on a horizontal surface, a_{ij} are a set of constants shown in the table 4.12 and ${}_{c}D_{c}$ is the circumsolar diffuse irradiance on a horizontal surface for a cloudless day (Page, 1986).

4.5.4 * Estimating the Slope Irradiance Due to Diffuse Radiation From the Clear Sky

The background diffuse irradiance on a surface ${}_{b}D_{c}$ (β,α) of slope β may be calculated from the following algorithm:

$${}_{b}D_{c}(\beta,\alpha) = {}_{b}D_{c} * 0.5\,(1 + \cos\beta) \qquad Wm^{-2} \qquad \text{Algorithm 4.35}$$

The circumsolar diffuse irradiance on a surface of solar (β) and orientation having angle of solar incidence (ν), ${}_{c}D_{c}$ (β,α) is calculated by:

$${}_{c}D_{c}(\beta,\alpha) = {}_{c}D_{c} \cos\nu / \sin\gamma \qquad Wm^{-2} \qquad \text{Algorithm 4.36}$$

By rearranging algorithm 4.35 and 4.36, the ratio of the clear sky inclined surface diffuse irradiance to horizontal surface diffuse irradiance (f_2^*), can be found:

$$f_2^* = 0.5\,({}_{b}D_{c} / D_{c})*(1 + \cos\beta) + (1 - {}_{b}D_{c} / D_{c}) \cos\nu / \sin\gamma \qquad \text{Algorithm 4.37}$$

4.5.5 * Overcast Sky Diffuse Irradiance on a Horizontal Surface D_b

As this overcast sky diffuse irradiance on a horizontal surface is sensitive to only one variable (solar altitude), it does not allow for variations in overcast sky irradiance caused by different types of cloud cover (Krochmann, 1964).

$$G_b = D_b = K_d\,(2.6 + 182.6 \sin\gamma) \qquad Wm^{-2} \qquad \text{Algorithm 4.38}$$

Where K_d is correction factor for sun earth distance and G_b is Overcast Sky Global Irradiance.

The ratio of overcast sky diffuse irradiance on a surface of slope β to that on a horizontal surface is calculated by algorithm 4.39. It is derived by analytic integration, using the Moon and Spencer overcast sky radiance distribution (Krochmann, 1979).

$$f_3 = 0.1819\ [1.178\ (1+\cos\beta) + \pi/180\ (180 - \beta)\cos\beta + \sin\beta] \quad \text{Algorithm 4.39}$$

Now it is simple to drive the overcast sky diffuse irradiance on an inclined surface, $\mathbf{D_b}$ (β,α), from the overcast sky diffuse irradiance on a horizontal surface, $\mathbf{D_b}$, using the following algorithm:

$$D_b(\beta,\alpha) = f_3 D_b \quad \text{units: } Wm^{-2} \quad \text{Algorithm 4.40}$$

4.5.6 * Monthly Mean Relative Sunshine Duration for a 4° Horizon σ_{4m}

This method is used as computational method to the measure of the monthly mean fraction of any hour during which the sun is assumed to be shining. The mean relative sunshine duration can estimate the monthly mean direct bean irradiance from the clear sky values. It also estimates the proportion of the monthly mean diffuse irradiance ascribed to blue clear sky conditions (the remaining diffuse fraction being treated as coming from an overcast sky). Since hourly sunshine records are unavailable for the majority of Iranian stations, the relative sunshine duration is calculated by a method on a monthly mean daily basis. The method cannot, therefore, deal with asymmetries of mean sunshine availability across the day. Around sunrise and sunset, when the path length is greatest, the solar beam intensity usually will not be strong enough to burn the card on the sunshine records. The result is an overestimation of the effective day length and therefore, an underestimate of the daily mean relative sunshine duration, if the possible day length is based on the astronomical day length. An additional complication is that few sites exist without some small obstruction of the horizon due to vegetation etc. With the aim to compensate for these effects, the effective day length is calculated assuming the horizon to be 4° above the horizontal plane. By using the monthly mean value of the solar declination from table 4.1, the monthly mean 4° sunrise day length is calculated. The monthly mean relative sunshine duration is calculated from the monthly mean daily sunshine data. This data is available for over 200 Iranian stations in the Islamic Republic of Iran Meteorological Organisation (IRIMO). It is a commonly available climatologically statistic.

The monthly mean relative sunshine duration calculated on a 4° degree sunrise basis, σ_{4m} is given by the following algorithm:

$$\sigma_{4m} = 7.5\ N/(\cos^{-1}((\sin 4° - \sin\phi \sin\delta)/(\cos\phi \cos\delta))) \quad \text{Algorithm 4.41}$$

Where, N is monthly mean daily-recorded bright sunshine (hours).

4.5.7 * Computation of Monthly Mean Direct Beam Irradiance From Clear Day Direct Beam Irradiance Values I_m (β,α)

The base of the calculation is to decrease the direct beam irradiance in proportion to the relative sunshine duration (σ_{4m}). This relative duration is determined assuming a 4° degree horizon for calculating day length. This method has practical weaknesses, which are caused by several reasons:

- The Linke Turbidity Factor on clear day has a tendency to be lower than the monthly average values. This is partly because the precipitable water vapour constituent tends to be lower than average on clear days. Therefore, there is less H_2O absorption in the infrared.
- When the sky is partially clouded (with broken cloud), the sunshine record has a tendency to be over-exaggerated on the broken card burn record.
- The card may not burn when the sun is very low and the weather is very turbid. Also in a very turbid condition, the card may not burn until the sun's altitude is quite high.

Algorithm 4.42 has been suggested by page (1986), for the calculation of monthly mean direct beam irradiance from clear day direct beam irradiance values I_m (β,α):

$$I_m(\beta,\alpha) = f_4\, \sigma_{4m}\, I_c(\beta,\alpha) \quad \text{Units: } Wm^{-2} \quad \text{Algorithm 4.42}$$

Where f_4 is calculated by the following procedure.

$$\text{If } \gamma<45°, \text{ then: } f_4 = \sum_{j=o}^{3}(\sum_{i=0}^{2} (a_{ij} * \gamma^{i})(\sigma_{4m})^{j}$$

$$\text{Otherwise: } f_4 = \sum_{j=o}^{3}(\sum_{i=0}^{2} (a_{ij} * 45^{i})(\sigma_{4m})^{j}$$

The values of aij are illustrated in the following table:

Table 4.13: Values of aij

j	i		
	0	1	2
0	-0.42907	0.098539	-0.011429
1	6.1280	-0.46284	0.0050835
2	-8.5179	0.64546	-0.0067794
3	3.8176	-0.28110	0.0028390

4$_{5.8}$ * Estimation of Monthly Mean Hourly Values of the Diffuse Irradiance on a Horizontal Surface D_m

Page (1986) has developed the following formulae with the aim to calculate the monthly mean hourly values of the diffuse irradiance on a horizontal surface (D_m),:

$$D_m = f_5 * {}_uD_m \qquad Wm^{-2} \qquad \text{Algorithm 4.43}$$

Where: $$f_5 = (\sum_{i=0}^{3} b_i\, \sigma_{4m}{}^{i})\,(\sum_{i=0}^{3} c_i\, \gamma^{i})\,/\,(\sum_{i=0}^{2} d_i\, (\overline{a+b})^{i})$$

$(\overline{a+b})$ = Annual mean value of Angstrom (a + b)

Values of b_i, c_i and d_i are shown in the following table:

Table 4.14: Values of b_i, c_i and d_i

i	b_i	c_i	d_i
0	0.5212	0.83202	7.12889
1	2.429	0.011619	-14.9747
2	-3.383	$-1.8832 * 10^{-4}$	9.10674
3	1.432	$9.8559 * 10^{-7}$	--

The uncorrected value of the monthly mean horizontal diffuse irradiance ${}_uD_m$ at solar altitude γ, is calculated by:

$${}_uD_m = \sigma_{4m} D_c + (1 - \sigma_{4m})\,(D_{0.25} - 0.25\, \sigma_{4m} D_c) / 0.75 \qquad Wm^{-2} \qquad \text{Algorithm 4.44}$$

The monthly mean diffuse irradiance for a monthly mean relative sunshine duration of 0.25, $D_{0.25}$, is calculated by the following algorithm:

$$D_{0.25} = (2 + 5.3\, \gamma)\, K_d \qquad Wm^{-2} \qquad \text{Algorithm 4.45}$$

4$_{5.9}$ * Monthly Mean Diffuse Irradiance From Sky Incident Upon an Inclined Surface D_{ms} (β,α)

At first, the horizontal component of the monthly mean diffuse irradiance at any solar altitude has to be divided into two components, a clear sky component, and an overcast sky/cloudy sky component. This division is achieved using the monthly mean relative sunshine duration σ_{4m}. Then the two separate horizontal components for clear and overcast/partially cloudy skies are converted into inclined surface values using the appropriate slope algorithms outlined earlier. It is assumed that the contribution from the clouds in the case of the partially clouded sky can be estimated on the basis that the mean radiance distribution is adequately described by the Moon and Spencer overcast sky luminance distribution function. The two components are then added together to calculate the monthly mean diffuse irradiance reaching the slope from the sky. Page developed the following algorithms (1986).

Stage 1: Splitting the Horizontal Diffuse Irradiance Into Two Components – Blue Sky Component and Overcast/Partially Clouded Component

Clear sky component of horizontal diffuse irradiance, is calculated by:

$${}_{c}D_m = \sigma_{4m} D_c \qquad \text{Units: } Wm^{-2} \qquad \text{Algorithm 4.46}$$

Overcast/partially clouded component of horizontal diffuse irradiance ${}_{pc}\mathbf{D}_m$ is calculated by:

$${}_{pc}D_m = D_m - \sigma_{4m} D_c \qquad Wm^{-2} \qquad \text{Algorithm 4.47}$$

Where $\mathbf{D}_m$ is monthly mean diffuse irradiance on a horizontal surface at a given solar altitude.

Stage 2: Converting horizontal components to slope values and recombining to find diffuse irradiance on slope from sky

The calculation continues in two stages:

1. The uncorrected clear sky contribution to monthly mean diffuse irradiance on slope, ${}_{uc}D_m$ (β,α) is calculated by:

$${}_{uc}D_m (\beta,\alpha) = f_2\ {}_{c}D_m = \sigma_{4m} D_c (\beta,\alpha) \qquad Wm^{-2} \qquad \text{Algorithm 4.48}$$

The uncorrected overcast sky/partially clouded sky contribution to monthly mean diffuse irradiance on slope, ${}_{uc}D_m$ (β,α) is calculated by:

$${}_{upc}D_m (\beta,\alpha) = f_3\ {}_{pc}D_m \qquad Wm^{-2} \qquad \text{Algorithm 4.49}$$

The monthly mean diffuse irradiance from the sky on the plane ${}_{uc}D_m$ (β,α) uncorrected is obtained by adding the two components, therefore:

$_uD_{ms}(\beta,\alpha) = f_2\ {}_cD_m + f_3\ {}_{pc}D_m$ Wm^{-2} Algorithm 4.50

2. An empirical additional correction factor C.F. is then applied, but only if the modulus of the wall solar azimuth angle lies between 45° and 135°. The additional correction is, for $45° < \alpha_f < 135°$,

$$C.F. = 1 + \sin\beta \sin 2(\alpha_f - 45)(0.19 - 0.14 \sin\gamma)$$

Otherwise C.F. = 1, thus the mean monthly diffuse contribution from the sky alone is:

$D_{ms}(\beta,\alpha) = {}_uD_{ms}(\beta,\alpha) * C.F.)$ Wm^{-2} Algorithm 4.51

$4_{5.10}$ * Ratio of Ground Reflected Irradiance on an Inclined Surface to Global Irradiance on a Horizontal Surface f_6

By using this ratio the amount of ground reflected irradiance on inclined surfaces $R_g(\beta,\alpha)$ from the global horizontal irradiance (G) may be calculated. The ratio can be applied to clear, overcast and average day calculations and is independent of orientation.

$f_6 = 0.5\ \rho_g (1.0 - \cos\beta)$ dimensionless Algorithm 4.52

$4_{5.11}$ *Ground Reflected Irradiance on Inclined Surfaces $R_g(\beta,\alpha)$

By using this algorithm the ground reflected irradiance under any conditions i.e., clear, overcast or average may be calculated (provided the global irradiance is known). It assumes that ground reflected irradiance is isotropically distributed. The algorithm may also be used on a daily basis to convert integrated horizontal surface values to slopes, as f_6 is solely dependent on slope angle and ground albedo (ρ_g) and is independent of time of day.

$R_g(\beta,\alpha) = f_6 * G$ Units: Wm^{-2} Algorithm 4.53

The monthly mean global irradiance on an inclined surface $G_m(\beta,\alpha)$, including direct sky, diffuses sky and ground reflected irradiances is calculated by:

$G_m(\beta,\alpha) = I_m(\beta,\alpha) + D_{ms}(\beta,\alpha) + R_{gm}(\beta,\alpha)$ Wm^{-2} Algorithm 4.54

Where $\mathbf{I_m(\beta,\alpha)}$ is monthly mean direct beam irradiance on inclined plane, $\mathbf{D_{ms}(\beta,\alpha)}$ is monthly mean sky diffuse irradiance and $\mathbf{R_{gm}(\beta,\alpha)}$ is monthly mean ground reflected irradiance on inclined plane.

By using the equations outlined in section 1 and 2, an example of solar radiation calculation in north, east, west, south and horizontal surfaces for the city of Tehran are presented in tables 4.15- 4.19.

Table 4.15: Mean hourly global radiation values for north orientation, for each month in Tehran, Solar time, W/m^2

Hours	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	39.01	129.28	89.48	0	0	0	0	0
6	0	0	4.96	70.15	147.86	191.31	180.11	117.29	24.25	0	0	0
7	5.58	5.55	19.13	51.37	114.90	157.28	143.94	78.93	29.83	5.65	9.78	0
8	11.92	8.50	23.72	41.62	59.62	90.66	73.38	46.87	30.52	12.29	9.94	13.95
9	20.14	15.33	20.15	33.38	44.43	49.97	47.12	37.44	25.04	14.74	18.72	21.19
10	27.85	22.63	16.50	25.09	34.52	39.47	36.93	28.55	18.22	19.16	26.26	28.93
11	32.61	27.23	17.60	19.79	28.45	32.79	30.57	23.09	15.64	23.57	30.97	33.70
12	34.28	28.80	18.86	17.98	27.19	32.27	29.70	21.38	15.63	25.09	32.59	35.38
13	32.67	27.29	17.64	19.73	28.40	32.74	30.52	23.03	15.64	23.63	31.03	33.75
14	27.95	22.74	16.49	24.98	34.42	39.37	36.83	28.44	18.13	19.27	26.36	29.03
15	20.28	15.46	20.00	33.23	44.29	49.83	46.97	37.29	24.88	14.75	18.86	21.32
16	12.08	8.52	23.54	41.43	58.87	88.99	71.96	46.69	30.34	12.19	10.10	14.11
17	5.63	5.67	18.94	50.69	113.41	155.65	142.23	77.41	29.65	5.63	9.89	0
18	0	0	4.76	69.30	146.68	189.98	178.76	116.04	23.66	0	0	0
19	0	0	0	0	38.77	128.58	88.96	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.16: Mean hourly global radiation values for east orientation, for each month in Tehran, Solar time, W/m^2

Hours	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	78.24	235.57	172.79	0	0	0	0	0
6	0	0	64.41	297.95	412.59	462.54	470.19	429.34	195.70	0	0	0
7	26.20	176.07	323.74	430.24	519.83	564.44	586.02	602.16	501.47	292.42	79.63	0
8	265.92	331.07	411.92	464.78	540.69	580.33	607.08	641.96	594.83	457.64	307.94	232.46
9	321.59	351.23	396.82	422.30	477.91	512.75	536.11	577.10	558.20	464.17	354.19	298.11
10	277.07	289.69	314.59	325.22	361.40	385.30	403.61	438.98	433.67	373.62	299.52	261.81
11	176.82	181.55	191.85	194.75	211.88	223.48	233.63	254.44	254.38	225.66	188.39	168.87
12	51.02	52.03	50.52	47.88	46.61	46.78	46.37	46.56	48.78	51.07	51.19	50.10
13	33.36	33.96	32.64	30.86	30.12	30.20	29.93	30.07	31.43	33.21	33.50	32.72
14	15.50	16.55	16.20	15.75	16.93	18.34	17.50	15.80	15.67	16.35	15.86	14.81
15	19.52	22.70	24.99	25.59	25.74	26.00	25.70	25.30	25.04	23.46	20.44	18.36
16	27.38	30.22	34.49	37.48	38.89	37.48	38.27	37.78	35.36	31.48	27.83	26.94
17	14.35	41.69	41.18	46.34	45.45	43.03	44.01	46.28	42.60	39.58	30.85	0
18	0	0	20.07	57.64	54.11	50.03	51.77	56.35	41.23	0	0	0
19	0	0	0	0	19.79	51.83	39.64	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.17: Mean hourly global radiation values for west orientation, for each month in Babolsar, Solar time, W/m²

Hours	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	19.79	51.83	39.64	0	0	0	0	0
6	0	0	20.07	57.64	54.11	50.03	51.77	56.35	41.23	0	0	0
7	14.35	41.69	41.18	46.34	45.45	43.03	44.01	46.28	42.60	39.58	30.85	0
8	27.38	30.22	34.49	37.48	38.89	37.48	38.27	37.78	35.35	31.48	27.83	26.94
9	19.52	22.70	24.99	25.59	25.74	26.00	25.70	25.30	25.04	23.46	20.44	18.36
10	15.50	16.55	16.20	15.75	16.93	18.34	17.50	15.80	15.67	16.35	15.86	14.81
11	33.36	33.96	32.64	30.86	30.12	30.20	29.93	30.07	31.43	33.21	33.50	32.72
12	51.02	52.03	50.52	47.88	46.61	46.78	46.37	46.56	48.78	51.07	51.19	50.10
13	176.82	181.55	191.85	194.75	211.88	223.48	233.63	254.44	254.38	225.66	188.39	168.87
14	277.07	289.69	314.59	325.22	361.40	385.30	403.61	438.98	433.67	373.62	299.52	261.81
15	321.59	351.23	396.82	422.30	477.91	512.75	536.11	577.10	558.20	464.17	354.19	298.11
16	265.92	331.07	411.92	464.78	540.69	580.33	607.08	641.96	594.83	457.64	307.94	232.46
17	26.20	176.07	323.74	430.24	519.83	564.44	586.02	602.16	501.47	292.42	79.63	0
18	0	0	64.41	297.95	412.59	462.54	470.19	429.34	195.70	0	0	0
19	0	0	0	0	78.24	235.57	172.79	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.18: Mean hourly global radiation values for south orientation, for each month in Tehran, Solar time, W/m²

Hours	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	9.78	27.96	20.29	0	0	0	0	0
6	0	0	2.13	22.23	28.54	27.13	27.89	26.36	8.40	0	0	0
7	11.69	66.48	81.50	54.60	44.23	40.84	42.28	47.44	87.83	93.67	34.03	0
8	190.50	196.21	177.77	122.99	67.45	52.74	56.17	116.60	204.83	238.60	207.93	175.87
9	326.36	302.95	264.12	193.93	133.92	97.08	120.25	211.31	317.03	363.64	342.50	316.59
10	420.39	379.74	330.15	250.47	191.12	156.17	184.28	289.00	406.35	457.42	437.05	412.92
11	475.78	426.01	371.15	287.37	229.08	195.09	226.67	340.46	463.59	515.19	493.48	469.04
12	494.21	441.44	385.06	300.28	243.71	211.35	243.56	358.78	483.29	534.69	512.28	487.66
13	475.78	426.01	371.15	287.37	229.08	195.09	226.67	340.46	463.59	515.19	493.48	469.04
14	420.39	379.74	330.15	250.47	191.12	156.17	184.28	289.00	406.35	457.42	437.05	412.92
15	326.36	302.95	264.12	193.93	133.92	97.08	120.25	211.31	317.03	363.64	342.50	316.59
16	190.50	196.21	177.77	122.99	67.45	52.74	56.17	116.60	204.83	238.60	207.93	175.87
17	11.69	66.48	81.50	54.60	44.23	40.84	42.28	47.44	87.83	93.67	34.03	0
18	0	0	2.13	22.23	28.54	27.13	27.89	26.36	8.40	0	0	0
19	0	0	0	0	9.78	27.96	20.29	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.19: Mean hourly global radiation values for horizontal, for each month in Tehran, Solar time, W/m²

Hours	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	2.53	18.57	8.62	0	0	0	0	0
6	0	0	4.01	51.85	108.22	141.78	132.40	84.96	18.44	0	0	0
7	2.13	39.83	103.03	173.85	247.53	292.86	290.09	249.55	162.02	69.61	10.44	0
8	97.28	147.97	222.88	301.77	389.79	445.57	451.38	426.22	332.69	209.05	117.45	80.23
9	198.86	251.61	333.27	415.66	515.32	580.30	594.43	585.72	491.92	345.98	227.07	176.81
10	283.09	334.57	419.32	503.42	612.42	684.88	705.72	710.51	617.68	456.19	317.52	257.54
11	337.55	387.21	473.40	558.61	673.91	751.34	776.48	789.89	697.70	526.57	375.83	310.00
12	356.28	405.18	491.82	577.48	695.02	774.16	800.79	817.17	725.15	550.70	395.87	328.07
13	337.55	387.21	473.40	558.61	673.91	751.34	776.48	789.89	697.70	526.57	375.83	310.00
14	283.09	334.57	419.32	503.42	612.42	684.88	705.72	710.51	617.68	456.19	317.52	257.54
15	198.86	251.61	333.27	415.66	515.32	580.30	594.43	585.72	491.92	345.98	227.07	176.81
16	97.28	147.97	222.88	301.77	389.79	445.57	451.38	426.22	332.69	209.05	117.45	80.23
17	2.13	39.83	103.03	173.85	247.53	292.86	290.09	249.55	162.02	69.61	10.44	0
18	0	0	4.01	51.85	108.22	141.78	132.40	84.96	18.44	0	0	0
19	0	0	0	0	2.53	18.57	8.62	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Section 3 – Validation of the Calculated Data

4₆ * Validation of the Calculated Data

Solar radiation data from the IRIMO was not available to allow an evaluation exercise to be carried out, however the School of Architecture has a copy of the Swiss produced simulation model – Meteonorm Version 3 which is able to estimate the values of solar radiation on any surface anywhere in the world. This programme uses published data from over 625 primary sites worldwide and if a chosen location is not at one of these sites the programme will estimate the values by interpolating between the values from the nearest site.

From the handbook of Meteonorm it is stated that the accuracy is 11% for monthly radiation values and comparisons of total radiation due to the length of the time period over which data is generated (10 year or longer periods) is less than 2%.

$4_{6.1}$ * Comparisons Between Gorji Calculated Data and Meteonorm

The evaluation was carried out for four sites in Iran as Meteonorm Version 3 only had data from these four primary sites and it was felt that by using other sites in Iran errors could be introduced due to the calculation process within Meteonorm itself.

4

4 6 1.1 * Site 1 – Tehran-Iran

Table 4.20: Solar radiation in different orientations-Tehran-Iran with Meteonorm programme (Kwhrs/sq.m)

Meteonorm	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	38	76	66	45	19	2	91
Feb.	47	75	60	47	26	4	98
Mar.	67	78	51	51	37	12	116
Apr.	91	77	38	46	42	20	143
May	118	75	24	45	52	34	178
Jun.	156	84	18	51	70	50	229
Jul.	165	96	24	54	69	46	239
Aug.	153	112	45	65	67	38	231
Sept.	117	120	71	70	55	21	194
Oct.	85	120	90	73	43	10	161
Nov.	48	90	76	57	26	2	109
Dec.	34	76	68	48	19	1	90

Table 4.21: Solar radiation in different orientations-Tehran-Iran with Gorji programme (Kwhrs/sq.m)

Gorji calculation	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	43.09	83.70	74.40	51.46	21.39	1.86	103.23
Feb.	49.28	78.12	62.44	48.72	25.20	4.48	101.36
Mar.	77.19	81.22	57.35	53.63	36.58	11.47	132.99
Apr.	97.50	81.60	41.10	49.20	43.50	20.10	150.60
May	136.40	84.01	26.97	50.22	56.73	29.76	197.78
Jun.	156.90	96.00	20.10	57.90	64.80	42.90	226.20
Jul.	165.85	108.50	27.59	61.69	68.51	39.37	238.70
Aug.	162.13	125.86	51.77	74.09	70.37	34.72	242.73
Sept.	126.00	130.20	77.70	76.80	58.20	21.90	206.40
Oct.	85.25	121.52	91.14	74.09	42.47	9.61	163.06
Nov.	49.50	92.70	78.60	58.50	26.40	2.10	113.10
Dec.	37.82	82.15	73.16	52.70	20.46	0.93	96.10

Table 4.22: Percentage difference between Meteonorm and Gorji solar radiation calculation-Tehran-Iran (Percentage=% Error)

Difference	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	13.39	10.13	12.73	14.36	12.58	-7	13.44
Feb.	4.85	4.16	4.07	3.66	-3.08	12	3.43
Mar.	15.21	4.13	12.45	5.16	-1.14	-4.42	14.65
Apr.	7.14	5.97	8.16	6.96	3.57	0.5	5.31
May	15.59	12.01	12.38	11.6	9.1	-12.47	11.11
Jun.	0.58	14.29	11.67	13.53	-7.43	-14.2	-1.22
Jul.	0.52	13.02	14.96	14.24	-0.71	-14.41	-0.13
Aug.	5.97	12.38	15.04	13.98	5.03	-8.63	5.08
Sept.	7.69	8.5	9.44	9.71	5.82	4.29	6.39
Oct.	0.29	1.27	1.27	1.49	-1.23	-3.9	1.28
Nov.	3.13	3	3.42	2.63	1.54	5	3.76
Dec.	11.24	8.09	7.59	9.79	7.68	-7	6.78

Figure 4.6: Solar radiation in different orientations-Tehran-Iran (Meteonorm)

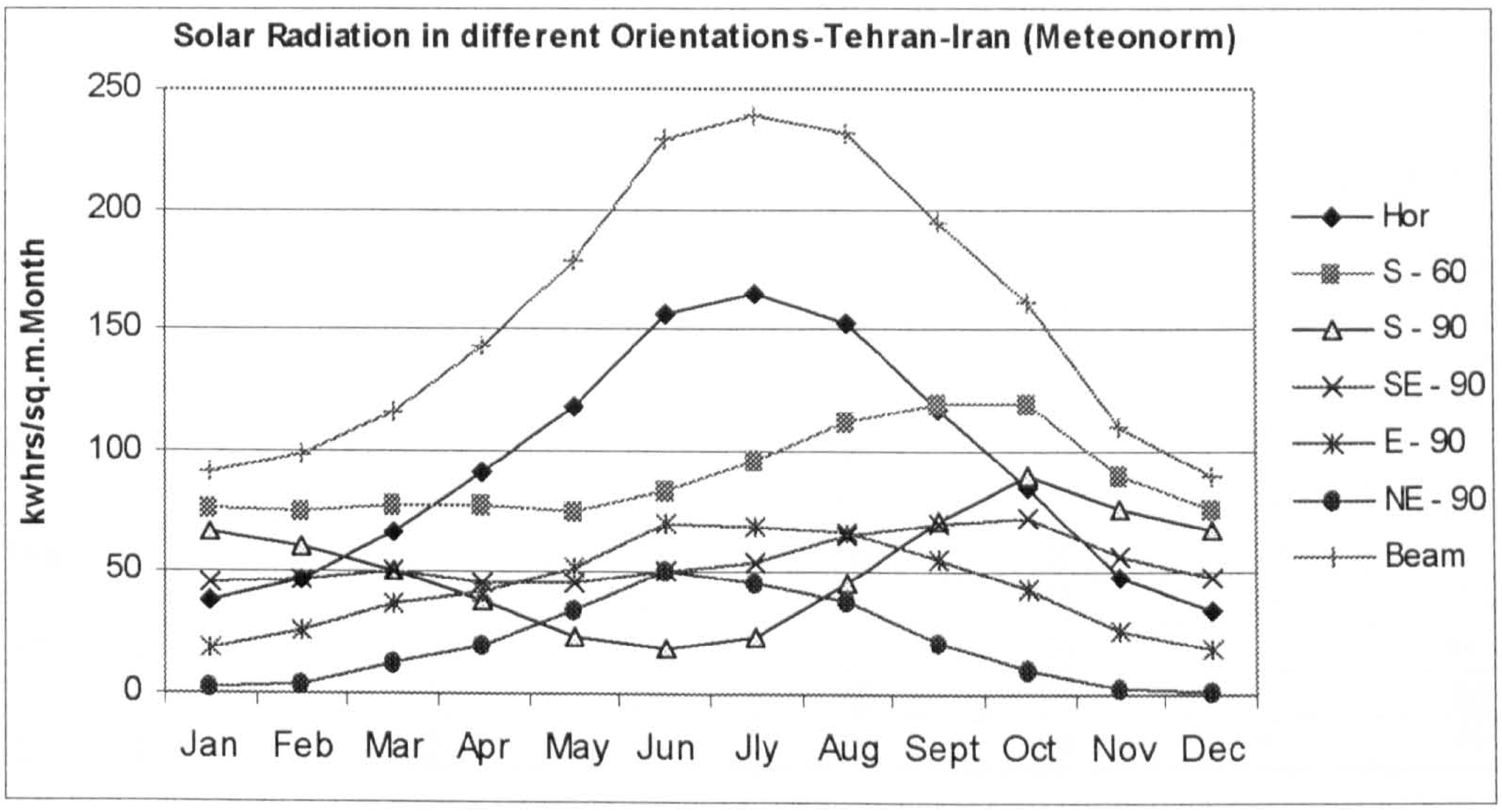


Figure 4.7: Solar radiation in different orientations-Tehran-Iran (Gorji calculation)

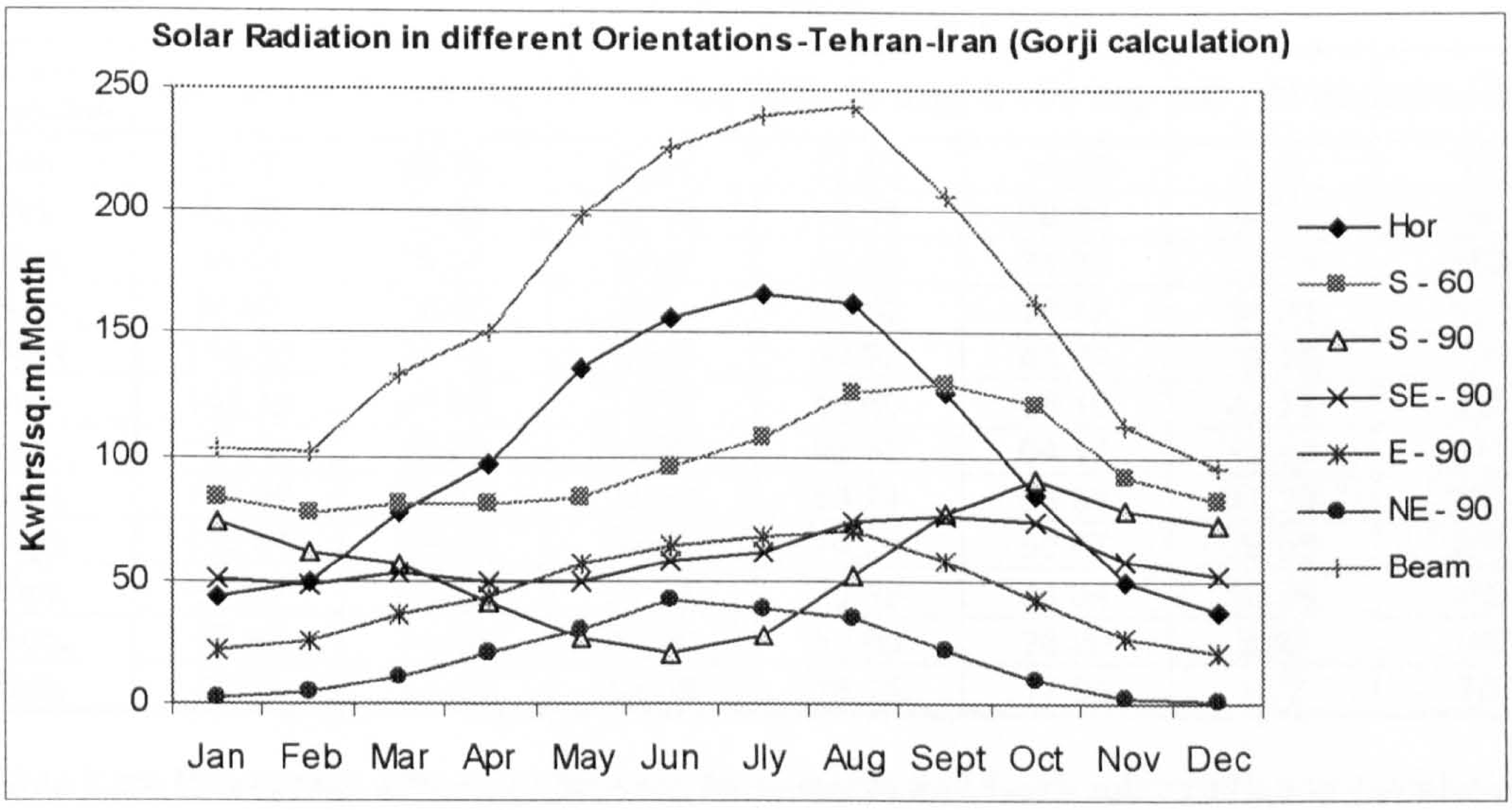
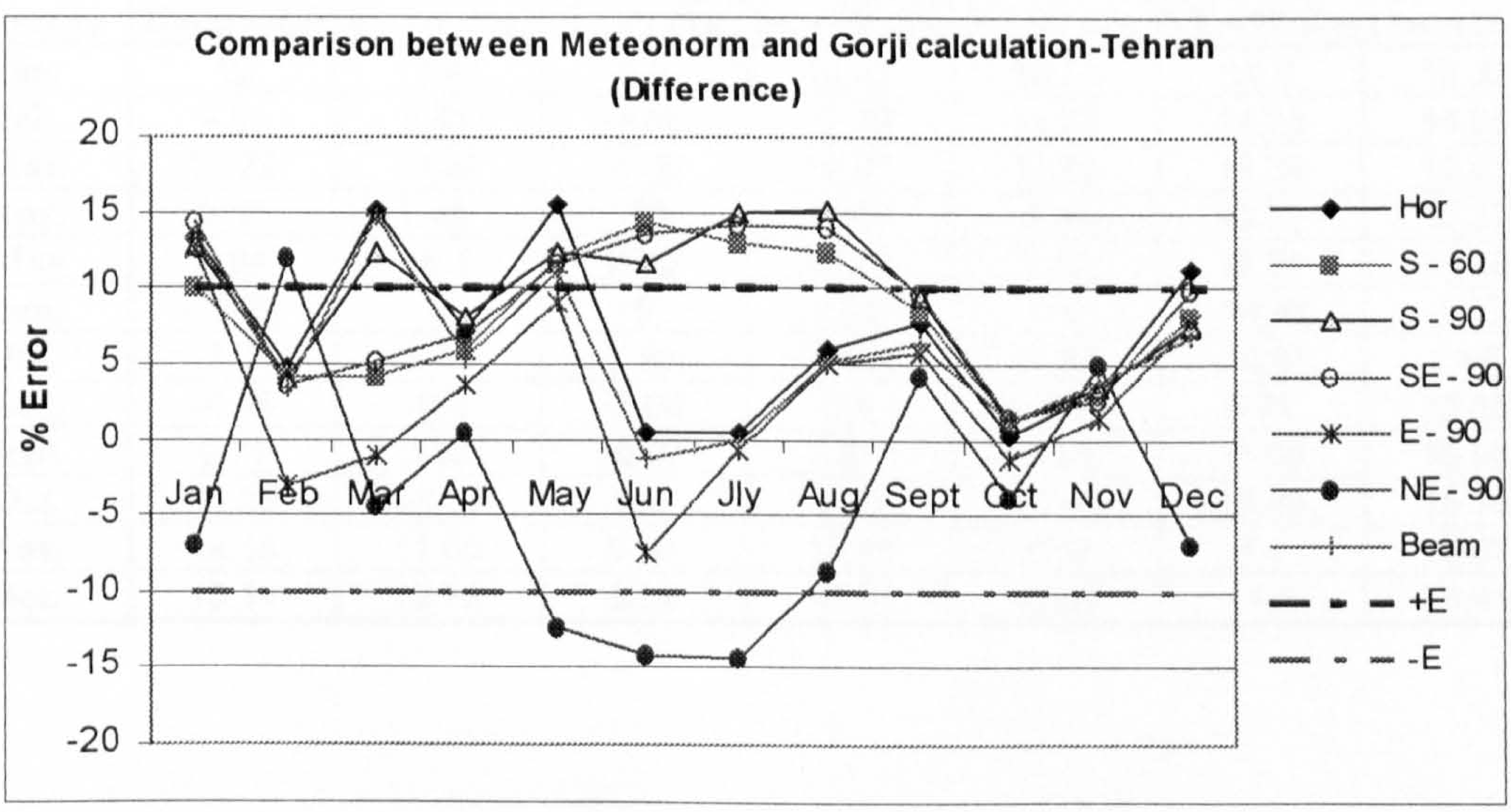


Figure 4.8: Comparison between Meteonorm and Gorji calculation-Tehran (Difference)



4612 * Site 2 –Yazd-Iran

Table 4.23: Solar radiation in different orientations-Yazd-Iran with Meteonorm programme (Kwhrs/sq.m)

Meteonorm	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	31	57	48	33	14	1	69
Feb.	45	66	50	39	23	5	88
Mar.	63	70	44	39	28	9	106
Apr.	87	67	28	39	40	22	136
May	109	63	16	36	45	30	158
Jun.	163	80	12	46	66	50	236
Jul.	166	88	17	51	71	51	238
Aug.	146	100	36	60	66	39	221
Sept.	112	107	58	65	55	23	179
Oct.	78	103	74	62	39	9	143
Nov.	41	71	59	49	25	3	88
Dec.	28	55	48	35	15	1	67

Table 4.24: Solar radiation in different orientations-Yazd-Iran with Gorji programme (Kwhrs/sq.m)

Gorji calculation	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	34.72	66.96	52.08	37.82	15.50	1.12	78
Feb.	49.28	71.68	48.16	43.96	26.04	5.71	101
Mar.	69.44	79.36	43.40	44.02	31.31	10.39	119
Apr.	88.80	72.00	25.20	43.50	39.42	24.25	157
May	116.56	74.40	16.62	40.92	48.23	33.25	181
Jun.	143.10	84.00	12.72	48.60	56.10	42.77	228
Jul.	153.14	89.28	18.35	53.32	64.17	45.49	241
Aug.	139.50	99.20	33.23	63.24	58.31	41.23	252
Sept.	112.80	108.00	54.48	70.20	50.67	25.68	208
Oct.	86.80	116.56	78.37	70.99	44.64	10.39	165
Nov.	46.80	79.20	64.80	55.80	28.20	3.42	102
Dec.	32.24	62.00	52.33	38.75	17.05	1.12	76

Table 4.25: Percentage difference between Meteonorm and Gorji solar radiation calculation-Yazd-Iran (Percentage=% Error)

Difference	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	12	17.47	8.5	14.61	10.71	11.6	12.32
Feb.	9.51	8.61	-3.68	12.72	13.22	14.24	14.55
Mar.	10.22	13.37	-1.36	12.87	11.82	15.39	12.01
Apr.	2.07	7.46	-10	11.54	-1.44	10.21	15.37
May	6.94	18.1	3.85	13.67	7.17	10.84	14.58
Jun.	-12.21	5	6	5.65	-15	-14.46	-3.57
Jul.	-7.75	1.45	7.95	4.55	-9.62	-10.81	1.45
Aug.	-4.45	-0.8	-7.69	5.4	-11.65	5.71	13.86
Sept.	0.71	0.93	-6.07	8	-7.88	11.66	15.98
Oct.	11.28	13.17	5.9	14.5	14.46	15.39	15.33
Nov.	14.15	11.55	9.83	13.88	12.8	14	15.57
Dec.	15.14	12.73	9.02	10.71	13.67	11.6	13.41

Figure 4.9: Solar radiation in different orientations-Yazd-Iran (Meteonorm)

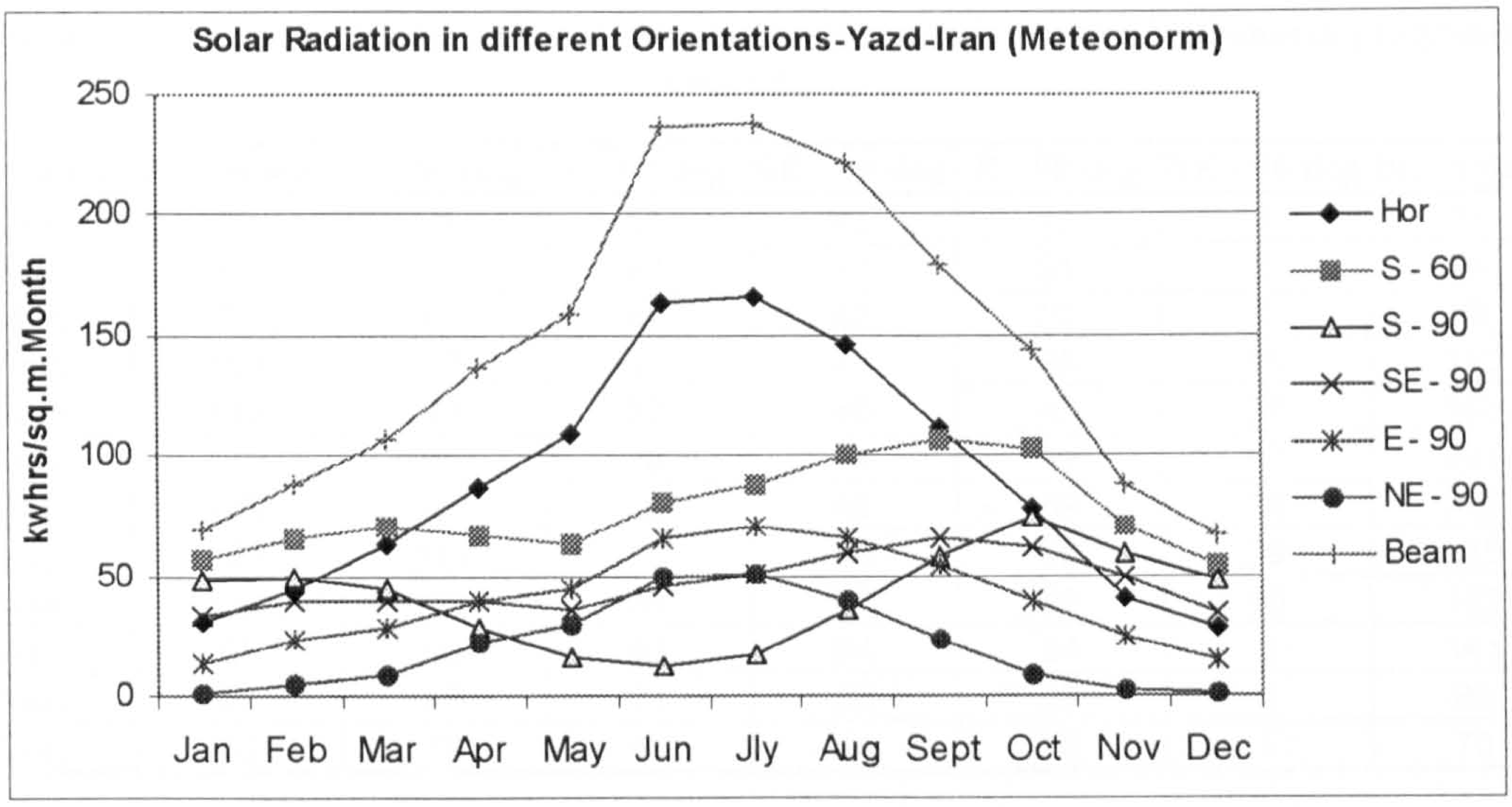


Figure 4.10: Solar radiation in different orientations-Yazd-Iran (Gorji calculation)

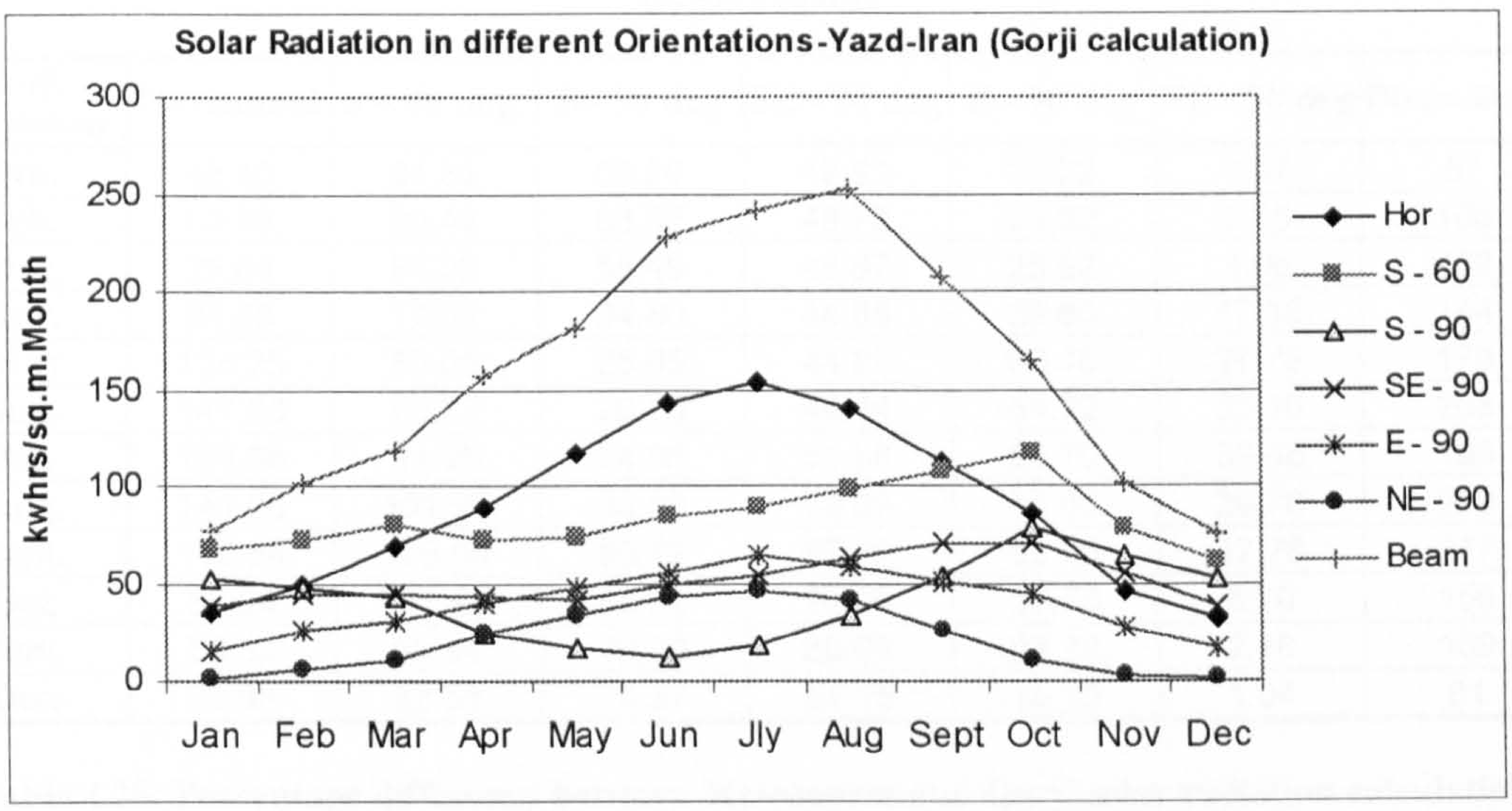
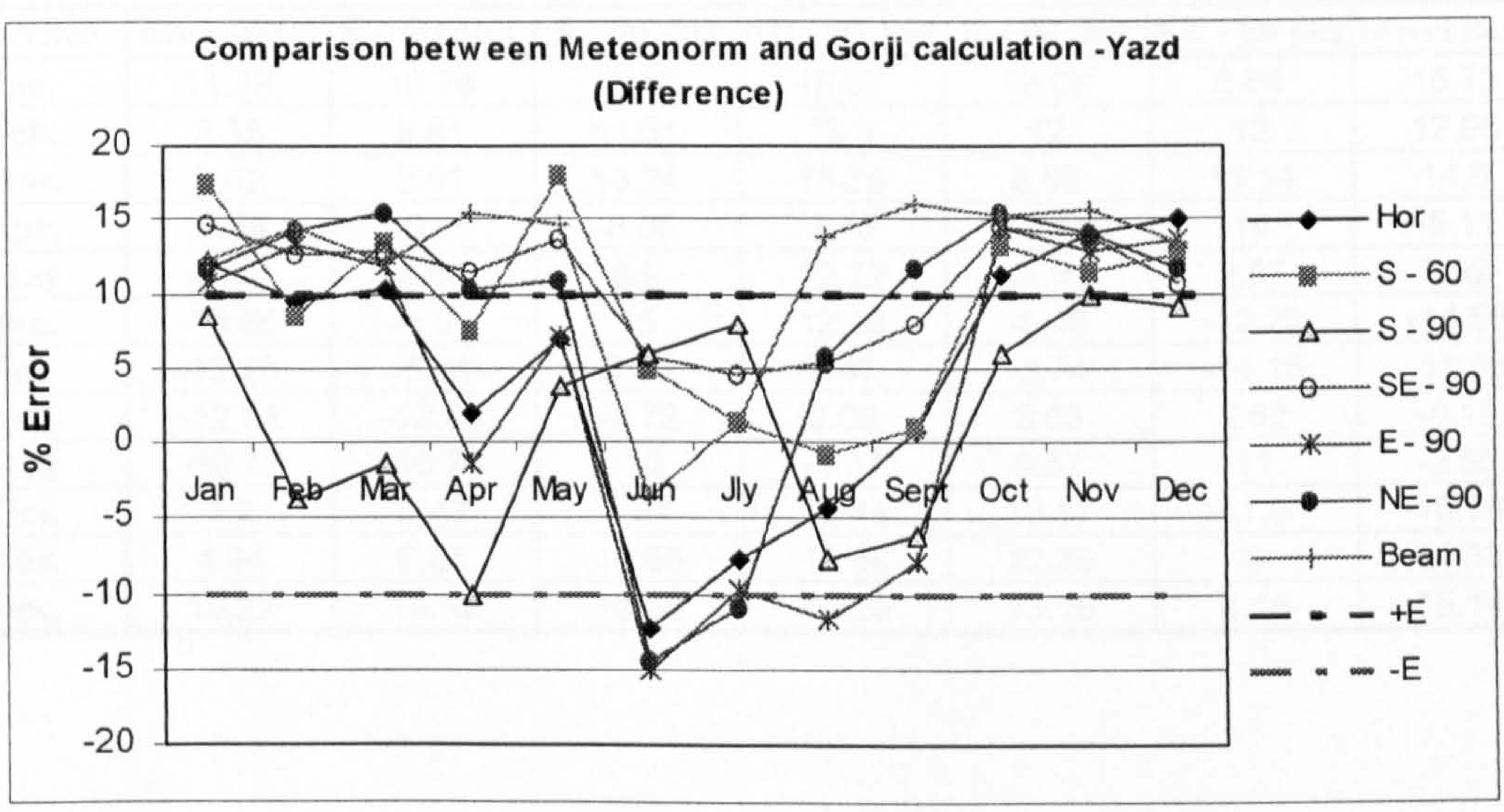


Figure 4.11: Comparison between Meteonorm and Gorji calculation-Yazd (Difference)



4613 * Site 3 – Isfahan-Iran

Table 4.26: Solar radiation in different orientations-Isfahan-Iran with Meteonorm programme (Kwhrs/sq.m)

Meteonorm	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	39	71	59	43	17	1	75
Feb.	52	76	57	43	21	3	94
Mar.	69	77	49	42	27	7	89
Apr.	100	82	37	41	35	15	152
May	132	83	23	40	45	27	165
Jun.	175	95	18	44	58	40	237
Jul.	176	101	22	48	59	39	226
Aug.	162	117	43	58	56	29	218
Sept.	124	121	69	64	46	16	182
Oct.	87	115	82	64	34	6	141
Nov.	51	87	71	52	22	2	95
Dec.	36	71	61	44	16	1	70

Table 4.27: Solar radiation in different orientations-Isfahan-Iran with Gorji programme (Kwhrs/sq.m)

Gorji calculation	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	43.40	84.32	68.20	49.91	19.22	1.07	87
Feb.	53.76	80.42	63.56	48.72	23.52	3.36	106
Mar.	75.64	84.32	55.49	48.67	28.52	8.06	102
Apr.	94.56	77.52	34.80	44.88	39.60	17.10	144
May	124.25	86.06	25.05	44.89	50.10	27.78	178
Jun.	147.60	90.72	20.70	49.44	54.72	35.10	203
Jul.	154.38	94.98	24.06	51.58	56.79	33.48	199
Aug.	141.05	101.93	39.68	58.03	58.03	29.76	200
Sept.	110.64	108.00	60.72	63.12	50.40	17.76	177
Oct.	88.04	117.80	85.31	70.68	37.70	6.70	156
Nov.	53.52	93.84	79.20	60.00	24.72	2.16	109
Dec.	39.68	82.58	70.37	51.15	18.10	1.04	81

Table 4.28: Percentage difference between Meteonorm and Gorji solar radiation calculation-Isfahan-Iran (Percentage=% Error)

Difference	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	11.28	18.76	15.59	16.07	13.06	6.64	15.73
Feb.	3.38	5.81	11.51	13.3	12	12	12.95
Mar.	9.62	9.51	13.24	15.88	5.63	15.14	14.6
Apr.	-5.44	-5.46	-5.95	9.46	13.14	14	-5.11
May	-5.87	3.68	8.9	12.22	11.32	2.87	7.92
Jun.	-15.66	-4.51	15	12.36	-5.66	-12.25	-14.56
Jul.	-12.28	-5.96	9.35	7.47	-3.74	-14.15	-11.88
Aug.	-12.93	-12.88	-7.72	0.06	3.63	2.62	-8.19
Sept.	-10.77	-10.74	-12	-1.37	9.57	11	-2.55
Oct.	1.2	2.43	4.04	10.44	10.87	11.6	10.98
Nov.	4.94	7.86	11.55	15.38	12.36	8	14.63
Dec.	10.22	16.32	15.36	16.25	13.15	4.16	15.14

Figure 4.12: Solar radiation in different orientations-Isfahan-Iran (Meteonorm)

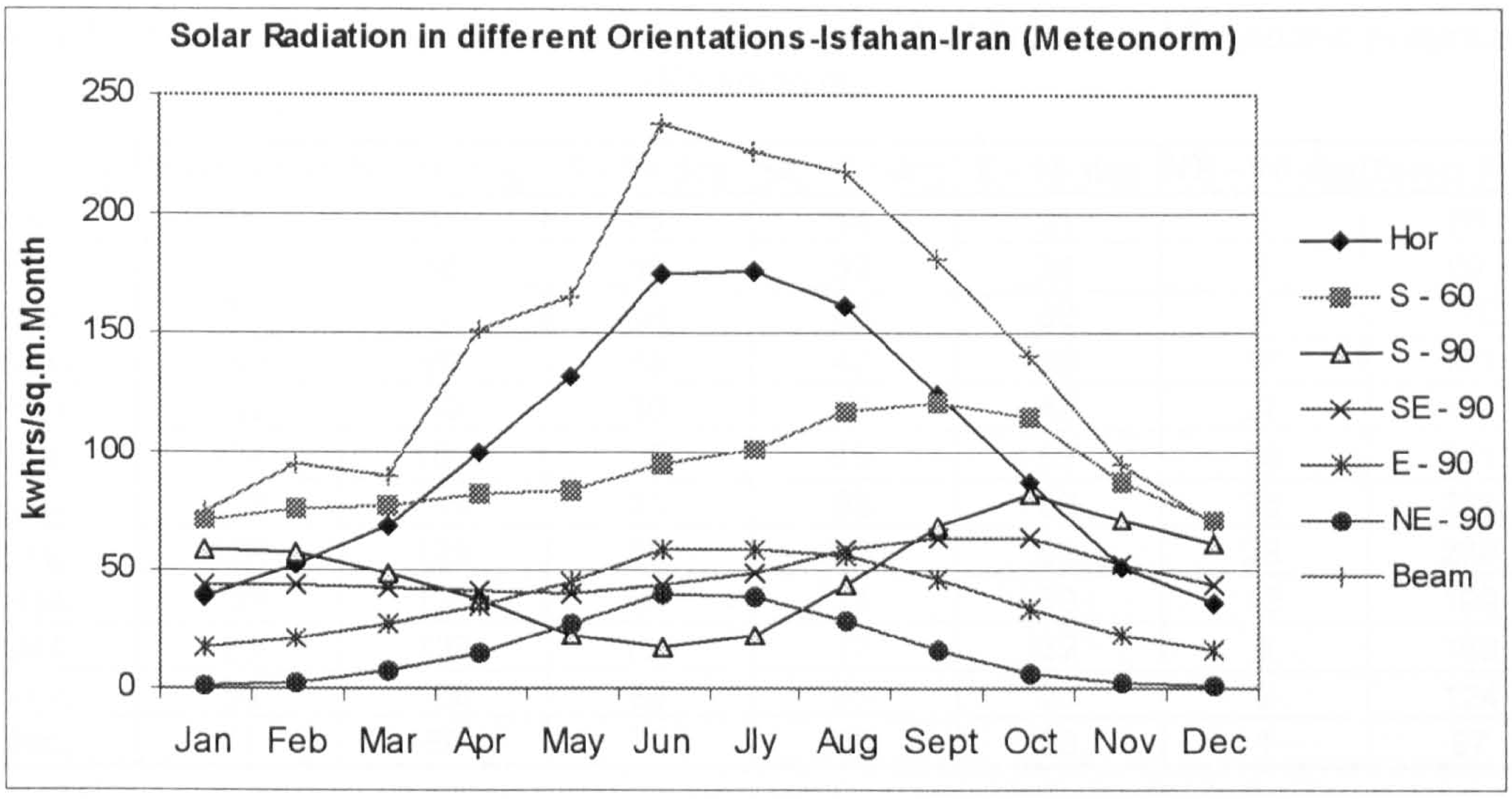


Figure 4.13: Solar radiation in different orientations-Isfahan-Iran (Gorji calculation)

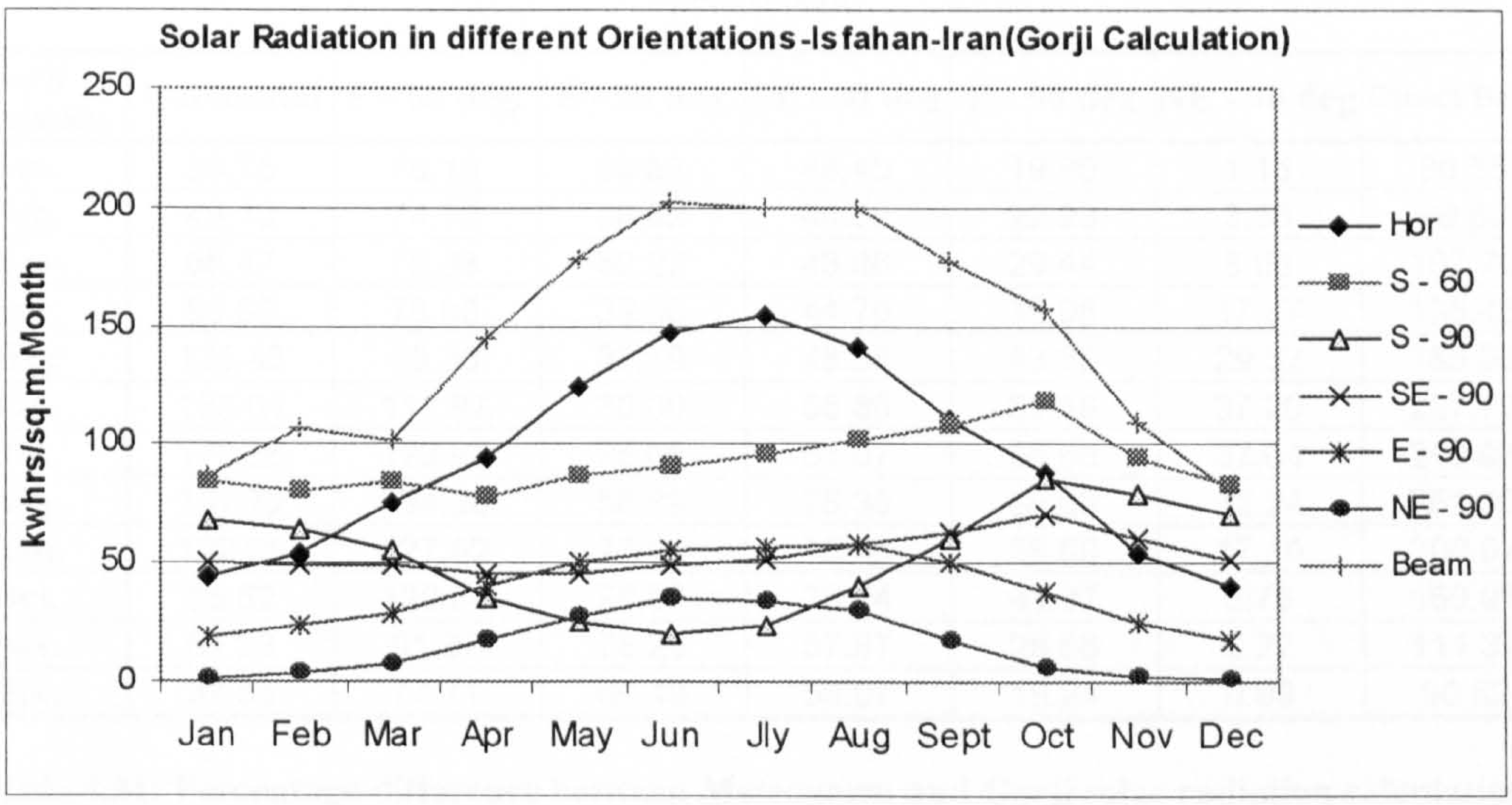
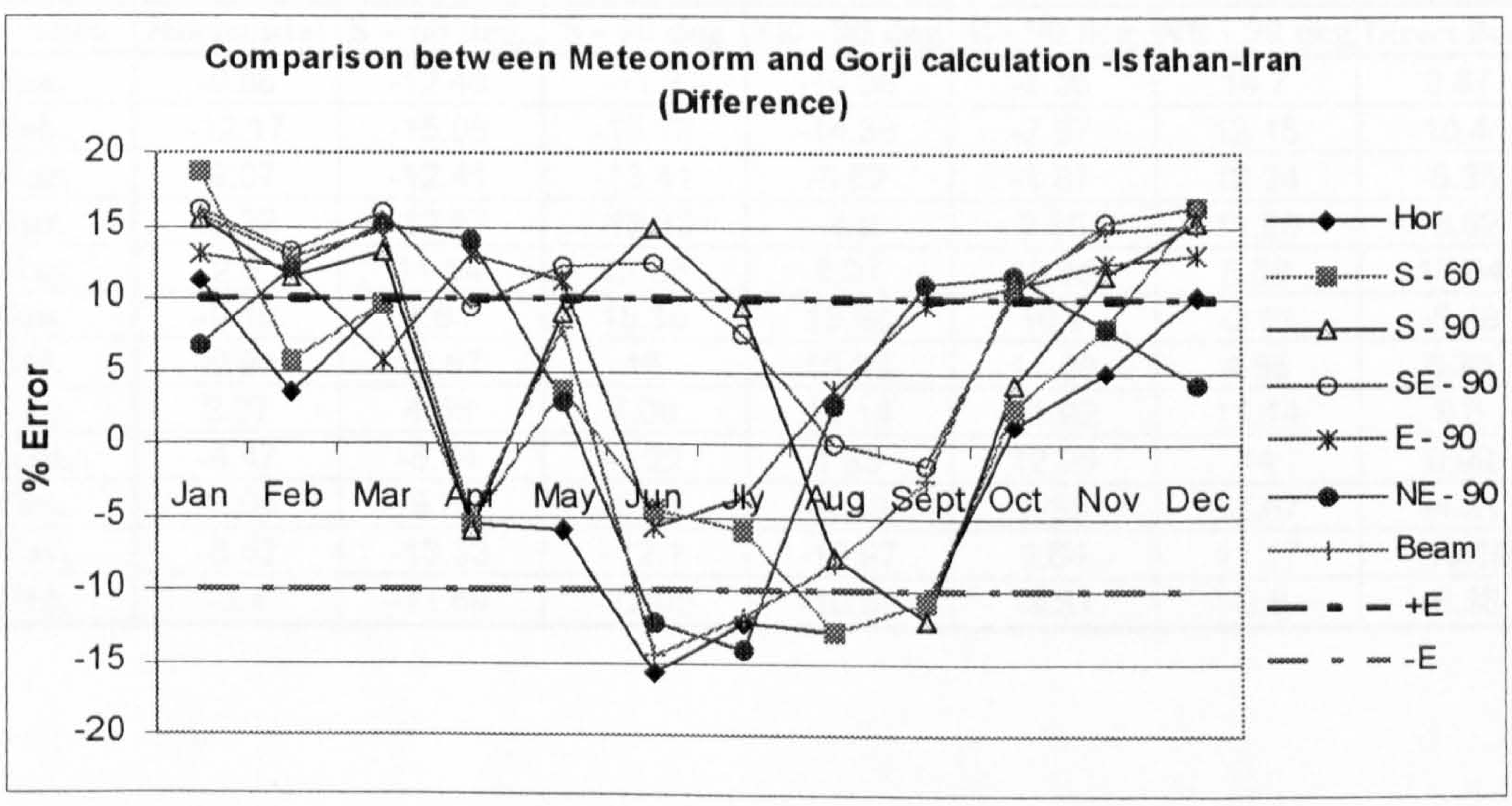


Figure 4.14: Comparison between Meteonorm and Gorji calculation-Isfahan (Difference)



4.6.1.4 * Site 4 – Mashhad-Iran

Table 4.29: Solar radiation in different orientations-Mashhad-Iran with Meteonorm programme (Kwhrs/sq.m)

Meteonorm	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	43	87	75	54	21	1	88
Feb.	56	88	69	52	24	3	99
Mar.	72	86	58	48	30	8	115
Apr.	103	90	45	47	38	16	141
May	132	89	30	44	47	27	164
Jun.	174	103	26	49	59	38	241
Jul.	175	110	31	53	60	36	235
Aug.	164	129	55	66	59	28	230
Sept.	128	136	84	74	50	15	199
Oct.	93	133	100	77	39	6	168
Nov.	56	106	89	65	25	2	124
Dec.	41	88	79	56	20	1	97

Table 4.30: Solar radiation in different orientations-Mashhad-Iran with Gorji programme (Kwhrs/sq.m)

Gorji calculation	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	38.75	76.19	66.52	48.40	19.90	1.15	90.35
Feb.	49.18	74.76	58.52	44.52	22.23	3.36	88.69
Mar.	65.47	75.33	50.22	43.86	29.44	8.98	107.70
Apr.	93.50	78.60	39.00	44.70	39.08	17.87	135.48
May	135.43	99.36	33.79	48.36	53.32	29.32	185.38
Jun.	158.01	111.87	30.00	55.80	65.19	37.20	227.79
Jul.	173.26	123.93	35.65	61.07	66.65	37.64	249.93
Aug.	167.72	134.88	58.89	75.33	66.03	32.24	251.39
Sept.	122.28	127.92	77.09	75.35	56.50	17.10	200.97
Oct.	85.52	120.54	90.87	73.54	41.87	6.76	160.93
Nov.	51.23	91.87	78.23	57.87	25.66	2.22	111.37
Dec.	37.55	77.71	69.48	50.07	19.24	0.99	90.82

Table 4.31: Percentage difference between Meteonorm and Gorji solar radiation calculation-Mashhad-Iran (Percentage=% Error)

Difference	Horizontal	S – 60 deg.	S - 90 deg	SE - 90 deg	E - 90 deg	NE - 90 deg	Direct Beam
Jan.	-9.88	-12.43	-11.3	-10.38	-5.25	14.7	2.67
Feb.	-12.17	-15.05	-15.19	-14.38	-7.37	12.15	-10.41
Mar.	-9.07	-12.41	-13.41	-8.62	-1.87	12.24	-6.35
Apr.	-9.22	-12.67	-13.33	-4.9	2.85	11.68	-3.92
May	2.6	11.64	12.63	9.91	13.45	8.58	13.04
Jun.	-9.19	8.61	15.38	13.88	10.5	-2.11	-5.48
Jul.	-0.99	12.67	15	15.23	11.08	4.55	6.35
Aug.	2.27	4.56	7.08	14.14	11.92	15.14	9.3
Sept.	-4.47	-5.94	-8.22	1.83	12.99	14	0.99
Oct.	-8.04	-9.37	-9.13	-4.49	7.35	12.67	-4.21
Nov.	-8.52	-13.33	-12.1	-10.97	2.64	11.17	-10.19
Dec.	-8.4	-11.69	-12.05	-10.59	-3.81	-0.8	-6.38

Figure 4.15: Solar radiation in different orientations-Mashhad-Iran (Meteonorm)

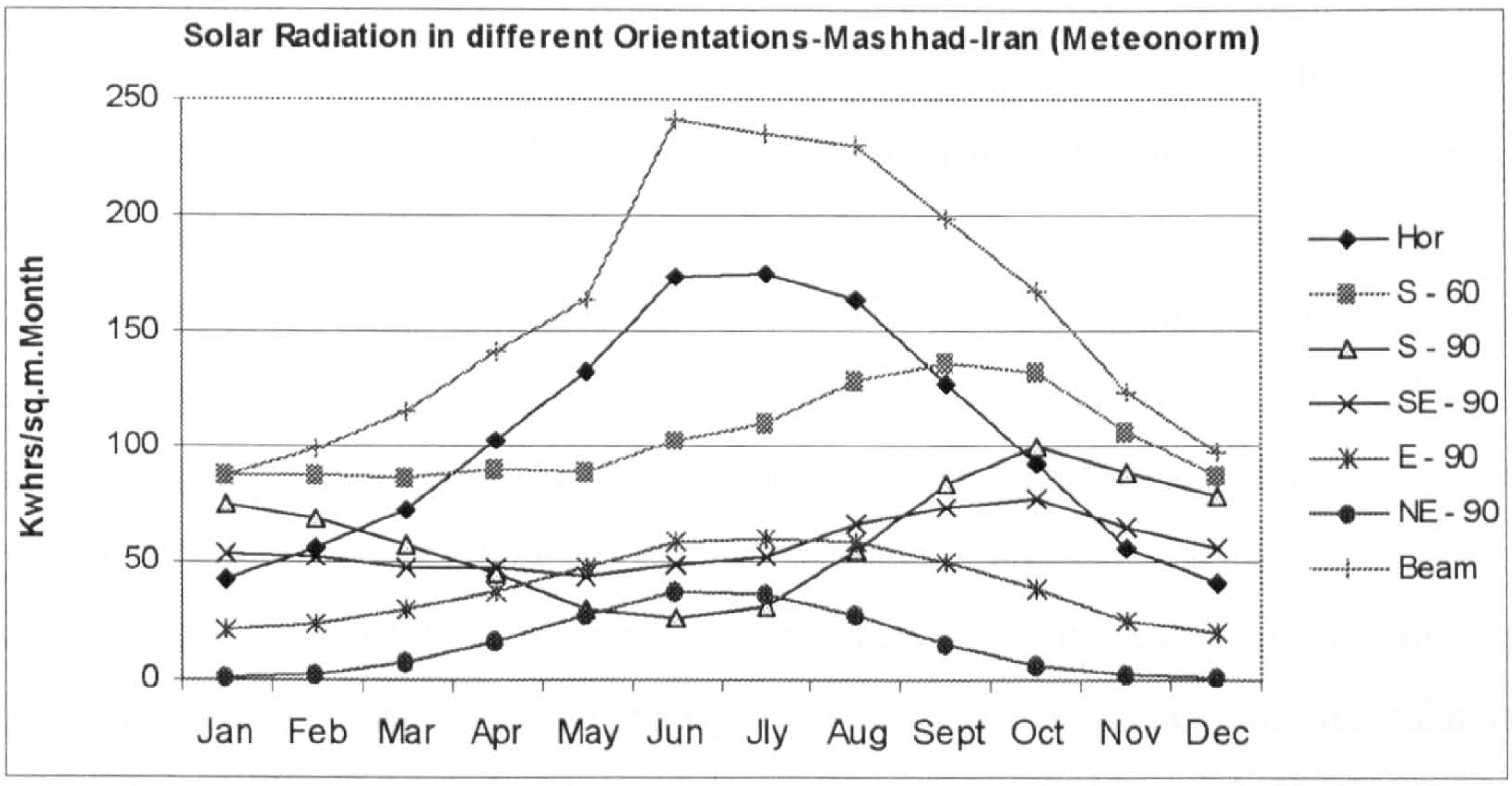


Figure 4.16: Solar radiation in different orientations-Mashhad-Iran (Gorji calculation)

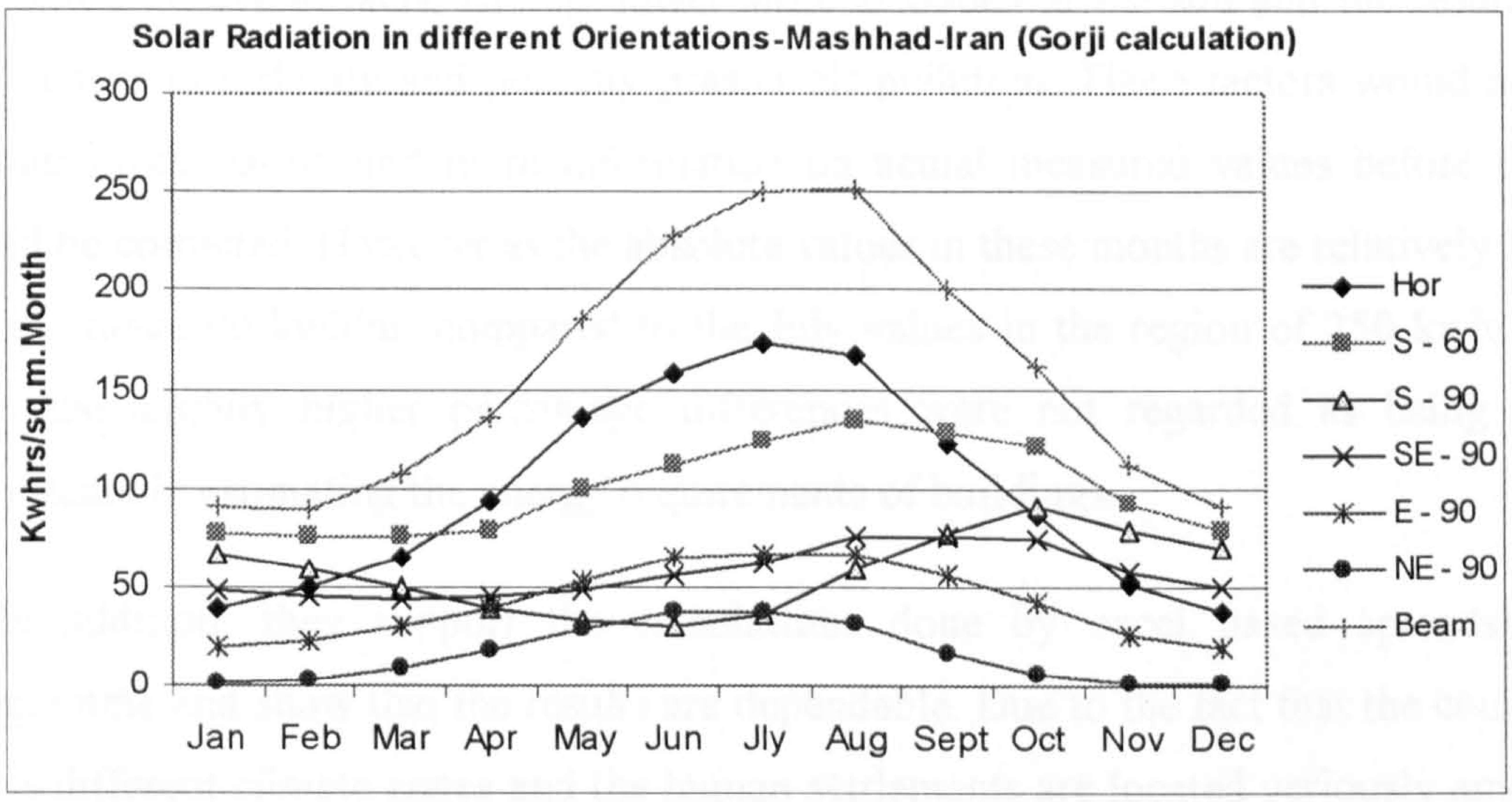
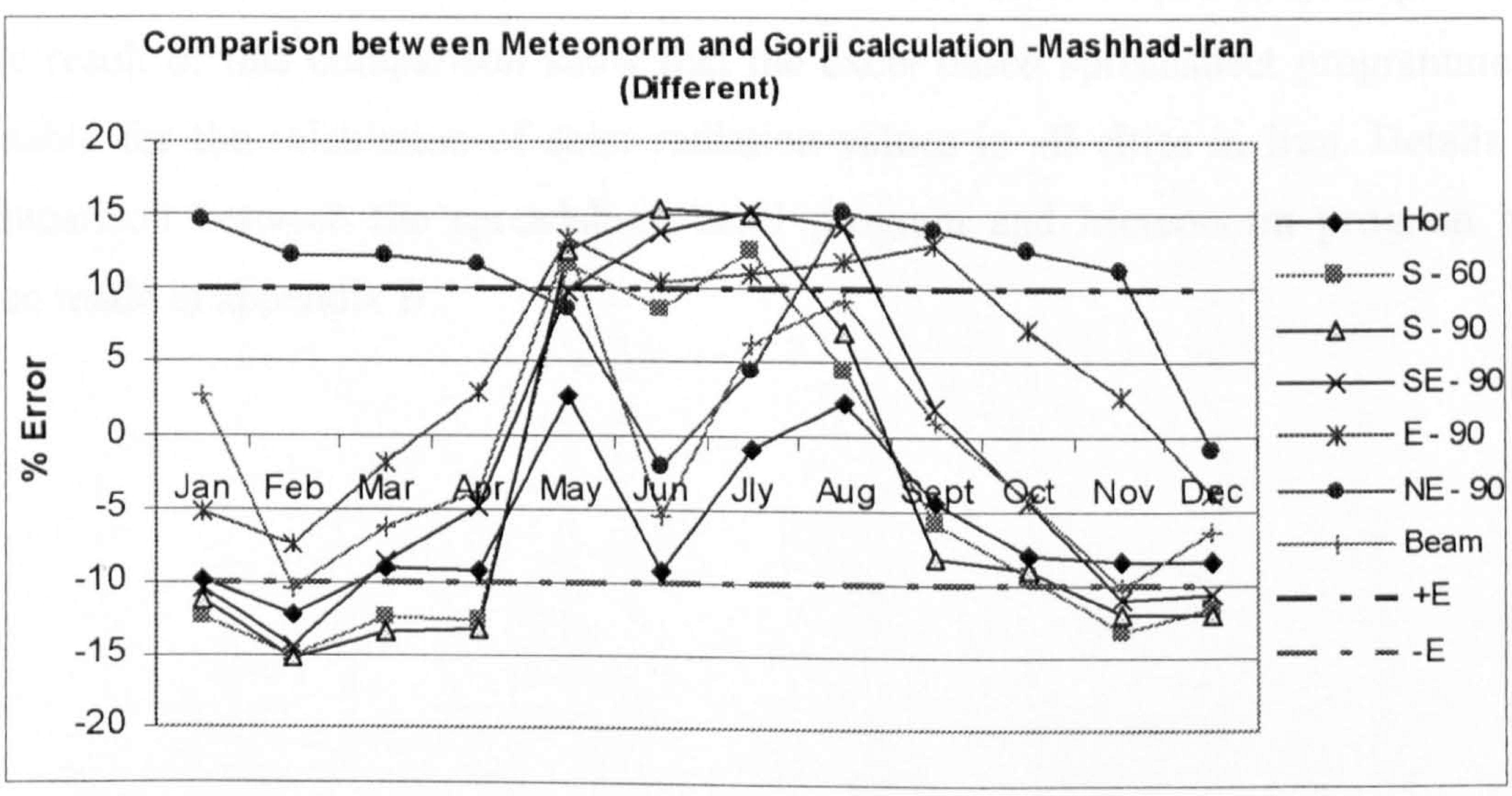


Figure 4.17: Comparison between Meteonorm and Gorji calculation-Mashhad (Difference)



4.6.2 * Conclusions from the Analysis

Four cities in Iran were selected and the solar radiation value for building surfaces was calculated using the excel based spreadsheet programme which was developed from the solar radiation algorithms outlined above. Figures 4.18 and 4.19 show an input and output screen of this programme. The climatic data of these cities are included in Meteonorm programme. The radiation values were then calculated for the four cities using the Meteonorm programme. The calculated data has been compared with data produced by Meteonorm programme and found to be within the normally accepted error bands of 10%. Although, there are small differences in the tables (see tables 4.20 to 4.31) and graphs (see figures 4.6 to 4.17), the results are relatively similar. These differences in the results between December and April could be attributed to several facts, namely lower altitude values of the sun and the resultant differences in turbidity and possibly greater air pollution. These factors would need further investigation and more information on actual measured values before they could be corrected. However as the absolute values in these months are relatively low (in the range 90 kwh/m^2 compared to the July values in the region of 250 kwh/m^2) then the slightly higher percentage differences were not regarded as being too significant in estimating the energy requirements of buildings.

In addition, they support the calculations done by excel based spreadsheet programme and show that the results are dependable. Due to the fact that the country has 8 different climate zones and the human settlements are located variously among these zones, solar radiation differs and should be estimated as precisely as possible. The result of this comparison show that the excel based spreadsheet programme is suitable for the calculation of solar radiation values in all cities in Iran. Details of comparison between the spreadsheet excel program and Meteonorm program has been made in appendix B.

4_7 * Summary

Solar radiation data are important in renewable energy resource planning. However, these data have not yet been made available calculated in Iran. Therefore, there is the need for the precise calculation of solar radiation for each and every city of Iran in order to better exploit the benefits of solar energy for the future of this country.

This chapter has discussed the method of calculation of solar radiation in different cities of Iran based on European Solar Atlas and Islamic Republic of Iran Meteorological Organisation's statistics (IRIMO). The equations developed in this chapter have been used in excel based spreadsheet to calculate the solar radiation values on any surface anywhere in Iran. An example of the input and output sheets of the hourly solar radiation calculation programme is presented in figures 4.18 and 4.19. The calculated data has been compared with data produced by the computer programme Meteonorm and found to be within the normally accepted error bands of 10%. The spreadsheet programme developed to calculate the solar radiation intensities was further developed to include a procedure to calculate the energy flows across the building elements and is discussed in Chapter 6.

Figure 4.18: The first input page of the hourly solar radiation calculations programme

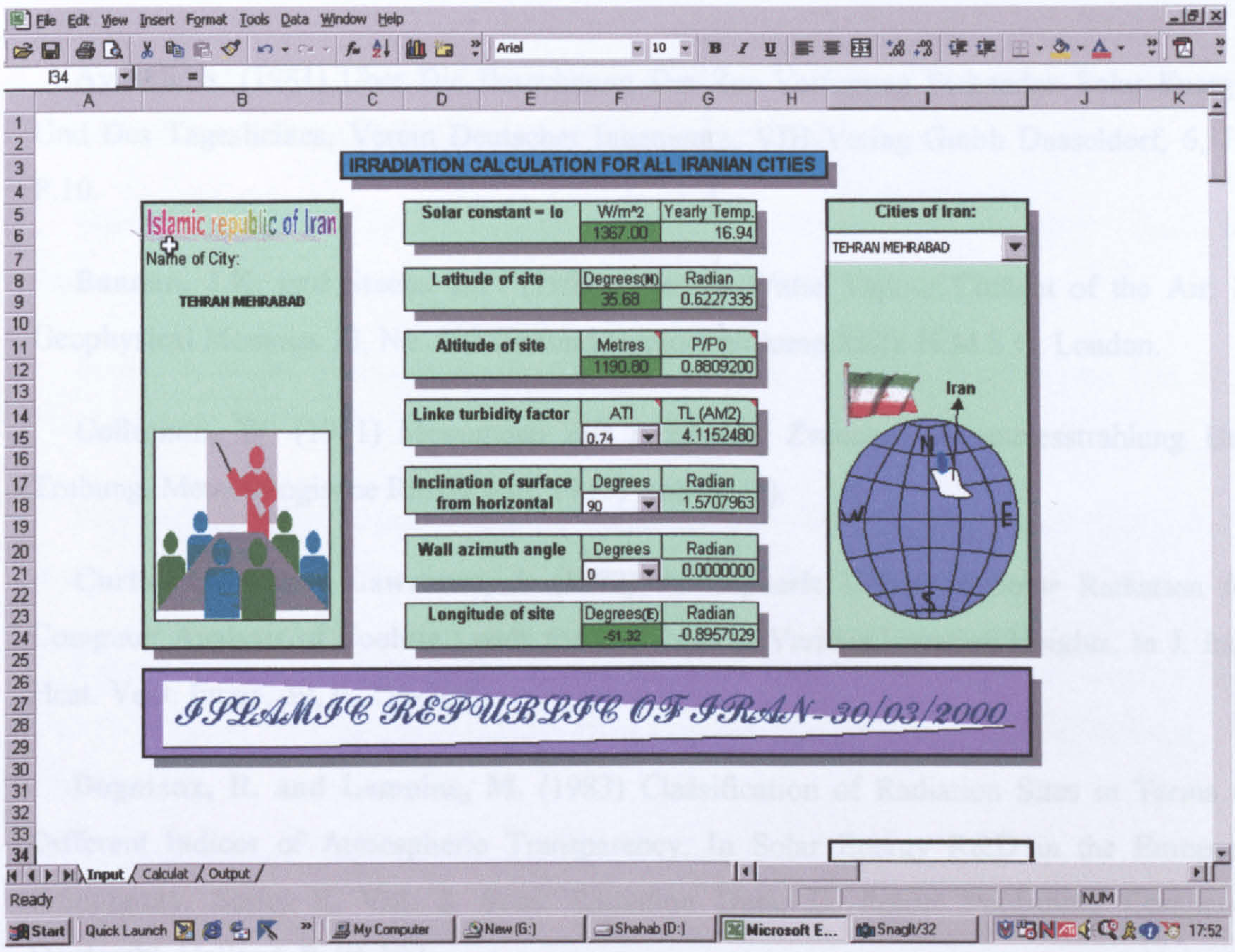
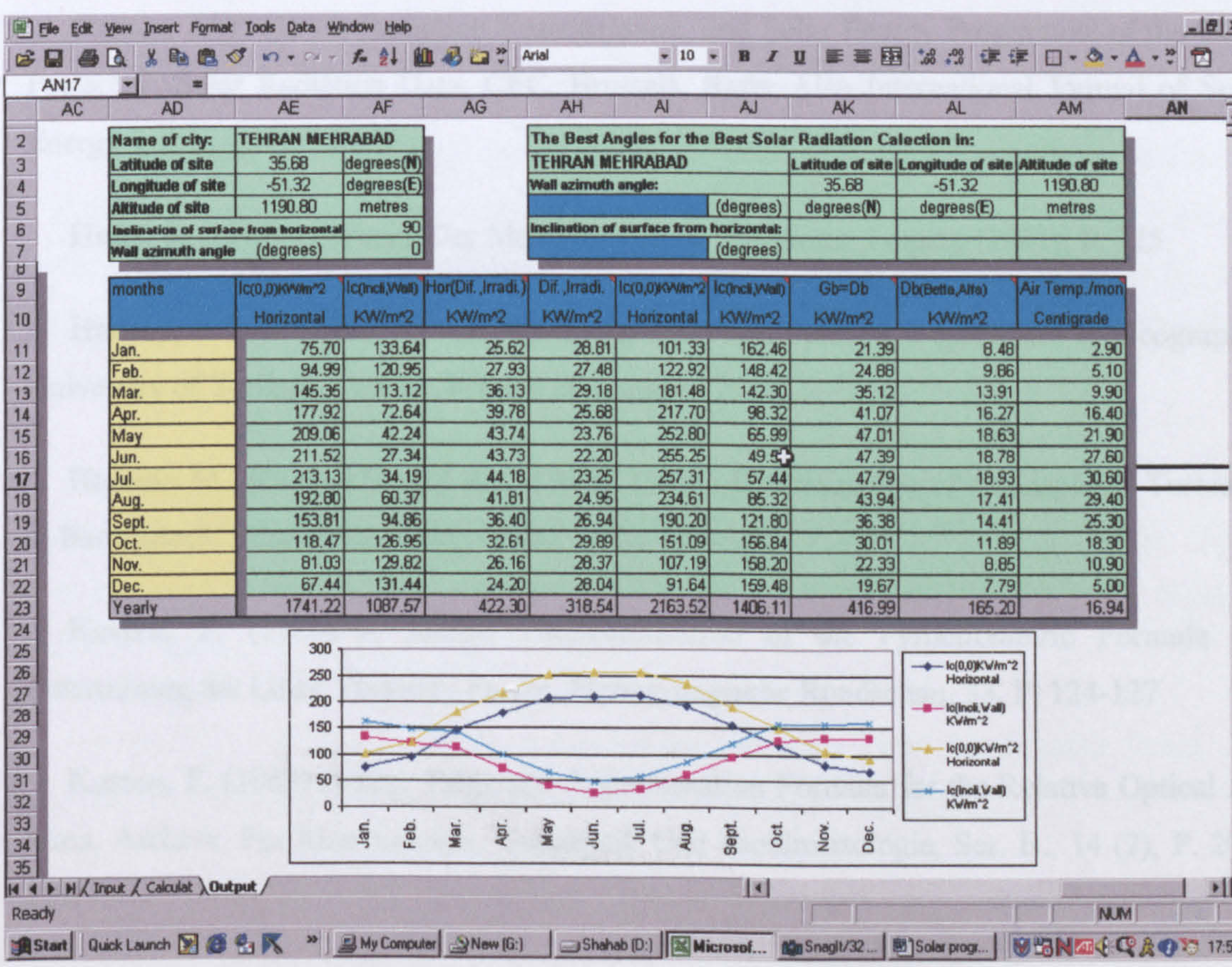


Figure 4.19: The output page of the hourly solar radiation calculations programme



Name of city:	TEHRAN MEHRABAD	
Latitude of site	35.68	degrees(N)
Longitude of site	-51.32	degrees(E)
Altitude of site	1190.80	metres
Inclination of surface from horizontal		90
Wall azimuth angle	(degrees)	0

The Best Angles for the Best Solar Radiation Calection in:				
TEHRAN MEHRABAD		Latitude of site	Longitude of site	Altitude of site
Wall azimuth angle:		35.68	-51.32	1190.80
	(degrees)	degrees(N)	degrees(E)	metres
Inclination of surface from horizontal:				
	(degrees)			

months	Ic(0,0)KW/m^2 Horizontal	Ic(Incli,Wall) KW/m^2	Hor(Dif. ,Irradi.) KW/m^2	Dif. ,Irradi. KW/m^2	Ic(0,0)KW/m^2 Horizontal	Ic(Incli,Wall) KW/m^2	Gb=Db KW/m^2	Db(Betta,Alfa) KW/m^2	Air Temp./mon Centigrade
Jan.	75.70	133.64	25.62	28.81	101.33	162.46	21.39	8.48	2.90
Feb.	94.99	120.95	27.93	27.48	122.92	148.42	24.88	9.86	5.10
Mar.	145.35	113.12	36.13	29.18	181.48	142.30	35.12	13.91	9.90
Apr.	177.92	72.64	39.78	25.68	217.70	98.32	41.07	16.27	16.40
May	209.06	42.24	43.74	23.76	252.80	65.99	47.01	18.63	21.90
Jun.	211.52	27.34	43.73	22.20	255.25	49.5[illegible]	47.39	18.78	27.60
Jul.	213.13	34.19	44.18	23.25	257.31	57.44	47.79	18.93	30.60
Aug.	192.80	60.37	41.81	24.95	234.61	85.32	43.94	17.41	29.40
Sept.	153.81	94.86	36.40	26.94	190.20	121.80	36.38	14.41	25.30
Oct.	118.47	126.95	32.61	29.89	151.09	156.84	30.01	11.89	18.30
Nov.	81.03	129.82	26.16	28.37	107.19	158.20	22.33	8.85	10.90
Dec.	67.44	131.44	24.20	28.04	91.64	159.48	19.67	7.79	5.00
Yearly	1741.22	1087.57	422.30	318.54	2163.52	1406.11	416.99	165.20	16.94

4_8 * Reference

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Web site 1, http://www.sunlitedesign.com/

Web site 2, http://www.schorsch.com/rayfront/manoal/skyedit.html

Chapter 5

Schools Lighting Requirements

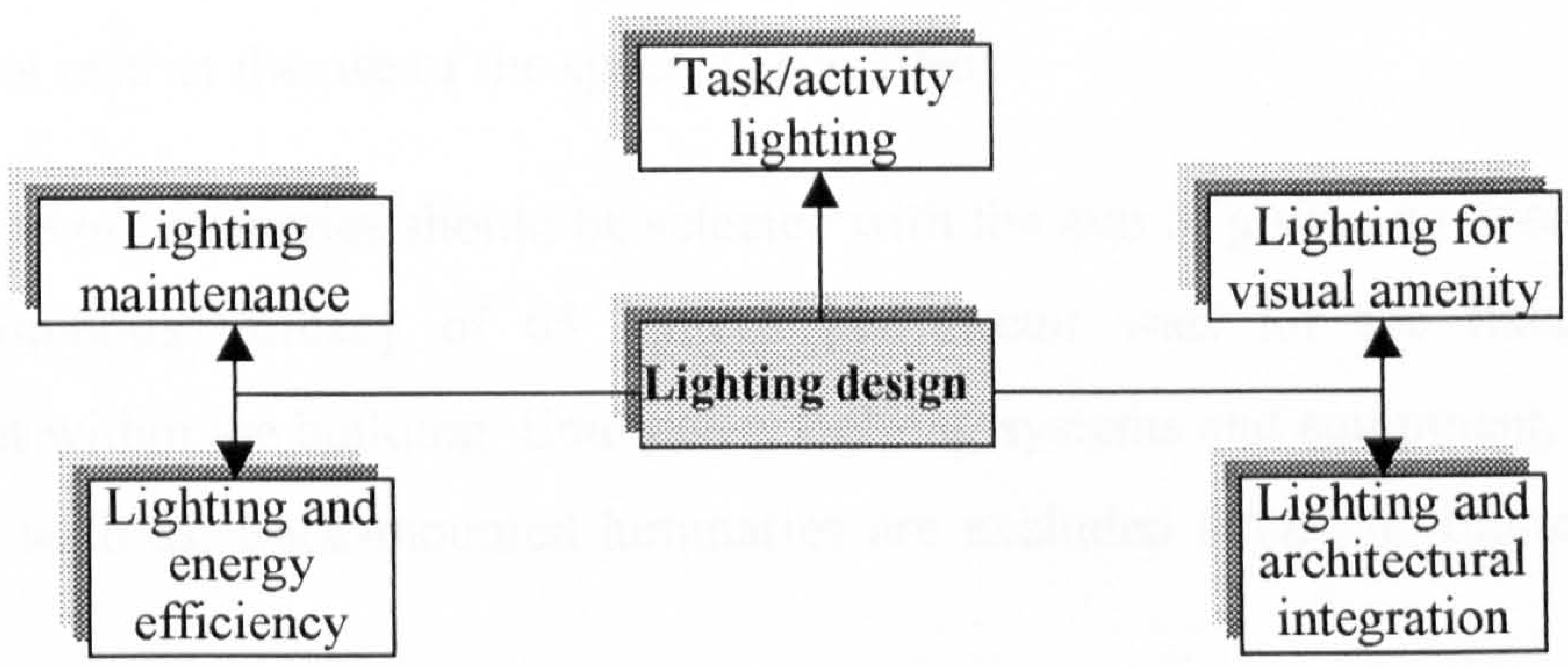
5 * Schools Lighting Requirements

5_1 * Introduction

One of the essential factors in the design of school buildings is lighting. It is necessary in every building, especially in schools where good natural lighting is required. A successful school design depends to a great deal on the quality of the visual environment (DES, 1967). Therefore, architects should keep in mind that good lighting conditions is very important in providing a suitable educational environment. Nevertheless, it is accepted that the visual comfort in schools depends on the quality of the whole visual environment. This leads to the concern upon the quality and quantity of lighting.

Different criteria of lighting design are shown in the following framework (figure 5.1). The role of these criteria in the lighting design will not be equal. However, in order to achieve the best solution all should be taken into account (DFEE, 1999).

Figure 5.1: Design framework (DFEE, 1999)



The Designer needs to consider the functional requirements of the special space. It is essential to examine the type of lighting required and the amount of light to be certain that the occupants of the space can carry out their special activities without visual difficulty and in a comfortable visual environment. Therefore the activity requirements for particular spaces have to be analysed.

In order to allow for various tasks it may be necessary to provide flexibility in the lighting. Local task lighting can be very useful for particular activities. One of the important factors that should be considered in selecting the type of local task light (such as surface temperature of the fitting) is safety. One of the alternatives to higher levels of illuminance (especially for the visually impaired) is an increase in the contrast or the size of the task detail.

This feature of lighting addresses the appearance of the lit scene and the aim is to create a visually interesting and pleasant environment. This means producing a light pattern that has variation in the luminance and a sensitive use of surface colour.

The installation of natural and electric lighting has to be integrated in the architecture. This will apply to the lighting elements, i.e. windows and luminaries, and their production of light patterns.

This will lead to the maximum use of daylight by using electric light to complement daylight and using energy-efficient electric lighting that only works when it is required. This last point can be dealt with the positions of the control switches, the organisation of the lighting circuits to have a connection with the daylight distribution and the use of the space. Useful energy savings can be provided by automatic controls however, it is necessary that any controls are used friendly, i.e., they do not restrict the use of the space, (BRE, 1996).

The type of luminaries should be selected with the aim of giving an average initial circuit luminous efficacy of 65 lumens per circuit watt for the fixed lighting equipment within the building. Emergency lighting systems and equipment, which are not fixed such as, track-mounted luminaries are excluded from this figure (HMSO, 1995).

After a period of time all lighting will worsen because of dirt build-up on the windows, on the lamps and luminaries, on the reflecting surfaces of the space and also due to a decrease in the output of the lamp's light. In order to be certain that the lit environment is satisfactory over the whole maintenance cycle, the designer has to examine these matters in making decisions. Therefore, there is a need to have liaison with the client with the aim of planning an appropriate maintenance programme.

It is important to remember that using a wide range of different types of lamp makes the next replacement much more complicated. All lighting elements including windows should be easy to clean and maintain.

5.2 * Design Criteria

5.2.1 * Daylighting

It has been suggested that the minimum level of daylight in school buildings should be 2% day light factor (DES, 1977). The daylight factor is defined as that percentage of the outside level reaching the working plane from the outside. This includes the light reflected from internal and external surfaces (see figure 5.2). Windows should provide light and view in school buildings. In table 5.1 the size of openings, which provides the 2% daylight are shown in percentage (DES, 1977).

Figure 5.2: Daylight factor components (designed by Gorji)

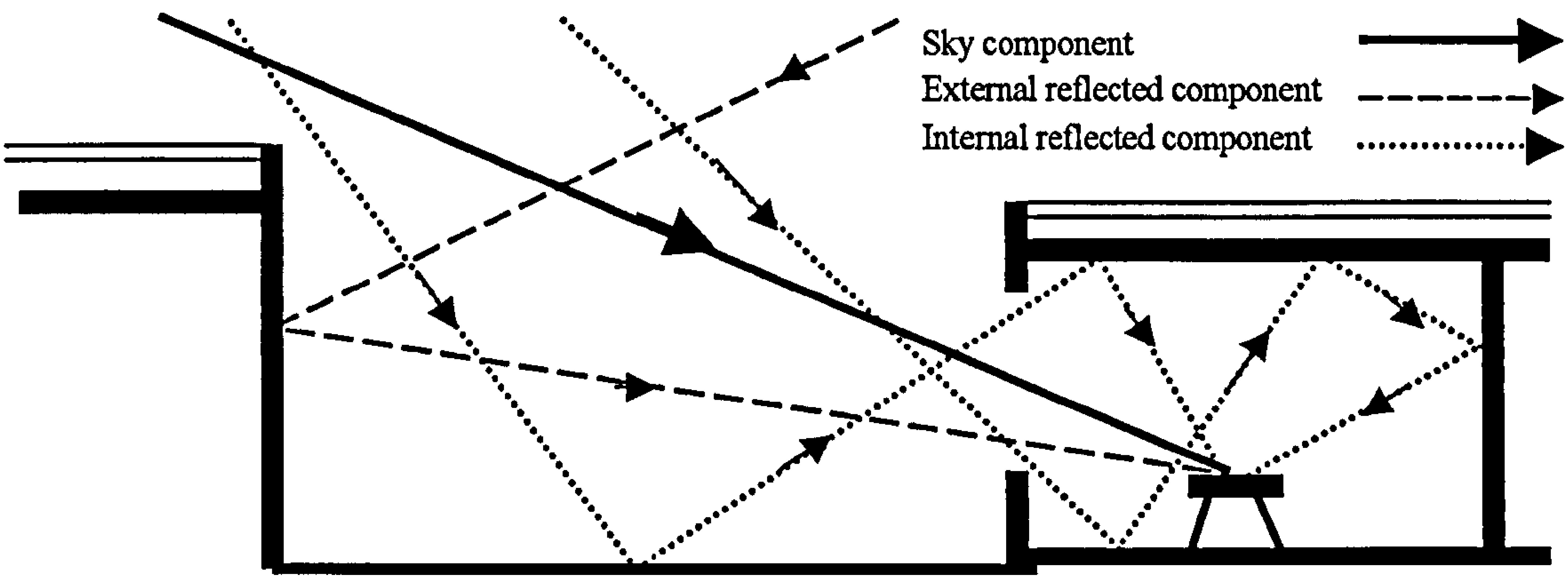


Table 5.1: Percentage of openings to the depth of the teaching space (DES, 1977).

Maximum perpendicular depth of the teaching space from an external wall in meters	Less than 8 m	8-11 metres	11-14 metres	More than 14 m
Maximum percentage internal elevation of the external wall area	20%	25%	30%	35%

Side windows or rooflights can obtain these percentages. By using rooflights the capital cost will increase and the view out will be eliminated (DES, 1977). Also, they will be difficult to shade and protect from direct sun. Side windows; provide light, view out, fresh air and possible escape (DES, 1967). The size of windows should be considered in the climate of Iran (especially in centre and south). Alan Konya suggests medium sized windows to ensure good airflow during summer and allow the penetration of sun during winter (Konya, 1980). The quality of good lighting can be obtained without excessively large areas of glass.

During daylight hours, natural light should be the first means of lighting. A space is likely to be considered well lit if the average daylight factor is 4-5%. For the daylight illuminance to be adequate for the task, it will be necessary to achieve a level of not less than 300 lux in the classrooms, and for particularly demanding tasks not less than 500 lux (see chapter 6 section 2). When this level cannot be obtained, it will be necessary that the daylight be supplemented by electric light. Sometimes, light exterior surfaces can be used in order to increase reflected light (Research centre, 1992 and DFEE, 1999).

The window design should be relevant to the layout and activities, which, are planned for the internal space (for example, to avoid silhouetting effects and excessive contrasts in brightness).

Daylight and particularly direct sunlight can cause discomfort and disability glare. This problem can often be resolved by careful and appropriate design of the window to minimise glare. The other alternative is to provide adjustable blinds in order to screen the glare source when necessary. Also, blinds can improve the thermal environment by decreasing heat gains. External blinds are more expensive than the internal blinds. Nevertheless, external blinds are more effective in preventing solar heat gain. Internal blinds are often difficult to maintain. Also, they are a source of noise when windows are open. Traditional architectural forms in Yazd were able to aid in the control of the internal environment through such devices as wind catchers to help in providing natural ventilation and dome structures to provide daylight and ventilation. In this thesis the author is interested in optimising school design in different climate zones in Iran. Devices, which may be appropriate in one climate zone may not be appropriate in another and therefore the author felt that to investigate the use of traditional forms would (although interesting) fall outside the scope of his work.

Windows provide natural variation of light through the day and external visual interest. Therefore, for the window area to be adequate for this purpose, for example in Babolsar, it is recommended that a minimum glazed area of 20% of the internal elevation of the exterior wall be provided (as a result in chapter 6 section 2). Windows need to be also examined in terms of other environmental factors such as, the thermal and acoustic performance together with the energy efficiency of the building.

5.2.2 * Electric Lighting

The electric lighting installation has to provide all the requirements illustrated in the design framework. According to task lighting, for most school tasks, an illuminance of 300 lux will be suitable. If the task is particularly demanding (e.g., the task detail content is small or it has a low contrast) a value of not less than 500 lux will be necessary: in some circumstances, this can be obtained by a local supplement to the general lighting. Although the human eye is able to operate in low lighting levels there is strong evidence that visual acuity drops off with low levels (Boyce,1973). Therefore in an education environment where reading plays an important part of the daily tasks it is necessary to ensure that the eye can function efficiently with minimum strain. It is therefore suggested that design guidelines adopted in countries where research effort has been carried out into visual acuity are adopted. For stairs and corridors a maintained illuminance at floor level in the range 80-120 lux is recommended. Entrance halls, lobbies and waiting rooms need a higher illuminance in the range 175-250 lux at an appropriate level. Reception areas should be lit to a level in the range 250-350 lux on the working plane (see table 5 2).

In order to avoid from discomfort glare, where a regular arrangement of luminaries is used, the Glare Index shall be limited to no more than 19, (CIBSE, 1985). Also, it will be important to avoid visual discomfort from individual luminaries and from reflected images, particularly on computer screens.

The avoidance of subliminal lamp flicker is another consideration on visual comfort. This is important because it can induce epileptic fits in susceptible pupils. It can be minimised by using high frequency control gear or using more than one phase of a three-phase supply in a lead-lag arrangement. The stroboscopic effect of lamp flicker must be addressed in areas with rotating machinery (e.g., circular saws).

One of the important parts of learning is colour appreciation. For this reason it is essential to use electric light sources that present colour perfectly (especially in art and design rooms). Providing good colour is not now very expensive to reach. Therefore, lamps with a CIE colour-rendering index of not less than 80 are recommended. With respect to colour appearance, lamps with a warm to intermediate classification (Correlated colour temperature 2527°C-3727°C) should be used. Switching arrangements should facilitate shared use of spaces where suitable (CIBES, 1985).

$5_{2.3}$ * Combined Daylighting and Electric Lighting

When the daylighting recommendations cannot be obtained throughout a space a particularly designed supplement of electric lighting should be provided. In addition to providing a combined illuminance for activities being undertaken, a suitable appearance should be achieved by a balance of brightness throughout the space to cope with relatively bright windows. Preferential lighting and especially wall lighting in areas far from the window can obtain this.

$5_{2.4}$ * Lighting Quantity

It is stated by the Department of Education and Science that the lowest level of illumination on a working plane at any point should not be less than 150 lumens and where fluorescent lighting is used it should not be less than 300 lumens (DES, 1977). In spaces, where combined lighting is needed (such as laboratory) illumination should not be less than 200 lumens (Ibid). The level of illumination for each space in the school is shown in the table 5.4.

$5_{2.5}$ * Lighting Quality

Lighting is divided in two types: natural and artificial. In schools, daylight should be the main source in working areas. Artificial lighting is needed to supplement daylight occasionally on the dullest days, in darkness or at night. In teaching areas, the level of maintained illumination and daylight factor should not be less than 108 lumens per m^2 and 2% respectively (DES, 1967). The 2% daylight factor could be obtained with a glazed area of 15 to 20% of the floor area. The main problems are glare and overheating, caused by the presence of the sun. Appropriate solutions should be taken at an early stage of design.

$5_{2.6}$ * Glare

In order to obtain a good visual environment, it is recommended that equilibrium of brightness throughout the room and a balance of direct and indirect lighting be achieved. This prevents the impacts of glare. The glare index for each space in a school is illustrated in the table 5.2. Glare can be caused by bright areas of sky seen through windows, projection of sunlight on desks and chalkboards, unscreened lamps, fluorescent lamps, etc. To avoid the inconveniences caused by glare it is recommended to:

1) Avoid putting windows on the visual focal points (for example chalkboards).

2) Increase the general brightness of the room by selecting the appropriate colour for ceilings and walls (bright colours are desirable).

3) Use blinds, curtains, screens and other shading devices (DES, 1967).

Table 5.2: Illuminance, uniformity ratio and limiting glare index for schools (DFEE, 1999)

General Teaching Spaces	Standard maintained illuminance-Lux	Uniformity Ratio	Glare index
	300	0.8	19
Teaching Spaces with Close and Detailed Work (e.g., Art and Craft Rooms)	500	0.8	19
Circulation Spaces: Corridors, Stairs	80-120	--	19
Entrance Halls, Lobbies& Waiting Areas	175-250	--	19
Reception Areas	250-350	--	19
Atria	400	--	19

5.2.7 * Emergency Lighting

The aim of emergency lighting is to produce sufficient illumination, in the event of a failure of the electricity supply to the normal electric lighting, in order to be able to evacuate the building quickly and safely and to control processes and etc., securely.

Emergency lighting in school buildings is provided only in areas where the general public have access in the evenings. Halls and drama spaces are also included. Emergency lighting is not usually provided on escape routes, except from public areas, since the children are familiar with the buildings and there is only a small part of the school year in the hours of darkness. Emergency lighting should be considered in upstairs escape corridors; escape stairways, corridors without windows and areas with dangerous machinery.

It is advised that the emergency lighting should be the maintained type for halls, gymnasium and other areas used by the public during the hours of darkness. Where part of the premises is licensed it will be essential to follow the guidance of the Local Fire Authority.

Emergency Lighting should make visible safe passageways out of the building, the fire alarm call points, the fire fighting equipment, escape signs and any changes of direction or stairs (DFEE, 1999).

5_3 * Lighting for Pupils With Visual and Hearing Impairments

Lighting and acoustic criteria are critical both to the hearing impaired and the visually impaired. The design of particular accommodation for the visually impaired is beyond the scope of this thesis but specialist advice can be obtained from the Royal National Institute for the Building. (RNIB/GBDA Joint Mobility and The Partially Sighted Society, London), However, design choices should be considered for all schools. Many of the low cost or no cost procedures can be applied to existing buildings such as tactile surfaces and types of luminaires.

Other means, such as providing or facilitating the use of visual aids can be examined as necessary. A general guide is given in the following part that can be helpful in the majority of cases. Visual impairment is composed of two main conditions:

1) Field Defects: In this condition, what is seen is clear but the visual field is restricted. In some cases only the central part of the field is seen (tunnel vision). Therefore, mobility would be impaired. However, in these cases the ability of reading and doing fine work would be largely unaffected (DFEE, 1999).

Conversely, in other cases there is a loss of central vision. This means that movements can be performed in safety but the ability of performing detailed tasks (such as reading or sewing) would be very difficult and sometimes impossible. In all types of field defect the amount of task illumination is not important supposing that normal advices are followed.

2) Loss of Acuity (blurring of vision): The extent of the blurring is widely variable. Some pupils need to bring objects very close to their eyes to see well. It may also be associated with loss of colour vision.

Depending on the cause of the loss of acuity, higher illuminance and large print can be helpful. Many schools now can produce their own reading material and the use of a san serif font of at least 14 point size can be a useful aid. Glare should be avoided because it can aggravate the effects of low acuity. A 'white' board on a dark coloured wall can be a source of glare whereas a traditional "blackboard" would not. Also, a view of a daylight scene through a window is another source of glare (DFEE, 1999).

Loss of visual field and acuity can coexist. Also, the special problems experienced by people suffering from visual impairment and their responses to light and other environmental features are very variable.

The usage of higher task illuminance is helpful to those whose acuity can be improved by the contraction of the iris, resulting in a greater depth of field. However, in some patients, such as those with central cornea opacities, the iris has to be dilated with the aim that the pupil can see around the opacity. In this condition, more light not only will not improve the difficulty but also will aggravate the problem.

5.3.1 * Positioning

The position of visually impaired pupil should be located where they can best see the work. This may be a seat outside the normal arrangement, such as immediately in front of the board or the teacher.

Also, it is important that any visual aids are available for usage. These can include a wide range from hand-held or stand mounted optical magnifiers to CCTV magnifiers. Local task lighting can also be useful.

In order to have access to an electrical supply, cope with excess daylight or use any other aid, it may be necessary to allow the student to change position and move within the teaching space.

5.3.2 * Use of Colour

Colour and contrast are especially important to the people with visual and hearing impairments (RNIB, 1995). For example down lighters in reception or teaching areas provoke harsh shadows, which limit lip-reading. Colour should be used carefully in order to assist pupils in the identification of a place. It may be more necessary than an elaborate lighting installation.

In some visually impaired cases there is some degree of colour blindness and it is of great importance that contrast should be introduced in luminance and not only colours. For example, pale green and pale cream may be clearly distinguished by the normally sighted pupils but be seen as a single shade of grey by some pupils with visual impairment. In order to aid orientation within a space, contrast should be used in the décor. For example, using a darker colour for the architrave around a door will help to identify the location of the door and a handle, which clearly contrasts with the surface of the door, will show which way it swings. In some spaces orientation may be introduced by the furniture arrangement or by windows during daylight hours. In others it can be established by making one wall distinctly different (for example by adding a large clock or changing the colour. Whatever method is used, it is best adhered to throughout the building, i.e., the different wall is always to the same side of the main exit from the space (ICI, 1997).

Surfaces finished with high gloss should be used carefully since they can reflect bright lights such as sunlight. Generally, eggshell finishes are to be preferred because some directional reflection is desirable rather than dead matt surfaces, which may be difficult to place precisely. Also, changing the tactile qualities of surfaces can be helpful to reinforce visual contrasts. In school buildings they are most important for the blind.

5.3.3 * Daylight

Daylight should be the principal light source in the design of schools. The colour of the window wall should be light, in order to reduce contrast with outdoor scene, and window reveals may be splayed to increase the apparent size of the glazing.

Depending on the type of visual impairment, sunlight can be either help or an obstruction. Therefore, some means for the control of its quantity should be provided. Traditionally this has been by means of blinds. In circulation spaces, the design of fenestration should decrease glare hazards. Large areas of glazing should to be clearly seen. Otherwise, it can be dangerous to the people with visual impairment. They can be marked with a contrasting feature at eye level in order to avoid accidents. This will make them visible even in low light levels.

5.3.4 * Electric Light

It is important to control the glare from overhead lighting especially for visually impaired pupils. For fluorescent lamps, high frequency electronic ballasts are more preferred since they avoid subliminal flicker. Also, they can prevent the demonstration of annoying visible flicker that can happen with conventionally ballasted lamps at the end of their life. If high frequency ballasts are used, attention should be given to the use of a regulated version, which can be darken to allow the adjustment of the illuminance level in order to suit the individual as well as to save energy. Usually, the additional cost is modest. It is not economic to install more than the recommended illuminance on the off chance that they will be useful some day to a hypothetical visually impaired pupil. Additional illuminance can be reading supplied when the need arises from local task lighting luminaries.

5.4 * Design of Shading Devices

In climatic consideration, shading has great importance. Although the external openings should be decreased as much as possible together with providing good view and light, they should be shaded as well. Generally, there are two types of shading devices, i.e. internal and external shading devices. External shading devices are most suitable for the type of climate in central and south of Iran (i.e. Yazd, Boshehr, Bandar-abbas, Kerman, etc.). Internal shading devices will be appropriate for other type of climate. They release the radiation absorbed to the interior and as glass prevent long wave radiation from escaping. This will create overheating problems (Givoni, 1981). Then, the solution for the climate of central and south are external shading devices. There are two types of external shading devices, depending on the altitude of the sun and the orientation of the façade, which needs to be shaded. These two categories are horizontal and vertical shading devices (Ibid).

5.4.1 * Determination of Shading Devices

The determination of under heated and overheated periods of the year could make possible the design of shading devices (Koenigsberger, et al. 1973). For this purpose, the temperature- shading chart has been prepared (Figure 5.3). The comfort zone for schools in the considered region varies from 20 to 24° C (Research centre, 1992). The shading chart has been obtained by the method described by Martin Evans (Evans, 1980), (Figure 5.4). The curved lines on the chart have been obtained by joining the equal temperatures at different periods. The overheated period has been located approximately between the 15th of June to the 30th of September between 10 a.m. and 6 p.m. The under heated period has been located from the 15th of November to the 30th of March. The overheated period has been repeated on the corresponding sun-path, latitude 32° north (Figure 5.5). By using a shadow angle protector several shadow angles have been determined for the following orientations: east (north-south axis), south-east (35° from the east-west axis), south (east-west axis), south-west (35° from the east-west axis), west (north-south axis) and north-west (35° from the south-north) (see table 5.3).

Figure 5.3: Yearly shading chart of the City of Yazd (Razjouyan, 1987)

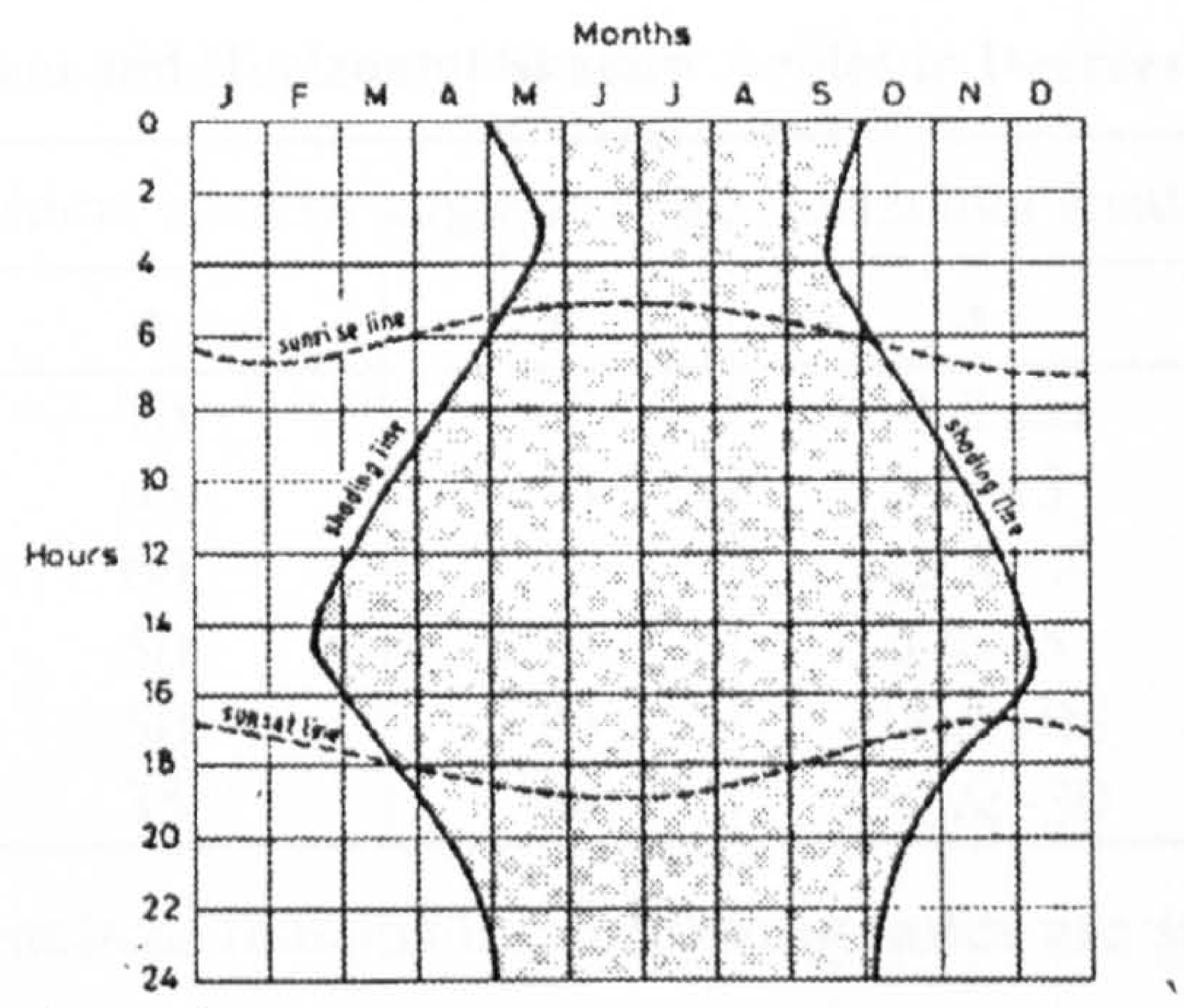


Figure 5.4: Chart Showing the months and Hours Lines for the Determination of Overheated and Under Heated Periods of the Year (Evans, 1980)

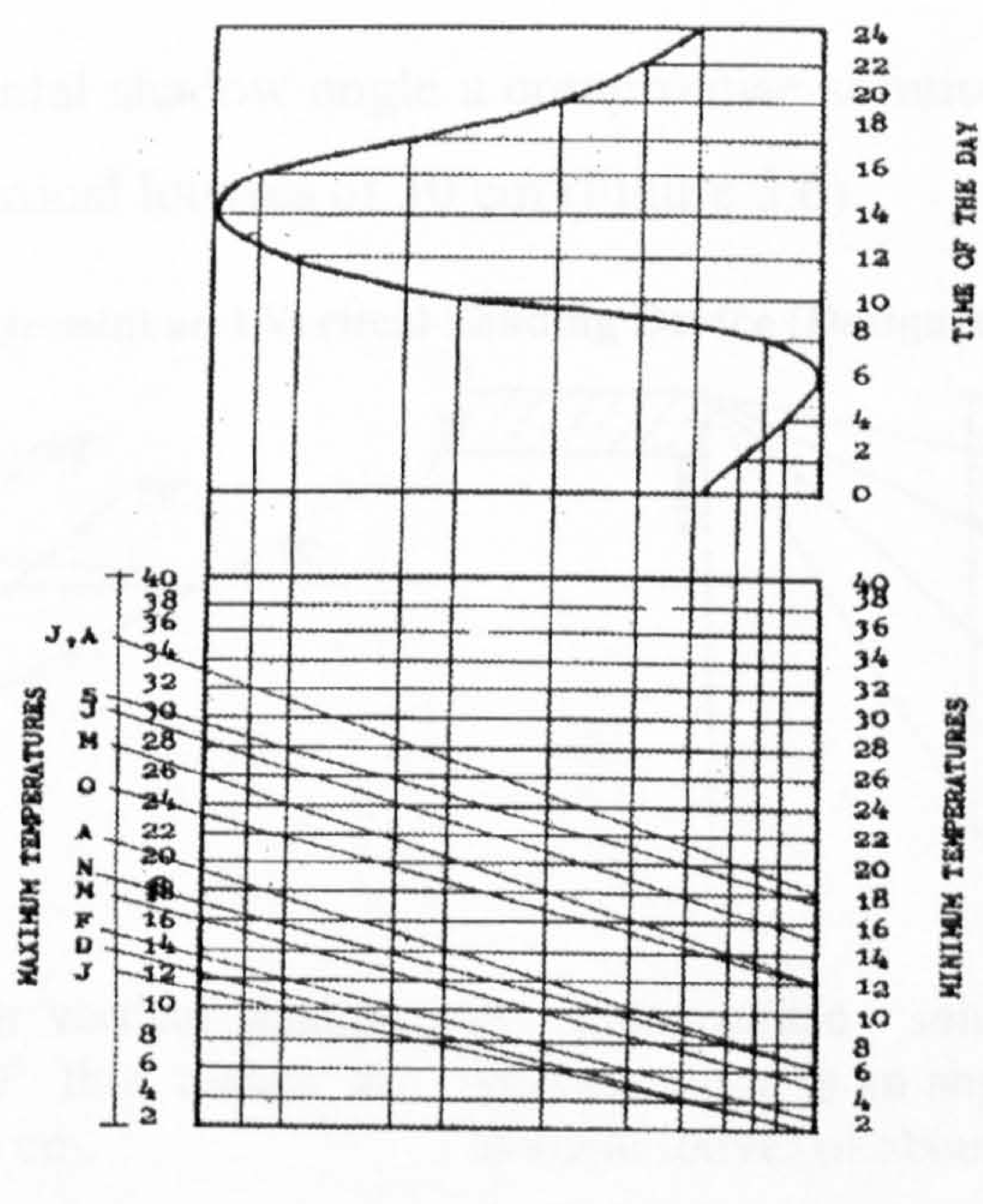


Figure 5.5: Solar chart of the city of Yazd (Koenigsberger, et al. 1973)
(Latitude 32° North)

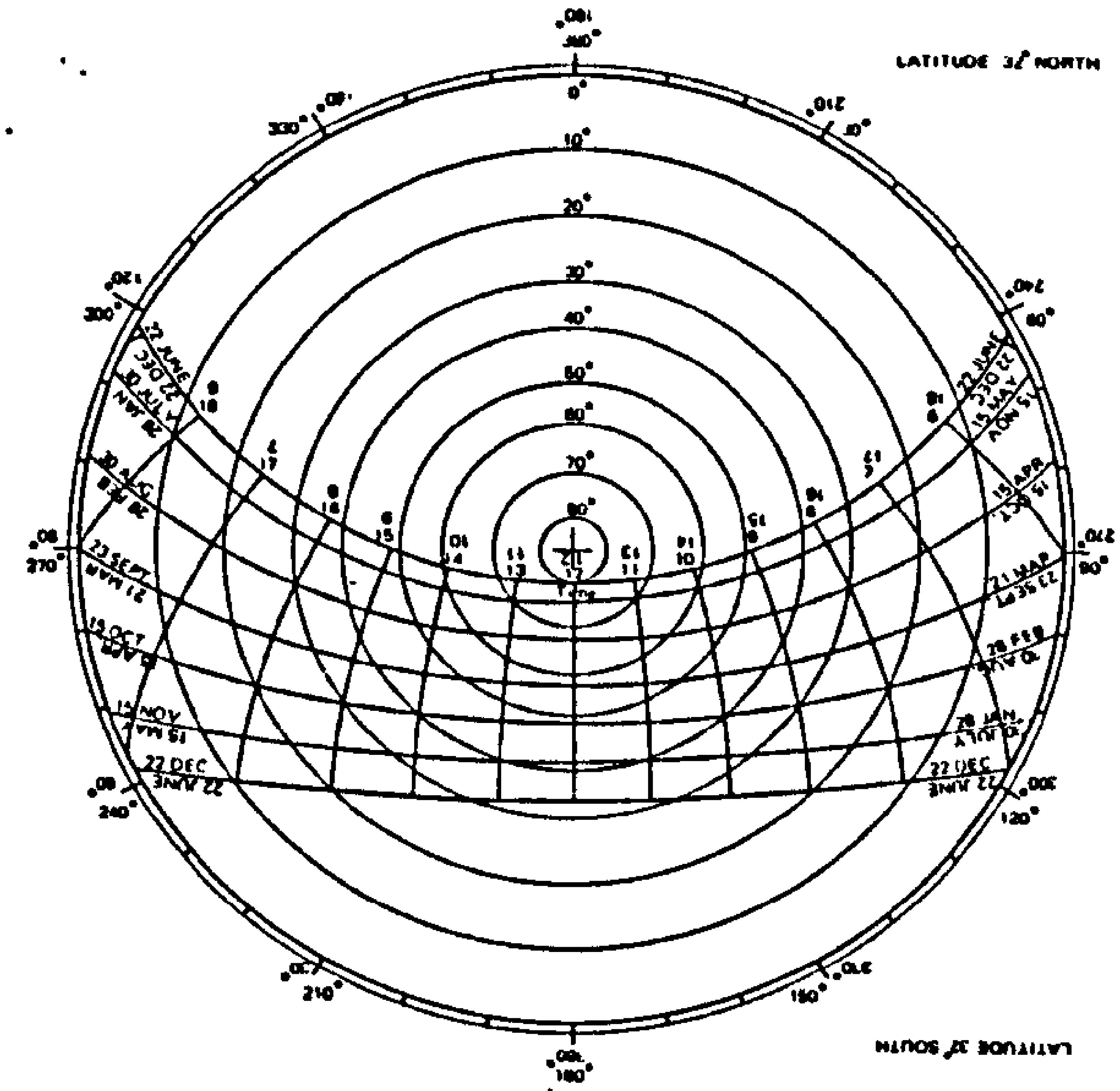


Table 5.3: Vertical and Horizontal Shadow Angles in Degrees (Aiche, 1987)

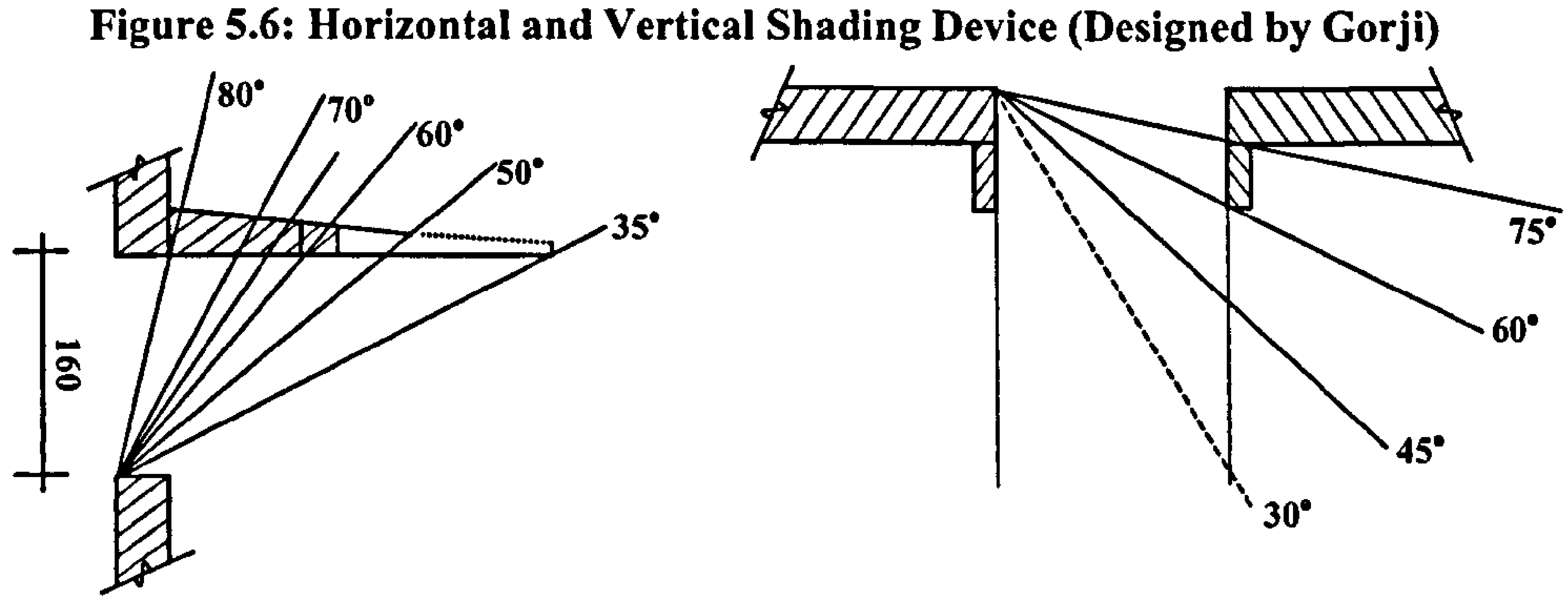
Orientation	Vertical shadow angle in deg.		Horizontal shadow angle in deg.	
	a	b	a	b
East	70	80	30 & 60	60 & 75
South-east	65	70	0 & 45	0 & 55
South	60	70	-45 & 80	-50 & 85
South-west	50	70	0 & 45	-40 & 20
West	50	70	-35 & -05	-60 & -30
North-west	35	60	-50 & -30	-65 & -45

For economical and practical reasons the following notes are suggested:

a) For east, west and near these orientations, a vertical shadow angle of 60° is a compromise solution (this means an overhang of 60 to 80 cm).

b) For the horizontal shadow angle a compromise solution is an angle of 60°. This means vertical louvres of 30 cm (Figure 5.6).

Figure 5.6: Horizontal and Vertical Shading Device (Designed by Gorji)



A compromise solution for vertical shadow angle is an angle of 60° this means an overhang of about 60 to 80 cm.

A compromise solution for horizontal shadow angle is an angle of 60° this means a vertical louver of about 30 cm.

$5_{4.2}$ * Economy of Shading Devices

Economy of shading devices can be provided if:

a) A compromise solution not exceeding two types of shading devices is found.

b) External openings are kept at their minimum; this limits the quantity of shading devices.

c) Parts of the building can be designed for shading as well. For horizontal shading devices, it is possible to project the roof to obtain an overhang. For the vertical shading devices, it is possible to shape the external elevation to produce vertical louvres.

d) Shading devices can act as a radiator in cold periods and brings heat during hot periods. Olgyay suggests that the shading device should be connected at necessary points only (Olgyay, 1963).

$5_{4.3}$ * Shading Effect of Trees and Vegetation

The microclimate of buildings is influenced to a large scale by trees. Olgyay explains in his book called "Design with climate" that:

"...Trees contribute much to the immediate physical environment. They reduce air borne sounds with great efficiency if densely planted. The viscous surface of leaves catches dust and filters the air. Vegetation can also secure visual privacy and reduce annoying effects" (Olgyay, 1963). Trees contribute also in the reduction of heat loss from building during winter and the absorption of radiation in summer. Their selection should then be subject to their shading performance and their position to different orientations.

5_5 * Summary

The daylight factor of 1.5%, which is generally recognised as being a suitable level of illumination on the working plane, is based upon a temperate zone sky with an internal level of approximately 300 lux.

In this chapter the assumption has been made that Iran has a mean sky value of 35 to 40 Klux (see tables 6.5 to 6.9 in chapter 6). The openings necessary to give the equivalent of a 1.5% daylight factor have been calculated on this basis. The point is emphasised that direct sun should not be allowed to penetrate into working rooms in order to reduce heat gain.

Priority should be given to daylight as the main source of light in working areas, except in special circumstances. Wherever possible a daylit space should have an average daylight factor of 4-5%.

Teaching spaces should have views out except in special circumstances. A minimum glazed area of 20% of the internal elevation of the exterior wall is recommended to provide adequate views out.

A maintained illuminance at floor level in the range 80-120 lux is recommended for stairs and corridors. Entrance halls, lobbies and waiting rooms require a higher illuminance in the range 175-250 lux on the appropriate plane.

Each room or other space in a school building shall have lighting appropriate to its normal use. The illuminance of teaching accommodation shall be not less than 300 lux on the working plane.

In teaching accommodation where visually demanding tasks are carried out (like painting room), provision shall be made for a task illuminance of not less than 500 lux on the working plane, for more recommended illuminance values for school building see table 5.4, which has been brought together from sources in Iran and UK:

Table 5.4: Recommended illuminance value for school building in Iran (Sources: Research centre, 1992 and DFEE, 1999)

Places:	Minimum/lux	Maximum/lux
Classrooms and Lecture Theatre	300	500
Painting and Hand works room	500	700
Blackboard (Vertical surfaces)	300	500
Reception areas	250	350
Laboratory	200	500
Gymnasium	150	300
Entrance hall, Lobbies and waiting rooms.	175	250
Stairs and corridors (Circulation spaces)	80	120
Changing room, Toilet and lavatory	50	100

5₆ * References

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Chapter 6

The Programme of Admittance Method and lighting

6 * The Programme of Admittance Method and lighting

6_1 * Introduction

In order to calculate the energy requirements of school buildings in Iran for heating, cooling and lighting it is necessary to use a simulation programme. In this thesis it was decided to use the Admittance procedure and a new programme was developed for this purpose. This chapter considers the details of the admittance method and lighting programme.

Chapter 6 is composed of two sections. The first section considers the Admittance Method Programme, which is used in the analysis of the energy requirements of buildings for heating and cooling loads.

The second section describes the method of calculation of daylighting, which is used in the lighting simulation programme. Effective daylighting design requires consideration of different factors such as daylight factor, luminous efficacy of solar radiation, orientation factor, glass transmittance factor, average reflectance of material and etc. which are need for calculation of exterior and interior illuminance, are discussed in this section.

Section 1: Admittance Programme

6_2 * Using the Monthly or Annual Admittance Programme

The programme used for the analysis of the energy performance of the school designs was developed within the school of Architecture for general research and building analysis. It is based on the Chartered Institute of Building Services Engineers Guide Book A – Admittance Procedure Section A6.

In the departmental version the solar radiation values are imported from the solar prediction model Meteonorm as tables in an excel worksheet. These tables are then accessed by the calculation worksheet. The version used in this thesis is based on the departmental version but has been modified so as to be able to use the solar radiation data calculated by the routines outlined in chapter 4. Other modifications included simplifying the input worksheets to either enable of disable heating or cooling and also to be able to specify to a greater extent the internal gains from people, lights and equipment. The input sheet was also re-written so as to give the necessary information for running the solar radiation model. Figures 6.5 to 6.9 show both the input sheets and the output sheets. It can be seen from these figures that the outputs are given in terms of the monthly energy requirements for heating/cooling as bar charts and also graphical representations of the constituent energy flows (Ventilation, solar gains, internal gains from people and equipment).

6.3 * Background

The traditional energy analysis of buildings was carried out using steady state techniques, which only considered the steady heat flows across a structure in terms of the thermal resistance of the structure and the temperature difference across the structure.

Q = A * U * (Inside temperature – Outside Temperature) Algorithm 6.1

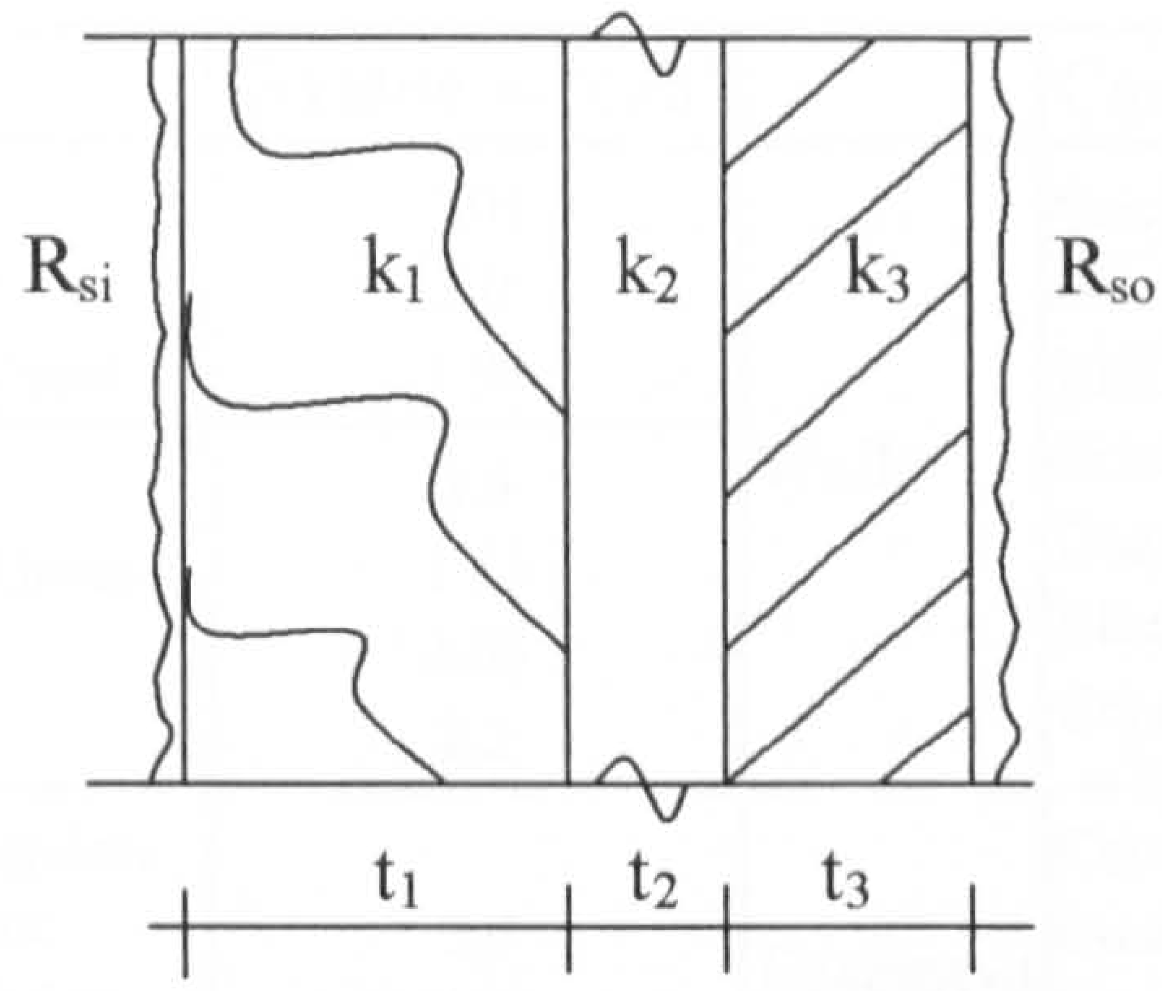
Where: **Q** is the heat loss in Watt, **A** is the area of the surface in square meter and **U** is the thermal resistance of the surface in $W/m^2\,°C$.

6.3.1 * Thermal Transmittance or U-value

Thermal transmittance or U-value is defined as the rate of heat flow in watts through one square meter of a non-homogeneous construction when the temperature differential of one degree centigrade is fixed across both sides of the construction. A unit is $W/m^2\,°C$. It is the reciprocal of the overall thermal resistance of construction, which includes the surface resistances.

The overall coefficient of heat transfer or thermal transmittance (U-value) in one way is a measure of the evaluation of thermal exchange in various construction units. The total flow of heat per unit area across any building component is the product of U-value and temperature differential of the air over two sides of the component. The overall thermal resistance of a construction is calculated as follows (see figure 6.1):

Figure 6.1: A typical wall construction



$U = 1 / R_t$ Algorithm 6.2

$R_t = 1 / R_{si} + t_1 / k_1 + t_2 / k_2 + \cdots + 1 / R_{so}$ Algorithm 6.3

Where: R_t = Overall thermal resistance of a wall (m^2 °C/W)

R_{si} = Inside surface conductance (W/m^2 °C)

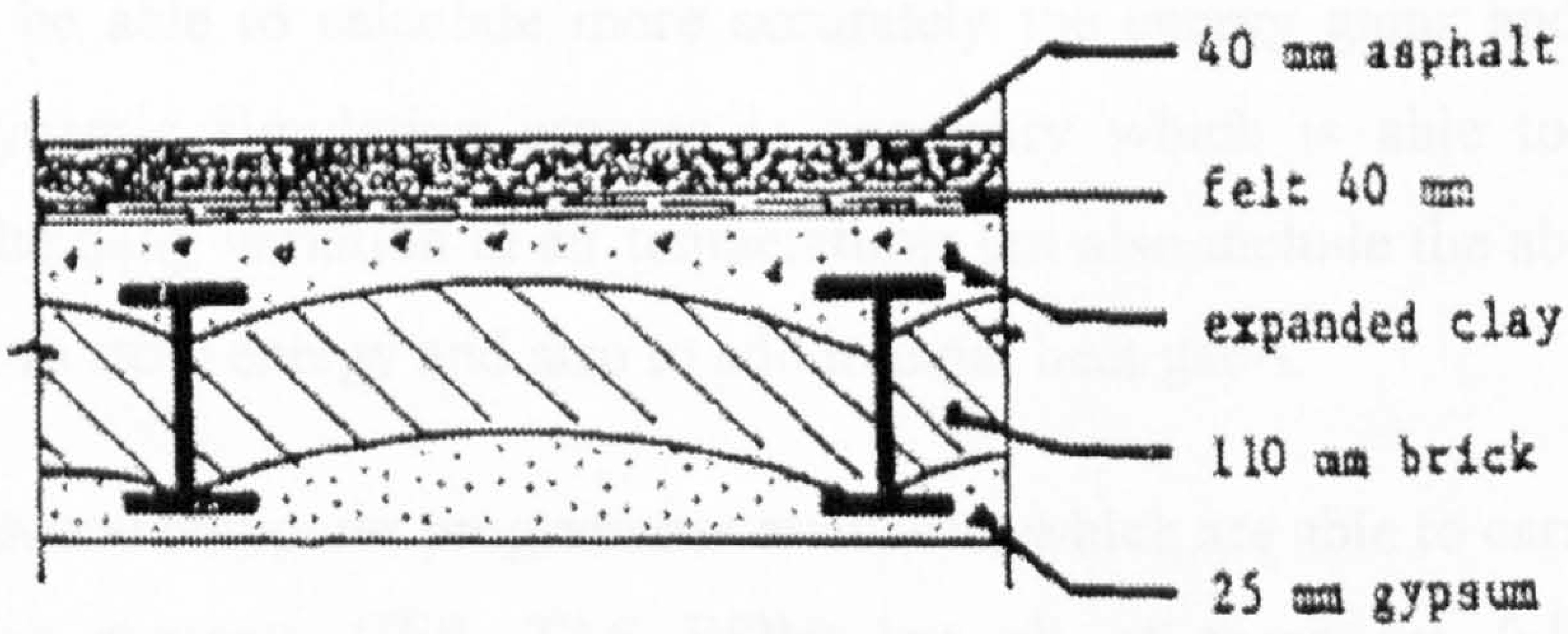
k = Thermal conductivity of material (W/m^2 °C)

t = Thickness of material, m

R_{so} = Outside surface conductance (W/m^2 °C)

The following is the calculation of U-value for a brick roof construction (see figure 6.2) typical to Iran. Table 6.1 also shows typical U values of constructions found in Iran.

Figure 6.2: A typical brick roof construction



$R_t = 1 /18.87 + 0.04 /0.43 + 0.04 /0.25 + 0.11 /0.96 + 0.025 /0.46 + 1 /4.59 = 0.693$ m^2.°c/w

$U = 1 /R_t = 1 / o.693 = 1.44$ w/°c.m^2

Table 6.1: U-value of some typical construction used in walls, roofs, floors and windows in Iran

	Constructions	U-value w/°c.m^2		Constructions	U-value w/°c.m^2
Roofs	Brick	1.05	Walls	Brick 110 mm	3.0
	Concrete Block	2.0		Brick 220 mm	2.1
	Hollow Concrete Panel	1.95		Brick 220 mm	2.1
Floors	Concrete Panel	2.4		Brick 330 mm	1.7
	Concrete Slab on Ground	1.25		Concrete 150 mm	3.5
	Brick	2.05		Block & Brick	1.85
	Block	2.2		Concrete Block	2.35
Windows	Double Glazing window with 6 mm Airspace	3.4	Basement Walls	Concrete Block	2.7
				Concrete 150 mm	4.3
	Single Glazing window	5.6		Brick 330 mm	1.9
Insulation	Polystyrene	0.036		Brick 110 mm	3.6
				Brick 220 mm	2.35

This type of analysis is unable to take into account the storage properties of the building materials or the hourly variation in temperatures. It is therefore limited in its use in determining the energy gains and losses of buildings.

Steady state analysis is often not sufficient because:

- The thermal properties of buildings can vary and in lightweight buildings give a rapid response to climate changes.
- Building services systems often have a rapid response, which the steady state analysis is unable to take into account.
- Intermittent occupancy patterns are more common which requires a rapid response from the building services.

In order to be able to calculate more accurately the energy gains and losses of buildings a dynamic simulation process is necessary which is able to take into account both the daily variation in air temperatures but also include the ability of the building fabric to store energy and also to add internal heat gains.

There are several computer programmes available, which are able to carry out such an analysis for example (IES, TAS ESPr) but all of these are full dynamic programmes, which require hourly temperature data along with a very detailed building specification. They also take a considerable time to both input the building information and to obtain results and because of their complexity it was decided not to use such tools.

The programme which was used in this thesis was an excel based spreadsheet Admittance model. This has the advantage that it is able to take into account some of the variables not able to be used in a steady state model but also being excel based it could be included with the solar radiation model to provide a seamless join between the two.

6_4 * The Admittance Procedure

The programme used in this thesis has been developed from the Admittance procedure given in the Chartered Institute of Building Services (CIBSE) Guide Book A – Section A6. This procedure was developed to give a prediction method for dynamic thermal performance. It takes into account:

a) The daily cycle in temperature

b) The modifying effect of the thermal mass of the building materials on temperature fluctuations

c) Solar heat gains

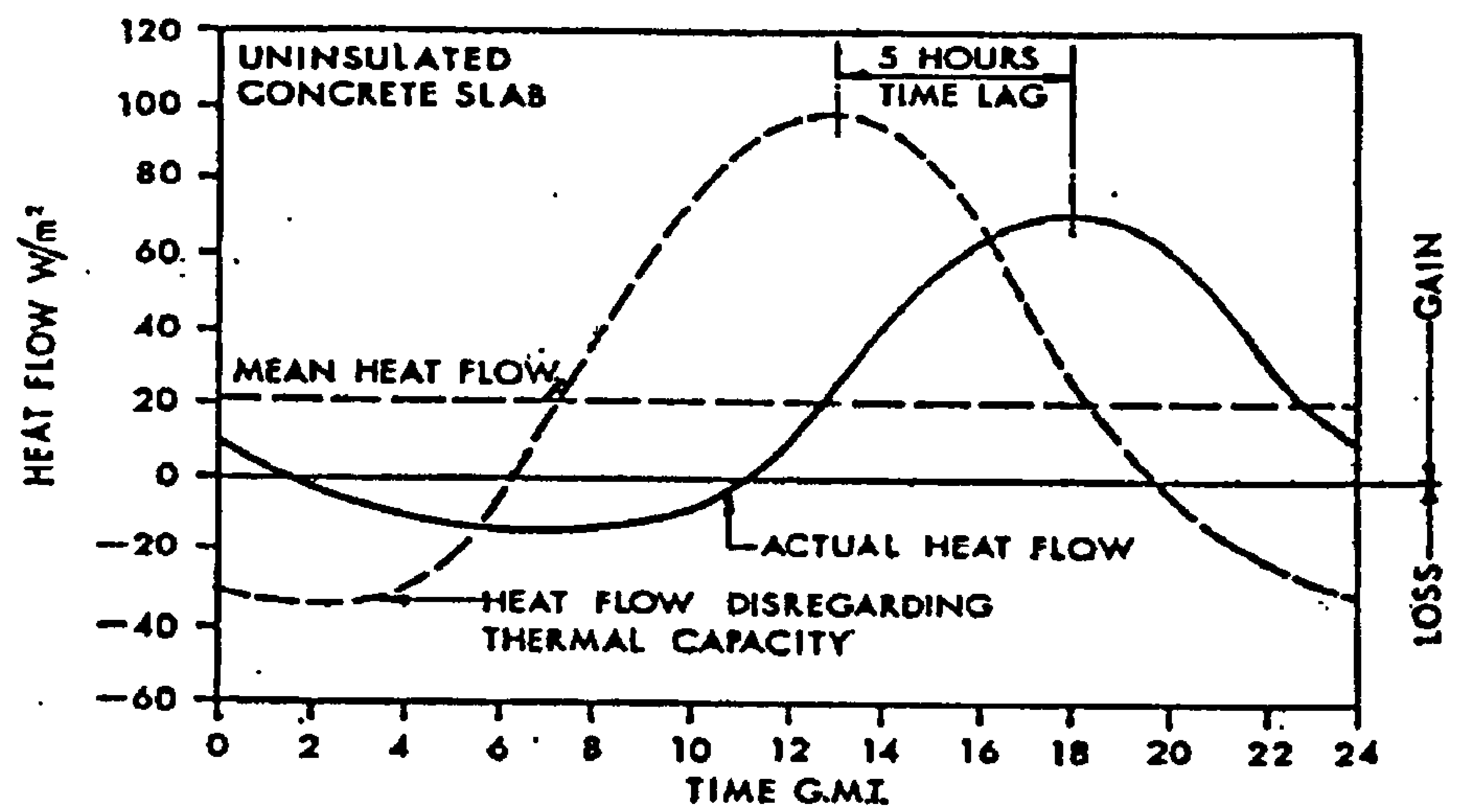
d) Variations in ventilation and internal gains

The model works by firstly estimating the mean energy flow across the structure and then adding or subtracting flows, which would be expected at specific time intervals (one hour). It assumes that the daily cycle in temperature and energy flows is cyclic.

Modification factors are applied to the flows to ensure that the model takes into account thermal storage and the re-admission of heat from the internal surfaces to the room/ building. These factors will be explained in this chapter.

An illustration of the type of curve, which would be expected from the use of the Admittance procedure, is shown in figure 6.3.

Figure 6.3: An illustration of the type of curve (CIBSE Guide A – A6)



6₅ * The Equations Used Within the Excel Programme

The equations used in this admittance procedure are set out below.

*** Mean Solar Gain**

$$Q'_s = S\, I'\, A_g \qquad \text{Algorithm 6.4}$$

Where: **Q'_s** is mean solar gain (Watt), **I'** is mean solar intensity (W/m²), S is solar gain factor and **A_g** is sunlit area of glazing (square meter).

*** Swing in Solar gain**

$$Q''_s = S_a\, A_g\, (I_p - I') \qquad \text{Algorithm 6.5}$$

Where: **Q''_s** is swing in effective heat gain due to solar radiation (Watt), **S_a** is glass blind correction factor and **I_p** is peak intensity of solar radiation (W/m²).

6₅.₁ * Glass Blind Correction Factors

If in the glazing system there exists blinds then these will have an effect of the transmission of solar energy into the space and therefore within the CIBSE procedure are given a rang of correction factors to the this into account. The factors are shown in table 6.2.

Table 6.2: Glass/ Blind correction factors (CIBSE, 1986)

Glazing/Blind configuration	Correction factor	
	Single glass	Double glass
None	0.76	0.64
No shading lightly heat absorbing glass	0.51	0.38
No shading densely heat absorbing glass	0.39	0.25
No shading lacquer coated	0.56	---
No shading heat reflecting	0.26	0.25
Internal shading open weave plastic	0.62	0.56
Internal white venetian blind	0.46	0.46
Internal white cotton curtain	0.41	0.40
Internal cream Holland linen	0.3	0.33
Mid- pane white venetian blind	---	0.28
External open weave plastic	0.22	0.17
External canvas roller blind	0.14	0.11
External white louvred sunbreaker	0.14	0.11
Dark miniature louvred blind	0.13	0.1

*** Mean fabric and ventilation gain**

$$Q'_t = F_{au} (\Sigma AU + C_v) (t'_{ei} - t'_{ao}) \qquad \text{Algorithm 6.6}$$

Where: ΣAU is sun of products of areas of exposed surfaces and the appropriate U values (W/°C), C_v is ventilation loss (W/°C), t'_{ei} is mean internal environmental temperature (°C) and t'_{ao} is mean outdoor air temperature (°C). The environmental temperature is defined as:

$$t'_e = (t_a / 3) + (2 * t_r / 3) \qquad \text{Algrothm 6.7}$$

Where t_a is the air temperature and t_r is the radiant temperature. In the climate of Iran it is normal that the surface temperatures are close to the air temperature and therefore in most situations the environmental temperature is taken as the air temperature.

*** Swing in fabric gain**

$$Q''_f = F_{ay} f\, AU\, (t_{so} - t'_{so}) \qquad \text{Algorithm 6.8}$$

Where: Q''_f is swing in the effective heat input due to structural gain (Watt), f is decrement factor dependent on the thickness of the wall or roof structure, t_{so} is sol-air temperature at time of peak hour less time lag (°C) and t'_{so} is mean sol-air temperature (°C).

6.5.2 * Sol-Air Temperature

In the calculation procedure the solar radiation values are included in a term known as the Sol-Air Temperature (for ease of calculation). This hypothetical temperature can be described as that temperature which, in the absence of solar radiation, would give the same rate of heat transfer through the wall or roof as exists with the actual outdoor air temperature and the incident solar radiation. It is given as:

$$T_{so} = t_{ao} + R_{so} (\alpha I_t + \varepsilon I_l) \qquad \text{Algorithm 6.9}$$

Where: T_{so} is the sol-air temperature, t_{ao} is the outside air temperature, R_{so} is the external surface resistance, α is absorption coefficient for the solar radiation at the external surface, I_t is the total solar radiation value incident on the surface, ε is the emissivity of the external surface (the proportion of long wave solar radiation reflected from the surface), and I_l is the long wave solar radiation incident on the surface.

6.5.3 * Decrement Factor

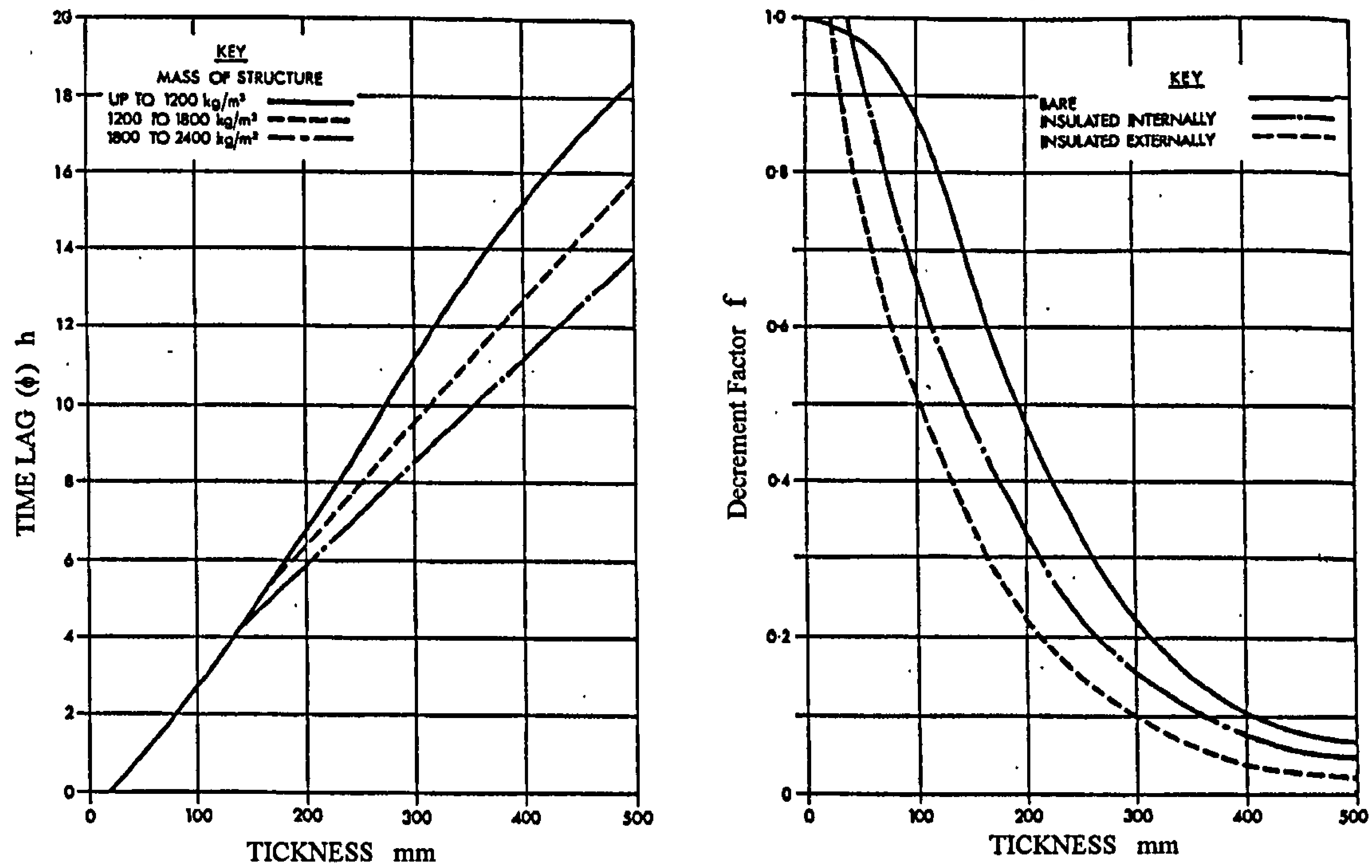
The decrement factor is the ratio of the rate of heat flow through a structure to the internal space temperature for each degree of swing in external temperature about its mean value, to the steady state rate of heat flow or U value. It is the attenuation of a wave travelling through an element of the building structure. For thin surfaces of low thermal capacity, the decrement factor could be taken as 1 but it decreases with increasing thickness and thermal capacity. An illustration of how the decrement varies with thickness and the degree of thermal insulation is shown in figure 6.4a (CIBSE Guide Book A).

6.5.4 * Time Lag

The time lag of a structure can be defined as the time it takes for an initial energy flux to travel across the structure. The higher the thermal mass the slower will be the rate of travel through the structure. Typically dense structures can have time lags in excess of 9 hours which means that if a structure is exposed to an energy flux at say 10 noon it will be 9pm when that flux reaches the inside surface. Figure 6.4b shows how the time lag can vary for different structures (CIBSE Guide Book A).

Figure 6.4: Values of time lag and decrement factor (CIBSE, 1986)

Figure 6.4b Figure 6.4a



65.5 * Surface Factor

The surface factor is the ratio of the variation of heat flow about its mean value readmitted to a space from the surface, to the variation of heat flow about its mean value absorbed in the surface. The surface factor decreases and its time lag increases with increasing thermal; capacity and they are almost constant with thickness. It is used when allowing for solar radiation and the radiative component of internal gains on internal surfaces. Values of surface factor are shown in table 6.3.

Table 6.3: Surface factors

Surface of material	Surface factor
Light	0.5
Medium	0.8
Heavy	0.9

65.6 * Factors F_{au} and F_{ay}

As all surfaces in an enclosure are able to absorb energy it is necessary to be able to take this into account in the calculation of energy flows. The two correction factors F_{au} and F_{ay} are therefore used to do so. These factors deal with the ability of the structure to absorb heat and can be calculated from a knowledge of the U value and the surface heat transfer coefficient along with the area of the surfaces bounding the space under consideration.

$$F_{au} = h_a \sum(A) / (h_a\sum(A) + \sum(AU)$$ Algorithm 6.10

And:

$$F_{ay} = h_a \sum(A) / (h_a\sum(A) + \sum(AY)$$ Algorithm 6.11

Where:

- h_a = surface heat transfer coefficient for the external wall (inside the room)
- A = the area of the internal surfaces
- U = values of surfaces
- Y = admittance of the surfaces

Quite often the F_{au} and F_{ay} are taken as 1 if details of the internal surfaces are not known or are unclear.

$6_{5.7}$ * Other Factors Taken Into Consideration

1. Mean internal air temperature (for each month)
2. Activity of occupants
3. Heating and cooling systems enabled/disabled (for each month)
4. Number of people occupying the space each hour of the day (for each month)
5. Lighting loads for each hour of the day (for each month)
6. Other heat gains for the space for each hour of the day (for each month)
7. Air changes per hour for each hour of the day (for each month)

In the model developed for this work the glazing ratio was specified along with the location, orientation and inclination. From this input the solar transfer across the windows was calculated.

6_6 * The Admittance Procedure Within the Excel Programme

The following is a list of the information necessary for running the excel programme.

$6_{6.1}$ * **Site Details** – necessary for calculating the solar radiation

- Location of building – Latitude and Longitude
- Orientation and inclination of the surfaces of the building

$6_{6.2}$ * **Building Details** – for running the excel programme

1. Area of surface
2. U value of surface
3. Time Lag
4. Decrement factor
5. F_{au} and F_{ay}
6. Glazing Ratio %
7. Glass/Blind correction factor
8. Mean internal air temperature
9. Activity level of the occupants
10. Internal heat gains form equipment
11. Natural ventilation rate

6_7 * Operation of the Admittance Model

The programme takes the input data and carries out the following calculations to arrive at a result.

1. Firstly the solar radiation values are calculated according to the equations given in chapter 4 and then this information is used to calculate the following:
2. The Sol- Air temperature and then modify it for time lag
3. The mean energy flow across the structural elements, modified by time lag surface factor and decrement factor
4. The difference in the energy flow from the mean (on an hour by hour bases)
5. The energy transfer through the windows, modified by the Glass/Blind correction factor

6. Internal heat gains from occupancy and other loads such as lighting and equipment

7. Natural ventilation loads

All of the above loads are then added together to produce a total energy load for the month under consideration.

The programme uses hourly data for each day of the year and therefore it is a simple matter of adding the daily loads to obtain monthly values.

6_8 * Input

An example of the input page is given below and shows the variables, which are considered.

Figure 6.5: The first input page of the analysis programme

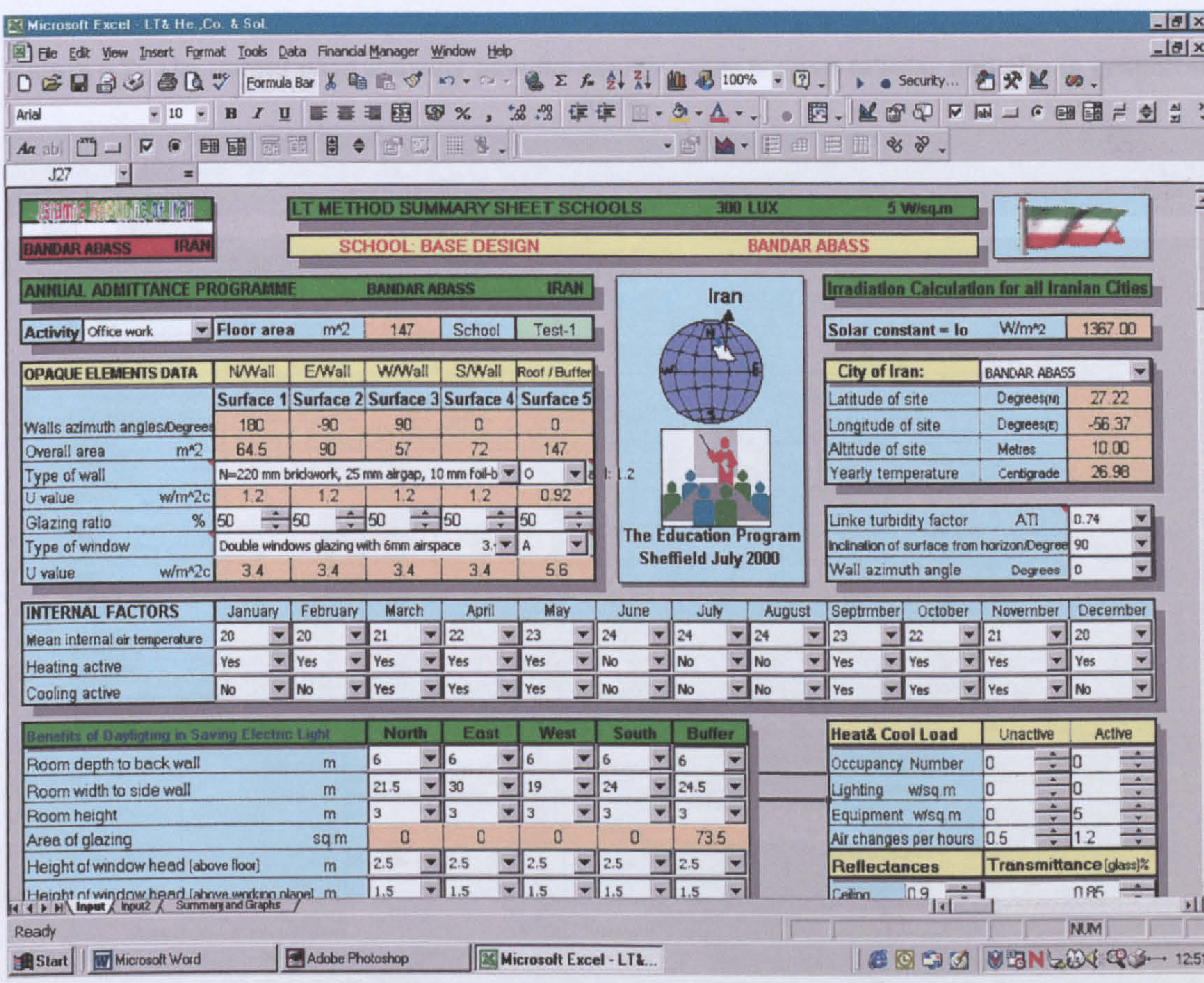
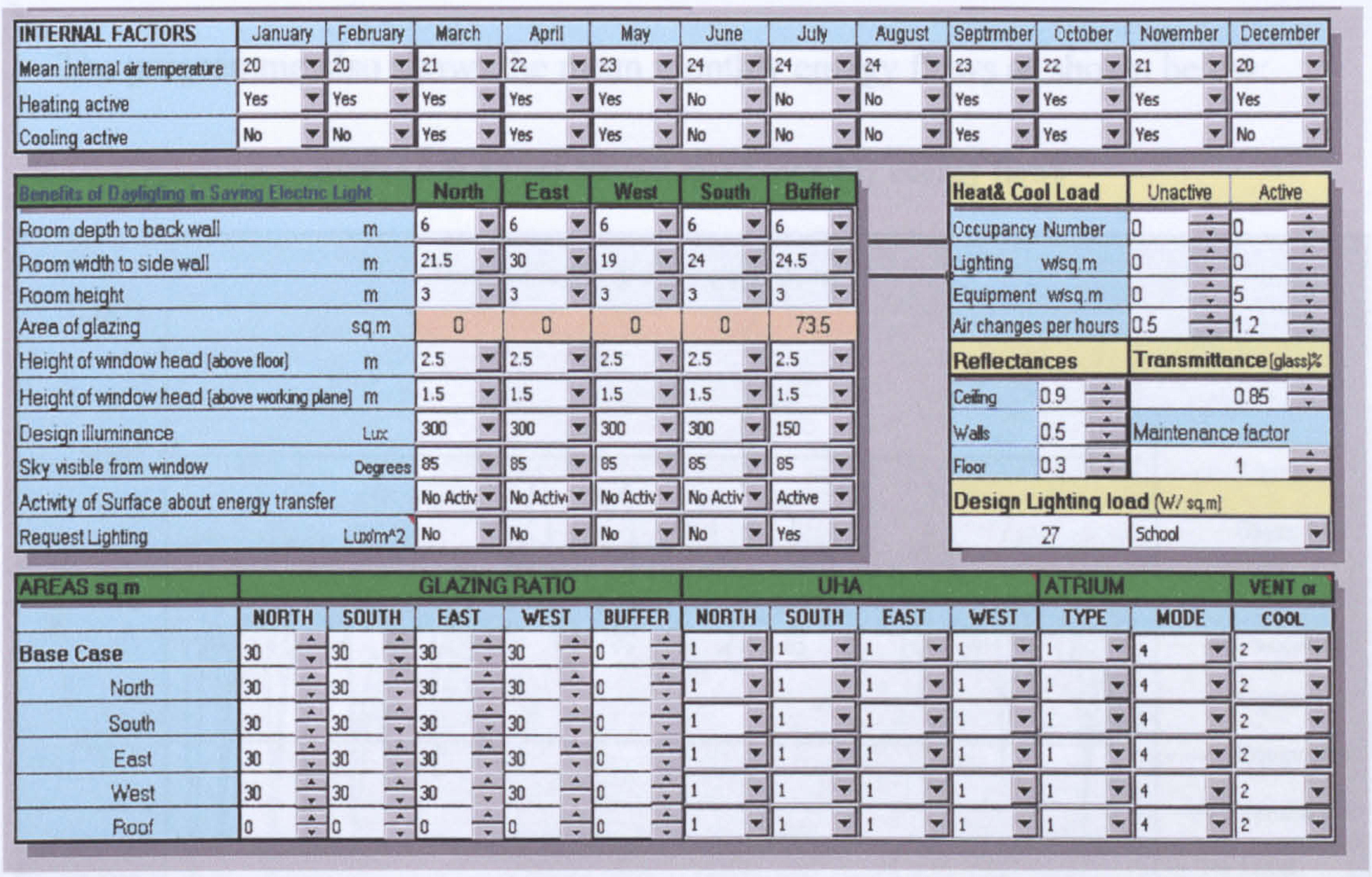


Figure 6.6: Internal variables considered in the programme



INTERNAL FACTORS	January	February	March	April	May	June	July	August	Septrmber	October	November	December
Mean internal air temperature	20	20	21	22	23	24	24	24	23	22	21	20
Heating active	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes
Cooling active	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No

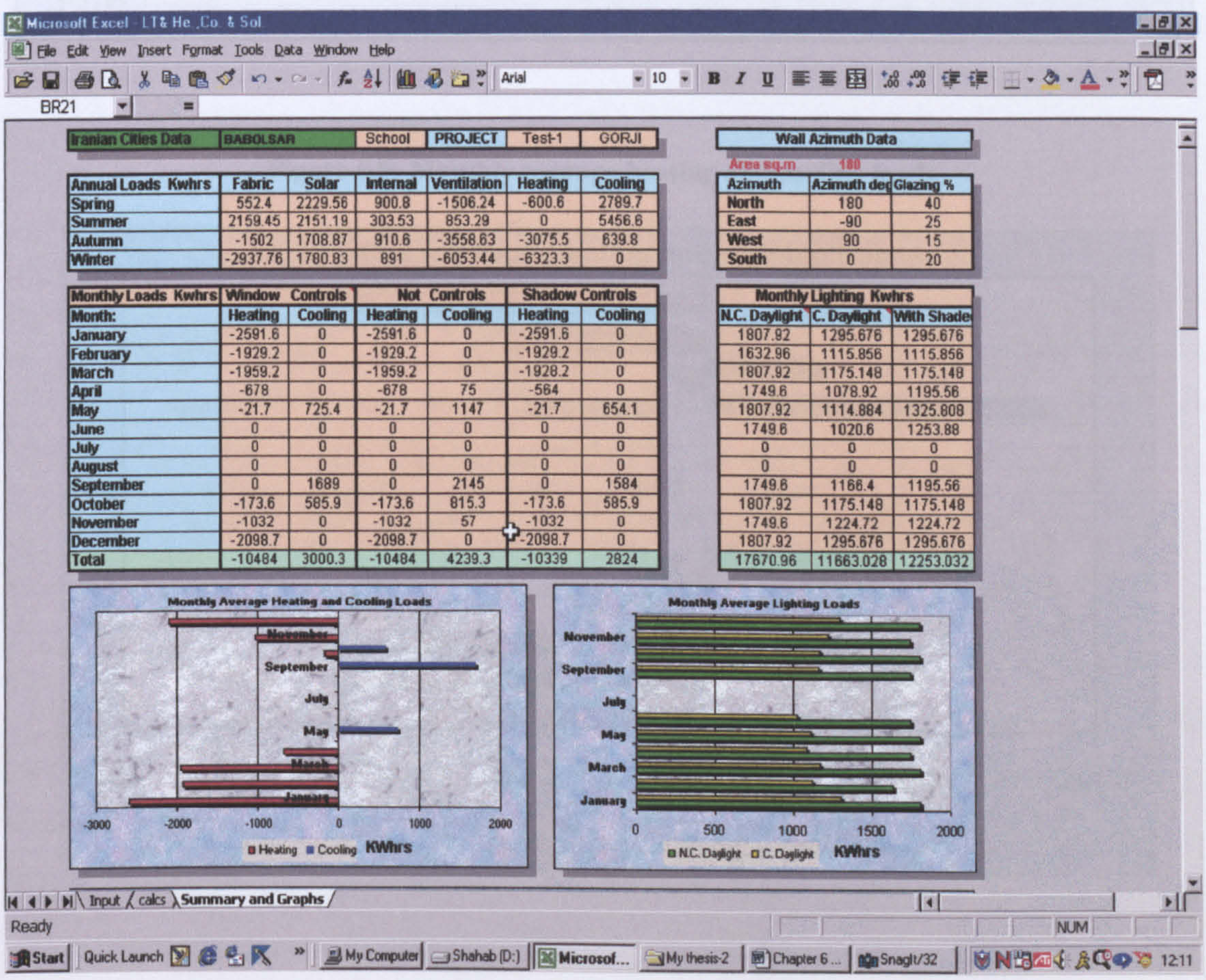
Benefits of Daylighting in Saving Electric Light		North	East	West	South	Buffer
Room depth to back wall	m	6	6	6	6	6
Room width to side wall	m	21.5	30	19	24	24.5
Room height	m	3	3	3	3	3
Area of glazing	sq.m	0	0	0	0	73.5
Height of window head (above floor)	m	2.5	2.5	2.5	2.5	2.5
Height of window head (above working plane)	m	1.5	1.5	1.5	1.5	1.5
Design illuminance	Lux	300	300	300	300	150
Sky visible from window	Degrees	85	85	85	85	85
Activity of Surface about energy transfer		No Activ	No Activ	No Activ	No Activ	Active
Request Lighting	Lux/m^2	No	No	No	No	Yes

Heat& Cool Load	Unactive	Active
Occupancy Number	0	0
Lighting w/sq.m	0	0
Equipment w/sq.m	0	5
Air changes per hours	0.5	1.2

Reflectances		Transmittance (glass)%
Ceiling	0.9	0.85
Walls	0.5	Maintenance factor
Floor	0.3	1
Design Lighting load (W/ sq.m)	27	School

AREAS sq.m	GLAZING RATIO					UHA				ATRIUM		VENT or
	NORTH	SOUTH	EAST	WEST	BUFFER	NORTH	SOUTH	EAST	WEST	TYPE	MODE	COOL
Base Case	30	30	30	30	0	1	1	1	1	1	4	2
North	30	30	30	30	0	1	1	1	1	1	4	2
South	30	30	30	30	0	1	1	1	1	1	4	2
East	30	30	30	30	0	1	1	1	1	1	4	2
West	30	30	30	30	0	1	1	1	1	1	4	2
Roof	0	0	0	0	0	1	1	1	1	1	4	2

Figure 6.7: The output page showing how the energy usage is given tabular and also in graphical form



Iranian Cities Data	BABOLSAR	School	PROJECT	Test-1	GORJI

Annual Loads Kwhrs	Fabric	Solar	Internal	Ventilation	Heating	Cooling
Spring	552.4	2229.56	900.8	-1506.24	-600.6	2789.7
Summer	2159.45	2151.19	303.53	853.29	0	5456.6
Autumn	-1502	1708.87	910.6	-3558.63	-3075.5	639.8
Winter	-2937.76	1780.83	891	-6053.44	-6323.3	0

Wall Azimuth Data

Area sq.m 180

Azimuth	Azimuth deg	Glazing %
North	180	40
East	-90	25
West	90	15
South	0	20

Monthly Loads Kwhrs	Window Controls		Not Controls		Shadow Controls	
Month:	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	-2591.6	0	-2591.6	0	-2591.6	0
February	-1929.2	0	-1929.2	0	-1929.2	0
March	-1959.2	0	-1959.2	0	-1928.2	0
April	-678	0	-678	75	-564	0
May	-21.7	725.4	-21.7	1147	-21.7	654.1
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	1689	0	2145	0	1584
October	-173.6	585.9	-173.6	815.3	-173.6	585.9
November	-1032	0	-1032	57	-1032	0
December	-2098.7	0	-2098.7	0	-2098.7	0
Total	-10484	3000.3	-10484	4239.3	-10339	2824

Monthly Lighting Kwhrs		
N.C. Daylight	C. Daylight	With Shade
1807.92	1295.676	1295.676
1632.96	1115.856	1115.856
1807.92	1175.148	1175.148
1749.6	1078.92	1195.56
1807.92	1114.884	1325.808
1749.6	1020.6	1253.88
0	0	0
0	0	0
1749.6	1166.4	1195.56
1807.92	1175.148	1175.148
1749.6	1224.72	1224.72
1807.92	1295.676	1295.676
17670.96	11663.028	12253.032

6_9 * Graph of Mean Monthly Energy Flows

The programme also shows the mean monthly energy flows as shown below:

Figure 6.8: Shows typical mean monthly energy flows

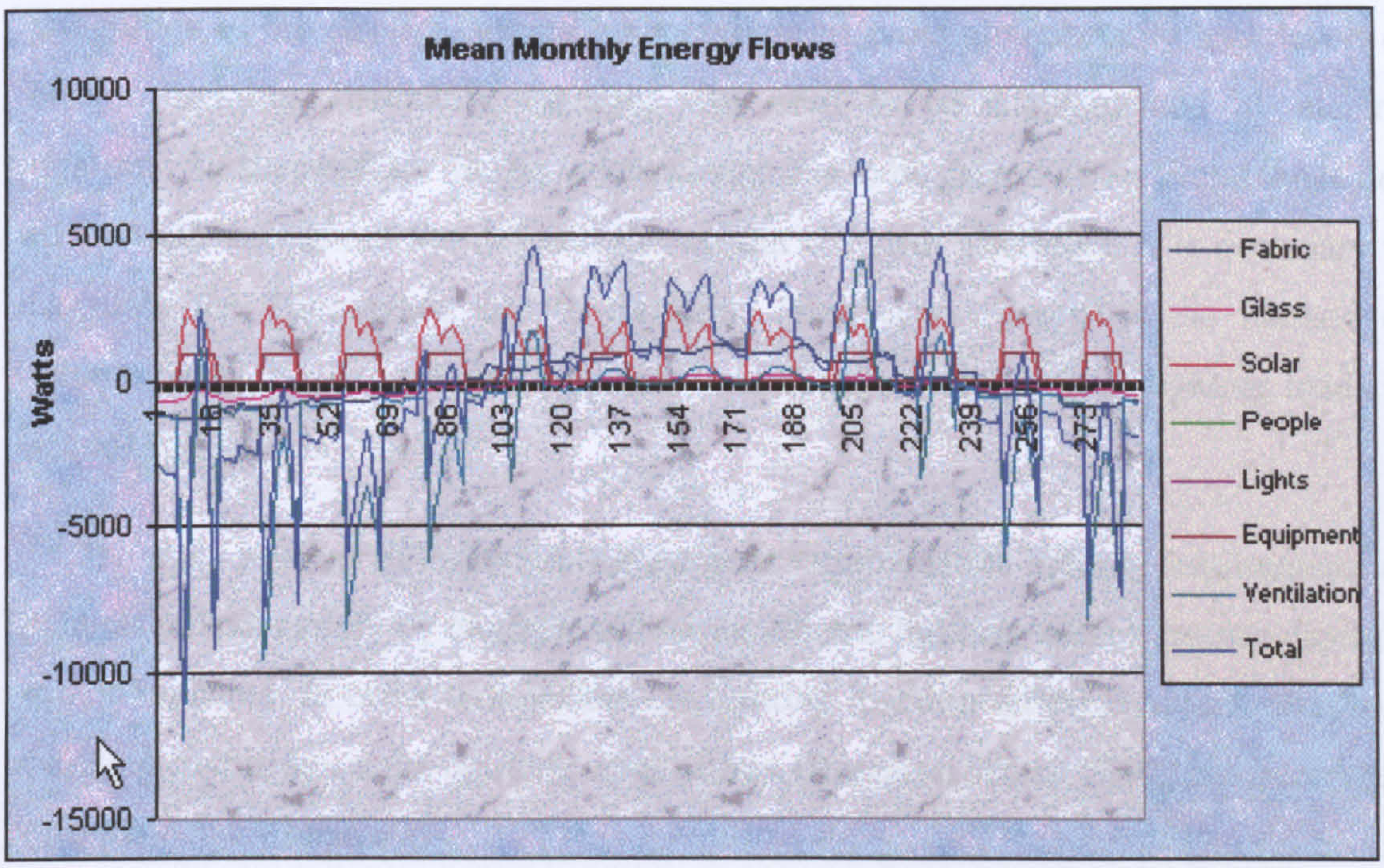
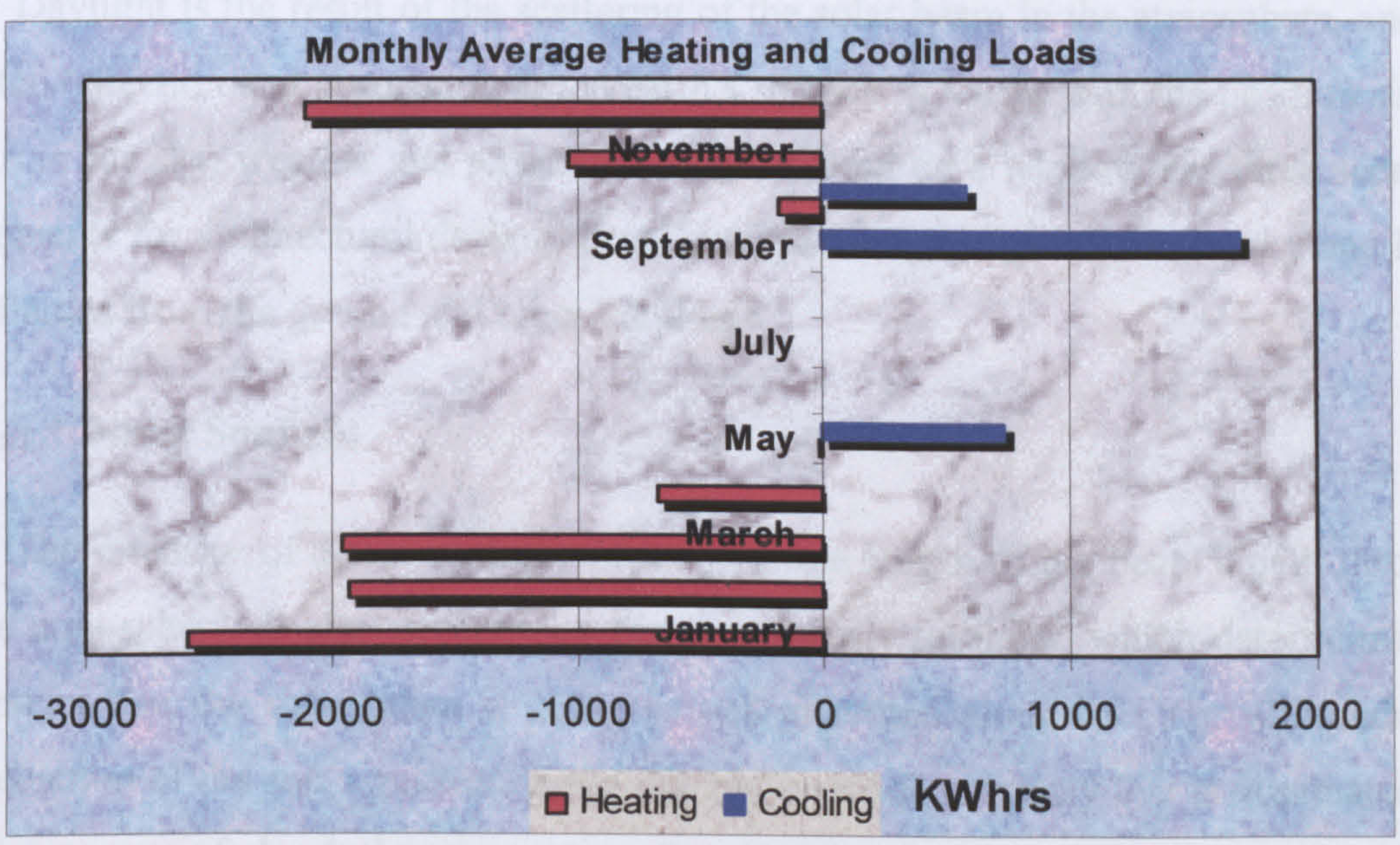


Figure 6.9: Monthly average heating and cooling loads



Section 2: Lighting Programme

6_{10} * Lighting

Key elements in the design of an energy efficient lighting system are the integration of the electric lighting with daylight to avoid unnecessarily high levels of electric lighting. Inevitably, daylight will need to be supplemented by electric lighting. To successfully do this, a knowledge has to be gained of the illuminance due to daylight throughout the day and throughout the year. Therefore, it is necessary to calculate the illuminance due to daylight. This section describes the method of estimation of this illuminance, which is used for the calculation of lighting loads in school buildings in Iran.

The main strategy of lighting programme is to provide the lighting requirements of schools in Iran mainly by daylight and to use electric lighting when adequate daylight is not available. In order to calculate the lighting loads in different spaces of school building in this thesis the building code of Iran (Research centre, 1992) has been used (see table 5.4, Chapter 5)

6_{11} * Daylighting Design

Daylight is the result of the scattering of the solar beam in the atmosphere, and its inter-reflection and absorption at the earth's surface. It varies with the position of the sun in the sky, weather and terrain. The light falling on a window has three separate elements for architectural design; direct sunlight, diffuse light from the sky and light reflected from the ground and other buildings.

$6_{11.1}$ * Direct Sunlight

The intensity of direct sunlight varies with the length of the beam's path through the atmosphere. It also depends on the atmospheric turbidity, which determines the amount that the solar beam is scattered and absorbed along its path. Although the prediction of the sun's position in the sky can be made precisely that is dominated by the presence of cloud, the occurrence of sunlight on the ground can be specified only in terms of frequency distributions (based on meteorological records). The intensity of the sun's beam is given in term of solar illuminance, which shows the amount of light falling on a surface directly facing the sun. The probability of sunlight is expressed by relative sunshine duration, the ratio of actual sunshine hours to the sunshine hours that would occur with cloudless skies. The description of atmospheric turbidity is made by the linke turbidity factor. This factor is the ratio of the optical thickness of a moist turbid atmosphere to that of a clean dry atmosphere, considering total solar radiation (Asimakopoulos, 1996).

$6_{11.2}$ * Diffuse Light from the Sky

As sunlight passes through the atmosphere, a portion is scattered by dust, water vapour and other suspended particles. This scattering, acting in concert with clouds, produces sky luminance. Skies are divided into three categories: clear, partly cloudy and cloudy. When the sky is not completely overcast, the sky luminance distribution may change rapidly and by large amounts as the sun is alternately obscured, partly obscured or fully revealed (Marks, 1993).

$6_{11.3}$ * Reflected Light

Direct sunlight is associated with overheating in hot climates. Therefore, windows are often designed to exclude it and solar control has a major role in the design of buildings in these types of climate. In order to exclude direct sunlight, shading devices can be used on windows. However, the amount of sky visible from the interior will be also reduced and the entry of skylight will be restricted. In such circumstances sunlight reflected from external surfaces, the ground and opposite buildings, can be a major source of diffuse light. It may provide the main daylighting in an interior. In cool climates, when windows are designed for overcast sky conditions, the externally reflected light is usually only a small fraction of the total daylight entering a room. However, sky brightness is affected by ground reflection (Asimakopoulos, 1996). There is significant inter-reflection between ground and clouds with large areas of light-coloured ground surface. Table 6.4 shows typical reflectance of building materials (British Standard, 1992): More information about solar radiation is given in chapter 4.

Table 6.4: Approximate values of reflectance under diffuse daylight (British Standard, 1992)

	Building Materials	Values		Building Materials	Values
Ground	Snow	0.8	Other external material	White glazed tile	0.7
	Sand	0.3		Portland stone	0.6
	Paving	0.2		Medium limestone	0.4
	Earth (dry)	0.2		Concrete	0.4
	Earth (moist)	0.1		Brickwork (buff)	0.3
	Green vegetation	0.1		Brickwork (red)	0.2
Paint colours	White	0.85		Granite	0.2
	Pale cream	0.81		Window glass	0.1
	Light grey	0.68		Tree foliage	0.1
	Strong yellow	0.64	Materials used internally	White paper	0.8
	Mid-grey	0.45		Stainless steel	0.4
	Strong green	0.22		Cement screed	0.4
	Strong red	0.18		Carpet (cream)	0.4
	Strong blue	0.15		Wood (light veneers)	0.4
	Dark grey	0.14		Wood (medium colours)	0.2
	Dark brown	0.10		Wood (dark)	0.1
	Deep red-purple	0.10		Quarry tiles	0.1
	Black	0.05		Window glass	0.1
				Carpet (deep colours)	0.1

6_{12} * Daylight Quantity

The illuminance provided by the daylight can be determined from the following algorithm by the definition of daylight factor (DF) (DfEE, 1999):

$$Lu_i = Lu_e \cdot (DF/100) \cdot O_f \quad \text{Algorithm 6.12}$$

Where: **Lu_i** is interior illuminance (lux), **Lu_e** is exterior illuminance (lux) and **O_f** Orientation factor.

$6_{12.1}$ * Exterior Illuminance

For calculation of exterior illuminance we need to know about luminous efficacy of solar radiation. The luminous efficacy of solar radiation is defined as the ratio between illuminance and irradiance. Thus, if irradiance measurements or calculations are available it is possible to estimate illuminance values using a luminous efficiency (Robledo and Soler, 2001). The luminous efficiency of energy-radiation depends on its spectral composition; there is no constant relationship between radiation intensity and its lighting effect or illuminance. However, as a general guidance, the value of 100 lumens/watt can be used for solar radiation. This would give an illumination of 100 lux for every W/m^2 intensity or 100 000 lux per kW/m^2 (Koenigsberger, et al.

1973, Marks, 1993 and Dr. N Baker, Martin Centre, Cambridge University, private communication).

As discussed in chapter 4,the amount of solar radiation can be calculated for different cities in Iran by using the designed excel sheet programme. Also using the following formula can perform the estimation of hourly or monthly illuminance value:

Solar radiation (W/m^2) x 100 lumens/watt = Illuminance (Lux) Algorithm 6.12

Five cities of Iran located in different climate have been selected and their average exterior illuminance are illustrated in tables 6.5 – 6.9.

Table 6.5: Mean hourly global illuminance values for each month in Babolsar, solar time

Average Exterior Illuminance kLux						Horizontal				BABOLSAR		
Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	2.28	1.20	0	0	0	0	0
6	0	0	0.41	5.31	11.02	14.36	13.38	8.55	1.86	0	0	0
7	0.12	3.67	10.14	17.36	24.68	29.11	28.73	24.48	15.70	6.56	0.80	0
8	9.10	14.34	21.97	29.97	38.61	44.00	44.43	41.61	32.20	20.03	11.06	7.39
9	19.03	24.56	32.86	41.16	50.86	57.12	58.34	57.09	47.64	33.33	21.75	16.84
10	27.29	32.74	41.32	49.75	60.33	67.30	69.16	69.21	59.85	44.05	30.59	24.76
11	32.63	37.92	46.62	55.15	66.33	73.77	76.05	76.92	67.61	50.90	36.30	29.91
12	34.47	39.69	48.43	56.99	68.39	76.00	78.42	79.57	70.28	53.25	38.26	31.68
13	32.63	37.92	46.62	55.15	66.33	73.77	76.05	76.92	67.61	50.90	36.30	29.91
14	27.29	32.74	41.32	49.75	60.33	67.30	69.16	69.21	59.85	44.05	30.59	24.76
15	19.03	24.56	32.86	41.16	50.86	57.12	58.34	57.09	47.64	33.33	21.75	16.84
16	9.10	14.34	21.97	29.97	38.61	44.00	44.43	41.61	32.20	20.03	11.06	7.39
17	0.12	3.67	10.14	17.36	24.68	29.11	28.73	24.48	15.70	6.56	0.80	0
18	0	0	0.41	5.31	11.02	14.36	13.38	8.55	1.86	0	0	0
19	0	0	0	0	0	2.28	1.20	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.6: Mean hourly global illuminance values for each month in Tehran, solar time

Average Exterior Illuminance kLux						Horizontal				TEHRAN MEHRABAD		
Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0.25	1.86	0.86	0	0	0	0	0
6	0	0	0.40	5.18	10.82	14.18	13.24	8.50	1.84	0	0	0
7	0.21	3.98	10.30	17.39	24.75	29.29	29.01	24.96	16.20	6.96	1.04	0
8	9.73	14.80	22.29	30.18	38.98	44.56	45.14	42.62	33.27	20.90	11.74	8.02
9	19.89	25.16	33.33	41.57	51.53	58.03	59.44	58.57	49.19	34.60	22.71	17.68
10	28.31	33.46	41.93	50.34	61.24	68.49	70.57	71.05	61.77	45.62	31.75	25.75
11	33.76	38.72	47.34	55.86	67.39	75.13	77.65	78.99	69.77	52.66	37.58	31.00
12	35.63	40.52	49.18	57.75	69.50	77.42	80.08	81.72	72.51	55.07	39.59	32.81
13	33.76	38.72	47.34	55.86	67.39	75.13	77.65	78.99	69.77	52.66	37.58	31.00
14	28.31	33.46	41.93	50.34	61.24	68.49	70.57	71.05	61.77	45.62	31.75	25.75
15	19.89	25.16	33.33	41.57	51.53	58.03	59.44	58.57	49.19	34.60	22.71	17.68
16	9.73	14.80	22.29	30.18	38.98	44.56	45.14	42.62	33.27	20.90	11.74	8.02
17	0.21	3.98	10.30	17.39	24.75	29.29	29.01	24.96	16.20	6.96	1.04	0
18	0	0	0.40	5.18	10.82	14.18	13.24	8.50	1.84	0	0	0
19	0	0	0	0	0.25	1.86	0.86	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.7: Mean hourly global illuminance values for each month in Yazd, solar time

Average Exterior Illuminance kLux					Horizontal			YAZD			
Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0.00	0.29	0.04	0	0	0	0	0
6	0	0	0.37	4.75	9.83	12.83	12.00	7.77	1.71	0	0	0
7	1.03	5.18	11.01	17.46	24.28	28.50	28.37	24.96	17.01	8.25	2.32	0
8	12.07	16.68	23.62	30.84	39.15	44.47	45.26	43.52	35.08	23.24	14.13	10.39
9	22.97	27.63	35.20	42.77	52.31	58.60	60.26	60.28	51.88	37.78	25.88	20.79
10	31.91	36.34	44.20	51.95	62.48	69.56	71.94	73.39	65.11	49.41	35.47	29.38
11	37.65	41.85	49.85	57.73	68.93	76.53	79.36	81.73	73.53	56.82	41.62	34.92
12	39.62	43.73	51.78	59.70	71.15	78.92	81.92	84.60	76.42	59.36	43.72	36.82
13	37.65	41.85	49.85	57.73	68.93	76.53	79.36	81.73	73.53	56.82	41.62	34.92
14	31.91	36.34	44.20	51.95	62.48	69.56	71.94	73.39	65.11	49.41	35.47	29.38
15	22.97	27.63	35.20	42.77	52.31	58.60	60.26	60.28	51.88	37.78	25.88	20.79
16	12.07	16.68	23.62	30.84	39.15	44.47	45.26	43.52	35.08	23.24	14.13	10.39
17	1.03	5.18	11.01	17.46	24.28	28.50	28.37	24.96	17.01	8.25	2.32	0
18	0	0	0.37	4.75	9.83	12.83	12.00	7.77	1.71	0	0	0
19	0	0	0	0	0.00	0.29	0.04	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.8: Mean hourly global illuminance values for each month in Mashhad, solar time

Average Exterior Illuminance kLux					Horizontal			MASHHAD			
Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0.35	2.10	1.05	0	0	0	0	0
6	0	0	0.41	5.25	10.96	14.35	13.39	8.58	1.86	0	0	0
7	0.15	3.80	10.19	17.37	24.79	29.33	29.02	24.86	16.02	6.75	0.90	0
8	9.37	14.51	22.08	30.06	38.88	44.46	44.99	42.34	32.88	20.50	11.37	7.66
9	19.40	24.78	33.03	41.35	51.32	57.80	59.15	58.12	48.62	34.02	22.19	17.20
10	27.74	33.01	41.57	50.05	60.93	68.15	70.16	70.46	61.06	44.92	31.14	25.18
11	33.13	38.23	46.93	55.52	67.02	74.73	77.17	78.31	68.97	51.89	36.91	30.38
12	34.99	40.01	48.76	57.39	69.11	76.99	79.57	81.01	71.69	54.28	38.90	32.17
13	33.13	38.23	46.93	55.52	67.02	74.73	77.17	78.31	68.97	51.89	36.91	30.38
14	27.74	33.01	41.57	50.05	60.93	68.15	70.16	70.46	61.06	44.92	31.14	25.18
15	19.40	24.78	33.03	41.35	51.32	57.80	59.15	58.12	48.62	34.02	22.19	17.20
16	9.37	14.51	22.08	30.06	38.88	44.46	44.99	42.34	32.88	20.50	11.37	7.66
17	0.15	3.80	10.19	17.37	24.79	29.33	29.02	24.86	16.02	6.75	0.90	0
18	0	0	0.41	5.25	10.96	14.35	13.39	8.58	1.86	0	0	0
19	0	0	0	0	0.35	2.10	1.05	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Table 6.9: Mean hourly global illuminance values for each month in Isfahan, solar time

Average Exterior Illuminance kLux					Horizontal			ISFAHAN			
Hours	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0.59	0.13	0	0	0	0	0
6	0	0	0.38	4.84	10.05	13.16	12.32	7.96	1.74	0	0	0
7	0.79	4.93	10.85	17.45	24.44	28.79	28.66	25.12	16.95	8.01	2.02	0
8	11.59	16.27	23.33	30.72	39.24	44.69	45.47	43.60	34.92	22.85	13.66	9.89
9	22.35	27.11	34.81	42.56	52.32	58.75	60.40	60.29	51.62	37.28	25.27	20.15
10	31.20	35.74	43.75	51.69	62.44	69.66	72.02	73.34	64.79	48.84	34.77	28.65
11	36.89	41.21	49.37	57.44	68.85	76.59	79.41	81.64	73.17	56.21	40.87	34.13
12	38.84	43.07	51.29	59.40	71.05	78.97	81.95	84.49	76.04	58.73	42.97	36.02
13	36.89	41.21	49.37	57.44	68.85	76.59	79.41	81.64	73.17	56.21	40.87	34.13
14	31.20	35.74	43.75	51.69	62.44	69.66	72.02	73.34	64.79	48.84	34.77	28.65
15	22.35	27.11	34.81	42.56	52.32	58.75	60.40	60.29	51.62	37.28	25.27	20.15
16	11.59	16.27	23.33	30.72	39.24	44.69	45.47	43.60	34.92	22.85	13.66	9.89
17	0.79	4.93	10.85	17.45	24.44	28.79	28.66	25.12	16.95	8.01	2.02	0
18	0	0	0.38	4.84	10.05	13.16	12.32	7.96	1.74	0	0	0
19	0	0	0	0	0	0.59	0.13	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

6.12.2 * Orientation Factor

The reason for the introduction of window orientation factor is that even with overcast skies, there is a considerable variation in luminance (the southern sky having the greatest effect). Table 6.10 gives values of orientation factor (DfEE, 1999):

Table 6.10: Window orientation factors for calculation of interior illuminance (DfEE, 1999)

Orientation of window	Orientation factor
North	0.97
East	1.15
West	1.21
South	1.55

6.12.3 * Daylight Factor

Average daylight factor is the process, which takes place as the human visual system adjusts itself to the brightness or the colour of the visual field (Saxon, 1997). The average daylight factor can be estimated from the following formula (DfEE, 1999):

$$\bar{DF} = (T\,W\,\theta) / A(1-R^2) \qquad \text{Algorithm 6.13}$$

Where: $\bar{DF}$ is average daylight factor (%), **T** is diffuse transmittance of glazing material including effects of dirt. Typical transmittance values for clean, clear single and double-glazing are 0.8 and 0.65 respectively. For the value T, the glass transmittance will need to be multiplied by a factor to take account of dirt on the glass (see table 6.6), **W** is net glazed area of window (m^2), θ is angle in degrees subtended, in the vertical plane normal to the window, by sky visible from the centre of the window (see figure 6.10), **A** is total area of interior surfaces including windows (m^2), and **R** is area-weighted average reflectance of interior surfaces, including windows (see table 6.4).

An example of the input page (daylight factor excel sheet programme, which has been developed in the main excel sheet programme) is given figure 6.11 and shows the variables, which are considered.

Table 6.11: Correction factors to transmittance values for dirt on glass (DfEE, 1999)

Type of location	Vertical glazing	Sloping glazing	Horizontal glazing
Clean	0.9	0.8	0.7
Industrial	0.7	0.6	0.5
Vertical	0.6	0.5	0.4

Figure 6.10: Angle of θ, which defines visible sky from centre of window/rooflight

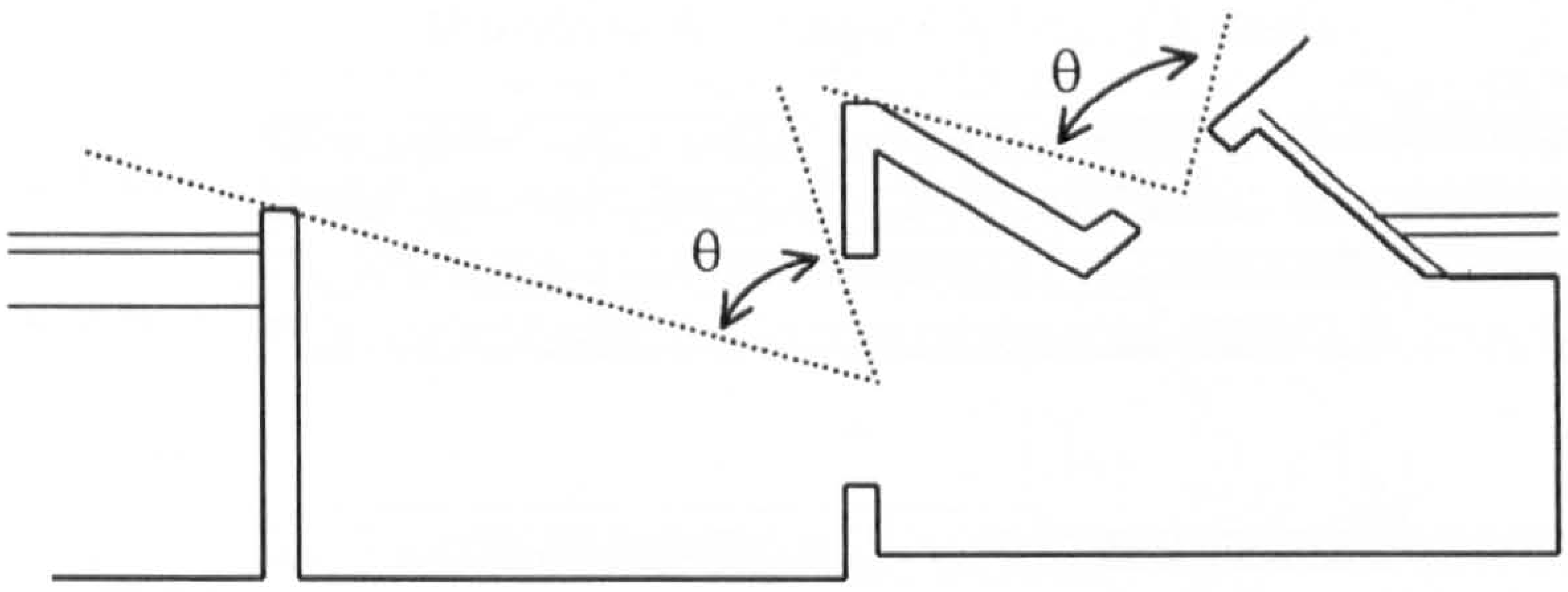
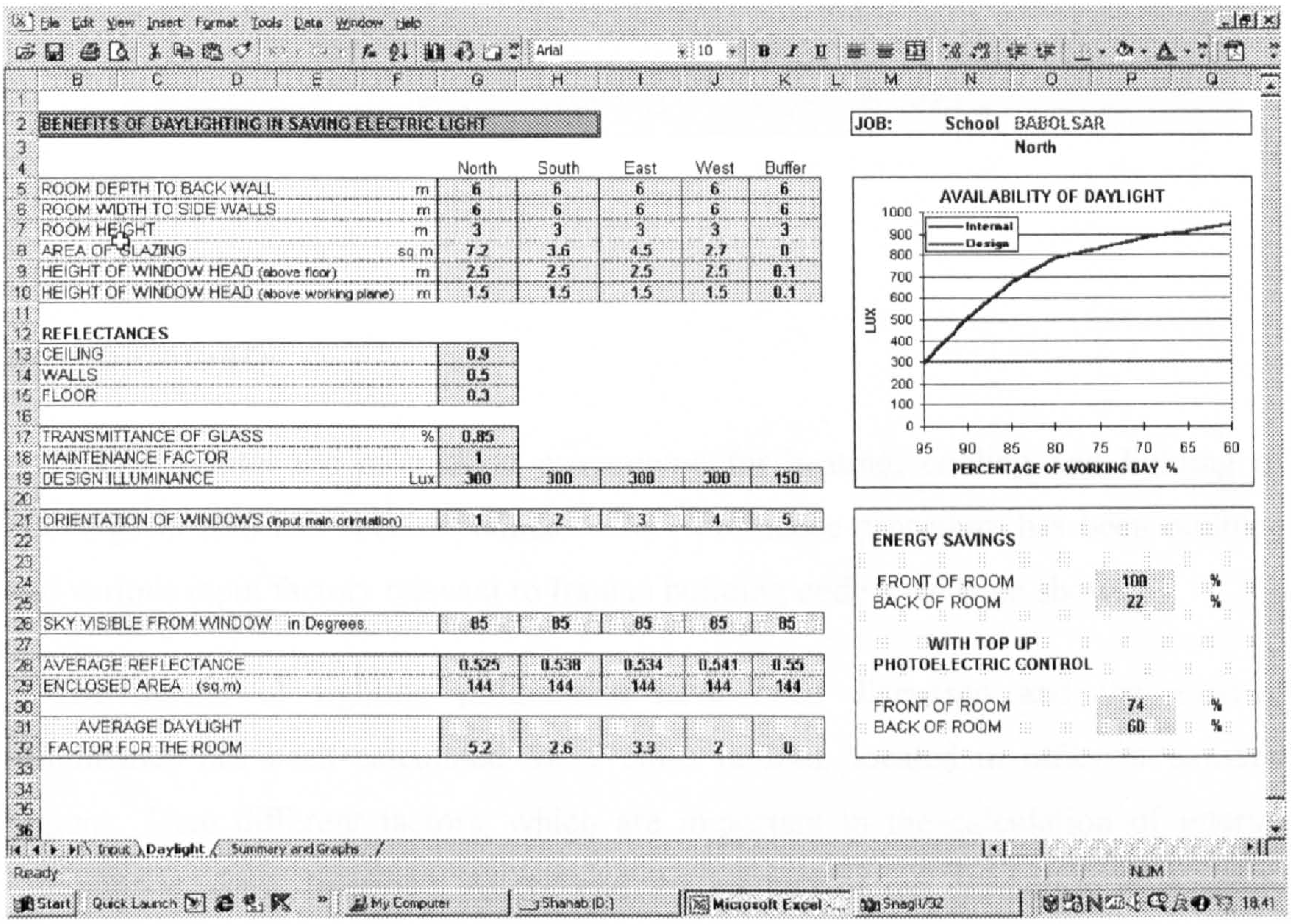


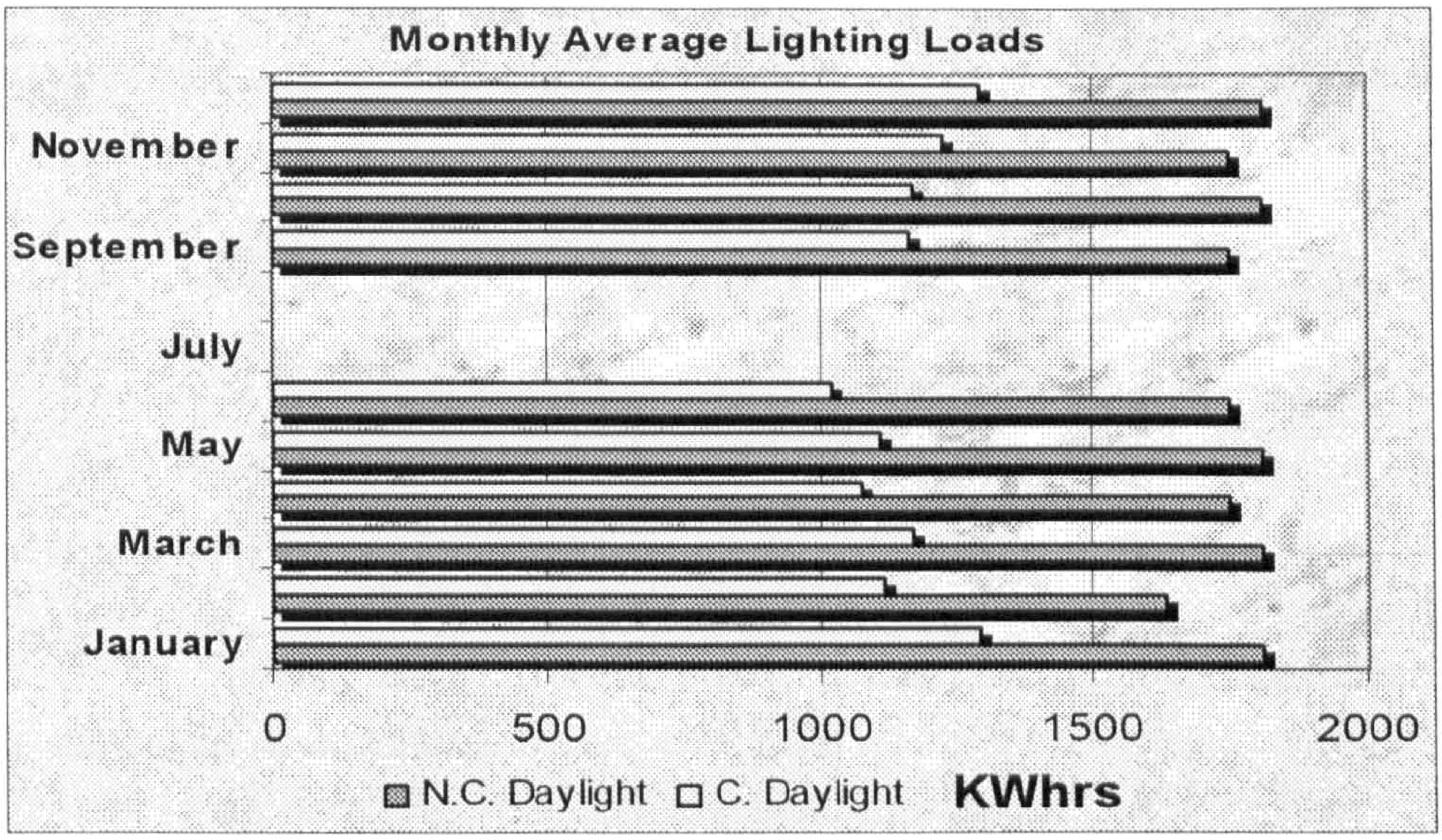
Figure 6.11: The calculation page of the daylighting analysis programme



6₁₃ * Output

This lighting programme enables the calculation of the period of time during the school day in which adequate daylight is available and from this information it is then possible to establish how much electric lighting is required during periods when adequate daylight is not available (These values are shown in Figure 6.12 and Figure 6.7). This electrical energy requirement is then used in the main Excel spreadsheet as the input for artificial lighting requirement.

Figure 6.12: Monthly average lighting loads



6_{14} * Summary

In this chapter the calculation programme for heating, cooling and lighting of buildings in Iran has been explained. The Admittance procedure has been outlined and various input factors relevant to Iranian building code have been shown.

The details of lighting programme have been discussed and the exterior illuminance has been calculated for 5 cities in Iran, located in different climatic regions. Then different factors, which are important in the calculation of interior illuminance, were described. At the end the method of the estimation of monthly lighting loads has been outlined.

Some examples of input and output of this programme has been shown as tables and figures.

The following chapters make use of this programme to calculate the heating, cooling and lighting energy use of schools in Iran.

6_{15} * Reference

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Web site 1, Http://www.esru.strath.ac.uk/

Chapter 7

The Effect of Window Design on the Thermal Performance of Buildings

7 * The Effect of Window Design on the Thermal Performance of Buildings

7₁ * Introduction

The type of window in a building has a considerable effect on its thermal and visual performance, construction and operating costs. Currently the role of window design in energy conservation is an area in which much research is being carried out.

Windows have an essential role in creating a balanced indoor environment in hot dry climates. The design practice of the moderate climates with large area of glazing has been chosen in contemporary designed buildings. This will increase the cooling load in air-conditioned buildings, and overheating problems in uncontrolled buildings.

The window has to be not only energy efficient, but also has to take other purposes such as daylight, privacy and view into account. Windows are the most practical method of providing fresh air, which is required for an inhabitable environment. Also, windows are used to create beauty to the façade of buildings.

There are large ranges of window systems, which can reduce the energy requirement of buildings and improve the energy balance of windows. There are two types of window systems. The first type is composed of some treatment of the glass itself, which might consist of reflective and absorptive films or application of multi-layer glazing such as double-glazing. The second type consists of opaque solar barriers and insulation, which may decrease the transfer of energy (Mckennan, 1984).

Although special glasses such as heat reflecting or heat absorbing glasses can reduce the heat transfer through windows, however they are expensive and affect the view and reduce the amount of daylight entering, and are not commonly used in school buildings. External shading devices are examples of opaque solar barriers, which are more practical in school buildings.

To quantify the effect of window design on energy use and the cost of controlling buildings, the excel program developed in chapter 4 and 6 was used to compare the effect of glazing area, orientation and shading. This special program has been developed for the calculation of solar radiation, heating, cooling and lighting of building in 152 cities of Iran. In this chapter the city of Yazd has been chosen and studied in detail.

7_2 * The Heat Transfer of Window in buildings

As will be discussed later, one variable that has an important influence upon the thermal performance of windows is the angle of incidence determined by the position of the sun relative to the Window. Therefore, the sun's position during the course of the year needs to be known.

$7_{2.1}$ * The Sun-Surface Geometry

The sun's position at any point on the earth's surface is defined by the altitude angle of the sun and its azimuth angle usually measured from the north. If the latitude of the site is known then these two angles are given by the following relationships:

$7_{2.1.1}$ * Solar Altitude (γ)

Solar altitude is the angle between the centre of the solar disc and the horizontal plane. For computation at the hourly level it is economical to calculate daily values of ($\sin\phi \cos\delta$) first because their values remain constant for the day, and then to retain the values for consequent calculation hour at different values of ω.

$\sin\gamma = \sin\phi \sin\delta + \cos\phi \cos\delta \cos\omega$ degrees Algorithm 7.1

- ϕ = Latitude of the site (N +ve, S -ve). degrees
- δ = Declination angle of the sun with respect to earth's equator. degrees
- ω = Solar hour angle. Degrees

$7_{2.1.2}$ * Solar Azimuth (ψ)

In the northern hemisphere the solar azimuth angle is between the vertical plane containing the direction of the sun, and the vertical plane running true north- south measured from south. The azimuth angle has a positive value when the sun is to the west of south i.e. during the afternoon in solar time. It has a negative value when the sun is east of south. For the southern hemisphere the reference direction is true north. The sun's position is often described as a bearing from true north, and this is sometimes incorrectly referred to as the solar azimuth angle. It is important to adopt the correct definition in using the algorithms below:

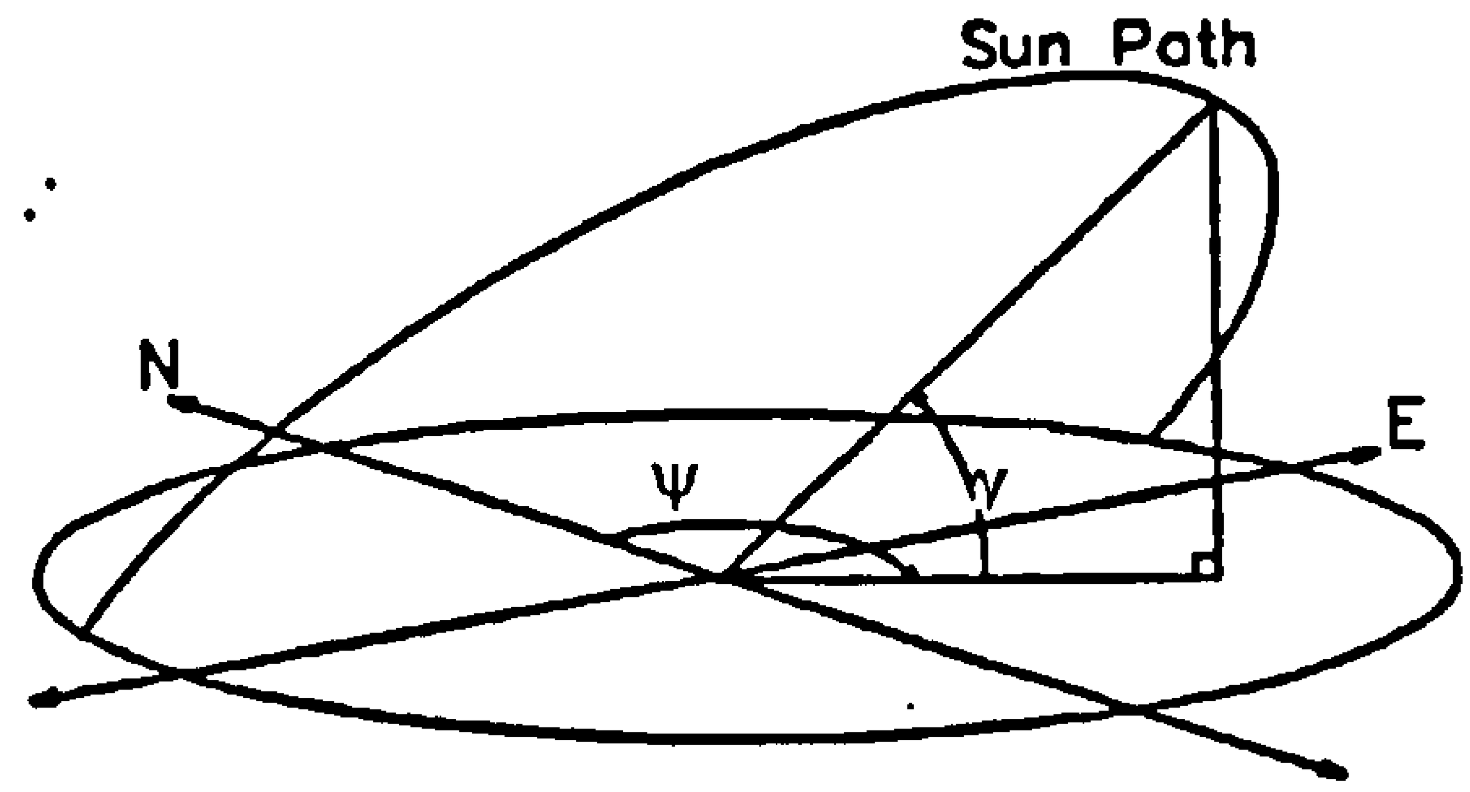
$\text{Cos}\ \psi = (\sin\phi \sin\gamma - \sin\delta) / \cos\phi \cos\gamma$ degrees Algorithm 7.2

$\text{Sin}\ \psi = \cos\delta\ \sin\omega\ /\ \cos\gamma$ degrees Algorithm 7.3

- If $\sin\psi < 0$ $-\cos\psi = \cos\psi$ If $\sin\psi > 0$ $\cos\psi = \cos\psi$

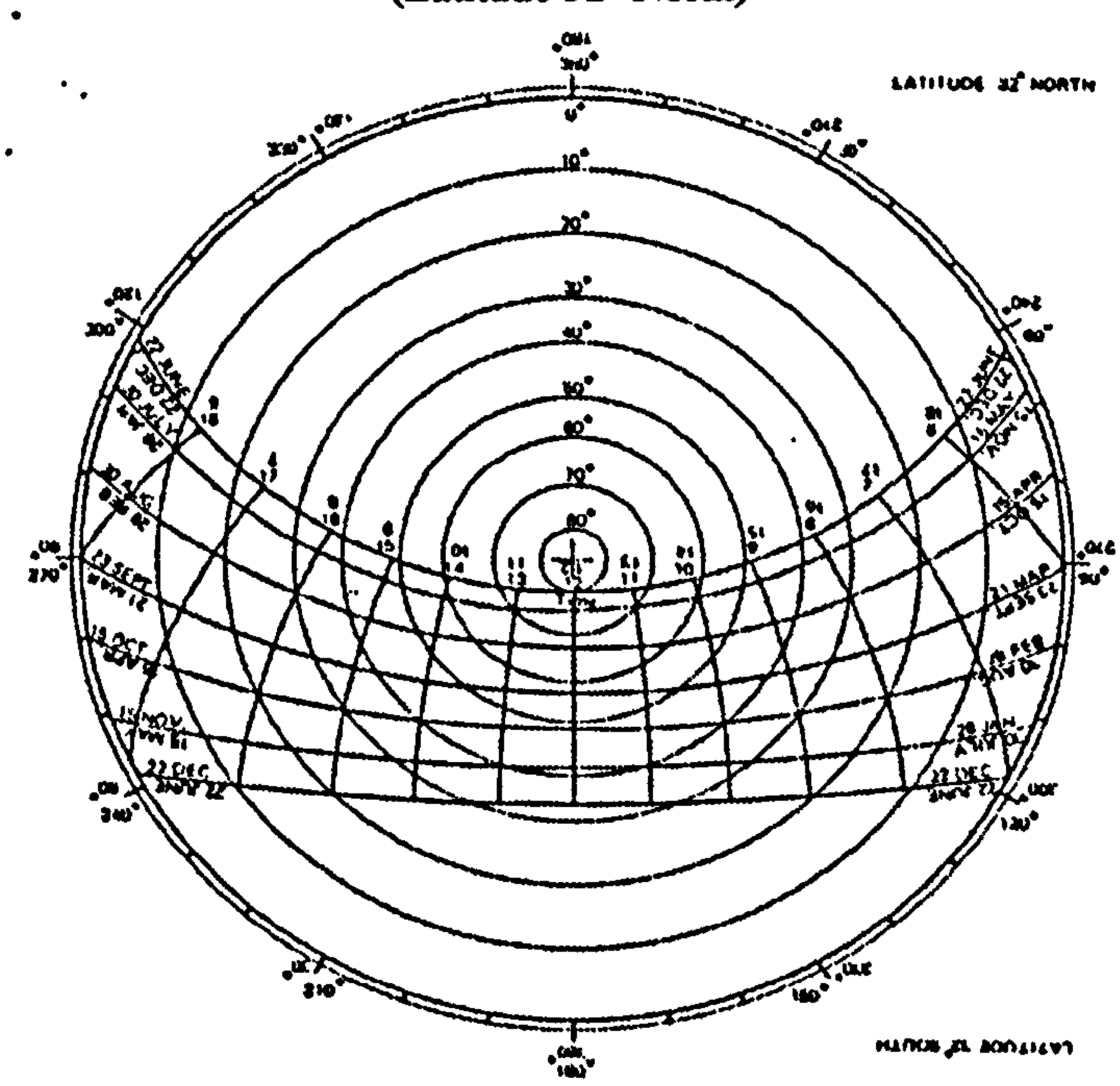
Figure 7.1 illustrates these angles. For different time of day and year, these angles can be found from various almanacs, can be calculated from astronomical equations or may be determined from solar charts.

Figure 7.1: Solar positions the azimuth is denoted by (ψ) and the altitude by (γ) (Source: Koenigsberger, et al. 1973)



Solar charts are arranged in a from which it is possible to read off solar altitude and azimuth angles to an accuracy sufficient for design purposes for different latitudes (Richards, 1978). In this form, they are helpful also in enabling one to visualise the extent of the apparent daily sweep of the sun across the sky. The solar chart corresponding to the site in question in this study, i.e. latitude 32° N, is shown in figure 7.2.

Figure 7.2: Solar chart of the city of Yazd (Source: Koenigsberger, et al. 1973) (Latitude 32° North)



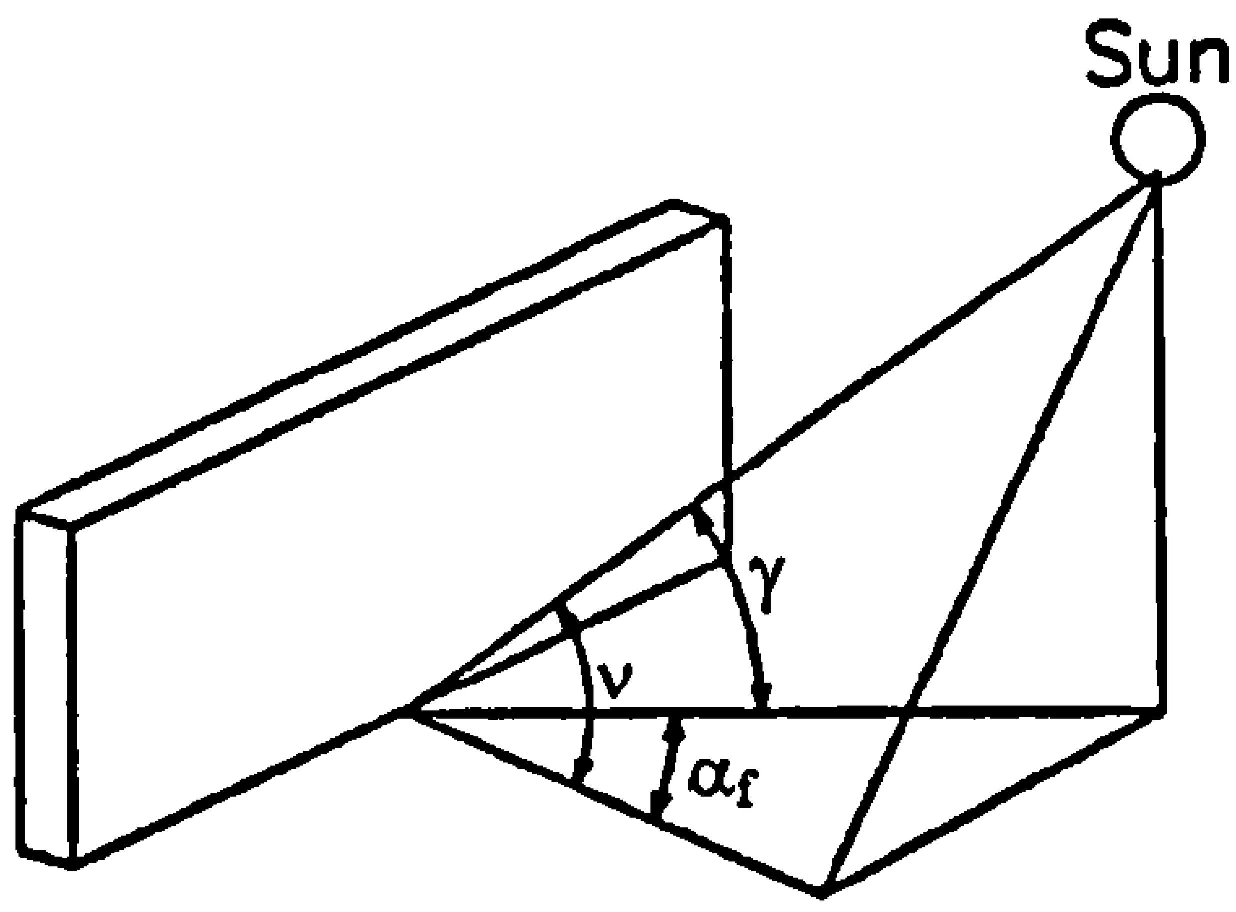
7.2.1.3 * Angle of Incidence of Solar Beam on Surface

The sun's position in relation to a surface can be determined from the solar altitude and azimuth angles. From figure 7.3, the horizontal component of the angle of incidence (α_f) will be the difference between the solar azimuth (ψ) and the wall azimuth (α). The wall azimuth, which determines the wall orientation, corresponds to the angle on the horizontal plane between true north and the line normal to the wall. Therefore for a wall facing west for example, the azimuth is 270 degrees. The vertical component is the same as solar altitude (γ). The angle of incidence (ν), i.e. the angle between a line perpendicular to the wall and the sun's direction, can be found by the following equation (for more information see Appendix B):

$$\text{Cos}\, \nu = \text{Cos}\, \gamma * \text{Cos}\, \alpha_f \qquad \text{Algorithm 7.4}$$

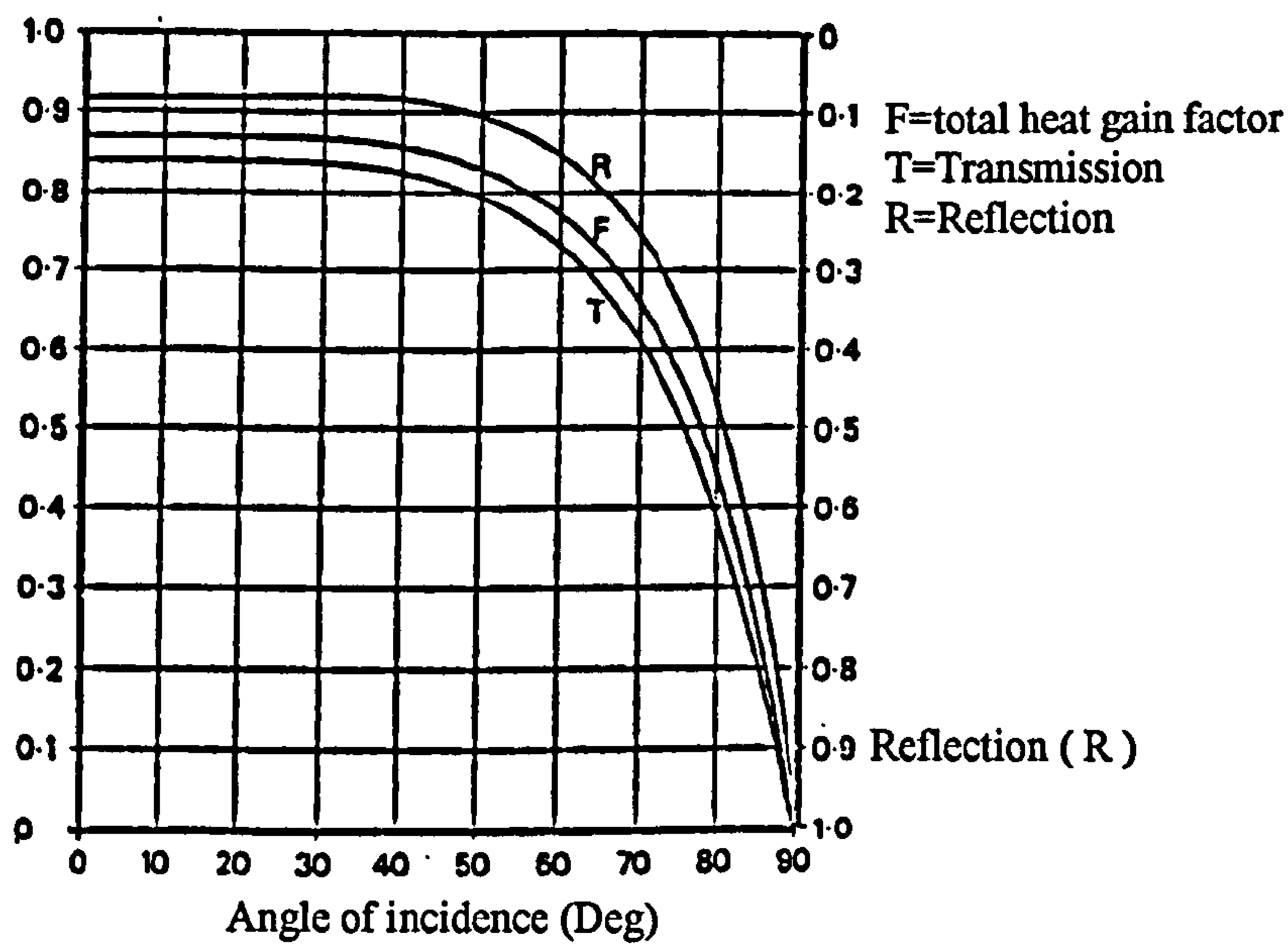
In the case of transparent material, e.g. glass, the proportion of energy directly transmitted through it, depends on the angle of incidence of the incoming radiation. As the angle of incidence increases, penetration through the glass drops off sharply.

Figure 7.3: The angle of incidence (ν) (Razjouyan, 1987)



As it can be seen from figure 7.4 the proportion of the energy transmitted through clear float glass changes little within angles of incidence from zero to 40 degrees, and then starts to decrease rapidly as the angle of incidence increases towards 90 degrees. This feature is helpful, as it reduces solar gain in summer when the sun is at high altitudes. Total heat gain factor is the fraction of the incident radiation that is transferred through the glass by direct transmission and by the inward release of absorbed energy (Figure 7.4). The relative proportion of reflected, absorbed and transmitted radiation for normal incidence is shown in figure 7.5.

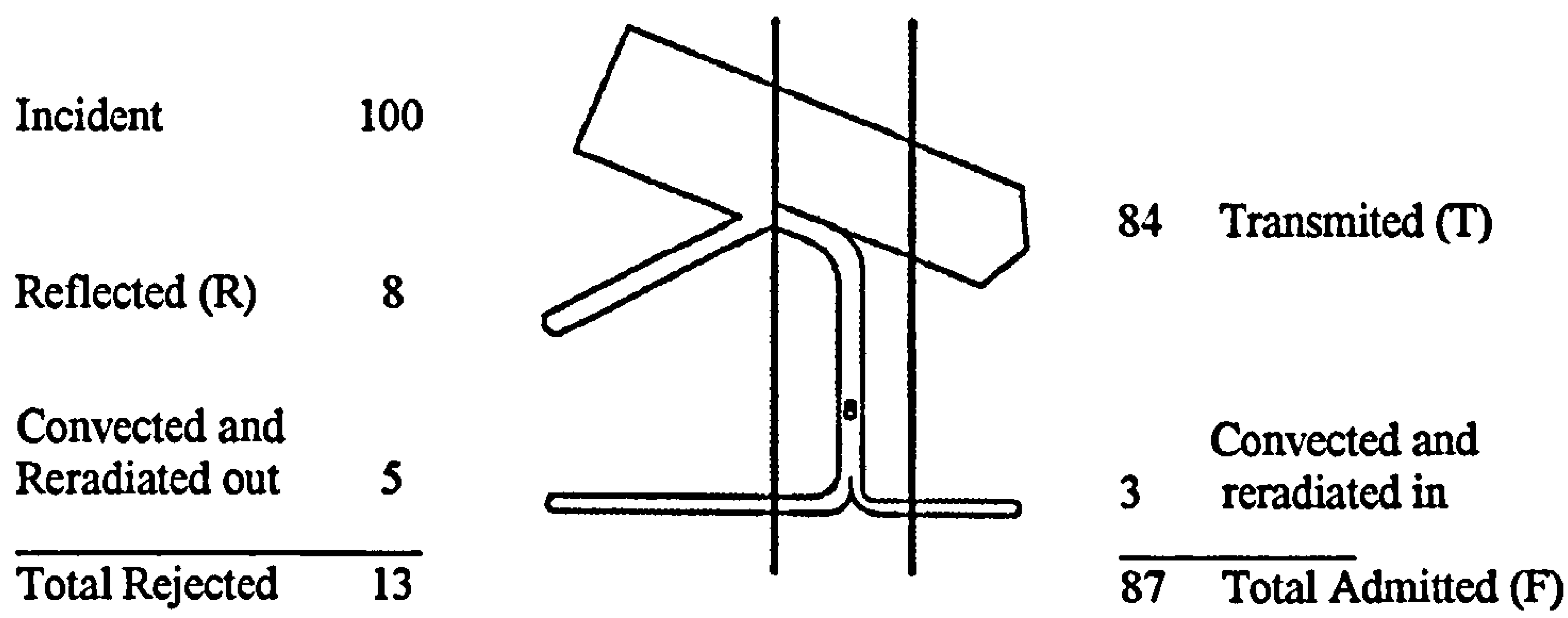
Figure 7.4: Transmission qualities of 4mm clear float glass (Koenigsberger, et al. 1973)



7.2.2 * Thermal Properties of Glass

When solar radiation meets the glass, a fraction of it passes directly through the glass, a fraction is reflected back into the atmosphere, and the remainder is absorbed (Figure 7.5). The angle of incidence of the incoming radiation and the spectral properties of the glass determine the relative proportions of these three components.

Figure 7.5: Relative proportion of reflected, absorbed and transmitted radiation for 4mm clear float glass for normal incidence (Givoni, 1969)



The solar energy absorbed by the glass provokes an increase in glass temperature until equilibrium is reached between the rate of heat absorption by the glass and the rate of heat dissipation from the glass by convection and radiation, both into the room and to the outdoors. The heat storage in the glass remains constant at equilibrium.

The differential transparency to short wave and long-wave radiation is the distinctive characteristic of glass. Glass transmits most of the radiation in the range

0.4 – 2.5 microns, which approximately coincides with the range of the solar spectrum. It is opaque to radiation of longer wavelength 10 microns (Givoni, 1969).

Therefore, the transmission of radiation by glass take place by a selective way, permitting solar radiation to penetrate into the buildings to be absorbed by the internal surfaces and objects and to increase their temperature. But the heated surfaces emit radiation at peak intensity with a wavelength of about 10 microns and this radiation cannot be transmitted outwards through the glass owing to its opaqueness to this wavelength. This event is called the 'green house' effect.

In different type of glasses the absolute and relative transmittance of light and heat are different. Glasses, which are used in the building industry, are divided into different types, based on their spectral transmission, absorption and reflection characteristics. The main types are divided into clear, heat absorbing and heat reflective glasses. The first type is the most common in school buildings in Iran.

Heat absorbing glasses absorb a large percentage of the incident solar radiation since they contain a higher proportion of iron oxide. This causes a considerable rise of the temperature of the glass. In practice the high temperatures reached by these glasses exposed to sunlight can in be a serious cause of discomfort to the occupants as a result of the effects of directional long-wave radiation from the glass (Van Straaten, 1964).

Heat-reflecting glasses are made by the deposition of a very thin metallic coating on the surface of the glass, which reflects selectively a larger proportion of solar radiation. While reflective glasses can be of considerable advantage during the cooling season, they reduce the transmission of solar heat in winter, when the heat would be desirable for distribution within the buildings.

7_3 * Performance Analysis of External Shading Devices

Shading is one of the most important parameters for achieving good climatic condition in building in countries with hot dry climates (Shaviv, 1984). Solar heat gain through windows is a major factor in increasing cooling loads in temperature controlled buildings and has a considerable impact on the rise of the indoor air temperature and overheating in free-floated buildings. To decrease the effect of solar heat, shaded structures and protected windows should be considered.

In the early stage of design the protection of structures against solar radiation should be examined. Planners should consider the provision of desirable shading in summer while allowing individual buildings to benefit from solar radiation in winter. Architects should give more attention to this issue when examining sitting, orientation, external features of buildings etc., otherwise, the extent of direct sunlight penetration may only be realised after the construction of a building is completed.

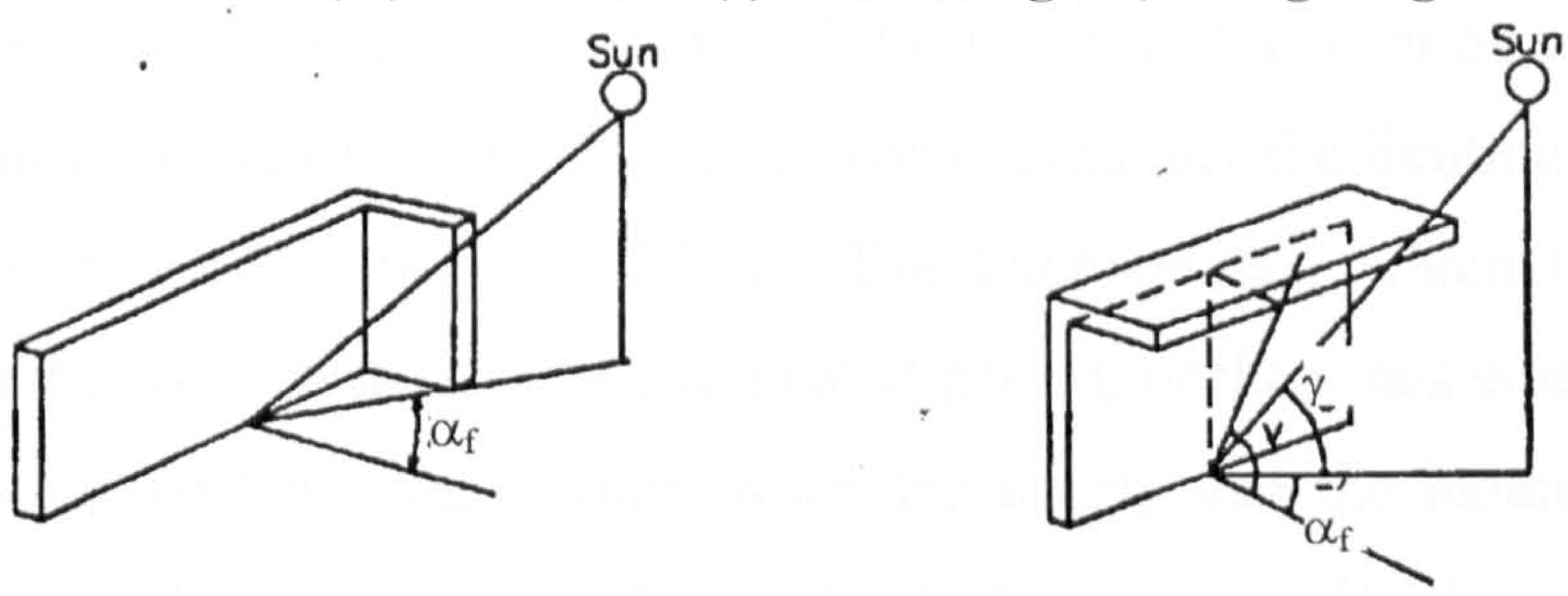
Shading the glass affects the quantity of incident radiation. Therefore it modifies the heat flow to the interior and eventually the indoor temperatures. The quantitative modification depends on the size and location of the shading with respects to the internal or external glass. When shading catches radiation outside the glass, the temperature of the device increases due to the absorption of radiation by the shading material. Because glass is opaque to long-wave radiation, heat flow by convection and radiation from the shade has minimum effect on the glass. Therefore, only a small fraction of the incident radiation reflected inwards by the shade might penetrate externally shaded glazed areas.

When internal shading, for example Venetian blinds are used, solar radiation is transmitted through the glass before interception. The radiation absorbed into the shading material is re-released to the interior. Nearly all of this heat remains within the space as the opaqueness of the glass prevents long-wave radiative heat dissipation. Only the radiation reflected outwards from the shading at the original wavelengths is transmitted partly to the exterior, which has no effect on internal heat. Therefore, the effectiveness of internal shading devices is limited to the extent to which short-wave radiation is reflected back through the glass. It is much less effective than the external shades in limiting heat admittance.

Most fixed shading systems are less efficient than controllable shading systems. For example, fixed shading devices may unnecessarily decrease the quantity of daylight indoors even when the sun is not shading on them. Consequently, more electrical light may have to be used than with adjustable or operable shades. Fixed shading devices can contribute to the heating system by obstructing the welcome radiation in cooler periods of the year. According to the capital and maintenance cost controllable shading systems are usually more expensive. This study is limited to the effects of fixed external shading devices, since they are the most feasible devices in practice.

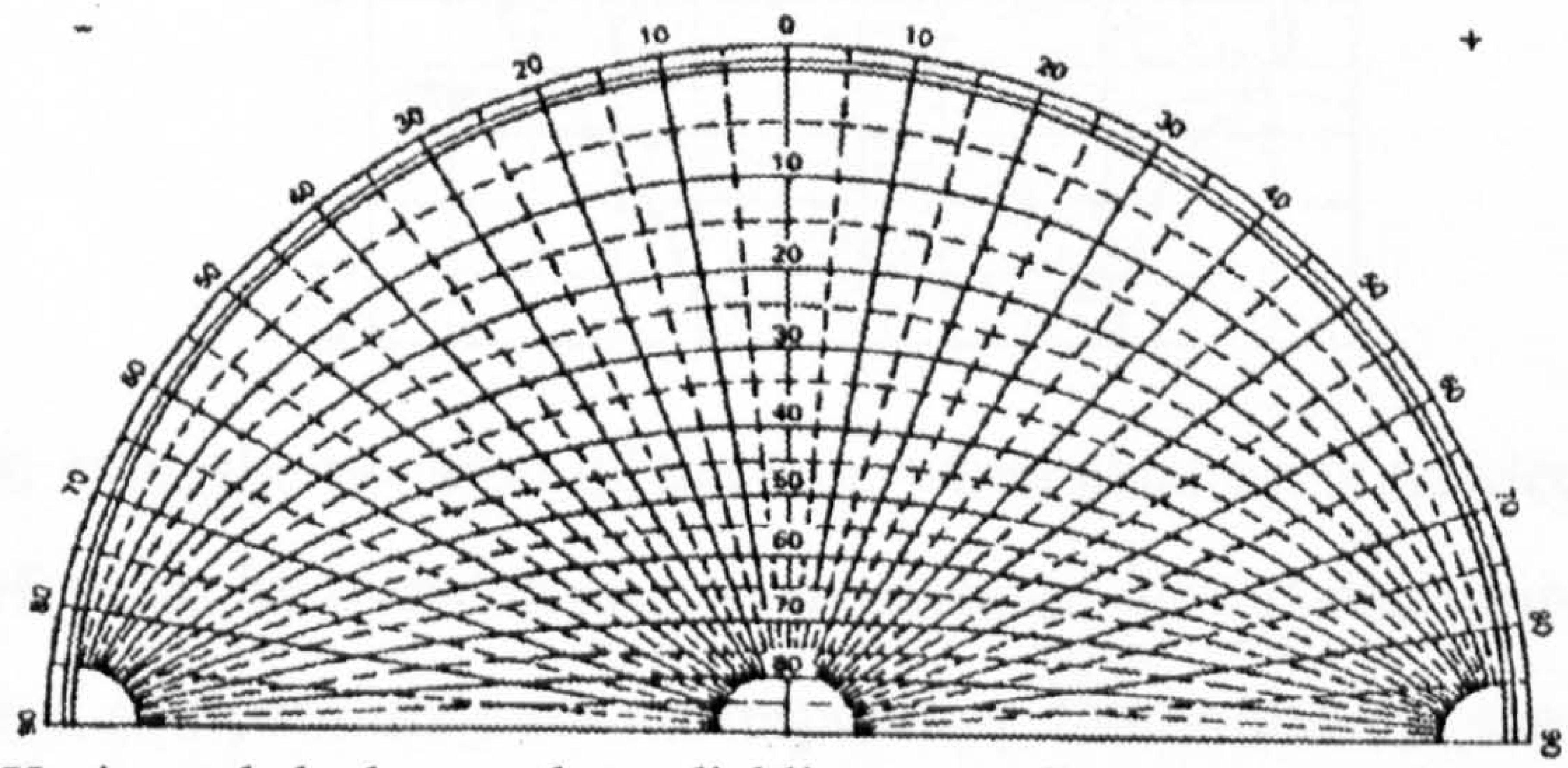
An appropriate method to analyse the performance of external shading devices is the use of the horizontal and vertical shadow angles. The horizontal shadow angle (α_f) is the difference between the wall azimuth and solar azimuth beyond which the sun is obstructed and characterises a vertical shading device. The vertical shadow angle (v) is measured on a vertical plane normal to the elevation considered and characterises a horizontal shading device. Figure 7.6 shows horizontal and vertical shadow angles.

Figure 7.6: Horizontal (α_f) and vertical (v) shadow angles (Koenigsberger, et al. 1973)



As it can be seen in figure 7.7, by using shadow-angle protractors, which represent horizontal and vertical shadow angles, shading masks can be constructed to show the performance of shading devices. The form of the shading mask is only identified by the angular relations and is independent of the actual size of the device. Therefore, a deep overhang, and a set of small horizontal louvers with the same vertical shadow angle, will have the same shading mask.

Figure 7.7: Shadow angle protractor (Olgyay, 1957)

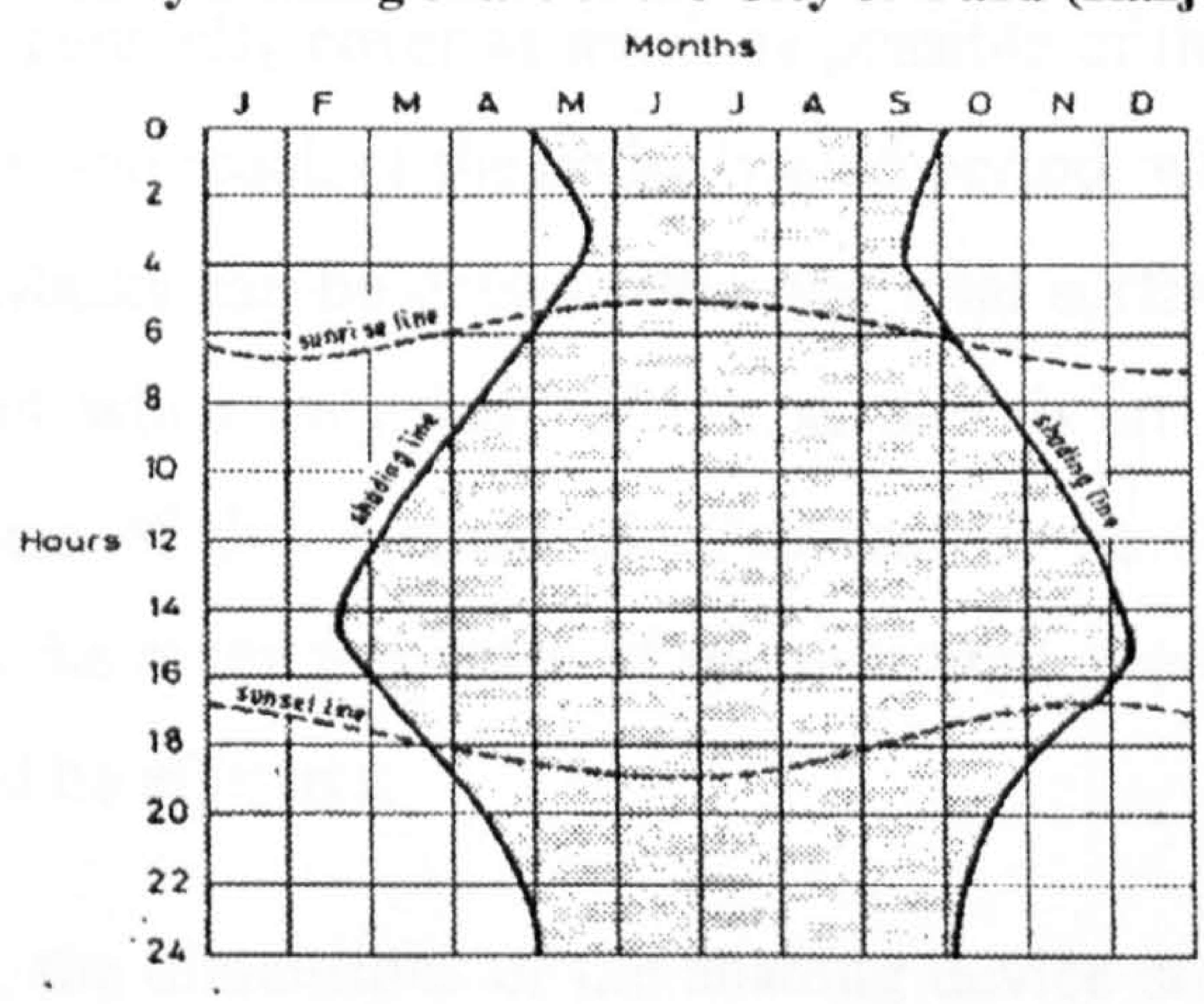


Horizontal shadow angles radial lines – reading on perimeter scale
Vertical shadow angles actual lines – 90° at centre. 0° at perimeter

The design of shading devices is done practically in most cases by using graphic sun charts, which allows one to relate the sun path in the sky vault to the orientation and shape of a specific window. In order to evaluate the performance of fixed external shading devices, the method of Olgyay (Olgyay, A. and Olgyay, V., 1957) was chosen firstly to estimate the size and type of shading devices. In the second attempt my excel program was used to predict the effect of proposed devices on the annual energy requirements of spaces.

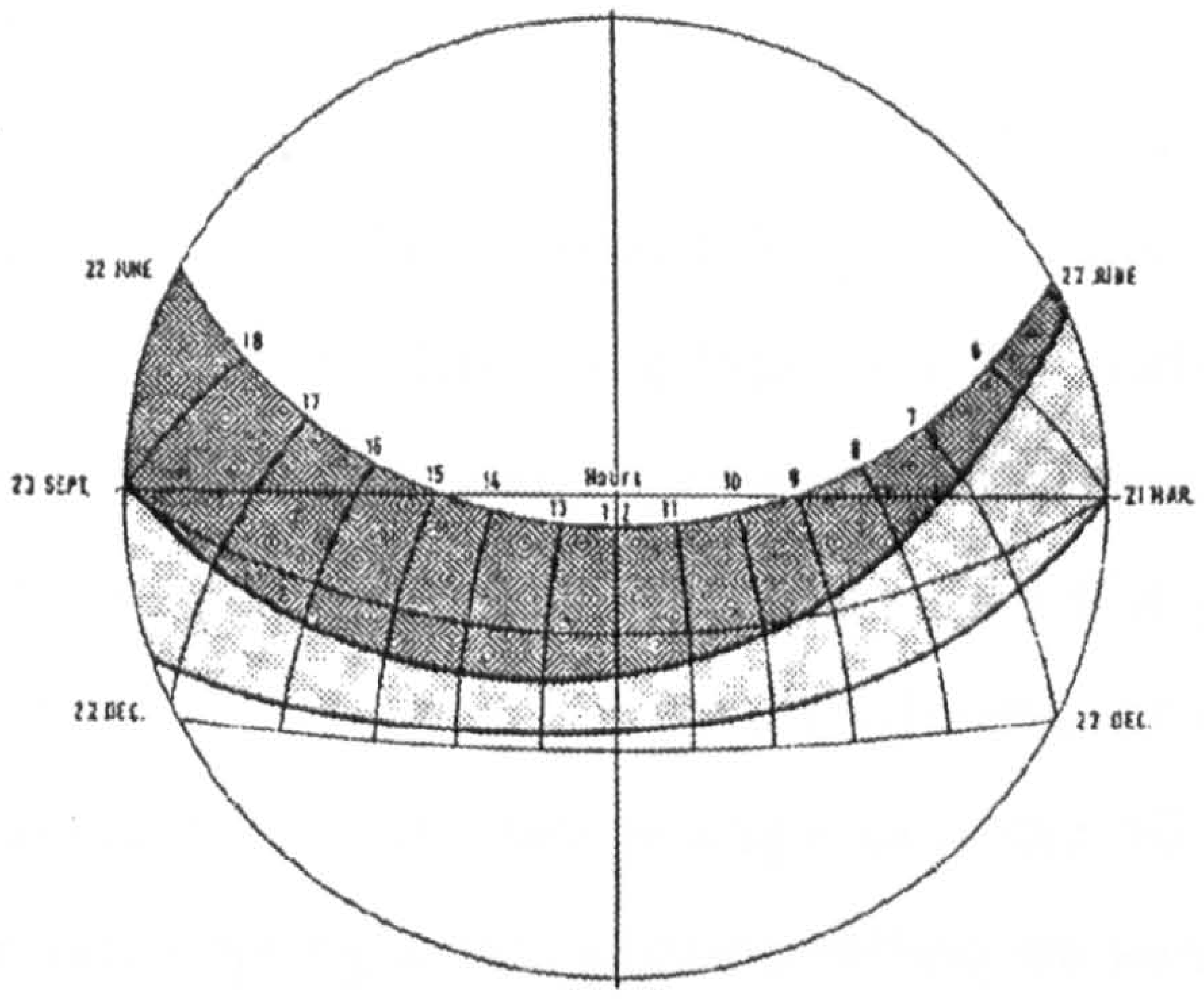
The design of shading devices using the Olgyay method can be carried out in four steps. In the first step, the time is determined when shading is needed (overheated period). According to the developers of the method, provision for shading is required at any time when the outdoor air temperature exceeds 21 °C in regions of latitude of 40 approximately. For every 5 degrees latitude change towards the equator the limiting temperature should be elevated by 0.44 °C for acclimatisation purposes. For example, Yazd (latitude of about 32° N), we considered that the limiting temperature during the overheated period was 22 °C. The temperatures, which fall over the limiting temperature, will define the overheated period, or the times when shading is needed. This can be listed on a chart, when the hourly and the monthly divisions serve as ordinates. Having done so, the yearly shading chart of Yazd was constructed and illustrated in figure 7.8.

Figure 7.8: Yearly shading chart of the City of Yazd (Razjouyan, 1987)



In the second step, the position of the sun, when shading is needed is determined. This can be performed by transferring the overheated period determined in the yearly shading chart to a sun-path diagram corresponding the latitude of the site (See figure 7.9).

Figure 7.9: Overheated period transferred from the yearly shading chart (fig. 7.8) to the solar chart (Razjouyan, 1987)



In the diagram, each line represents two dates when the sun has the same path during the course of the year. As shown in figure 7.9, the darker area of the overheated period indicates when shading is required on both dates.

Any shading device has a characteristic-shading mask, which explains the performance of the device. Shading masks are independent of latitude, orientation and time, because they are a conventionalised geometric description. They are also independent of the scale of the device. As mentioned before, the performance of shading devices is defined by their angular relation to the facade.

The shading masks of shading devices can be constructed in the third step. The shading mask should generally cover as much as possible of the indicated overheated period while not cover too much of the under heated period, when sunshine is needed for its warm effect. Masks can be drawn when the total surface is in shade (i.e. 100 percent shading), and when only half of the surface is in shade, i.e. 50 percent shading. The designers of this method observe that if the 50 percent border of a shading mask covers the outer perimeter of the indicated overheated period area, the shading device should be effective.

In the fourth step, the dimensions of the shading device are determined. This can be easily done using the shadow angle protractor of the same scale as the solar chart. In figures 7.10 to 7.13, the shadow angle protractor of the same scale of the solar chart is placed on the solar chart with the centre of the protractor directly over the mid-point of the chart. The protractor is then turned about its centre until the base-line assumes the orientation of the exposed wall, which it is supposed to present. The 100 and 50 percent shading masks indicated by darker and lighter areas respectively were superimposed accordingly for four cardinal orientations. Shading windows facing south is relatively an easy task. The 100 and 50 percent masks presented in figure 7.10. Constructed shading masks define the type and the angle of device only, and possibilities remain for various design arrangements. For example, the shading device for south facing windows of the reference school (window's height = 1.5m) can be an overhang with a depth of 1.26m directly over the window, or can comprise a set of horizontal louvers having a vertical shadow angle of about 50 degrees. Vertical fins are more effective in intercepting solar radiation falling on windows facing north. A set of vertical fins at a 16 degrees angle measured from the wall seems to be satisfactory (Figure 7.11).

Figure 7.10: Shading mask for south facing windows (Razjouyan, 1987)

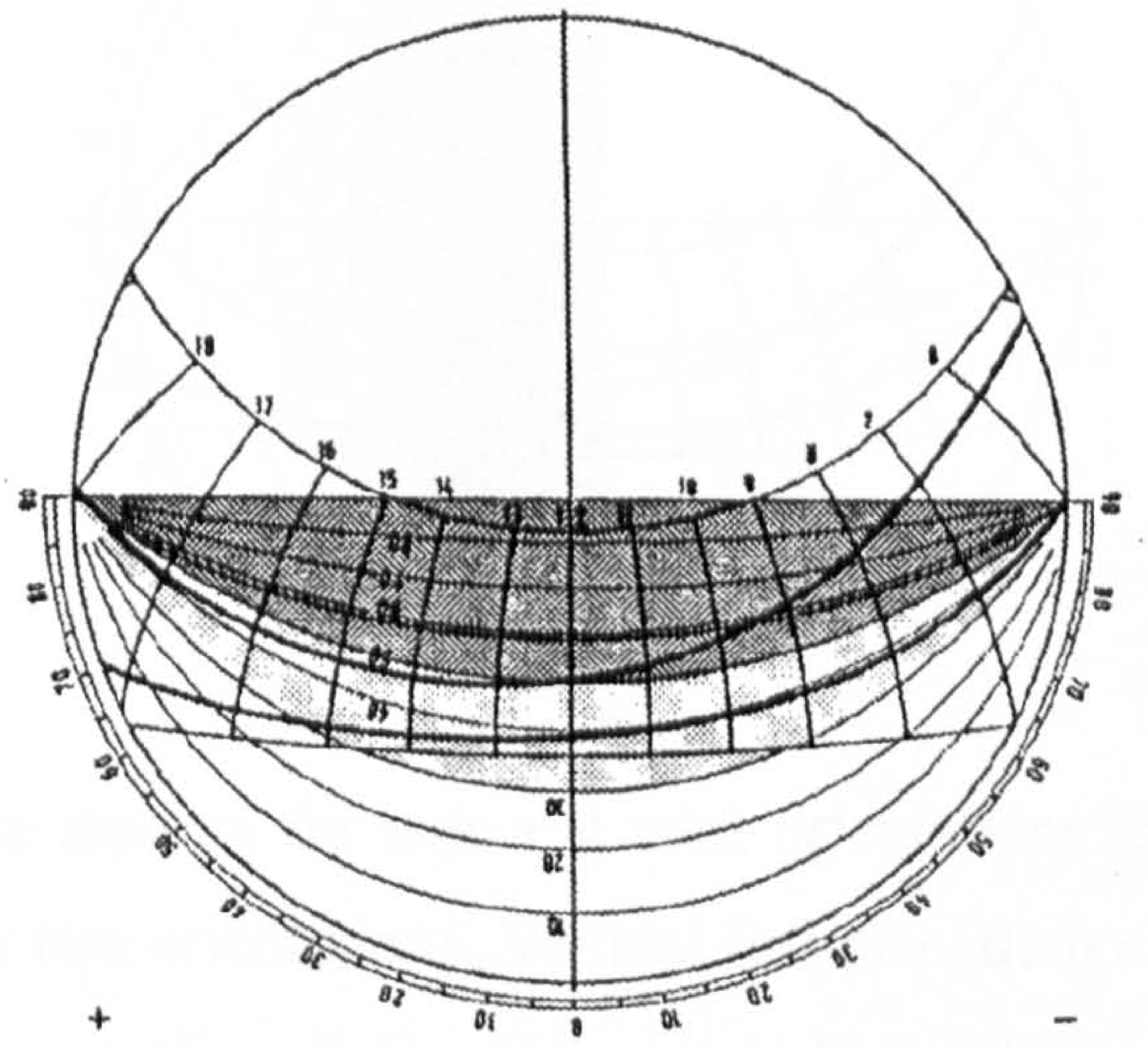


Figure 7.11: Shading mask for north facing windows (Razjouyan, 1987)

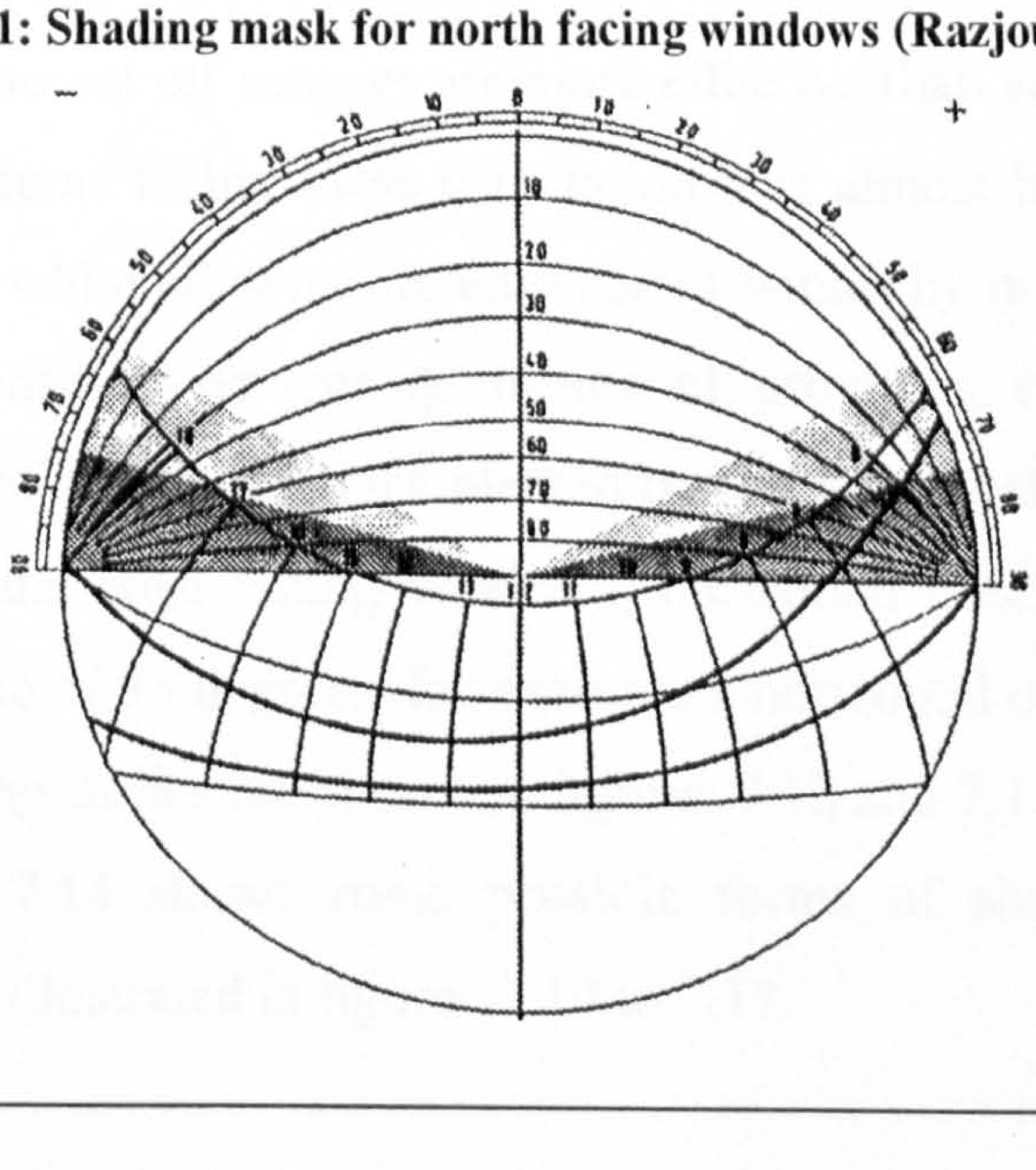


Figure 7.12: Shading mask for east facing windows (Razjouyan, 1987)

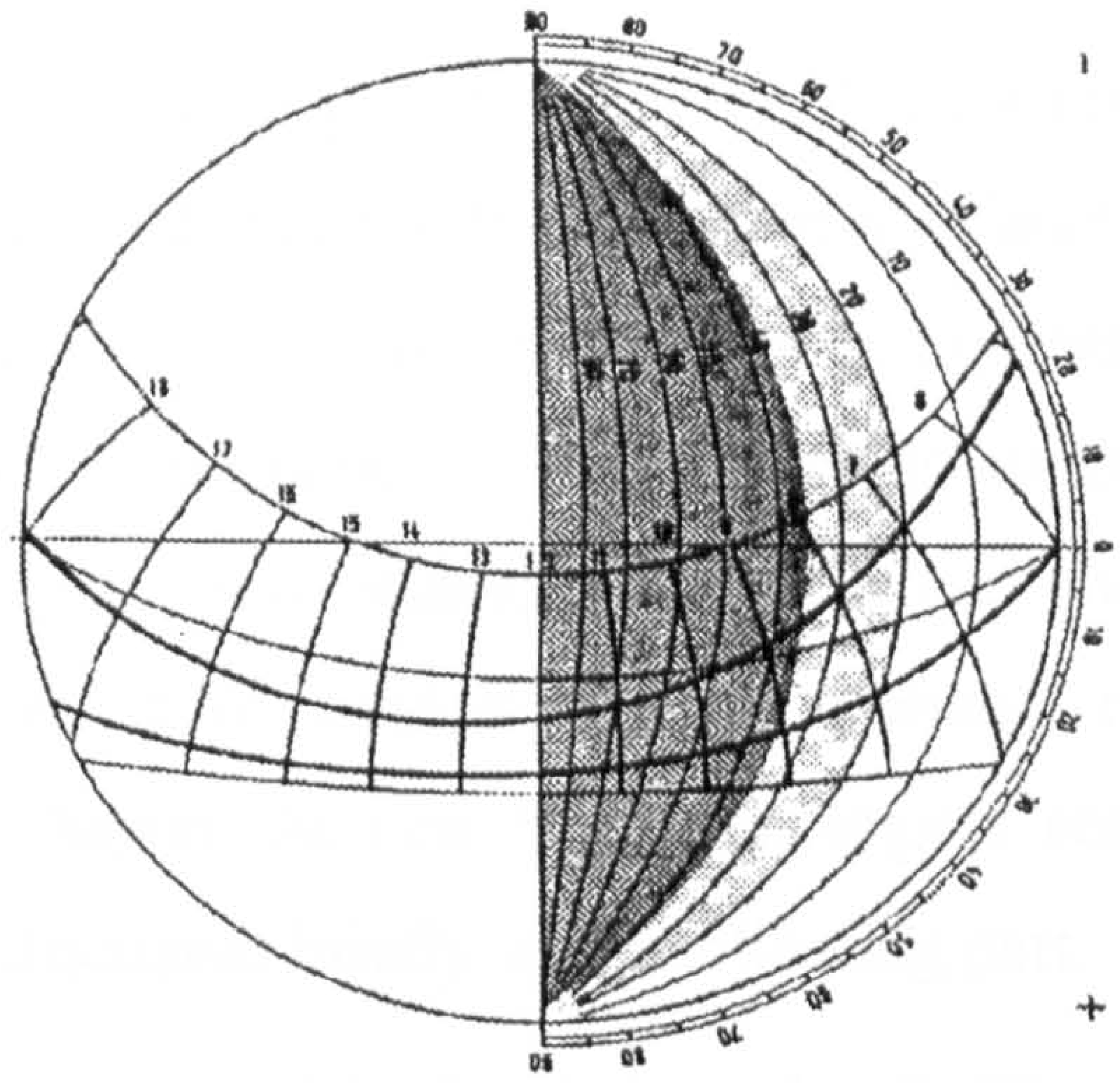
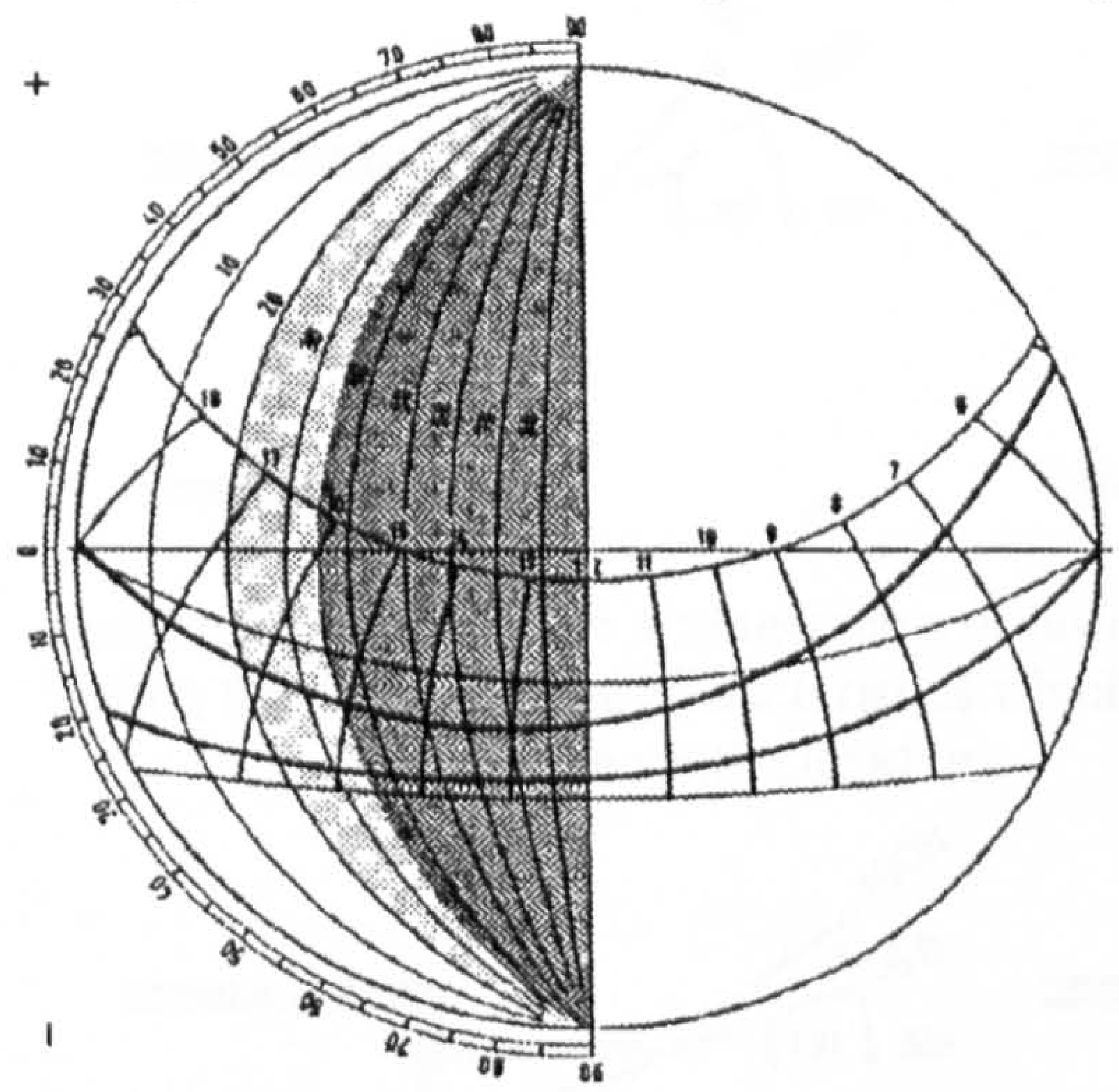


Figure 7.13: Shading mask for west facing windows (Razjouyan, 1987)

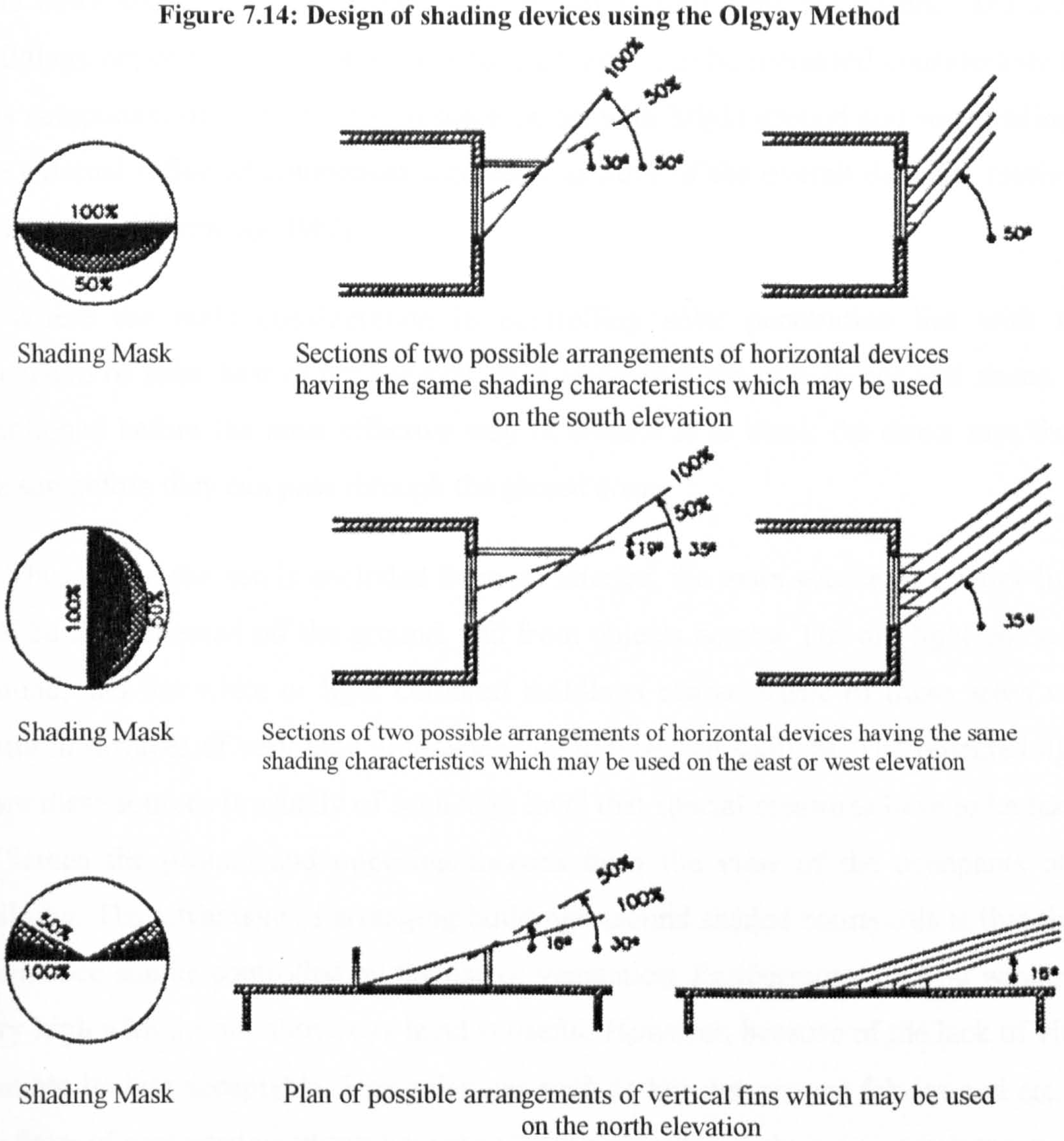


Providing adequate shading for east and west orientations is not accomplished as easily as for the other two orientations. Vertical fins provide poor shading in summer, while cutting off almost all radiation in winter. Vertical fins with their members oblique to the south to cut off sunrays are more effective than vertical ones normal to the wall. For classrooms facing these orientation it is almost impossible to stop the sun rays in summer while allowing its entrance in winter by means of fixed shading devices. Movable shading devices or means of providing seasonal shading, for example by means of deciduous trees planted opposite the wall, and could be more effective. For east and west facing windows, horizontal shading devices having a vertical shadow angle of 35 degrees, for example a horizontal overhang of a depth of 2.15m, whose shading masks are shown in figures 7.12 and 7.13 respectively may be considered. Figure 7.14 shows some possible forms of shading devices whose shading masks were illustrated in figures 7.10 to 7.13.

7_4 * Windows Dimensions

According to studies concerning with the psychological reactions associated with windows it can be concluded that the limitation of the function of windows to the provision of light and air would be incorrect. In order to create an environment both thermally and visually comfortable to the occupants other benefits ascribed to windows such as daylight, view, sunshine, privacy, etc. should be considered in design processes. The effect of window design on energy requirements would be discussed later in this chapter. At first the psychological reactions associated with window design will be discussed briefly in the following part.

Figure 7.14: Design of shading devices using the Olgyay Method



The visible part of the global solar radiation, i.e. daylight, has always been used as the major light source to illuminate building interiors. Providing an adequate quantity of light for the tasks involved, with satisfactory distribution of brightness to give freedom from visual discomfort, is the aim of good interior daylighting. The basic principles of good lighting apply in tropical conditions as elsewhere (Hopkinson, et al. 1966).

For design purposes two main climatic patterns for daylight calculation, i.e. the overcast sky and the clear sky have been described.

The characteristic of hot dry climates is the presence of continuous sunshine from cloudless skies. Therefore, direct sunlight as well as skylight should be considered. One more source of interior light will be that reflected off the ground, and from buildings opposite. The amount of indoor daylight can be increased considerably by this component of illumination. In some cases, with bright ground and surroundings, the external reflected component can reach as 50% of the overall daylight received (Ne'eman and Shrifteilig, 1982).

Where the main consideration in controlling solar penetration lies with the exclusion of solar heat in hot seasons, as is invariably the case in hot arid zones, as mentioned before the most effective way of control is to block the direct rays from the sun before they can pass through the glazed areas.

Thus, when the sun is excluded from an interior, the main source of interior light will be that reflected off the ground, and from objects nearby. The dry light-coloured ground, and the white or light coloured buildings characteristic of these areas will result in surfaces of very high luminance due to reflected sunlight. The reflected light from these sources is usually of such high level that special measures have to be taken to screen the ground and opposing facades from the view of the occupants of a building. The advantage of arranging buildings around shaded courtyards is that their luminance can be controlled by the use of vegetation. Furthermore, placing windows very high with the sill above eye level is useful. However, because of the lack of view it might be less acceptable. Using devices such as louvers, woven fabrics and etc. in the form of protected windows known as "mashrabias", has also some advantages.

In daylighting design, the fact that a greater proportion of light flux is more likely to enter a classroom from below the horizontal plane if external sun control devices, e.g. overhangs, are used is important. A large spectrum of human tasks needs downward illumination on horizontal surfaces. This can be provided by using internal surfaces of high reflectance and taking advantage of the high proportion of the incident flux received on the ceiling and upper section of walls in the classroom as externally reflected light coming from the ground and opposing facades.

There is a considerable relationship between our desire for sunshine and the prevalent climate. This desire may be strongest for people living in the northern latitudes where the duration of sunshine can be quite limited. Conversely in hot climates with an abundance of sunshine, people have a tendency to avoid sunshine in their buildings in hot periods of the year because of its excessive heat. However, during cold periods of the year, they welcome some sun in their buildings. By reducing heating loads this will contribute to the heating system.

Therefore, the aim of achieving an energy efficient design should be to maximise solar gain when it is wanted and to exclude it when it is not. In this respect, factors such as orientation, the positioning of openings in external walls, depth of the reveals, the placing of structural projections, e.g. balconies, overhangs, sun-break walls, canopies, etc. and means of landscaping should be all considered in the planning and design.

Privacy is the other factor that must be considered in window design. Windows express social relationship, since through them one may see others and be seen. The importance of privacy is variable depending on the type of culture and buildings and the task involved.

In the context of Islamic culture the maintenance of visual privacy is of prime significance in school design. It is recommended that windows open to public spaces, e.g. streets, should be protected to provide school privacy so that people can not observe the pupil activities specially in girls schools. Protected windows, known as "mashrabias", were helpful since they not only filtered the light and controlled the glare, but also let people to see through them without being seen. However, today's rapidly developed buildings with outward orientation have not been capable to solve this problem (Tavassoli, 1984).

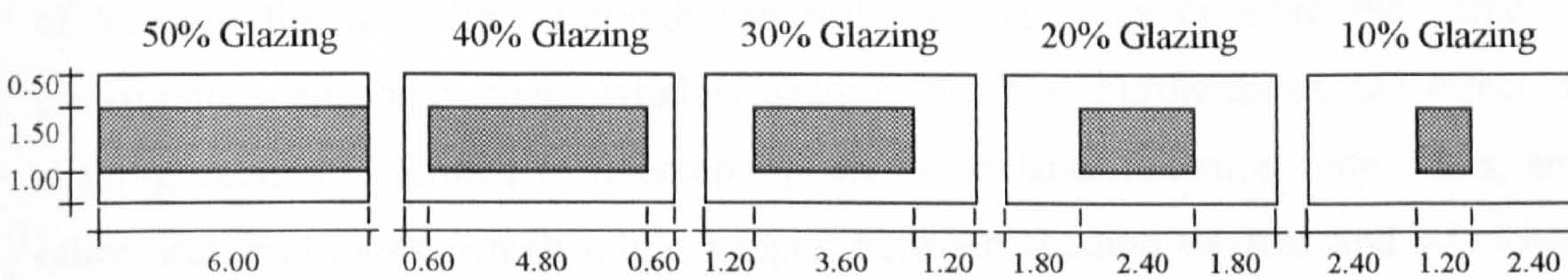
It seems that the easiest way to control solar heat gain and to maintain visual is decreasing the size of windows. However, if windows are too small, they may no longer provide adequate daylight or a good view out. Very small windows can create annoying glare spots through contrast with the darker surrounding wall (Hopkinson, 1972). By graduation of brightness, splayed reveals can decrease the glare of small windows to some extent.

There are window sizes, which are too small to satisfy the visual comfort of the occupants. If a recommendation has to be made (provided visual privacy can be satisfied), it would be that windows should occupy at least 20% of the wall area [Ne'eman and Hopkinson, 1970, Keighley, 1973.a, Baxter, 1979).

7_5 * Window Design and Energy Requirements

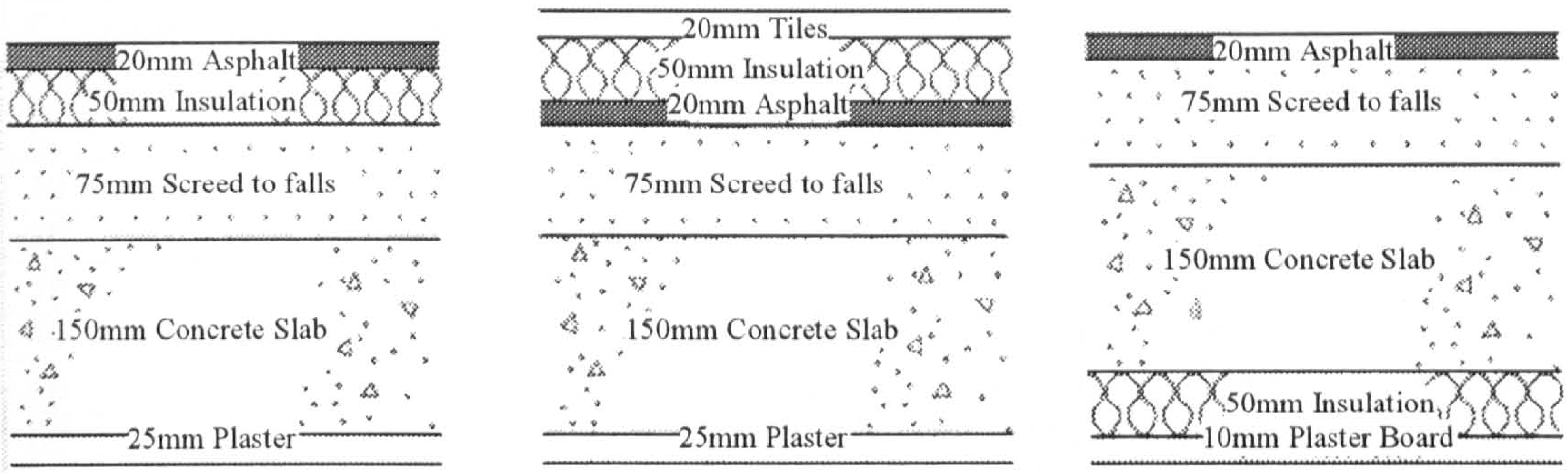
With the aim of investigating the effect of different window systems on the thermal performance of buildings, the energy requirements of four classrooms of the reference school facing four cardinal orientations (south, north, east and west) were examined. In all cases the lighting loads were determined from a required lighting level of 300 Lux and by using the daylighting programme the electrical energy required to meet this requirement was found (Chapter 6). Different areas of glazing were obtained by changing the window width whilst keeping the height at a constant 1.5 metres. Changing the width from 1 to 6 metres in increments of 1 metre, results in window to wall ratios of 10, 20,30,40 and 50 percent respectively. The arrangement of windows on the facade of classrooms is shown in figure 7.15:

Figure 7.15: Different window arrangements (Designed by Gorji)



It was considered that identical zones surrounded internal partitions, with no heat flow through them. The roof is a "warm type" roof whose design specification is similar to that shown in figure 7.16. Construction details of the floor, external walls and partitions are the same as those shown in table 7.1. Control strategies are the same for four classrooms and as those for intermittent operations. The glass chosen is a single pane of 4mm clear float, which is the most common and available glass, used in schools.

Figure 7.16: Roof Types



Warm roof **Protected Membrane Roof** **Cold Roof**

Table 7.1: Construction details

	Thickness (mm)	Material
Floor	150 150 100	Concrete Hard-core Earth
External walls	220 25	Brick wall Plaster
Partitions	25 105 25	Plaster Brick wall Plaster

Depending on the extent of the projection of shading devices over windows, they may cast some shadow on adjacent structures. In the simulations whose results are reported here, it was imposed that the shadow of the devices would fall only on the glazing and not on adjacent components. This can be for example the case of small devices in the form of external louvers, etc. This assumption was made with the aim of keeping the heat flow through the walls as much as possible the same in classrooms with and without window shading devices. Furthermore, the effect of shading devices is limited to intercepting the direct solar radiation only. Thus, any other heat exchanges, which might happen between shading devices and windows, i.e. by radiation, convection, or between the device and the opaque fabric, are neglected.

Figures 7.17 to 7.20 show the calculated annual cooling, heating and lighting requirements of classrooms having different window systems.

Table 7.2: The effect of window size and shading on the cooling, heating and lighting requirements of the north facing classroom

Glazing Ratio	Cooling Kwhrs		Heating Kwhrs		Lighting Kwhrs	
	Unshaded	Shaded	Shaded	Unshaded	Shaded	Unshaded
0	3280.5	3280.5	3054.4	3054.4	3534.192	3534.192
10	3453	3453	3290.5	3290.5	3446.712	3446.712
20	3619.4	3619.4	3523.6	3523.6	3297.996	3297.996
30	3782.7	3782.7	3762.7	3762.7	3208.572	3208.572
40	3958.3	3958.3	3998.8	3998.8	3091.932	3091.932
50	4124.7	4124.7	4243.8	4243.8	2915.028	2915.028
60	4294.2	4294.2	4479.8	4479.8	2679.804	2679.804
70	4460.5	4460.5	4718.9	4718.9	2323.08	2323.08
80	4626.9	4626.9	4964.2	4964.2	1967.328	1967.328
90	4796.4	4796.4	5203.3	5203.3	1561.032	1561.032
100	4962.8	4962.8	5445.2	5445.2	1470.636	1470.636

Figure 7.17: The effect of window size and shading on the cooling, heating and lighting requirements of the north facing classroom

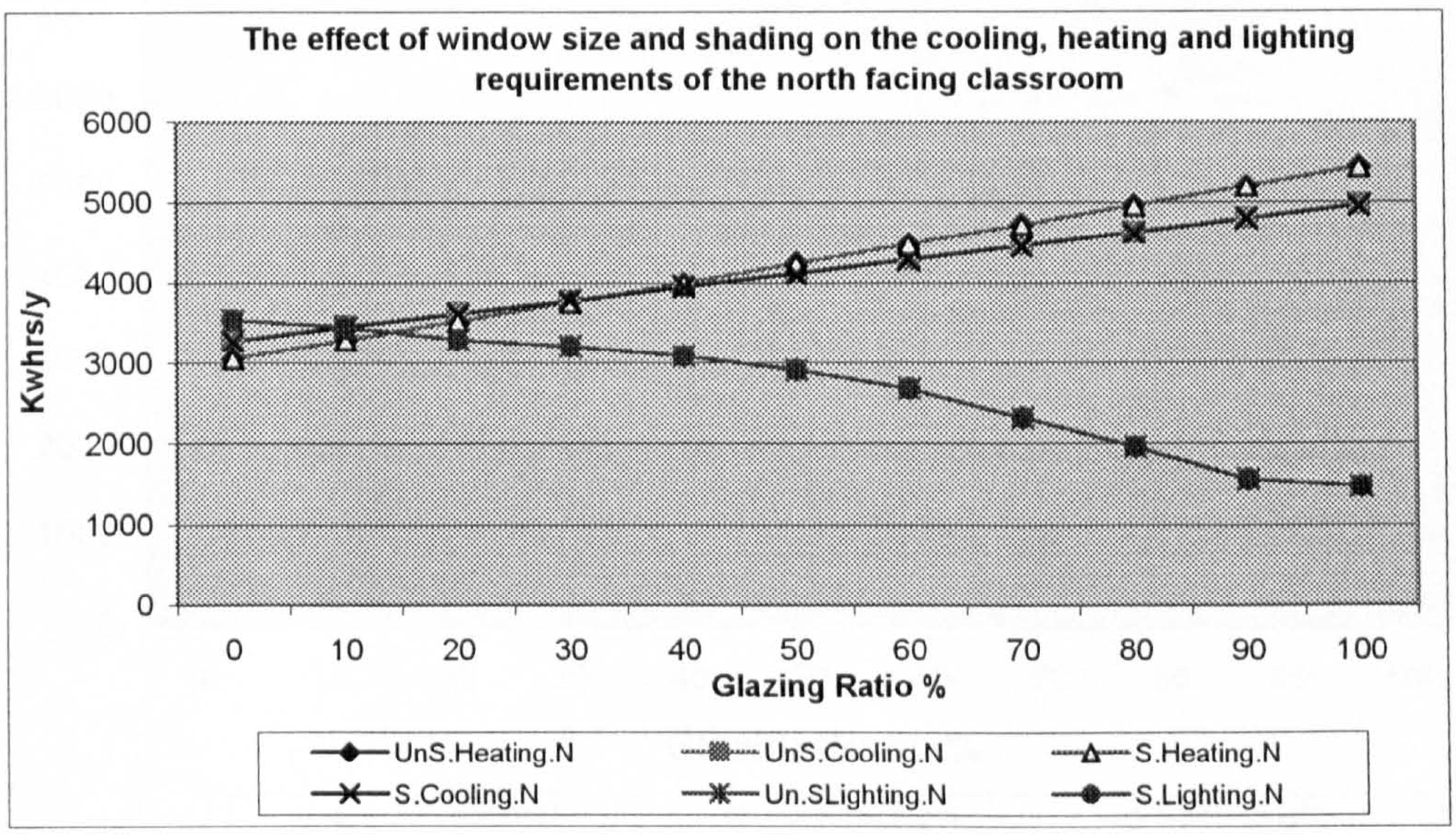


Table 7.3: The effect of window size and shading on the cooling, heating and lighting requirements of the east facing classroom

Glazing Ratio	Cooling Kwhrs		Heating Kwhrs		Lighting Kwhrs	
	Unshaded	Shaded	Shaded	Unshaded	Shaded	Unshaded
0	3383.6	3383.6	2930.4	2930.4	3534.192	3534.192
10	3783.5	3725.9	2890.1	2890.1	2358.072	2121.876
20	4177.4	4074.1	2946.2	2946.2	2327.94	2091.744
30	4580.4	4422.5	3042.4	3042.4	2151.036	2091.744
40	4977.3	4764.7	3171.9	3171.9	2032.452	2032.452
50	5377.2	5113	3344.1	3344.1	1562.004	1562.004
60	5774.1	5455.2	3537.4	3537.4	1210.14	1210.14
70	6171	5797.4	3743.4	3743.4	912.708	912.708
80	6570.9	6145.7	3940.2	3940.2	797.04	797.04
90	6964.8	6487.9	4146	4146	648.324	648.324
100	7367.8	6839.3	4355.1	4355.1	531.684	531.684

Figure 7.18: The effect of window size and shading on the cooling, heating and lighting requirements of the east facing classroom

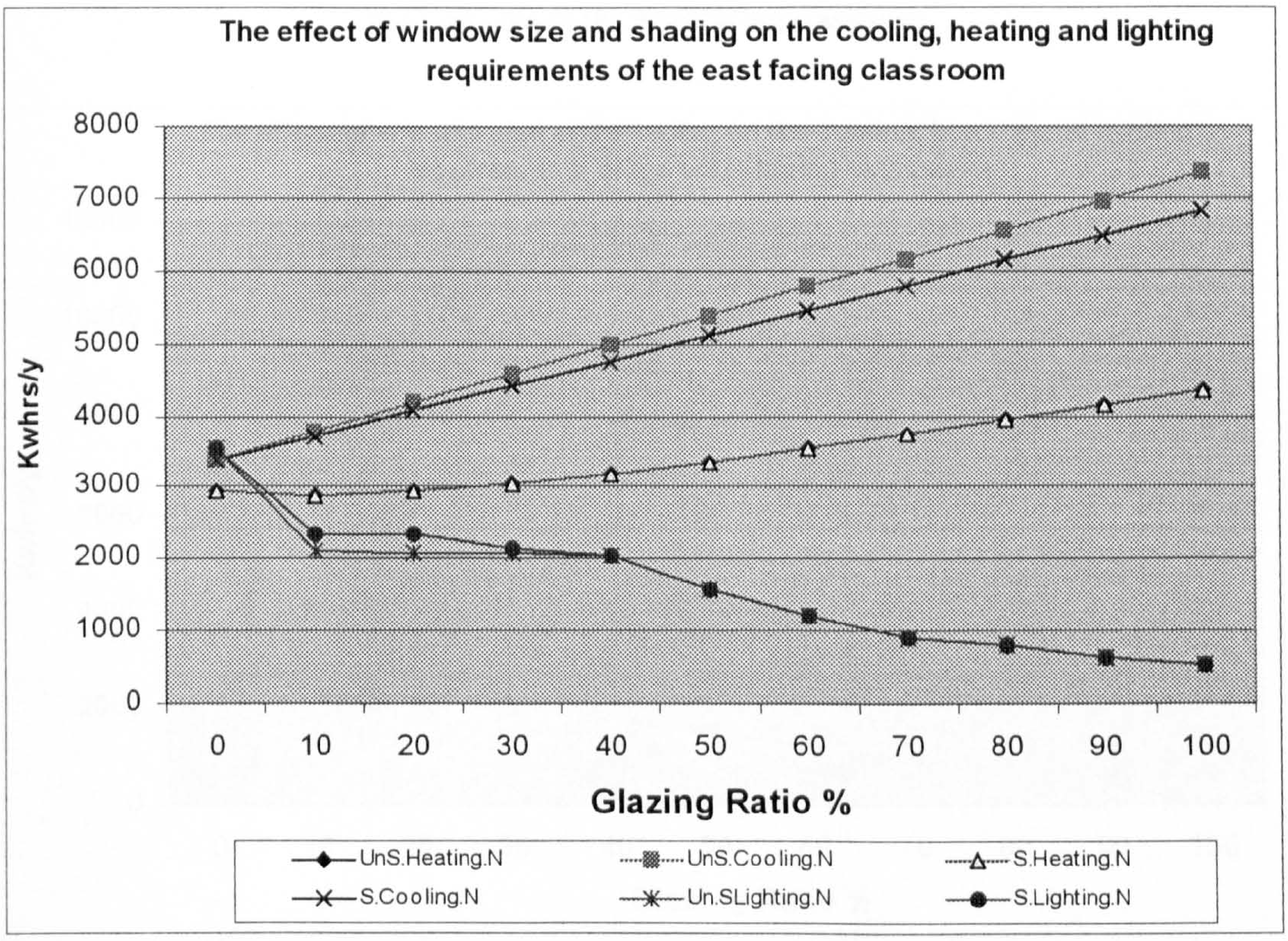


Table 7.4: The effect of window size and shading on the cooling, heating and lighting requirements of the west facing classroom

Glazing Ratio	Cooling Kwhrs		Heating Kwhrs		Lighting Kwhrs	
	Unshaded	Shaded	Shaded	Unshaded	Shaded	Unshaded
0	3368.4	3368.4	2940.6	2940.6	3534.192	3534.192
10	3994.6	3921.7	3063.7	3063.7	2240.46	2004.264
20	4620.8	4472	3247.7	3247.7	2210.328	1974.132
30	5247	5028.4	3459.3	3459.3	2003.292	1944
40	5867.1	5578.6	3677.4	3677.4	1944	1944
50	6499.4	6132	3898.2	3898.2	1531.872	1531.872
60	7122.5	6682.2	4113.2	4113.2	1180.008	1180.008
70	7748.8	7238.6	4337.1	4337.1	882.576	882.576
80	8374.9	7788.9	4561.3	4561.3	766.908	766.908
90	8998.1	8342.2	4785.2	4785.2	618.192	618.192
100	9627.3	8892.6	5000.2	5000.2	531.684	531.684

Figure 7.19: The effect of window size and shading on the cooling, heating and lighting requirements of the west facing classroom

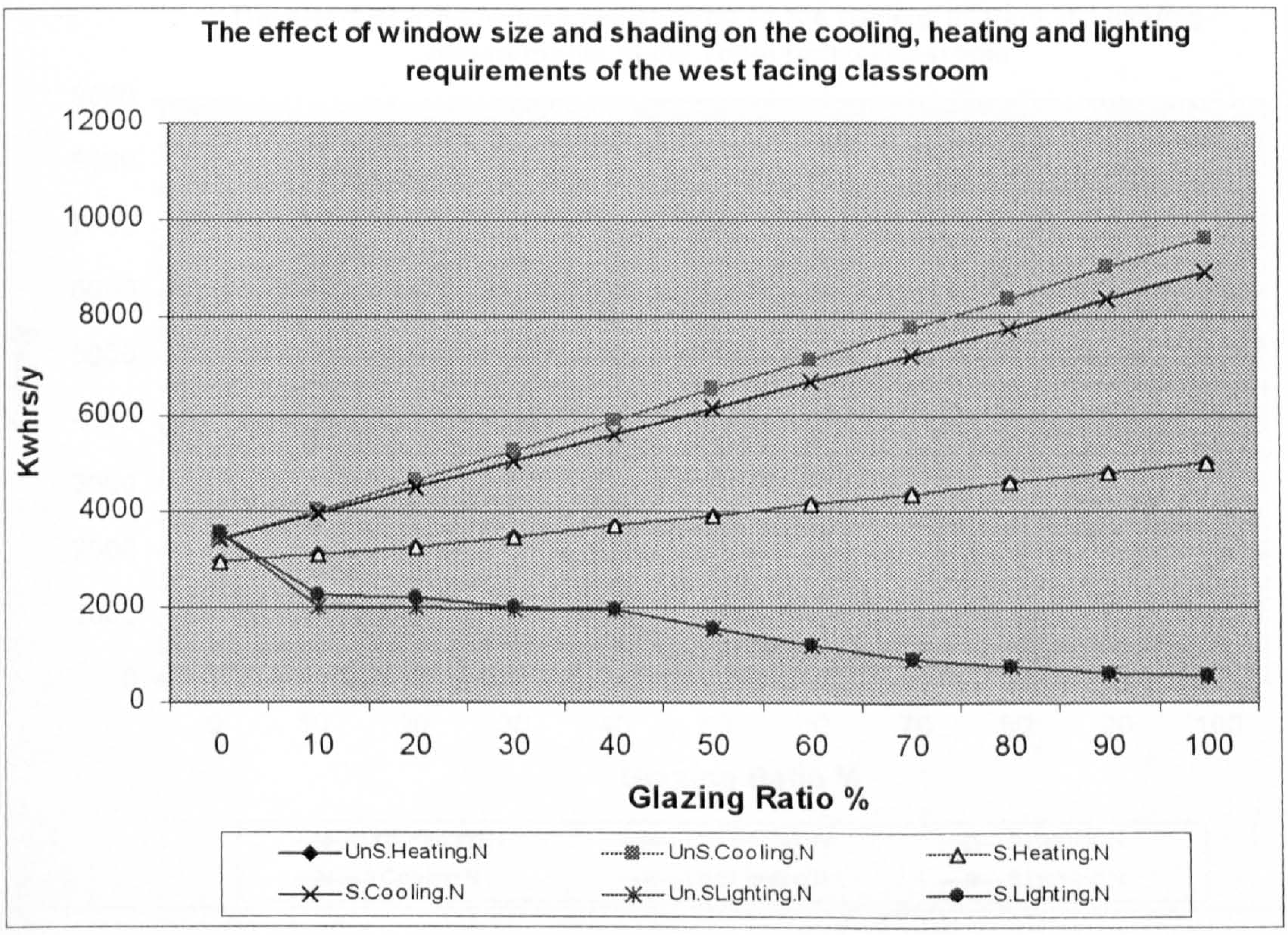
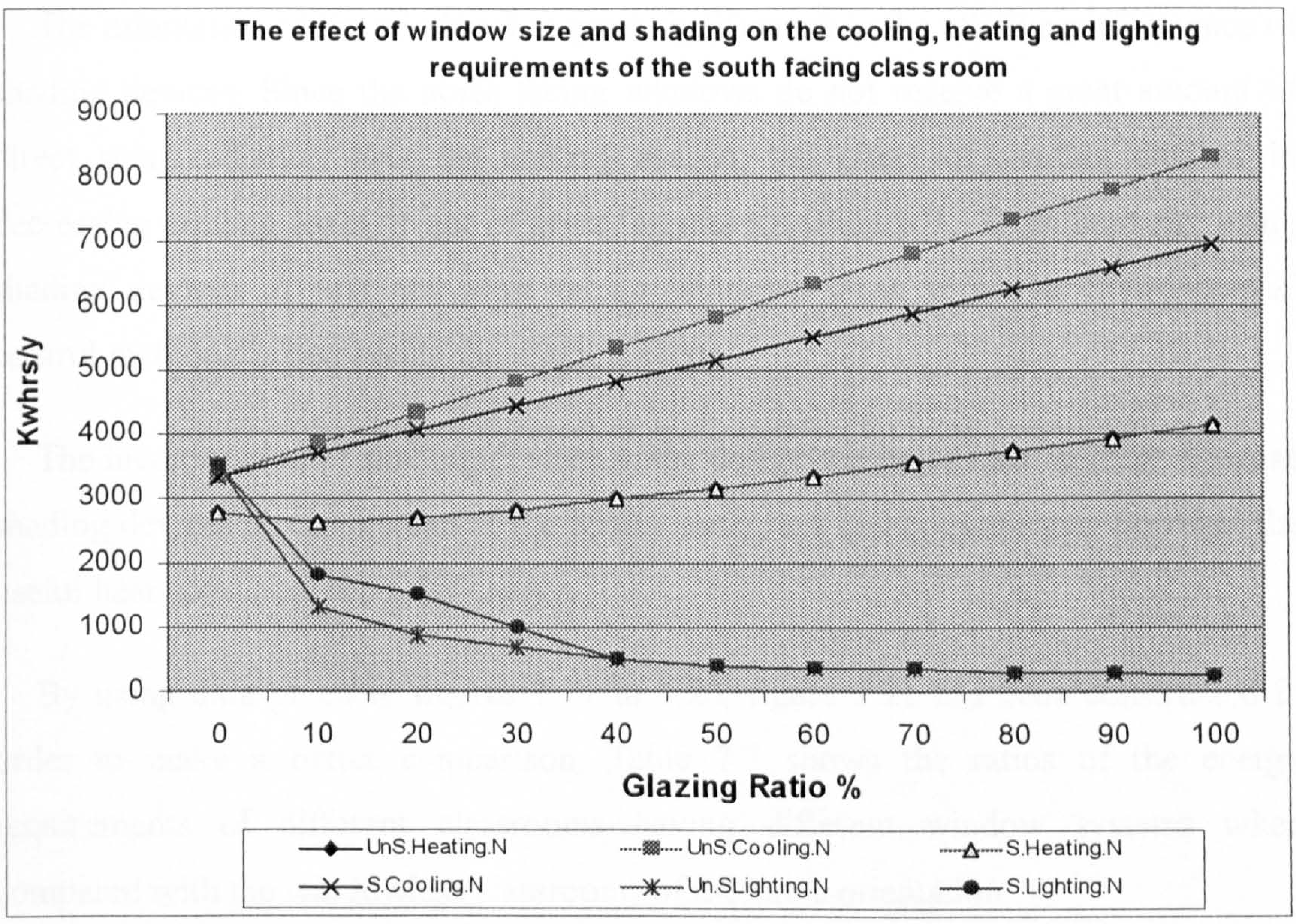


Table 7.5: The effect of window size and shading on the cooling, heating and lighting requirements of the south facing classroom

Glazing Ratio	Cooling Kwhrs		Heating Kwhrs		Lighting Kwhrs	
	Unshaded	Shaded	Shaded	Unshaded	Shaded	Unshaded
0	3344.4	3344.4	2772.8	2772.8	3534.192	3534.192
10	3840.9	3707.6	2646.7	2646.7	1799.172	1324.836
20	4334.4	4064.8	2700.3	2700.3	1505.628	885.491
30	4831	4428	2818.2	2818.2	1005.048	708.588
40	5336.7	4797.3	2987.9	2987.9	531.684	531.684
50	5827.1	5154.4	3163.5	3163.5	413.1	413.1
60	6326.7	5514.6	3351	3351	354.78	354.78
70	6826.4	5880.9	3547.7	3547.7	354.78	354.78
80	7322.9	6241	3747.5	3747.5	295.488	295.488
90	7816.4	6604.3	3941.1	3941.1	295.488	295.488
100	8315.9	6964.4	4140.7	4140.7	266.328	266.328

Figure 7.20: The effect of window size and shading on the cooling, heating and lighting requirements of the south facing classroom



The difference between the rate of heat gain and loss through the glazing area, i.e. the energy balance of glazing, shows whether the glazing would increase or decrease the energy demand of an enclosure over a given period. The trend in the annual cooling requirements of the classrooms whose energy demands are shown in figures 7.17 to 7.20 indicates that there are energy penalties associated with windows regardless of the orientation of classrooms. In other way, during the cooling season the value of the energy balance of glazing has a positive sign:

$$|\text{Heat gain through glass}| - |\text{heat loss through glass}| > 0$$

Also it can be concluded from figures 7.17 to 7.20 that increasing the window areas reduce the heating requirements in all orientations (because the useful heat content of the solar energy can be transmitted indoors by larger areas of glazing) except north. Since at latitude 32° N, windows facing north do not receive any sunshine over the entire heating season, larger windows slightly increases the heating demand of the north facing classrooms during the heating period.

The orientation of the window has great significance in the relative performance of shading devices. Since the north facing windows do not receive a great amount of direct solar radiation over the cooling season, the effect of shading devices in decreasing cooling loads is not of great importance (Figure 7.17). In contrast, using shading devices in east and west facing windows is an effective environmental control method for decreasing the cooling needs.

The incorporation of shading devices in the design increases heating loads because shading devices obstruct some of the winter sun's rays and consequently decrease the useful heat content of the solar energy,

By using data given in figures 7.17 to 7.20, figure 7.21 has been constructed in order to make a better comparison. Table 7.7 shows the ratios of the energy requirements of different classrooms having different window systems when compared with the windowless classrooms of the same orientation.

Table 7.6: The effect of window size and shading on loads

Orientation	Load	Shading	Glazing ratio 0	10	20	30	40	50
North	Cooling	Yes	3280.5	3453	3619.4	3782.7	3958.3	4124.7
		No	3280.5	3453	3619.4	3782.7	3958.3	4124.7
	Heating	Yes	3054.4	3290.5	3523.6	3762.7	3998.8	4243.8
		No	3054.4	3290.5	3523.6	3762.7	3998.8	4243.8
	Lighting	Yes	3534.192	3446.712	3297.996	3208.572	3091.932	2915.03
		No	3534.192	3446.712	3297.996	3208.572	3091.932	2915.03
East	Cooling	Yes	3383.6	3725.9	4074.1	4422.5	4764.7	5113
		No	3383.6	3783.5	4177.4	4580.4	4977.3	5377.2
	Heating	Yes	2930.4	2890.1	2946.2	3042.4	3171.9	3344.1
		No	2930.4	2890.1	2946.2	3042.4	3171.9	3344.1
	Lighting	Yes	3534.192	2358.072	2327.94	2151.036	2032.452	1562.01
		No	3534.192	2121.876	2091.744	2091.744	2032.452	1562.01
West	Cooling	Yes	3368.4	3921.7	4472	5028.4	5578.6	6132
		No	3368.4	3994.6	4620.8	5247	5867.1	6499.4
	Heating	Yes	2940.6	3063.7	3247.7	3459.3	3677.4	3898.2
		No	2940.6	3063.7	3247.7	3459.3	3677.4	3898.2
	Lighting	Yes	3534.192	2240.46	2210.328	2003.292	1944	1531.87
		No	3534.192	2004.264	1974.132	1944	1944	1531.87
South	Cooling	Yes	3344.4	3707.6	4064.8	4428	4797.3	5154.4
		No	3344.4	3840.9	4334.4	4831	5336.7	5827.1
	Heating	Yes	2772.8	2646.7	2700.3	2818.2	2987.9	3163.5
		No	2772.8	2646.7	2700.3	2818.2	2987.9	3163.5
	Lighting	Yes	3534.192	1799.172	1505.628	1005.048	531.684	413.1
		No	3534.192	1324.836	885.491	708.588	531.684	413.1

Figure 7.21: The effect of window size and shading on loads

Comparing the numbers shown in table 7.7 can assess the potential energy savings and penalties associated with the window design. By increasing the area of unshaded windows the cooling loads would considerably be increased. For example, the cooling requirements of the east facing classroom having a window comprising 50% of its wall area is 2.7 times greater than that of the windowless classroom of the same orientation. Or, increasing the window area of the east facing classroom from 20 to 50% would result in an increase in the cooling load by 63% ((2.7/1.66)*100%).

The increase in the percentage of the cooling loads as the result of increasing the glazing areas would be smaller when shading devices are incorporated into the design. For example, the cooling requirements of the east facing classroom would increase by 38% ((1.82/1.32)*100%) when the area of the shaded window increases from 20 to 50% of the wall area.

Table 7.7: The effects of window design and orientation on the annual energy requirements of classrooms

Orientation	Load	Shading	Glazing ratio					
			0	10	20	30	40	50
North	Cooling	Yes	1.00	1.05	1.10	1.15	1.21	1.26
		No	1.00	1.05	1.10	1.15	1.21	1.26
	Heating	Yes	1.00	1.08	1.15	1.23	1.31	1.39
		No	1.00	1.08	1.15	1.23	1.31	1.39
	Lighting	Yes	1.00	0.98	0.93	0.91	0.87	0.82
		No	1.00	0.98	0.93	0.91	0.87	0.82
East	Cooling	Yes	1.00	1.10	1.20	1.31	1.41	1.51
		No	1.00	1.12	1.23	1.35	1.47	1.59
	Heating	Yes	1.00	0.99	1.01	1.04	1.08	1.14
		No	1.00	0.99	1.01	1.04	1.08	1.14
	Lighting	Yes	1.00	0.67	0.66	0.61	0.58	0.44
		No	1.00	0.60	0.59	0.59	0.58	0.44
West	Cooling	Yes	1.00	1.16	1.33	1.49	1.66	1.82
		No	1.00	1.19	1.37	1.56	1.74	1.93
	Heating	Yes	1.00	1.04	1.10	1.18	1.25	1.33
		No	1.00	1.04	1.10	1.18	1.25	1.33
	Lighting	Yes	1.00	0.63	0.63	0.57	0.55	0.43
		No	1.00	0.57	0.56	0.55	0.55	0.43
South	Cooling	Yes	1.00	1.11	1.22	1.32	1.43	1.54
		No	1.00	1.15	1.30	1.44	1.60	1.74
	Heating	Yes	1.00	0.95	0.97	1.02	1.08	1.14
		No	1.00	0.95	0.97	1.02	1.08	1.14
	Lighting	Yes	1.00	0.51	0.43	0.28	0.15	0.12
		No	1.00	0.37	0.25	0.20	0.15	0.12

The effect of incorporating shading devices into the design of windows on the energy requirements of classrooms can also be calculated from the numbers shown in table 7.7. For example, the cooling requirements of the east facing classroom with a window comprising 20% of its wall area would be decreased by 20% ((1-1.32/1.66)*100%) as the result of the effect of the shading device in intercepting the passage of direct solar radiation into classroom.

7₆ * Economic Considerations

The cooling and heating loads indicate the energy that has to be extracted and added respectively and are not energy consumptions. Energy consumptions depend on the refrigeration system coefficient of performance and the heating system efficiency.

According to economic considerations, changes in loads require to be taken into account with regard to their fundamental effect on purchasing energy. The designer of a school and the education council will be concerned with running costs and the cost effectiveness of any change in the design of the building. Without taking the full steps of estimating savings associated with an investment that occurs over an extended period of time, an important comparison of estimated savings can be made by casting the computed results into current cost savings.

If the annual cooling load is given by L_c (Kwhrs), the heating load L_h (Kwhrs) and the lighting L_l (Kwhrs), then the total annual energy requirements, Q_t, is calculated by the following algorithm:

$$Q_t = L_l + (L_c / cop) + L_h / f \quad \text{(Kwhrs)} \qquad \text{Algorithm 7.5}$$

Where cop is the coefficient of performance of the cooling system (the efficiency) and f the overall efficiency of the heating system. For Iran the cooling system is typically electricity driven whilst gas is used for heating. If the cost of electricity is C_e per Kwhrs and that of gas C_g per Kwhrs, the total annual cost C_t is calculated by:

$$C_t = (L_l + (L_c / cop)) * C_e + (L_h/f) * C_g \qquad \text{Algorithm 7.6}$$

This can be written as:

$$C_t/C_g = (L_l + (L_c / cop)) * N + (L_h/f) \qquad \text{Algorithm 7.7}$$

Where N is the ratio of electricity cost to gas cost, C_e/C_g. Values of cop, f and N vary depending on the efficiencies of the refrigeration system, heating system and the local prices of fuels respectively. By assuming that values of cop may vary between 2 and 3, and those of f between 0.6 and 0.8, and N between 3 to 6, different scenarios may be considered. We studied 3 scenarios. In scenario 1 (SC1), we took middle range variables, i.e. values of 2.5, 0.7 and 4.5 for cop, f and N respectively. By substituting these values in equation 7.7 we will obtain the following algorithm:

$$C_t/C_g = 4.5\ L_l + 1.8\ L_c + 1.43\ L_h \qquad \text{for SC1} \qquad \text{Algorithm 7.8}$$

Scenario 2 (SC2) was in the favour of heating loads, i.e. values of 2, 0.8 and 6 were selected for cop, f and N respectively. And finally in scenario 3 (SC3), values of 3, 0.6 and 3 were assigned for cop, f and N respectively. By substituting these values in equation 7.7, we obtain:

$$C_t/C_g = 3\ (2L_l + L_c) + 1.25\ L_h \qquad \text{for SC2} \qquad \text{Algorithm 7.9}$$

and:

$$C_t/C_g = 3\ L_l + L_c + 1.67\ L_h \qquad \text{for SC3} \qquad \text{Algorithm 7.10}$$

The cost effectiveness of design solutions, e.g. modifications in window design now can be cast into values of C_t/C_g named as Annual Cost factor (C_t/C_g = ACF).

As discussed before, in order to provide more realistic performance determinants the effect of design solutions on energy needs may be cast into the cost of purchasing energy. As an example, Figure 7.22 has been constructed assuming the conditions of scenario 1 apply, i.e. using equation 7.8. South orientation is the optimal orientation under the conditions set. Unobstructed windows comprising up to about 25% of the south facing wall, appear to be more efficient in energy terms than those incorporating shading devices designed using the Olgyay method. At other orientations, small shaded windows are preferable. It seems that shading north facing windows makes no significant savings.

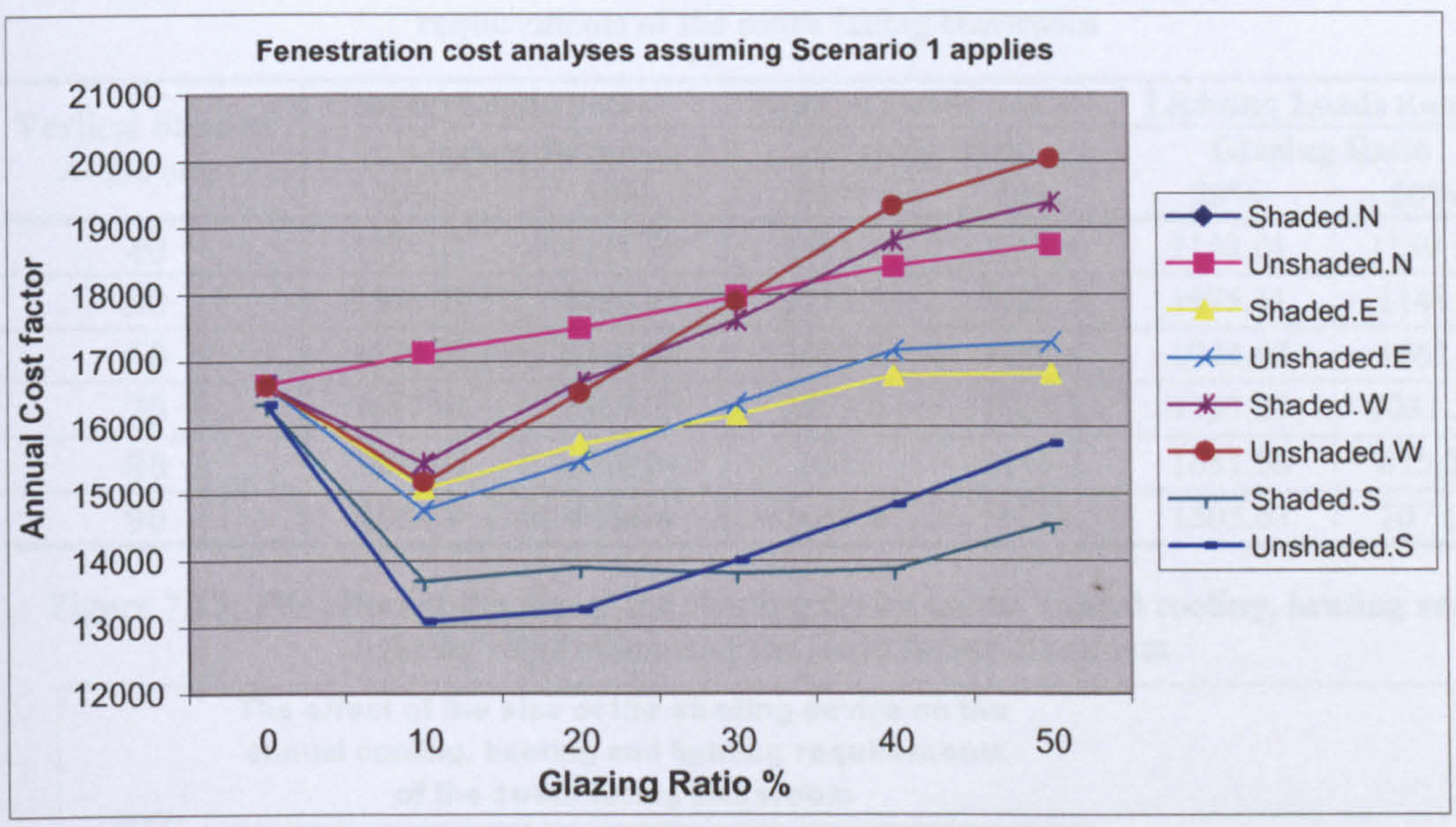
The differences between the Annual Cost factors of classrooms with that of windowless classrooms of the same orientation indicate that except for the classroom facing south, having an unshaded window comprising 10% of its wall area, the presence of windows is associated with cost penalties (Figure 7.22).

Table 7.8: Fenestration cost analyses assuming Scenario 1 applies

(cop = 2.5, f = 0.7, N = 4.5)

Orientation	Load with	Glazing ratio					
		0	10	20	30	40	50
North	Shaded	16634.24	17124.90	17490.06	17964.95	18408.70	18740.14
	Unshaded	16634.24	17124.90	17490.06	17964.95	18408.70	18740.14
East	Shaded	16642.50	15083.99	15736.74	16183.00	16770.69	16797.07
	Unshaded	16642.50	14762.52	15497.53	16360.49	17153.37	17272.63
West	Shaded	16629.72	15472.98	16672.40	17603.84	18799.36	19369.40
	Unshaded	16629.72	15179.05	16515.09	17890.60	19318.66	20030.72
South	Shaded	16346.57	13696.97	13888.20	13809.51	13864.87	14545.31
	Unshaded	16346.57	13083.11	13257.23	14001.28	14835.79	15756.17

Figure 7.22: Fenestration cost analyses assuming Scenario 1 applies



The efficiency of shading devices depends on their ability to intercept solar radiation as much as possible during summer while allowing its entrance into the building in winter. With the aim to investigate the accuracy of graphical methods in determining the size of devices, the thermal performance of devices of other dimensions was analysed. Some results are stated in the following paragraphs.

In figures 7.23 and 7.24, annual cooling, heating and lighting needs of the south and east facing zones under a series of different window arrangements are illustrated shading devices of different sizes (note that shading devices designed using the Olgyay method have vertical shadow angles of 50 and 35 degrees for south and east orientations respectively) were included in the design of windows comprising 20% and 50% of the wall area. The former percentage gives a suitable window size to satisfy view and be reasonably energy efficient. The latter reflects recent tendencies in current domestic architecture.

In the case of the south facing classroom, the cooling loads are practically the same for devices having shadow angles greater than 60 degrees, e.g. overhangs deeper than 0.90 meter (Figure 7.23). However, using extensive shading devices over east facing windows keeps reducing the cooling loads with a diminishing effect (Figure 7.24). On both orientations, larger shading devices tend to increase heating loads as they obstruct the winter sun to higher amount.

Table 7.9: The effect of the size of the shading device on the annual cooling, heating and lighting requirements of the south facing classroom

Vertical Shadow Angle (deg.)	Cooling Loads Kwhrs		Heating Loads Kwhrs		Lighting Loads Kwhrs	
	Glazing Ratio		Glazing Ratio		Glazing Ratio	
	20%	50%	20%	50%	20%	50%
40	3429.11	4221.99	2783.1	3251.1	2152.01	1180.17
50	3506.71	4296.41	2730.7	3223.3	1975.11	1148.9
60	3575.03	4370.58	2699.4	3189.6	1944.97	1062.4
70	3647.99	4567.25	2677.8	3165.1	1797.23	1031.29
80	3866.87	4866.64	2662	3146.1	1681.56	825.23
90	4064.8	5154.4	2649.4	3130	1505.63	707.62

Figure 7.23: The effect of the size of the shading device on the annual cooling, heating and lighting requirements of the south facing classroom

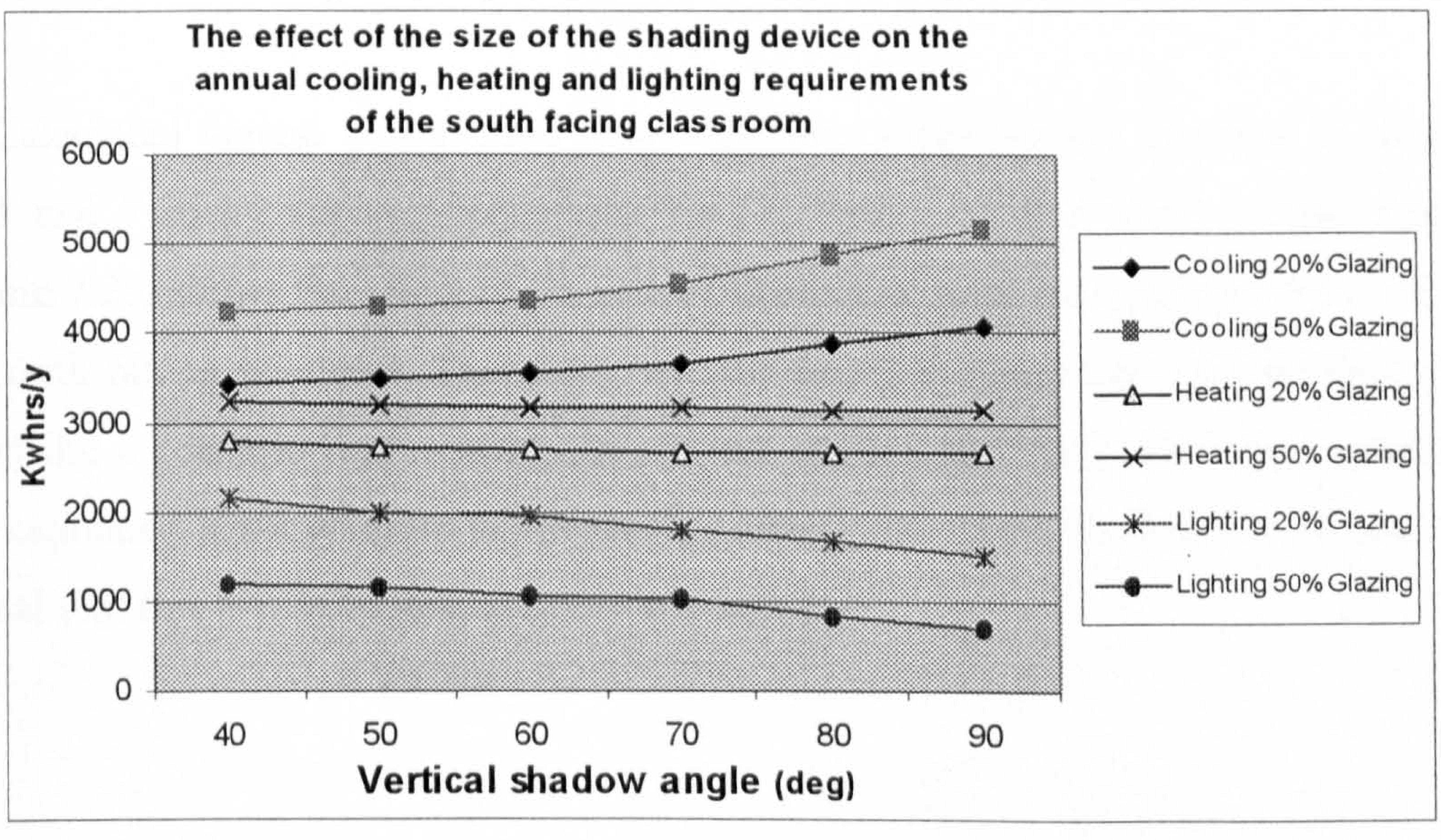
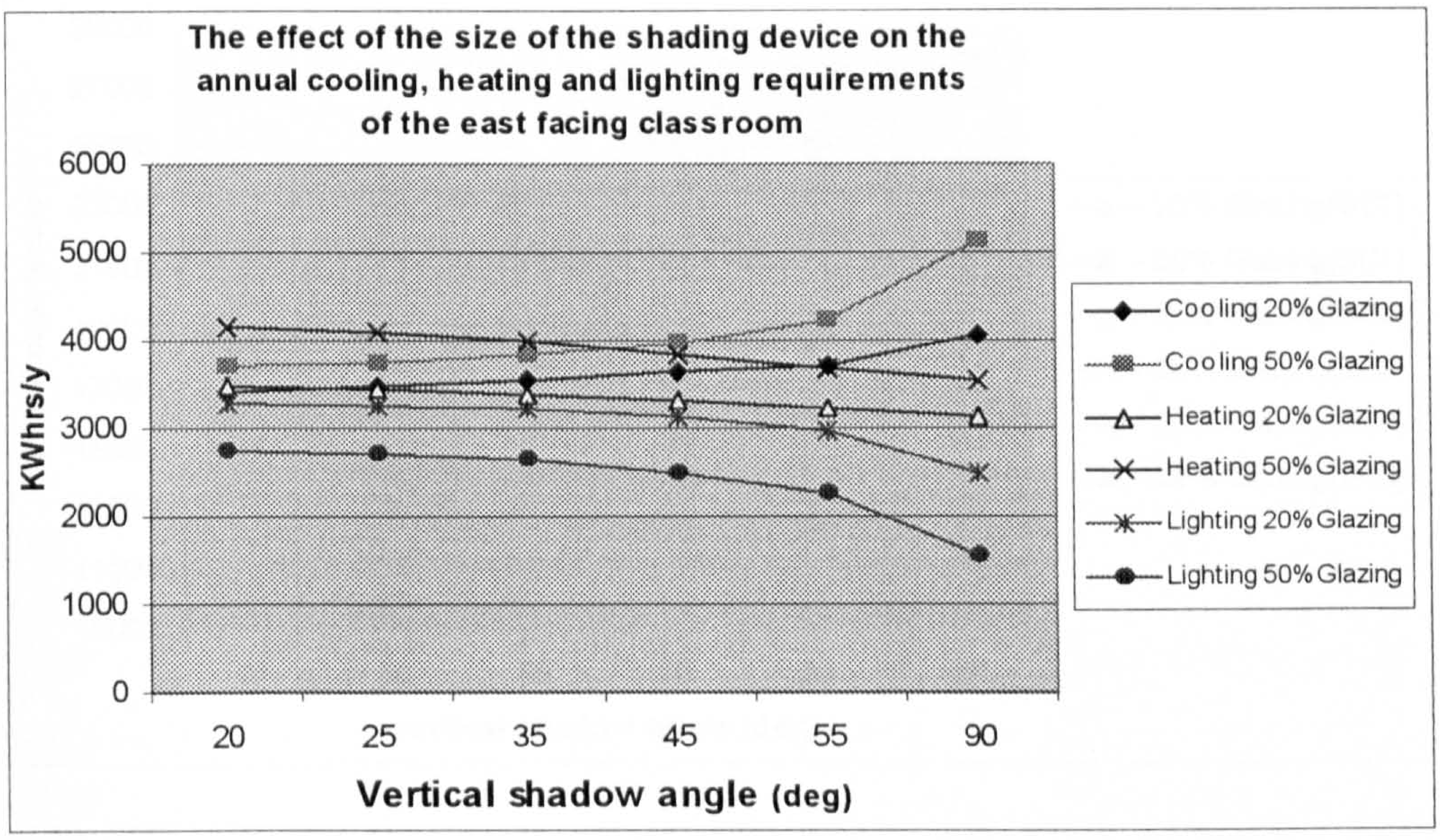


Table 7.10: The effect of the size of the shading device on the annual cooling, heating and lighting requirements of the east facing classroom

Vertical Shadow Angle (deg.)	Cooling Loads Kwhrs		Heating Loads Kwhrs		Lighting Loads Kwhrs	
	Glazing Ratio		Glazing Ratio		Glazing Ratio	
	20%	50%	20%	50%	20%	50%
20	3431.04	3697.48	3487.2	4164.9	3281.03	2731.63
25	3489.5	3749.57	3441.8	4086.8	3267.86	2709.94
35	3547.96	3827.7	3384.8	3992	3239.68	2648.7
45	3635.65	3981.71	3306.9	3840.1	3120.12	2499.98
55	3694.11	4237.63	3217.4	3684.8	2976.26	2270.59
90	4074.1	5113	3124.4	3550.5	2474.71	1562.01

Figure 7.24: The effect of the size of the shading device on the annual cooling, heating and lighting requirements of the east facing classroom



Calculated annual cost factors under different scenarios are outlined in figurers 7.25 and 7.26 by applying equations 7.8, 7.9 and 7.10 developed in this chapter. Figure 7.25, shows the effect of the size of shading devices incorporated in the design of south facing windows. Therefore, we can find the optimal size of the device by choosing a scenario representing the nearest conditions. Using the Olgyay method, the estimated shadow angle of the device determined to be 50 degrees. Figure 7.25 reveal that this is overestimated under any scenario.

Table 7.11: Fenestration cost analyses for south facing classroom

Vertical Shadow Angle (deg.)	Annual Cost Factor					
	Scenario 1		Scenario 2		Scenario 3	
	20% Glazing	50% Glazing	20% Glazing	50% Glazing	20% Glazing	50% Glazing
40	19836.276	17559.42	26678.265	23810.865	14532.917	13191.837
50	19104.974	17512.907	25784.165	23811.755	13992.309	13126.021
60	19047.561	17208.972	25769.16	23473.14	13917.938	12884.412
70	18483.171	17387.948	25074.6	23845.865	13511.606	12946.837
80	18334.046	16972.41	25017.47	23483.925	13357.09	12596.317
90	17880.617	16938.11	24539.93	23621.42	13006.188	12504.36

Figure 7.25: Fenestration cost analyses for south facing classroom

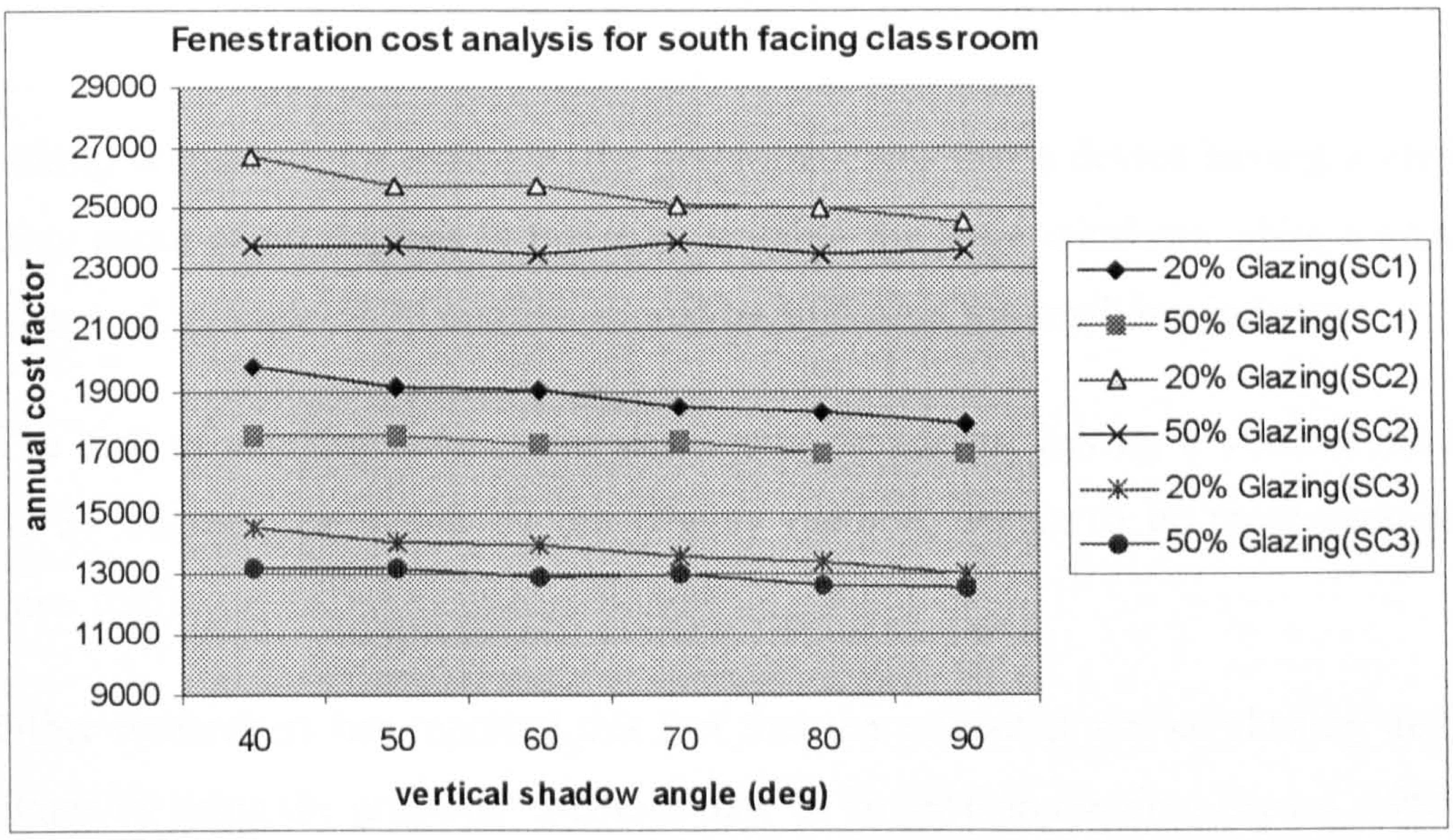
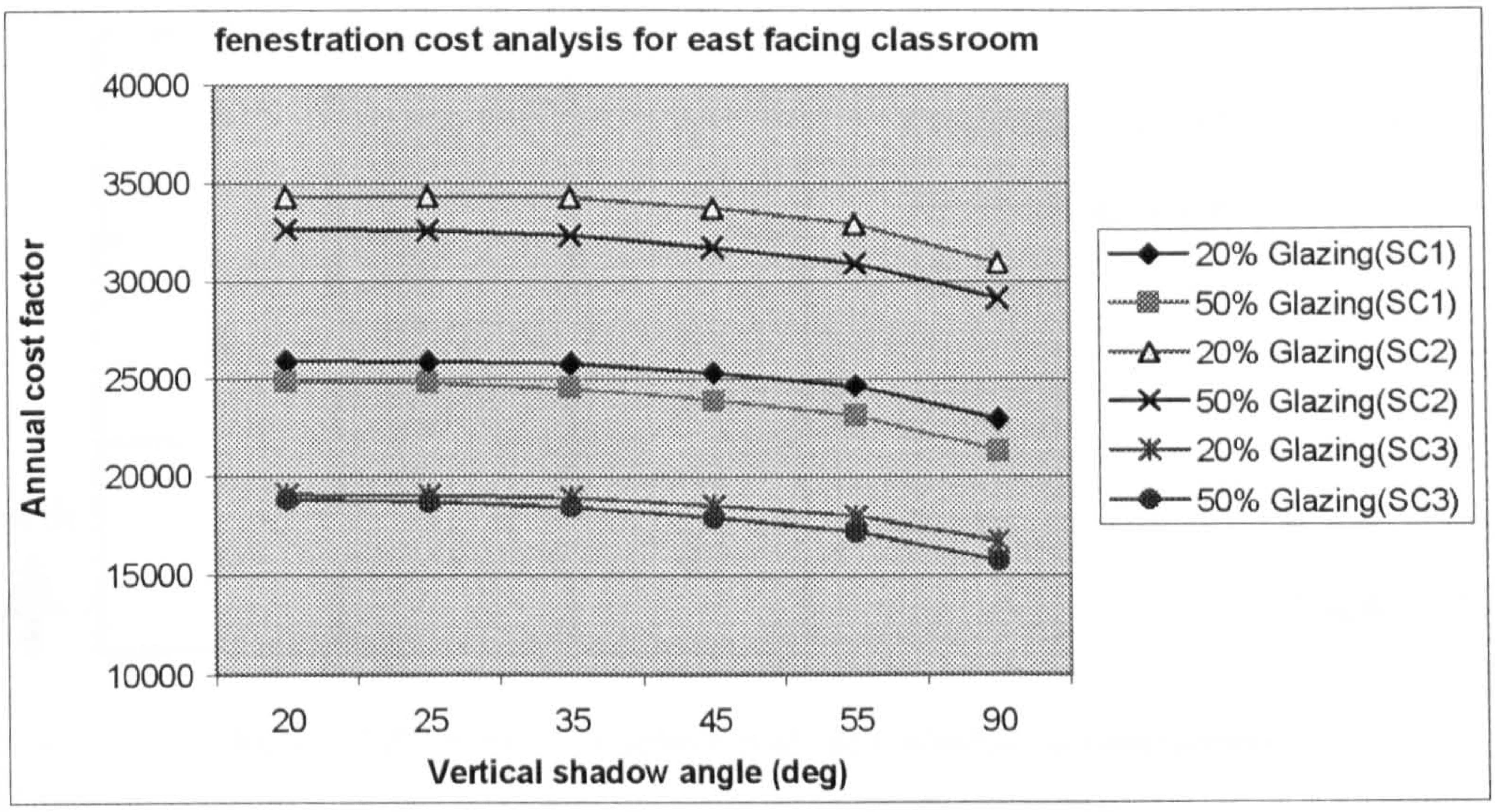


Table 7.12: Fenestration cost analyses for east facing classroom

Vertical Shadow Angle (deg.)	Annual Cost Factor					
	Scenario 1		Scenario 2		Scenario 3	
	20% Glazing	50% Glazing	20% Glazing	50% Glazing	20% Glazing	50% Glazing
20	25927.203	24903.606	34338.3	32688.345	19097.754	18847.753
25	25908.244	24788.08	34377.91	32616.85	19040.886	18704.346
35	25805.152	24517.57	34312.96	32365.3	18919.616	18440.44
45	25313.577	23908.331	33761.295	31745.135	18518.533	17894.617
55	24643.45	23114.653	32961.64	30942.43	17995.948	17203.016
90	22937.467	21309.66	30976.06	29149.185	16715.978	15728.365

Figure 7.26: Fenestration cost analyses for east facing classroom



Taking scenario 1 for example, the graph indicates that a device having a vertical shadow angle of 60 degrees is the most suitable for large windows while a smaller overhang of an angle of 70 degrees should be sufficient for smaller windows.

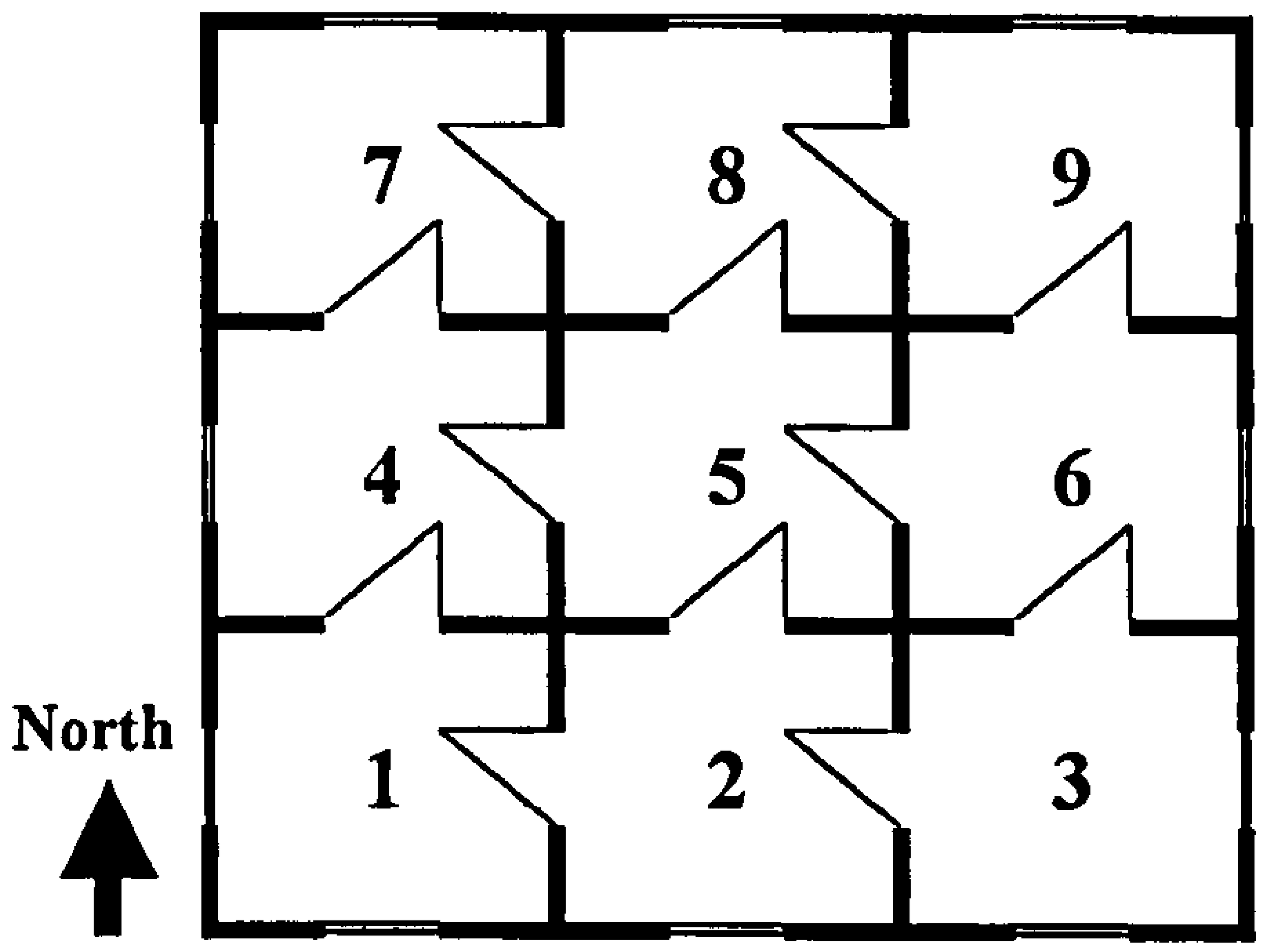
The size of shading devices for east facing windows, having a vertical shadow angle 35 degrees, estimated by the Olgyay method, seems to be more reasonable (Figure 7.26).

Other researchers has reported this fact that the estimated size of shading devices designed by using the graphical methods may be larger than required (Etzion, 1985).

According to the results obtained, the fenestration design of the reference school (Figure 7.27) was modified as shown in figure 7.28. The size of the windows of the reference school, each comprising 20% of its wall area, was not changed, as it is appropriate to satisfy view out, while being reasonably energy efficient. East and west facing windows in four corner classrooms, i.e. zones 1,3,7, and 9, were eliminated because of their poor thermal performance.

No devices were considered for north facing windows since shading on these windows does not show significant savings. Shading devices having a vertical shadow angle of 70 degrees were placed over south facing windows, and those with an angle of 35 degrees on east and west facing windows.

Figure 7.27: Floor plan of the reference school



Notes:

Classroom Dimensions: 6.00* 6.00m

Floor-ceiling height: 3.00m

Windows: width: 2.40m

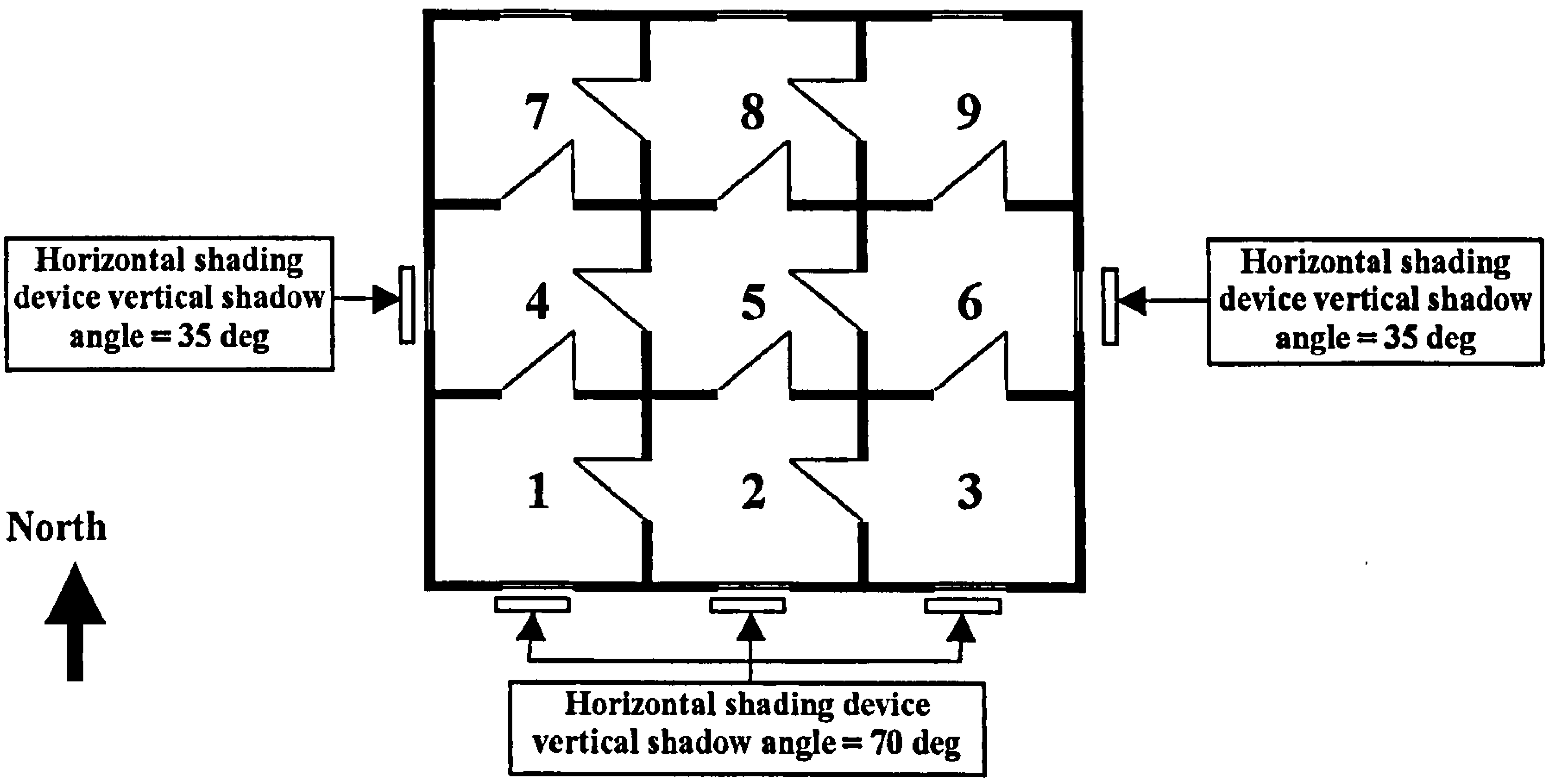
Sill height: 1.00m

Head height: 2.50m

Doors: Width: 1.00m

Height: 2.00m

Figure 7.28: Reference school with new window arrangements



The external walls of the models are 220 mm brickwork plastered internally. The floor is concrete and the roof is a traditional warm roof consisting a concrete slab insulated externally and internal partitions are 110 mm brickwork plastered on both sides. The glass chosen is a single pane of 4 mm clear float, which is the most commonly available glass, used in the school industry.

In figure 7.29 are shown the annual heating, cooling and lighting loads and the associated annual cost factors (assuming scenario 1 applies) of both the original reference school (Figure 7.27) and the school with the new window arrangements (Figure 7.28). A substantial saving in the annual running cost as much as 14% has been achieved under the new design strategy (Gorji and Ward, 2001).

Note: Figures 7.27 and 7.28 are just model plans with two different passive and non-passive zones for calculation of heating, cooling and lighting energy requirements in these zones. They are not real school plan.

Table 7.13: The effect of fenestration design on energy requirements

Orientation	Load	Shading	Glazing Ratio %					
			0	10	20	30	40	50
North No. 8	Cooling	New	3280.5	3453	3619.4	3782.7	3958.3	4124.7
		Old	3280.5	3453	3619.4	3782.7	3958.3	4124.7
	Heating	New	3054.4	3290.5	3523.6	3762.7	3998.8	4243.8
		Old	3054.4	3290.5	3523.6	3762.7	3998.8	4243.8
	Lighting	New	3534.19	3446.71	3298.00	3208.57	3091.93	2915.03
		Old	3534.19	3446.71	3298.00	3208.57	3091.93	2915.03
East No. 6	Cooling	New	3383.6	3725.9	4074.1	4422.5	4764.7	5113
		Old	3383.6	3783.5	4177.4	4580.4	4977.3	5377.2
	Heating	New	2930.4	2890.1	2946.2	3042.4	3171.9	3344.1
		Old	2930.4	2890.1	2946.2	3042.4	3171.9	3344.1
	Lighting	New	3534.19	2358.07	2327.94	2151.04	2032.45	1562.01
		Old	3534.19	2121.88	2091.74	2091.74	2032.45	1562.01
West No. 4	Cooling	New	3368.4	3921.7	4472	5028.4	5578.6	6132
		Old	3368.4	3994.6	4620.8	5247	5867.1	6499.4
	Heating	New	2940.6	3063.7	3247.7	3459.3	3677.4	3898.2
		Old	2940.6	3063.7	3247.7	3459.3	3677.4	3898.2
	Lighting	New	3534.19	2240.46	2210.33	2003.29	1944	1531.87
		Old	3534.19	2004.26	1974.13	1944	1944	1531.87
South No. 2	Cooling	New	3344.4	3707.6	4064.8	4428	4797.3	5154.4
		Old	3344.4	3840.9	4334.4	4831	5336.7	5827.1
	Heating	New	2772.8	2646.7	2700.3	2818.2	2987.9	3163.5
		Old	2772.8	2646.7	2700.3	2818.2	2987.9	3163.5
	Lighting	New	3534.19	1799.17	1505.63	1005.05	531.68	413.1
		Old	3534.19	1324.84	885.49	708.59	531.68	413.1
North-West No. 7	Cooling	New	3482.8	4278.3	5071	5857.4	6656.2	7448.8
		Old	3495	3667.5	3833.9	3997.2	4172.8	4339.2
	Heating	New	3351.7	3724.6	4166.6	4629.7	5086.9	5558.9
		Old	3323.7	3559.8	3792.9	4032	4268.1	4513.1
	Lighting	New	3534.19	2152.98	1974.14	1677.67	1501.74	912.71
		Old	3534.19	3446.71	3297.99	3208.57	3091.93	2915.03
North-East No. 9	Cooling	New	3494.55	4067.4	4630.7	5190.9	5763.4	6329.7
		Old	3495	3667.5	3833.9	3997.2	4172.8	4339.2
	Heating	New	3354.4	3690.1	4122.8	4564.9	5003.6	5460.5
		Old	3323.7	3559.8	3792.9	4032	4268.1	4513.1
	Lighting	New	3534.19	2270.59	2091.74	1825.42	1590.19	942.85
		Old	3534.19	3446.71	3297.99	3208.57	3091.93	2915.03
South-West No. 1	Cooling	New	3546.7	4532.9	5516.4	6502.7	7494.39	8478.5
		Old	3558.9	3922.1	4279.3	4642.5	5011.8	5154.4
	Heating	New	3070.1	3080.8	3343.3	3685.2	4075.7	4478.6
		Old	3042.1	2916	2969.6	3087.5	3257.2	3432.8
	Lighting	New	3534.192	505.45	181.77	0.00	0.00	0.00
		Old	3534.19	1799.17	1505.63	1005.05	531.68	413.1
South-East No. 3	Cooling	New	3558.9	4322	5076.1	5836.2	6602.4	7359.4
		Old	3558.9	3922.1	4279.3	4642.5	5011.8	5154.4
	Heating	New	3042.1	3046.3	3299.5	3620.4	3992.7	4380.2
		Old	3042.1	2916	2969.6	3087.5	3257.2	3432.8
	Lighting	New	3534.192	623.05	299.38	0.00	0.00	0.00
		Old	3534.19	1799.17	1505.63	1005.05	531.68	413.1
Buffer No. 5	Cooling	New	1917.7	1917.7	1917.7	1917.7	1917.7	1917.7
		Old	1917.7	1917.7	1917.7	1917.7	1917.7	1917.7
	Heating	New	2486	2486	2486	2486	2486	2486
		Old	2486	2486	2486	2486	2486	2486
	Lighting	New	3534.19	3534.19	3534.19	3534.19	3534.19	3534.19
		Old	3534.19	3534.19	3534.19	3534.19	3534.19	3534.19

Table 7.14: The effect of fenestration design on energy requirements and energy cost

Loading		Glazing Ratio					
		0	10	20	30	40	50
Cooling Loads Kwhrs	New	29377.55	33926.5	38442.2	42966.5	47532.99	52058.2
	Old	29402.4	32168.9	34896.1	37638.2	40426.3	42733.3
Heating Loads Kwhrs	New	27002.5	27918.8	29836	32068.8	34480.9	37013.8
	Old	26915.8	27328.6	28428.8	29807.6	31372.6	33027.4
Lighting Loads Kwhrs	New	31807.722	18930.676	17423.112	15405.228	14226.188	11811.76
	Old	31807.718	22923.638	21390.793	19914.334	18381.478	16612.46
Annual Cost Factor	New	88187.77	80775.98	85701.31	90440.53	96240.08	100883.8
	Old	88125.92	82421.14	84715.69	87360.13	90180.38	92373.16

Old = Reference School (Fig 5.27) **New** = Reference School (Fig 5.28)

Figure 7.29: The effect of fenestration design on energy requirements

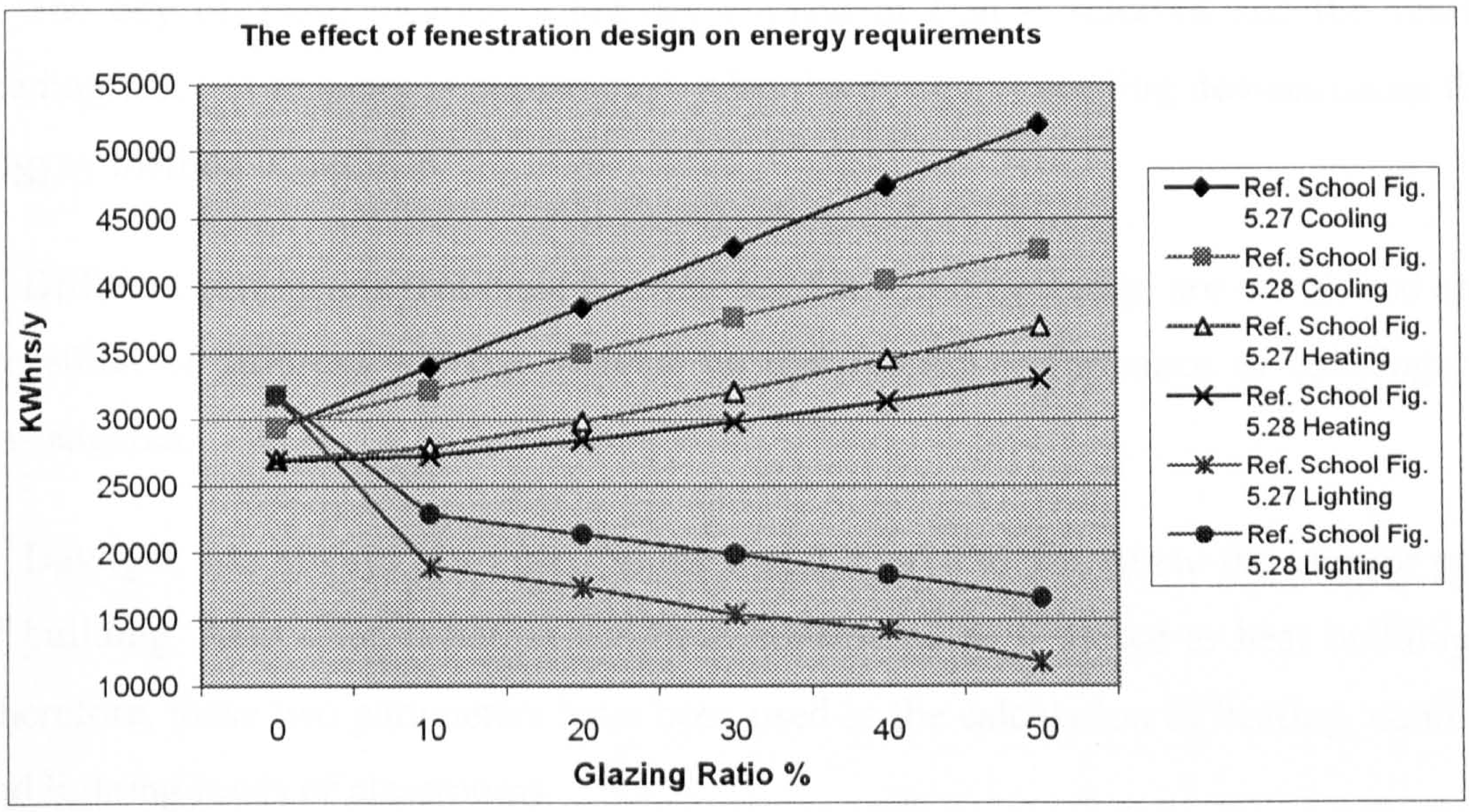
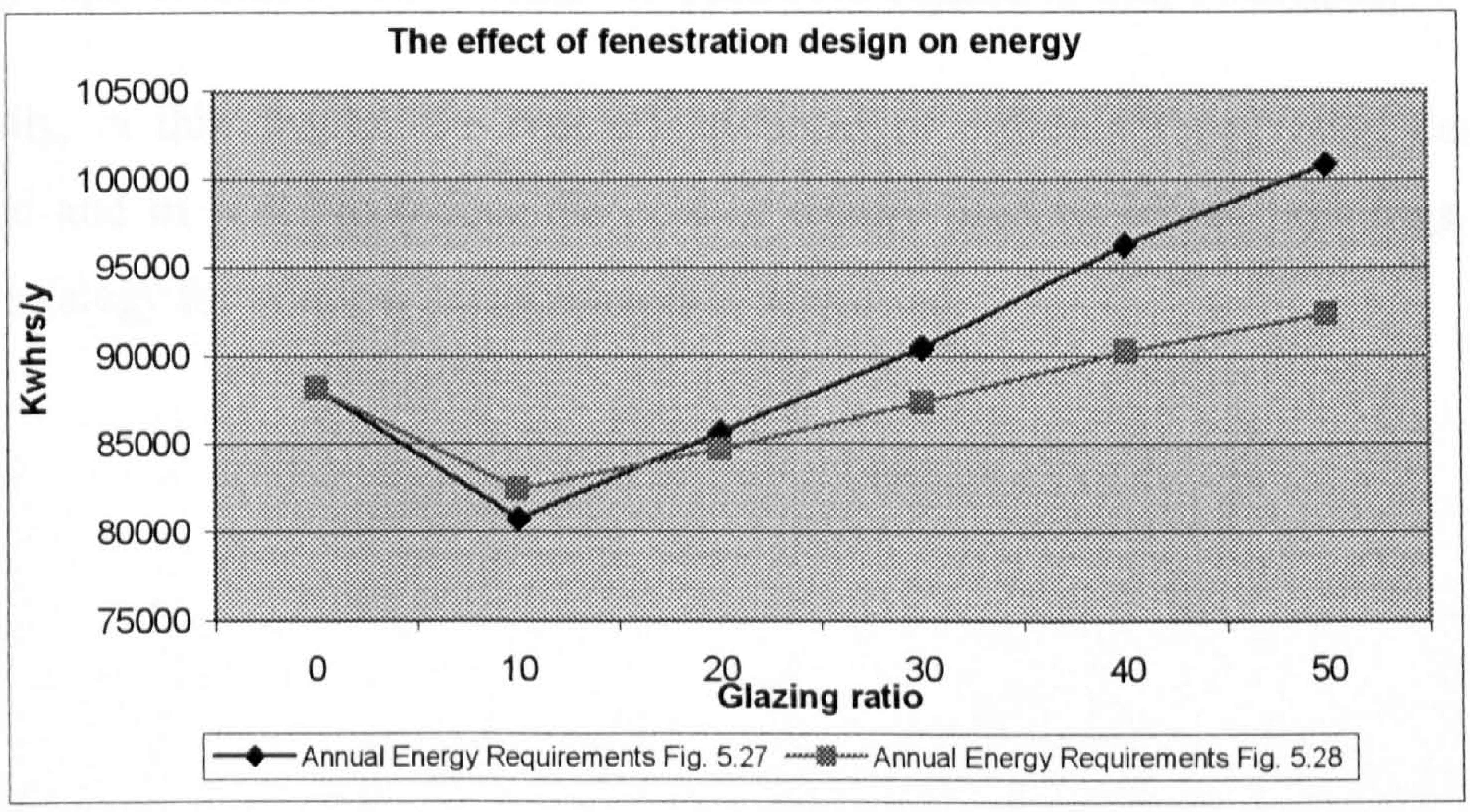


Figure 7.30: The effect of fenestration design on energy requirements



7_7 * Summary

The role of windows in energy conservation and the design of fenestration have a particular importance in buildings. Many researchers have given special attention to improve the energy balance of windows in order to reduce the energy requirements of buildings. The consequences of these researches are the large and growing range of different window systems.

In this chapter the effect of glazing areas, orientation and shading on the use and saving of energy in buildings is discussed.

The city of Yazd, located in hot dry climate of Iran is selected and the yearly shading chart of this city is constructed. Also the design of shading devices using the Olgyay method is outlined.

Different parameters that must be considered in window design are mentioned and the effect of different window systems on the thermal performance of buildings is investigated.

Daylight, has always been used as the major source to illuminate the interior part of building. Also solar radiation has been considered as a source to heat buildings. Therefore, these two parameters have been used in the calculation of heating, cooling and lighting loads of classrooms.

Furthermore, the effect of window size and shading on the cooling, heating and lighting requirements of classrooms has been investigated in four directions.

Finally, in this chapter the cost effectiveness of different fenestration design is analysed and in order to reduce the cost of energy used in school buildings a new design strategy for window arrangements is suggested.

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Chapter 8

The Educational System and Current School's Design in Iran

8 * The Educational System and Current School's Design in Iran

8_1 * Introduction

The philosophical concept of education in Iran could be defined as aiming for the creation of a good and righteous man. This is a major aspect of an education, which must achieve a basic objective: It must enable man to understand and feel Allah so that he worships him in full conviction of his Oneness.

In this way, man should develop all his knowledge, facilities, to equip him, for a better life, knowing that these things all come from Allah so he should pray for them. The sources of knowledge of Islamic education have been classified into the following categories:

1) The human intellect and its tools are in a constant interaction with the physical universe on the levels of observation, contemplation, experimentation and application. In Iran knowledge presented initially in school is continued at university.

2) The human being is developed spiritually and morally as well as physically. So the best ways to develop these qualities are by obedience to Allah's laws. Determining of these laws, in Iran, there are some specialised organisations, similar to universities, which present these subjects. These systems also accept students who have completed high school.

The Iranian education system is controlled by four organisations. The school system including high schools are organised by the Ministry of Education; universities and colleges are organised by the Ministries (Science, Research and Technology) and (Health and Medicine Education) and religious universities are organised by the "Hozeh- Elmieh".

In order to suggest a new design for school buildings in Iran, it would be necessary to review the history of the educational system, the population of pupils and the design of the existing schools. Therefore, a case study will be performed in various climatic regions of Iran. Furthermore, a comparison will be made between the calculated annual energy used and the actual energy consumption of the current school buildings.

8_2 * The History of Education in Iran

Prior to the mid-nineteenth century, it was traditional in Iran for education to be associated with religious institutions. The clergy, Shia and non-Shia, assumed responsibility for instructing youth in basic literacy and the fundamentals of religion. Knowledge of reading and writing was not considered necessary for all the population, and thus education generally was restricted to the sons of the economic and political elite. Typically, this involved a few years of study in a local school, or maktab. Those who desired to acquire more advanced knowledge could continue in a religious college, or madraseh, where all fields of religious science were taught. A perceived need to provide instruction in subjects that were not part of the traditional religious curriculum, such as accounting, European languages, military science, and technology, led to the establishment of the first government school in 1851. For many years this remained the only institution of higher learning in the country (Cyberiran, 1996).

By the early twentieth century there were several schools teaching foreign languages and sciences, including a few for girls. These schools were run by foreign missionaries, private Iranians, and the government. Their function was to educate the children of the elite. During the Constitutional Revolution (1905-1907), a number of reform-minded individuals proposed the establishment of a nationwide, public, primary school system. Progress in opening new schools was steady but slow, and by the end of the Qajar dynasty (1925) there were approximately 3,300 government schools with a total enrolment of about 110,000 students (Ibid).

During the Pahlavi era (1925-79), the government implemented a number of policies aimed at modernising the country and expanded the education system. The Ministry of Education was given responsibility for regulating all public and private schools and drafted a uniform curriculum for primary and for secondary education. The entire public system was secular and for many years remained based upon the French model. Its objective was to train Iranians for modern occupations in administration, management, science, and teaching. This education system was the single most important factor in the creation of the secularised middle class.

The goal of creating a nationwide education system was never achieved during the Pahlavi era. In 1940 only 10 percent of all elementary-age children were enrolled in school, and less than 1 percent of youths between the ages of 12 and 20 were in secondary school. These statistics did not increase significantly until the early 1960s, when the government initiated programs to improve and expand the public school system. By 1978 approximately 75 percent of all elementary-age children were enrolled in primary schools, while somewhat less than 50 percent of all teenagers were attending secondary schools (Ibid).

Modern college and university education also was developed under the Pahlavis; by the 1920s, the country had several institutes of higher education. In 1934 the institutes associated with government ministries were combined to form the University of Tehran, which was coeducational from its inception. Following World War II, universities were founded in other major cities, such as Tabriz, Esfahan, Mashhad, Shiraz, and Ahvaz. During the 1970s, these universities were expanded, and colleges and vocational institutes were set up in several cities.

One of the first measures adopted by the government after the Revolution in 1979 was the desecularisation of the public school system. This was a three-pronged program that involved purging courses and textbooks believed to slander Islam and substituting courses on religion; purging teachers to ensure that only those who understood the true meaning of Islam (i.e., were not secular) remained in the schools; and regulating the behaviour and dress of students.

Although the government reintroduced the study of religion into the public school curriculum from primary grades through college, it did not act to alter the basic organisation of the education system. Thus, as late as the school year 1986-1987, schools had not changed significantly from the pattern prior to the Revolution. Students studied in primary schools for five years, beginning the first grade at about age seven. Then they spent three years, designated the guidance cycle, in a middle school. In this cycle, the future training of students was determined by their aptitude as demonstrated on examinations. Students were then directed into one of three kinds of four-year high schools: the academic cycle, preparing for college; the science and mathematics cycle, preparing for university programs in engineering and medicine; and the vocational technical cycle.

The Ministry of Education announced that nearly 11.5 million students were registered for elementary and secondary schools during the academic year 1986-1987 (Ibid). Statistics on the percentage of young people aged seven through nineteen enrolled in school have not been available since the Revolution. It is generally estimated that the percentages have remained similar to those before the Revolution: school attendance of about 78 percent of elementary-age children and less than 50 percent of secondary-age youth.

Since the Revolution, high school education has experienced significantly more drastic changes than elementary and secondary school education. High school education (Reform system) covers three years and a one-year pre-university programme. This education offers three branches: theoretical, technical-vocational and skill-knowledge (kar-Danesh). Each are divided into different fields. The required total number of credits leading to the High School Certificate is 96. The courses offered in the first year are common and after successfully completing the first year, based on aptitude, interest and the grades obtained in guidance school, students can continue their studies. The one-year pre-university programme prepares students to enter university and higher education institutions. To enter this course, students should pass the appropriate exam. After successfully passing the one-year period, they are granted the Pre-University Certificate and can sit for the National Entrance Exam of universities and higher education institutions. Qualified students entering the technical-vocational branch can continue studies leading to the Post-Diploma degree (technician) or sit for the Pre-University Examination. Those who wish to acquire skills before completing secondary education can enter the skill-knowledge branch and obtain first or second class Skill Certificate or sit for the Pre-University Examination as well (UNESCO, 2000).

8_3 * The Population and Pupils in Iran

The Population in Iran is increasing at a similar rate to that in other developing countries. The sharp increase in the last century in particular is considerable (see table

8.1). Around the year 1900 the population of the country was about 9 million. During the first part of the twentieth century the population grew relatively slowly. Subsequently a rapid increase occurred by factors such as the non-restriction on birth control and improvement in general health conditions, which took place in Iran from 1979 (Statistical centre, 1998).

After the revolution in 1979, Iran with 3.8% annual average population growth rate was one of the countries in which the population was growing very fast. This population passed from 36 million in 1979 to 66 million inhabitants in 2000. With a simple estimate near the 42.5% of the total population is between 0-18 years old. The high annual growth rate and the percentage of the young population explains the big task of the government to provide this population with the basic facilities of life, the most important of which is providing them with schooling. However, in recent years the government is encouraging people to use birth control, a policy which is having some effects as is shown by the fall in the birth rate down to 2.12% in the 1995 (Ibid) and 0.72% in the year 2001. (see tables 8.1,8.2). In order to achieve the schooling needs of the country; the ministry of education has build up almost 93,247 schools (70% of the total existing number) during the last 22 years, i.e. since the revolution in 1979. The total number of school buildings in Iran in year 2001 is almost 133,210. Although the huge numbers of new school buildings, more than 50% of schools has been used in two different shifts during the same working day i.e. morning and afternoon during the last educational year (Bourbour, 2001). Therefore, the government has still some problems in, providing new school buildings.

In the educational year 2001-02 the total number of 18,034,616 pupils will attend three different levels of education throughout the country. The detail of the number of pupils in1996 and 2001 has been shown in table 10.3 (UNESCO, 2000 and IRNA, 2001).

Table 8.1: The population of Iran from 1901-2000
(UNESCO, 2000 and Statistical centre 1998)

Year	1901	1911	1926	1935	1946	1956	1966	1976	1986	1996	2000
Population	8,613,000	9,143,000	10,456,000	11,964,000	14,159,000	18,954,704	25,788,722	33,708,744	49,445,010	60,055,488	65,619,363
Growth Rate	0.6	0.6	1.43	1.44	1.83	3.38	3.6	3.1	4.66	2.12	0.83

Table 8.2: The population of Iran from 2000 - 2001
(UNESCO, 2000 and CIA, 2001)

Years	Age Structure							Growth Rate
	Population	0-14 Years		15-64 Years		65 Years and Over		
2000	65,619,363	34%	22,578,151	61%	40,030,515	5%	3,010,970	0.83%
		M	11,542,446	M	20,151,083	M	1,592,753	
		F	11,035,705	F	19,879,432	F	1,418,217	
2001	66,128,965	32.97 %	21,804,937	62.38%	41,253,673	4.65%	3,070,355	0.72%
		M	11,150,053	M	20,765,001	M	1,617,045	
		F	10,654,884	F	20,488,672	F	1,453,310	

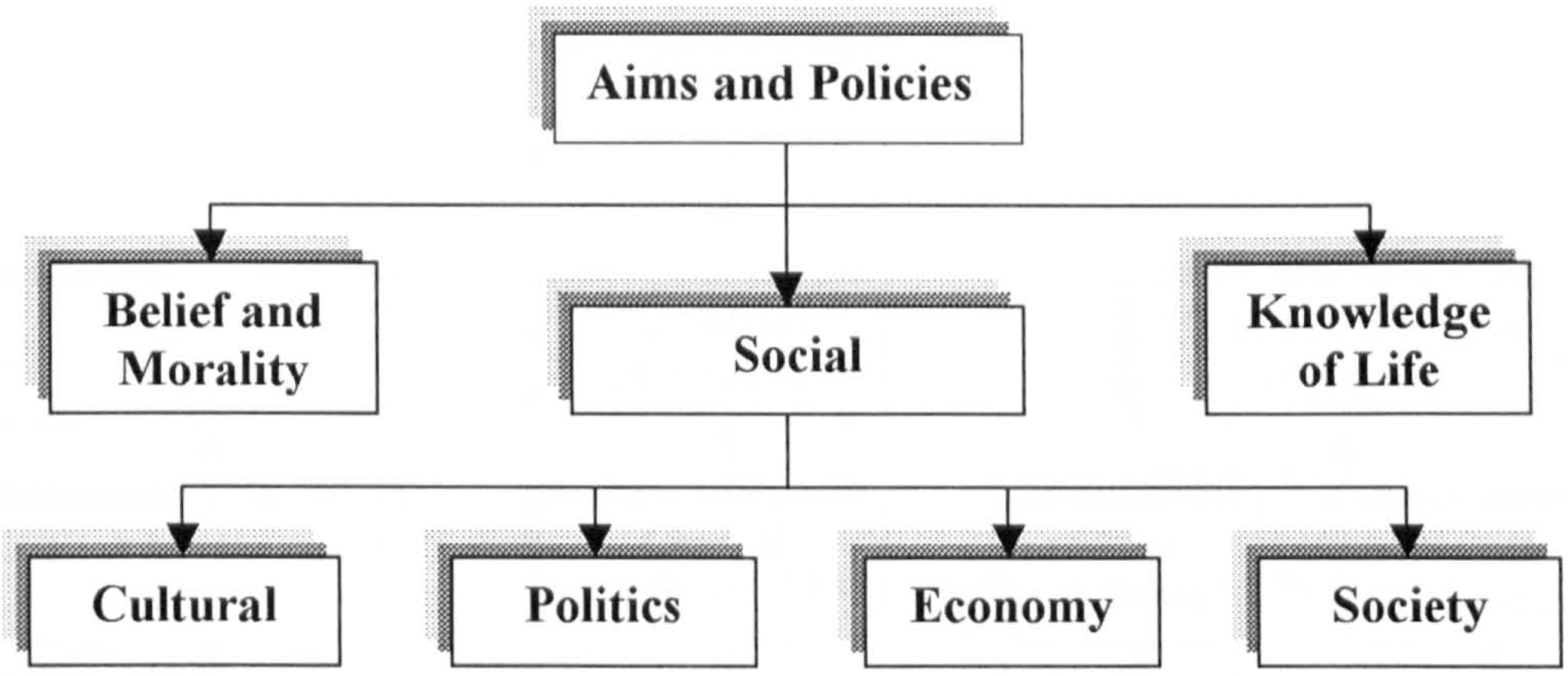
Table 8.3: Pupils by grade both sex in three levels of education in Iran (1996, 2001)
(NESCO, 2000 and IRNA, 2001)

Year	Total	Grade																			
		Pre-primary		Primary School							Secondary School					High school					
		Total		Total		1	2	3	4	5	Total		1	2	3	Total		1	2	3	4
1996	1,821,1366	MF	196,181	MF	9,238,393	1,905,324	1,818,331	1,773,651	1,849,888	1,891,199	MF	5,188,872	1,933,431	1,726,338	1,529,103	MF	3,587,920	1,204,922	984,903	853,399	544,696
		M	99,842	M	4,885,665						M	2,785,491				M	1,926,068				
		F	95,339	F	4,352,728						F	2,403,381				F	1,661,852				
2001	18,034,616	MF	358,319	MF	7,568,084	1,402,791	1,475,927	1,484,542	1,573,543	1,631,281	MF	5,063,082	1,754,825	1,674,704	1,633,553	MF	5,045,131	1,261,060	1,289,223	1,318,011	1,176,837
		M	185,123	M	3,870,122						M	2,597,328				M	2,608,306				
		F	173,196	F	3,697,962						F	2,465,754				F	2,436,825				

8_4 * The Aims and Policies of Iranian Education

The aims and policies of Iranian education are based on three categories i.e. the belief and morality, social objectives and the knowledge of life. There are four different social policies in Iranian education as shown in below (Figure 8.1):

Figure 8.1: The aims and policies of Iranian education



8_5 * The Structure of Education in Iran

The following chart shows the structure of education in Iran at different stages in Iran (Figure 8.2).

The pattern of the general educational system in Iran comprises four levels:

A) From age 3 to 6, the children go to kindergarten and nursery. The children have freedom to attend during this period and mostly; these schools are in the private sector.

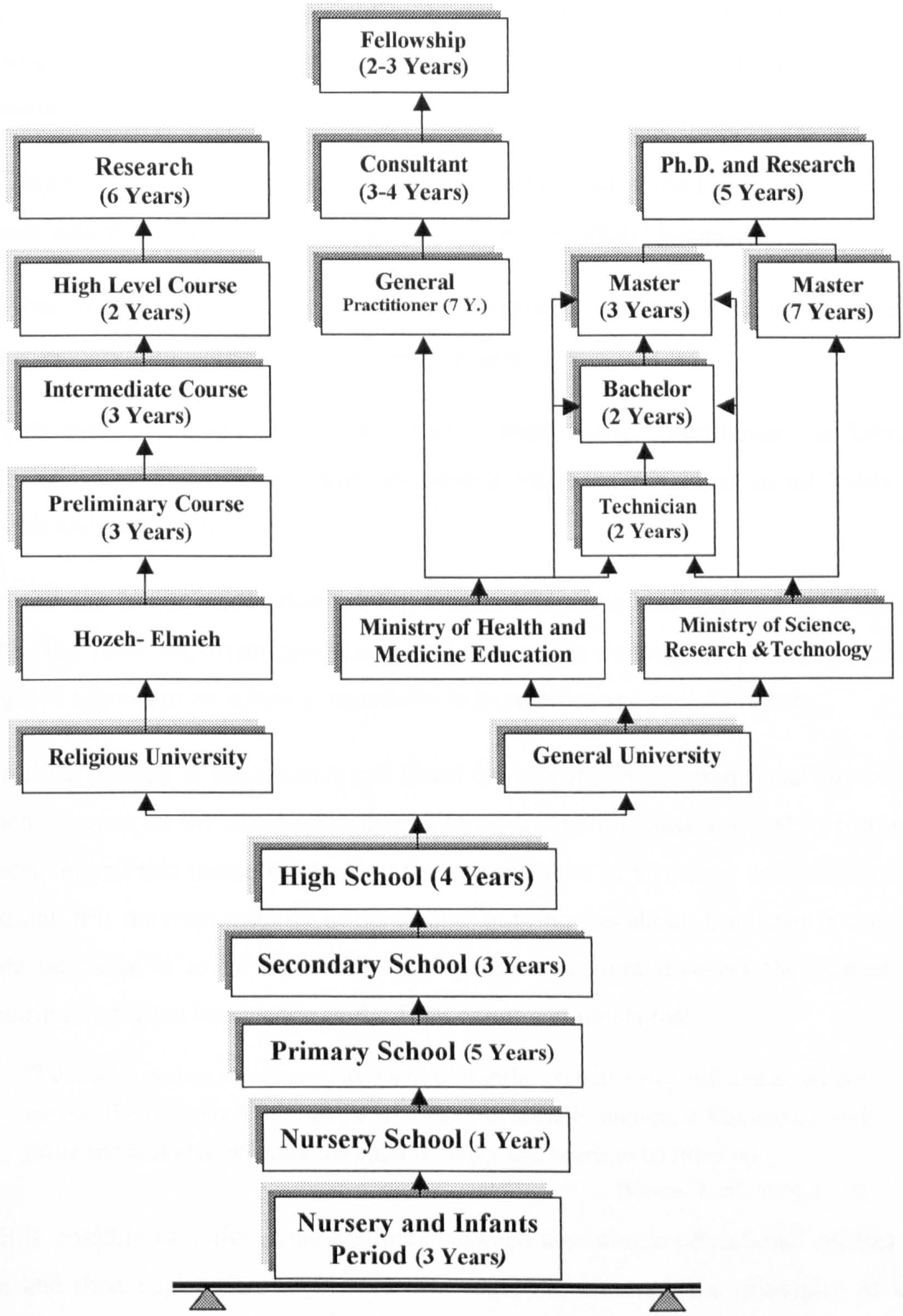
B) From age 7, to 11, the children go to primary for 5 years.

C) From age 12 to 14, the children attend to Secondary school for 3 years.

D) From age 15 to 18, the children are admitted to high school for 4 years.

One of the most important features that characterises the Iranian system is the complete separation of boys and girls education. This requires duplication of facilities and administration as well as instruction throughout the elementary, intermediate and high school periods. But in general at university males and females study together.

Figure 8.2: The structure of Iranian education



8_6 * The Curriculum and Teaching Methods

Male and female have almost the same curriculum and text books are prescribed by the central authorities at all levels for both sexes.

Teaching method and curriculum are based on a class group organisation, where age groups split all students up and each age group is divided into classes usually between 30-40 students. This is similar to the traditional pattern found in western countries.

Despite the philosophy of Islamic education at the head of the hierarchical order of Iranian educational aims, educational system is not yet totally Islamised.

What is happening in Iran is that the traditional western method of general education has been adapted for the Iranian situation.

This system started in 1851 in a high school called "Darolfonon" in Tehran (Zamiry 1992). Several years later, the system had been developed in all levels in schools and universities.

Since the Iranian revolution (1979), Iranian education was changed in different parts. The most important one was the change in the contents of books that were taught in schools in all subjects, especially in humanities and social sciences.

But the method of education is still based on the concept of a traditional approach, which depends on the assumption that children are more or less ambivalent towards education, and that means of teaching them are matters of direction, compulsion and restraint. It is the responsibility of the teacher to bring this about. Emphasis is usually made on 'what is to be learned' assuming that education involves the student in acquiring important knowledge skills. T. W. Moor comments that:

> "Education is thus represented as a sort of translation between a full and an empty vessel. The teachers a full man, a repository of socially important Knowledge and skills and attitudes, whereas the pupil is empty and needs to be filled up."
>
> (Moore, T. W., 1974, p. 20)

It is possible to notice some conflicts between the Islamic educational aspects in Iran and their application in practice. For example, although the principles of the educational policy encourage the spirit of scientific research and thinking among students, and it also allows individual differences to be discussed among them. Teaching methods in schools tent to respond to that individualism by following the traditional approaches.

Finally, the educational approach at the moment and in the future, in Iran will accommodate a change towards new Islamic education best described as 'human centred' which includes 'child centred', 'teaching and learning' and uses 'teacher personality' and 'social cultures'.

It is considered important to illustrate this by including some views of Iranian schools and some pictures from this kind of life. Several plants of schools in Iran will be shown to develop this theme.

$8_{6.1}$ * Classroom Types

Figure 8.3: Fixed desks and chairs

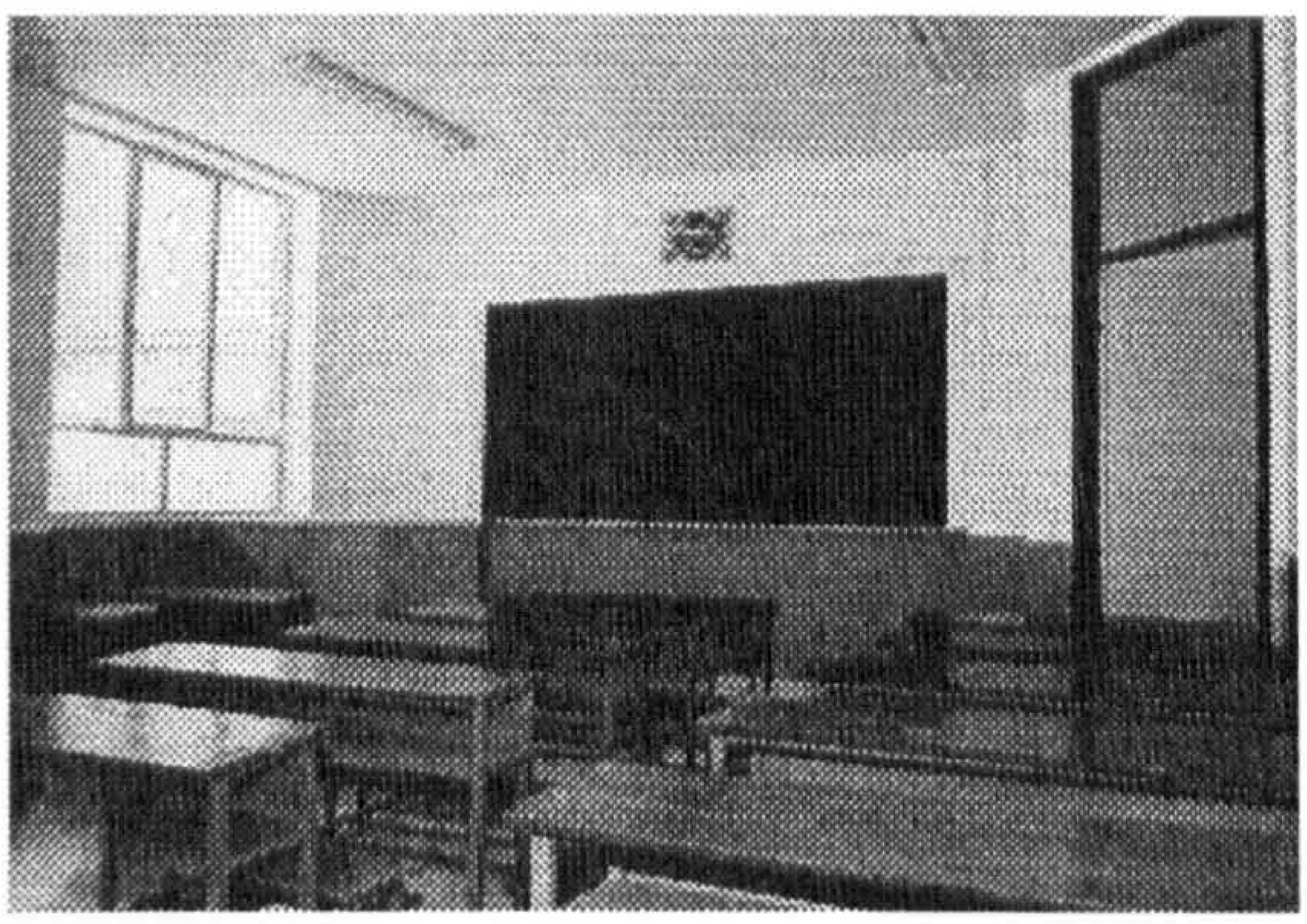
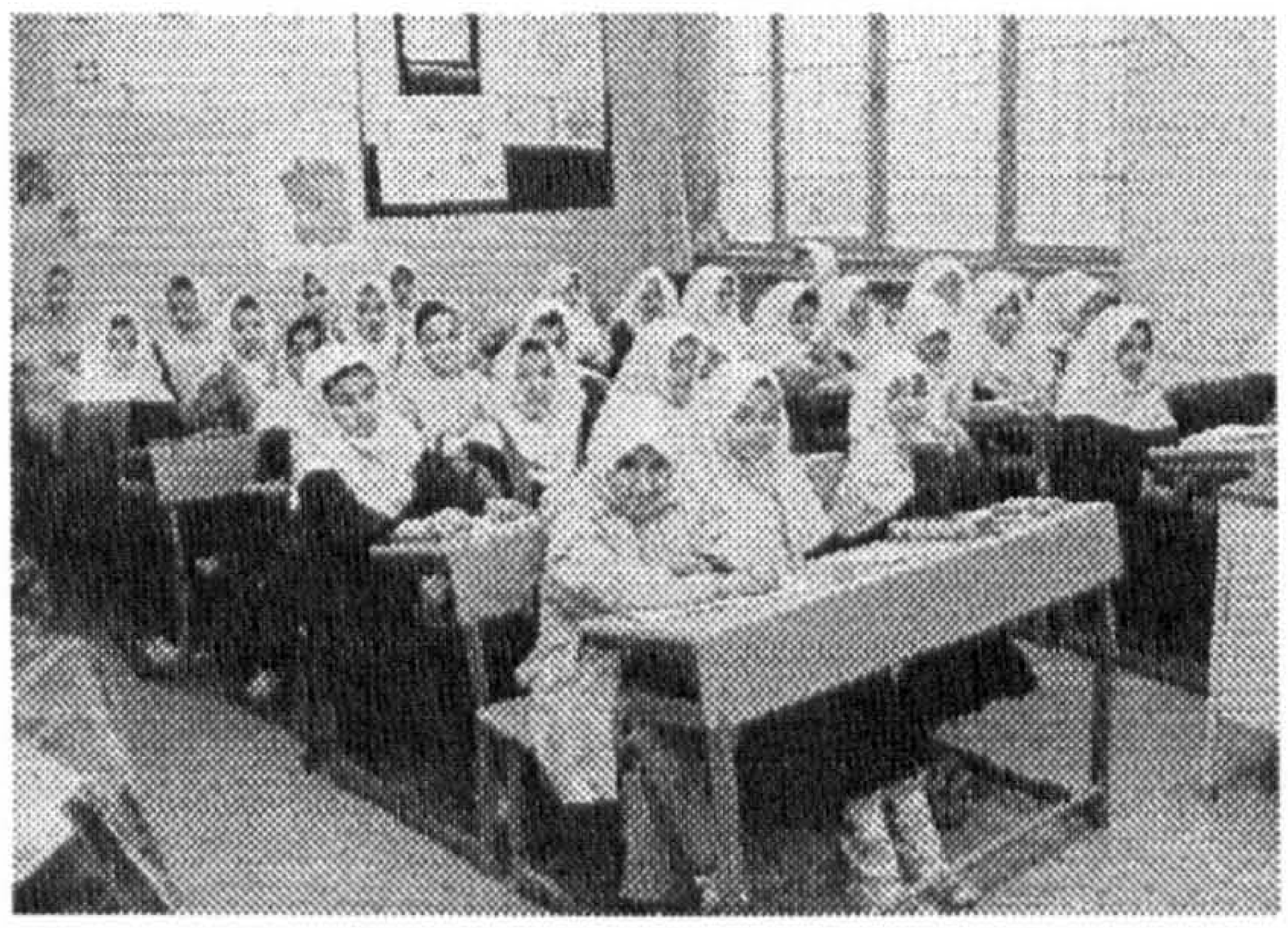


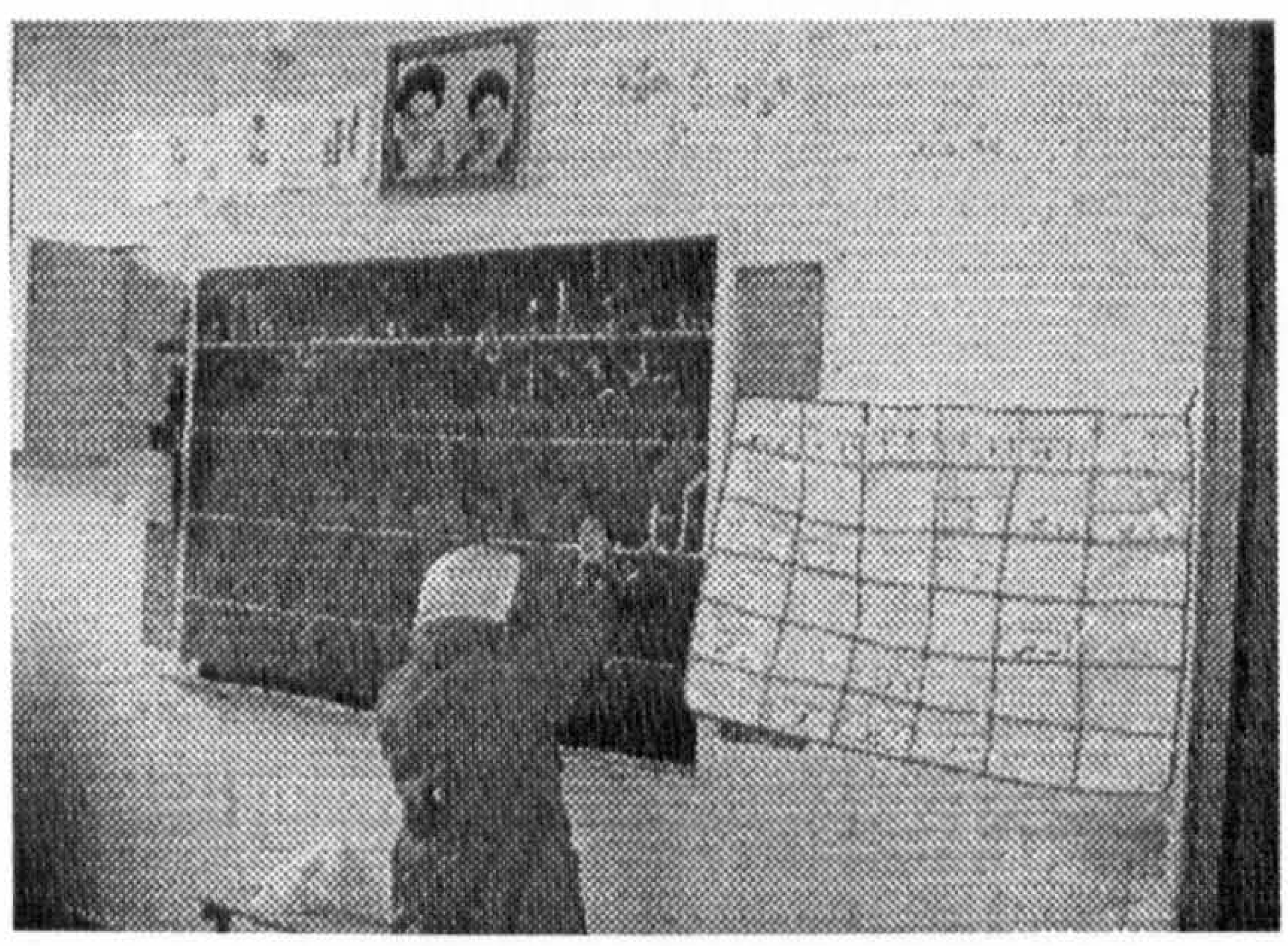
Figure 8.4: Pupils have their own places



$8_{6.2}$ * Answering or Explaining the Subject

Figure 8.5: Based on individual works and not group work

Figure 8.6:Blackboard has a special position



$8_{6.3}$ * Facilities in Classroom

Figure 8.7: Education equipment accessible only by teachers

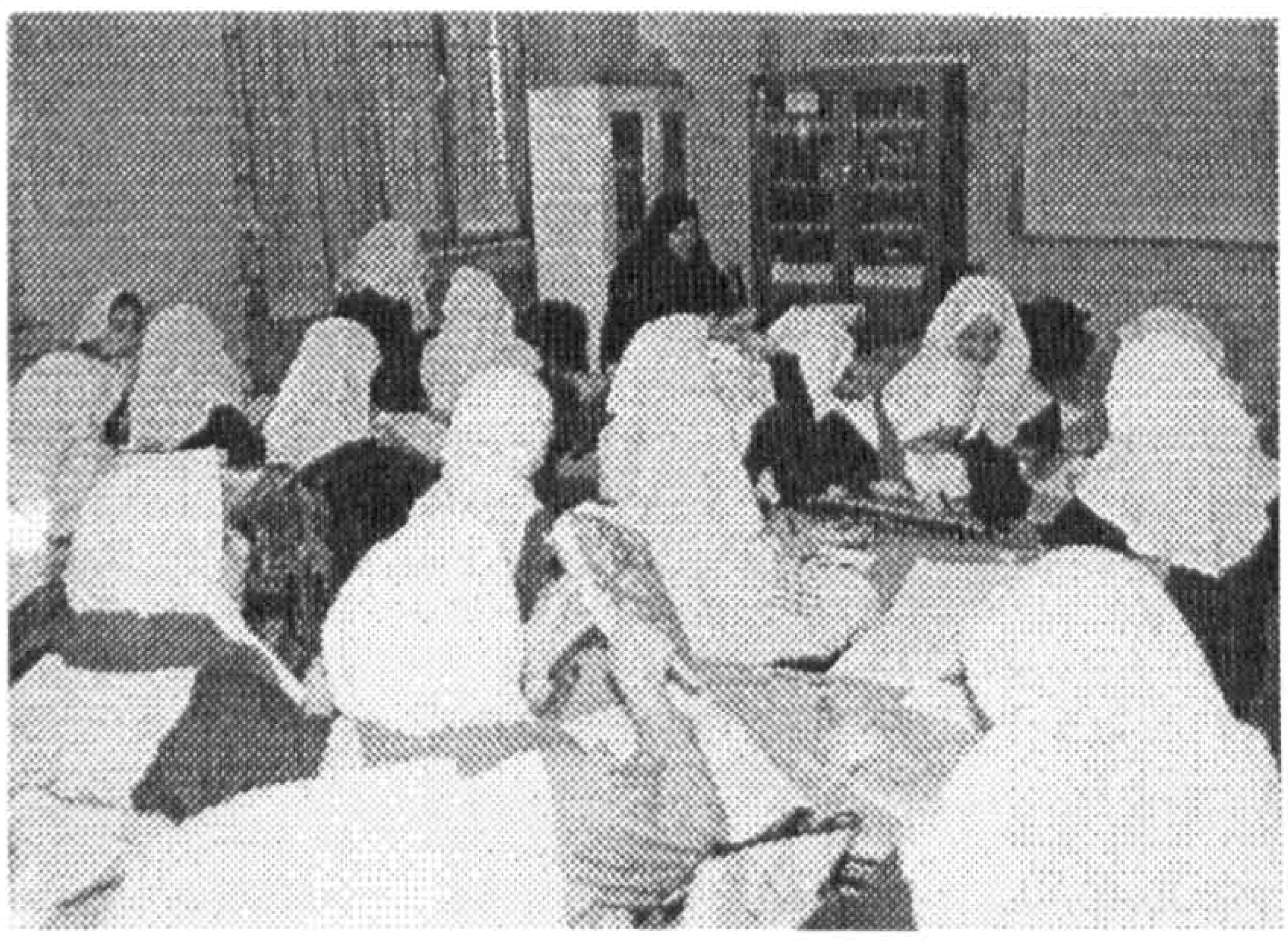
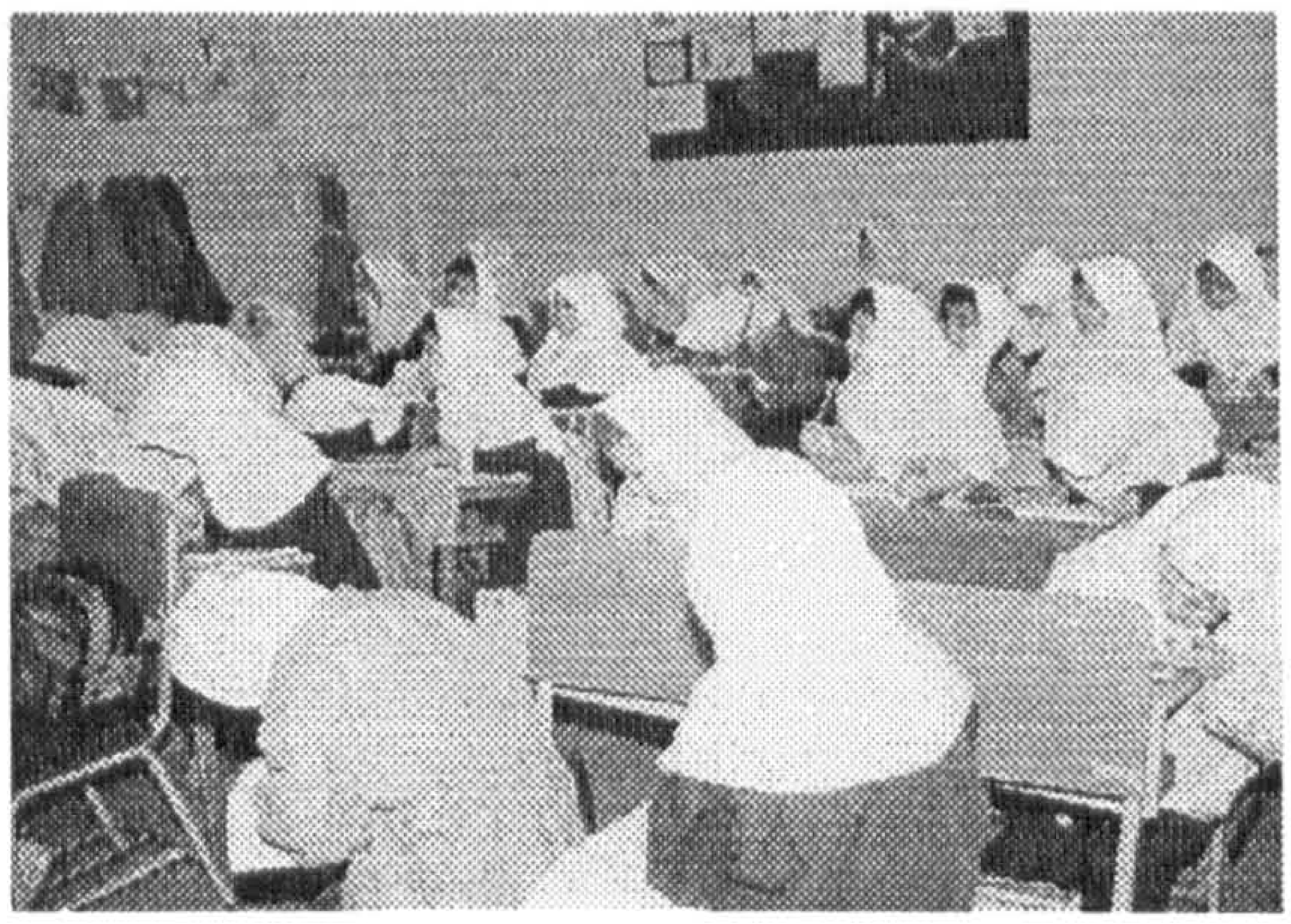


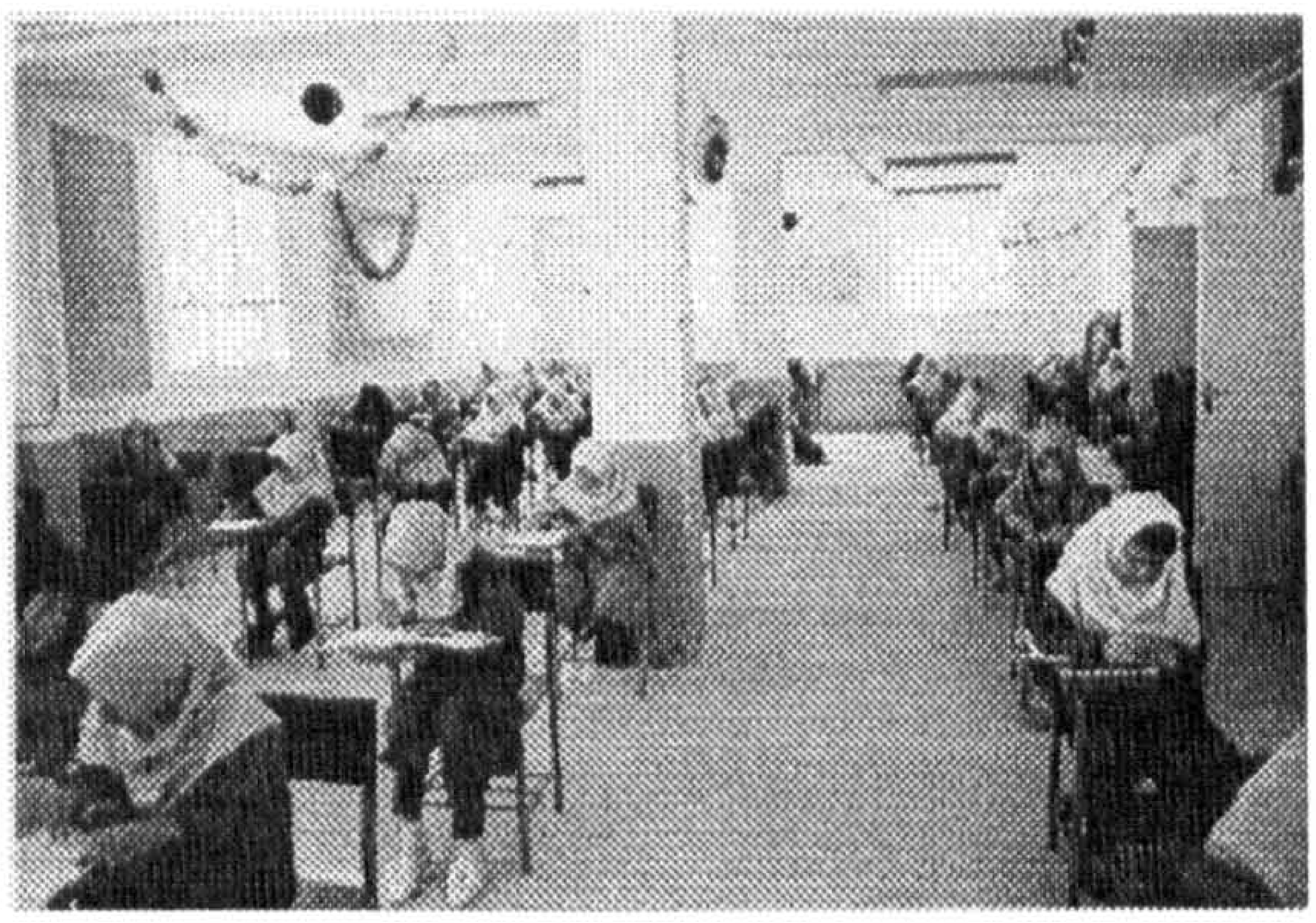
Figure 8.8: Display board and clotheshorse accessible by pupils



$8_{6.4}$ * Examinations

Figure 8.9: Teachers control students

Figure 8.10: Examinations in school



$8_{6.5}$ * Assembly Hall

Figure 8.11: Place for meetings or examinations or community activities

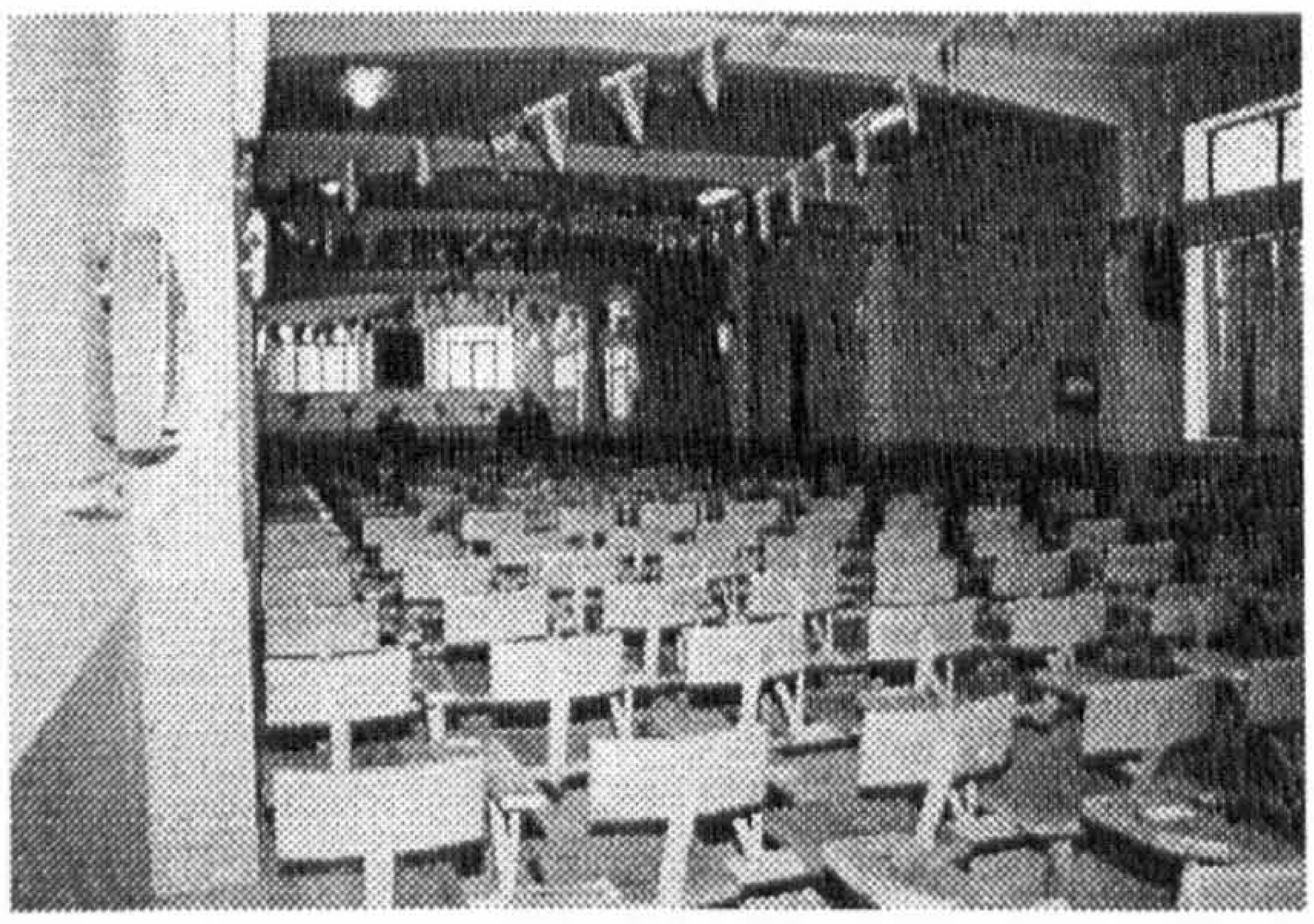
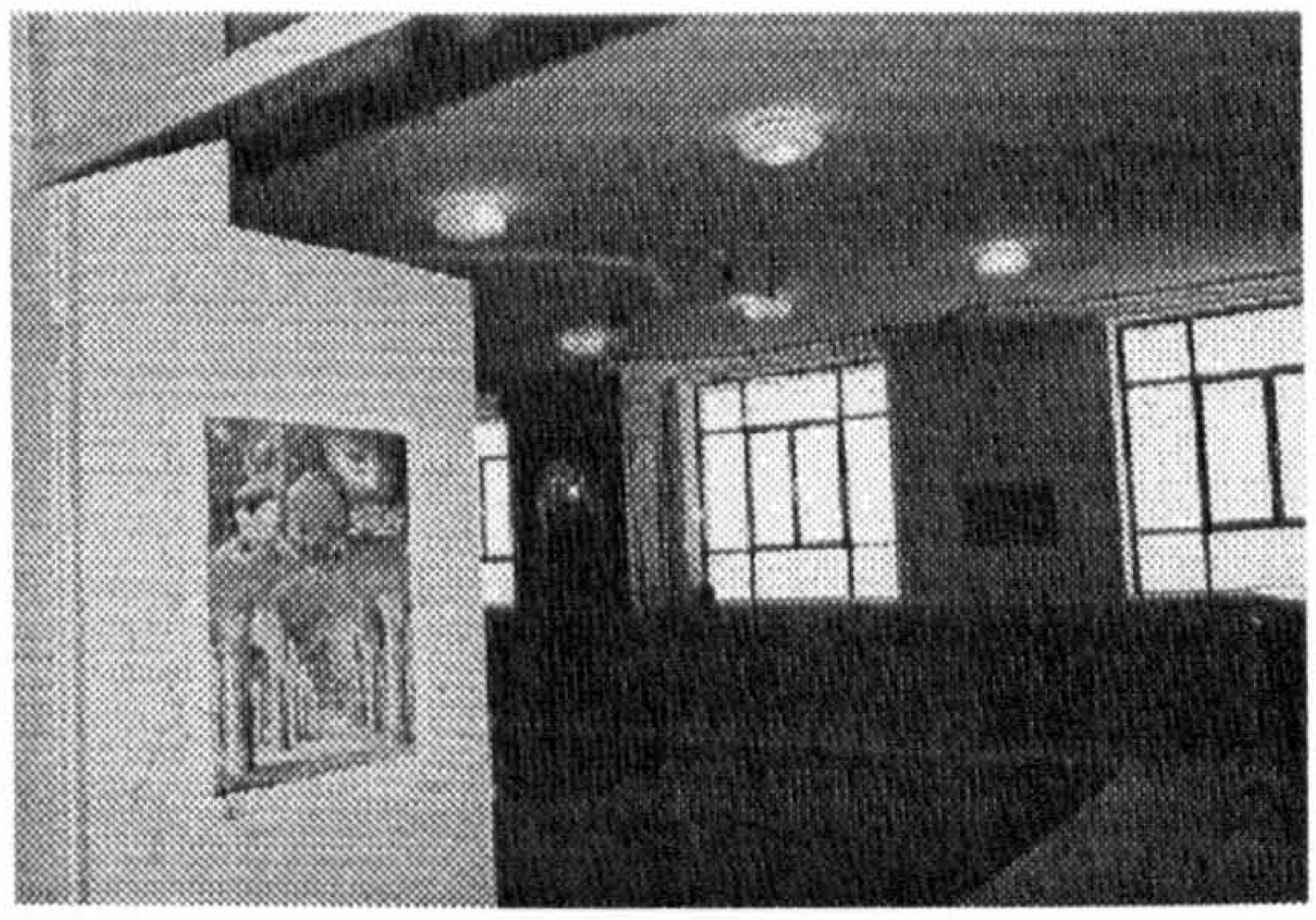


Figure 8.12: Place for religious activities and prayers



8$_{6.6}$ * Corridors

Figure 8.13: Main circulation for all activities

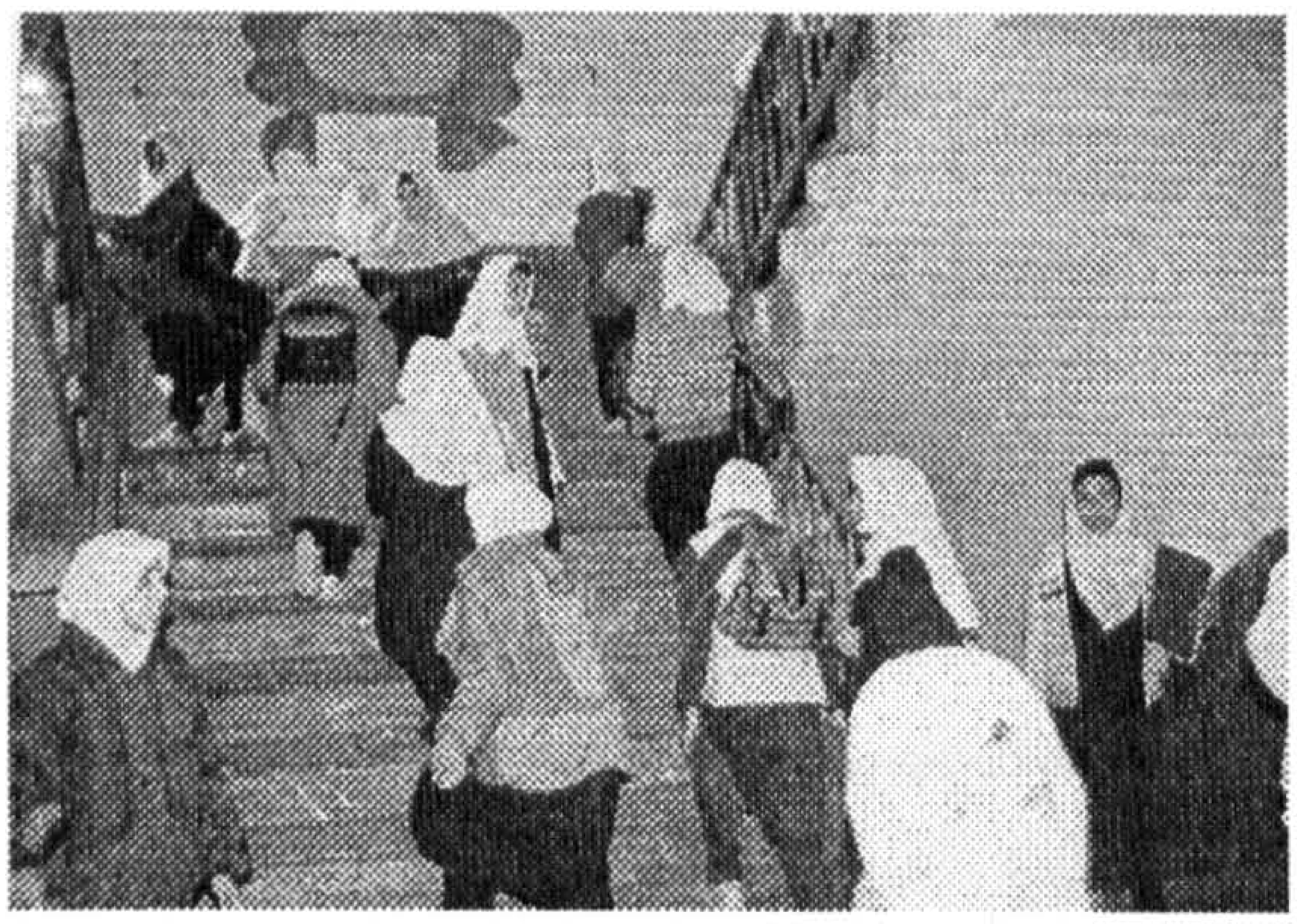
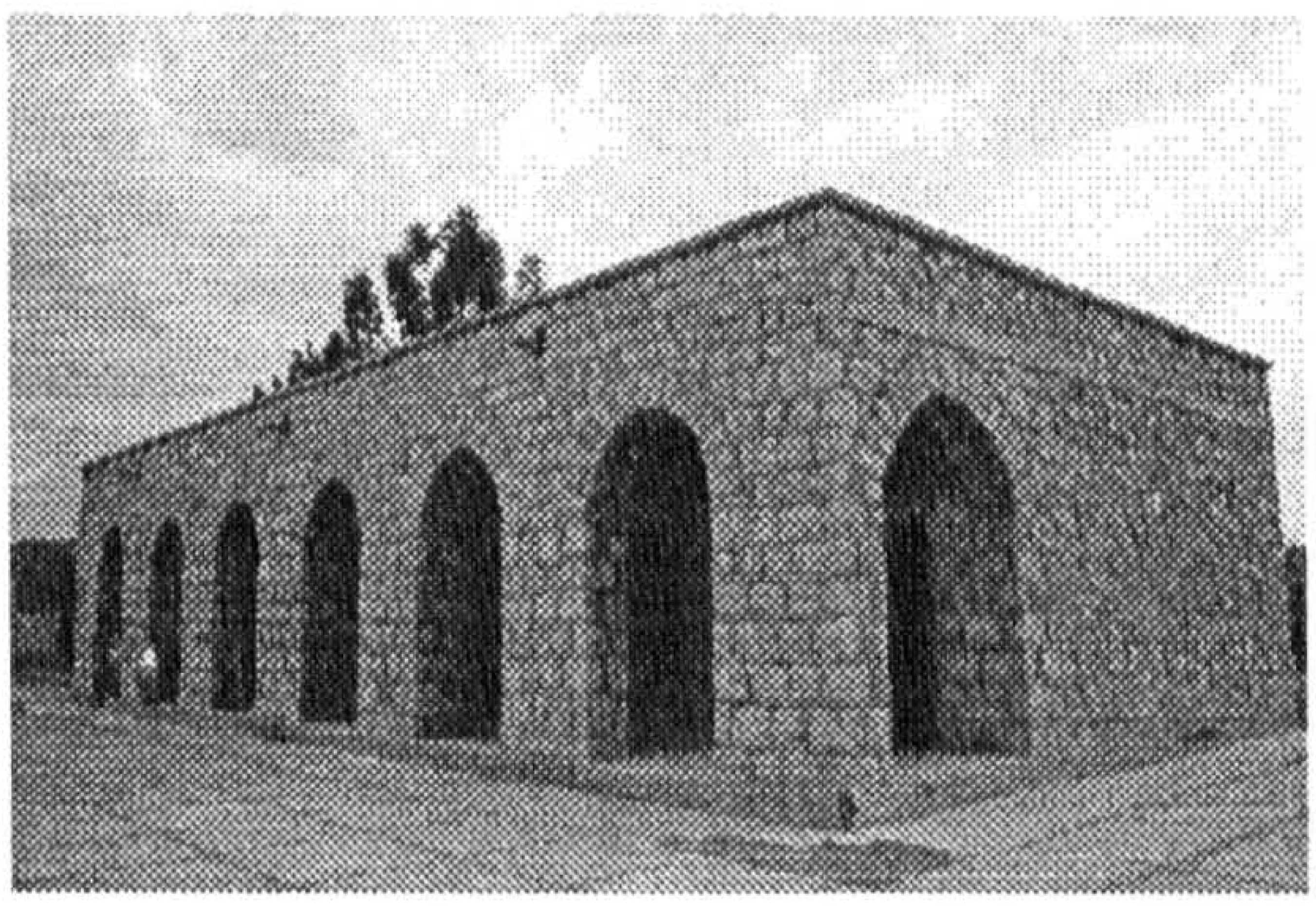


Figure 8.14: Access to classrooms and different floors

8$_{6.7}$ * The View of School's Design in Rural Regions of Iran

Figure 8.15: A school with three classrooms in the hot and dry weather in a rural region in Iran



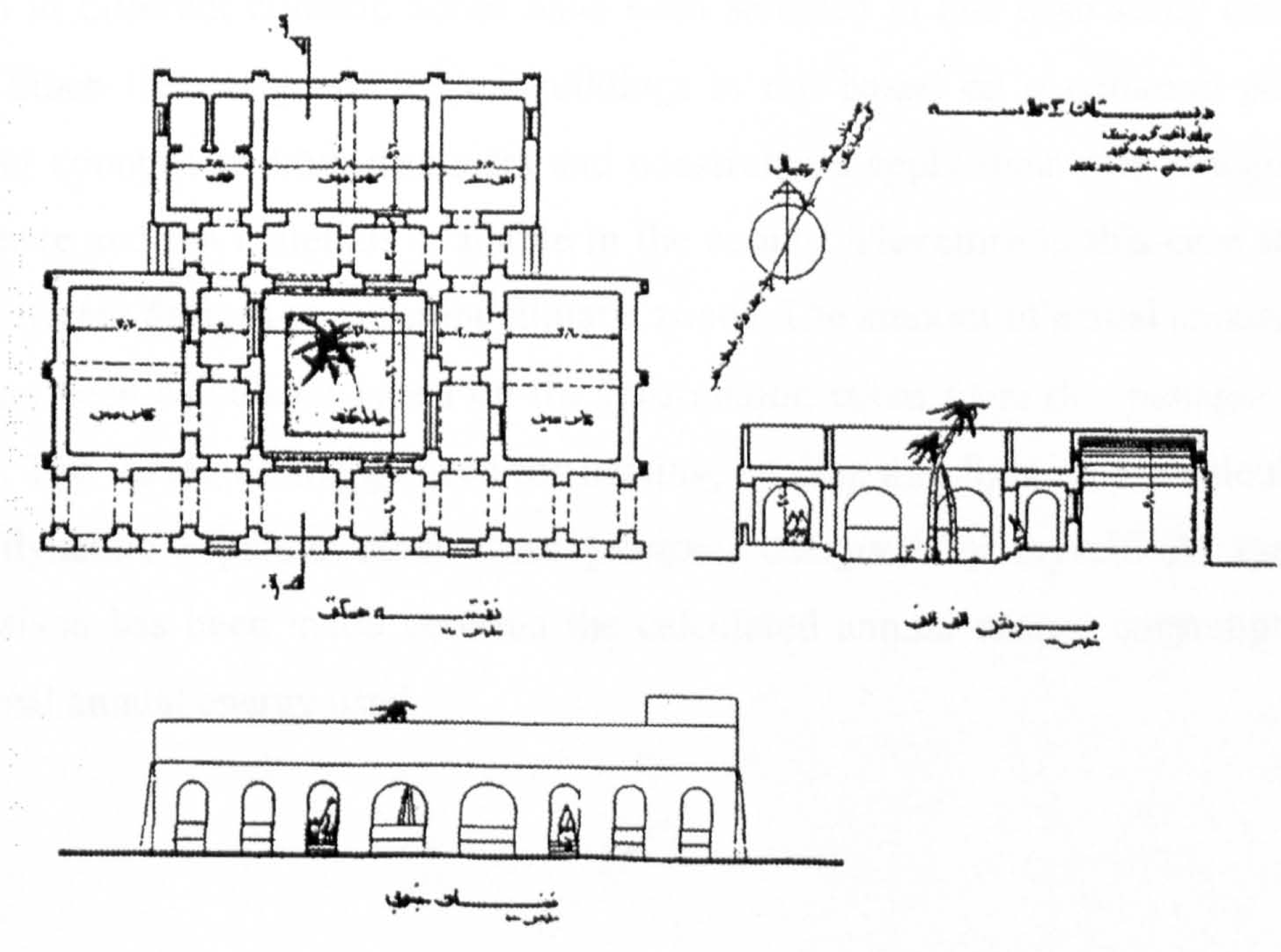
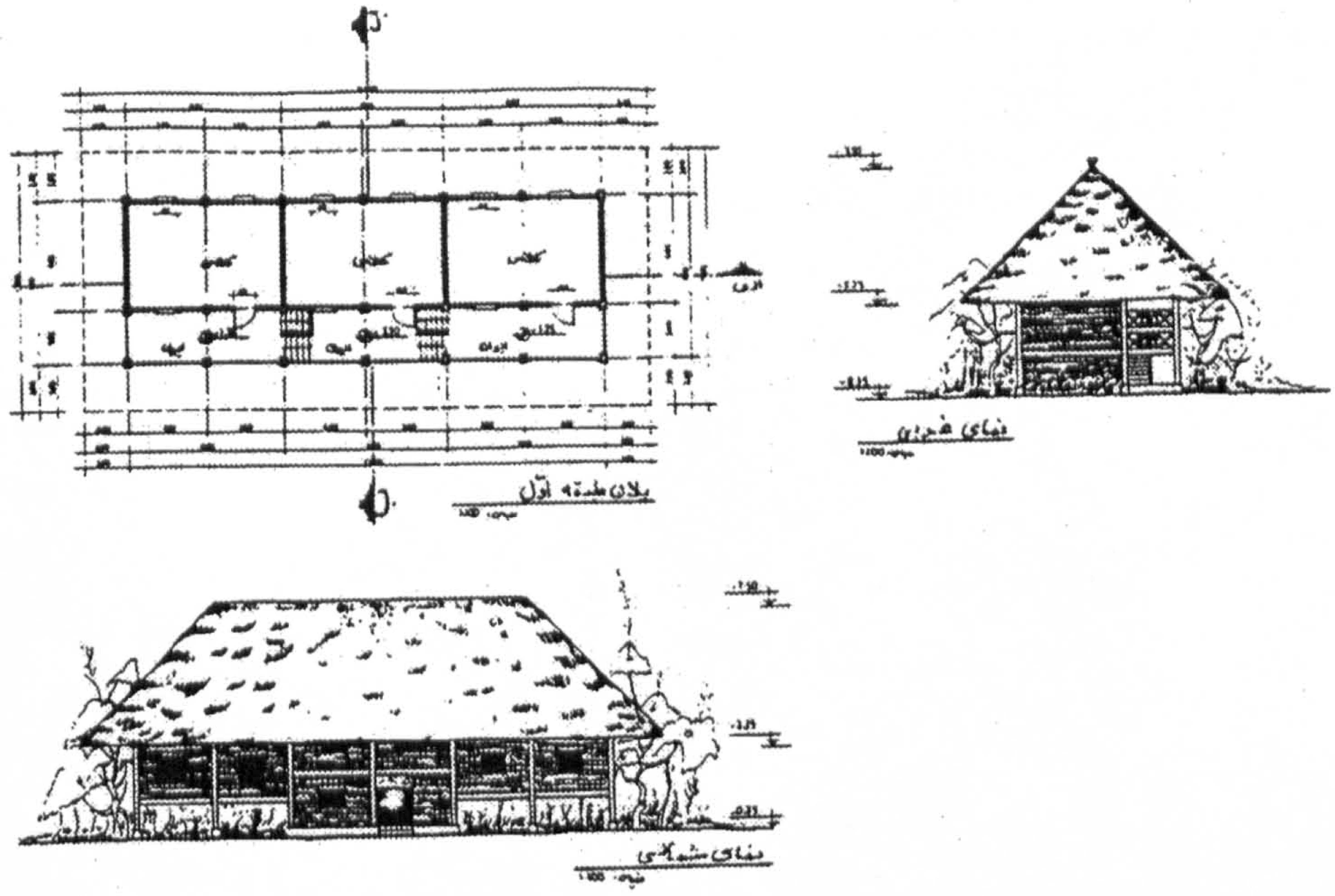


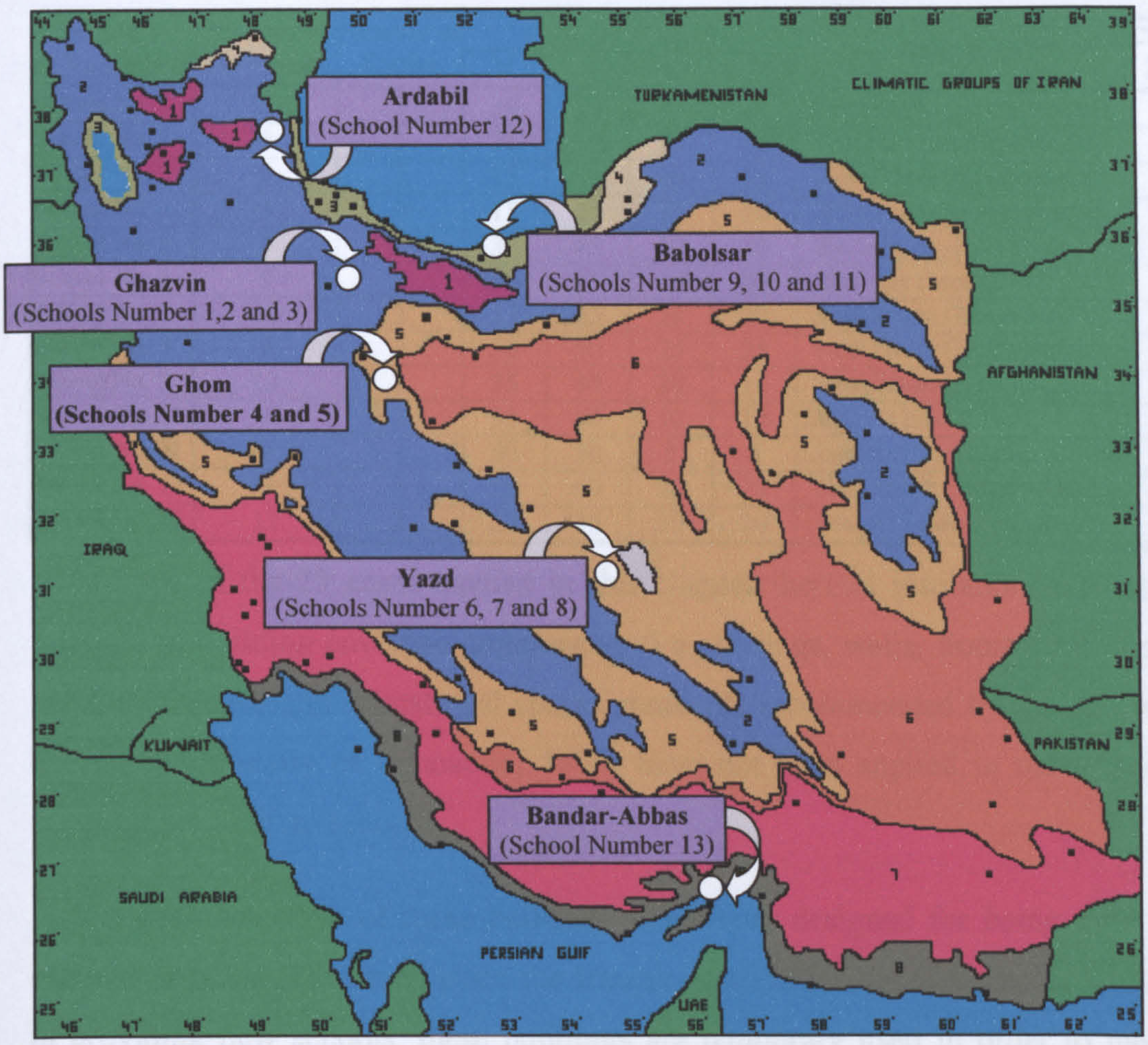
Figure 8.16: A school with three classrooms in the humid weather in a rural region in Iran



8_7 * The Design of Current Schools in Iran (Case Study)

In this section thirteen types of primary, secondary and high school built in different climatic regions of Iran has been selected. The basic data of the case study is summarised in the table 8.4. The details of the design, construction materials, amount of energy used and geographic characteristics of the cities are explained. In order to investigate the impact of climate on energy consumption of school buildings, schools located in different climatic zones have been selected in this case study (see figure 8.17). Since the design of school buildings is not based on a common pattern in different counties of Iran, designers and constructors apply their own designs based on climate and the materials available in the county. Therefore in this case study we have different designs in different climatic zones. The amount of actual annual energy used has been calculated based on the information taken from the manager of each school. The values of energy used for heating, cooling and lighting are calculated by using dynamic separate excel sheet program designed by myself. At the end a comparison has been made between the calculated annual energy consumption and the actual annual energy used.

Figure 8 17: Climatic zones and location of the case study



Climatic conditions in two critical seasons in Iran					
Climatic Subgroup	Winter	Summer	Climatic Subgroup	Winter	Summer
Climatic Group 1			**Climatic Group 5**		
			Ghom (Schools Number 4 and 5)		
1-1	Strongly Cold	Suitable	5-3	Relatively Cold	Hot
			Yazd (Schools Number 6, 7 and 8)		
			5-4	Relatively Cold	Hot and Arid
Climatic Group 2			**Climatic Group 6**		
Ardabil (School Number 12)			6-1	Relatively Cold	Very Hot and Arid
2-2	Very Cold	Temperate	6-2	Semi Cold	Semi Hot
Ghazvin (Schools Number 1,2 and 3)			6-3	Semi Cold	Very Hot
2-5	Cold	Temperate	6-4	Semi Cold	Hot and Arid
			6-5	Semi Cold	Very Hot and Arid
			6-6	Cold	Hot and Arid
Climatic Group 3			**Climatic Group 7**		
Babolsar (Schools Number 9, 10 and 11)			7-1	Cold	Very Hot and Arid
3-3	Cold	Humid	7-2	Cold	Strongly Hot and Arid
			7-3	Cold	Strongly Hot and Semi Humid
			7-4	Temperate	Strongly Hot and Arid
			7-5	Temperate	Strongly Hot and Semi Humid
Climatic Group 4			**Climatic Group 8**		
4-1	Very Cold	Hot and Humid	**Bandar-Abbas** (School Number 13)		
4-2	Cold	Hot and Humid	8-2	Temperate	Very Hot and Humid
4-3	Relatively Cold	Hot and Humid			

Table 8.4: Summary table of the basic data of the case study

Schools Number	Number of Classrooms	Number of Stories	Glazing Ratio %				Structure	Climatic Zone
			N	S	E	W		
School No. 1	20	3	30	50	25	25	Steel Frame (Heavy weight)	2-5
School No. 2	3	1	25	30	10	10	Masonry (Medium weight)	2-5
School No. 3	9	2	35	35	20	15	Steel Frame (Heavy weight)	2-5
School No. 4	5	2	15	25	30	10	Masonry (Medium weight)	5-3
School No. 5	9	2	35	45	10	10	Steel Frame (Heavy weight)	5-3
School No. 6	9	2	20	25	20	20	Masonry (Medium weight)	5-4
School No. 7	12	2	35	45	20	20	Steel Frame (Heavy weight)	5-4
School No. 8	9	2	30	50	25	25	Steel Frame (Heavy weight)	5-4
School No. 9	13	3	35	40	20	15	Steel Frame (Heavy weight)	3-3
School No. 10	9	2	30	40	10	10	Concrete Frame (Heavy weight)	3-3
School No. 11	9	3	50	50	5	5	Concrete Frame (Heavy weight)	3-3
School No. 12	9	4	50	50	20	20	Steel Frame (Heavy weight)	2-2
School No. 13	12	2	20	25	20	20	Masonry (Medium weight)	8-2

In none of the 13 cases studied in this chapter thermal insulation has not been installed in building envelope components (i.e., ceilings, walls, floors). All windows are single glazed and educational spaces standards recommended by the Ministry of Education (Ministry of Education, 1995) have not been applied in the design and construction of these schools.

It seems that some of these buildings have been designed for being used as an office or a house. However, since the Iranian government faces financial limitations in providing new schools, these buildings are temporary used in order to meet the existing educational requirements of the country.

8.7.1 * **Primary School with 20 Classrooms** (School number 1)

Type: Primary school
Usable area: 1850 m^2
Pupils: 600
Location: Ghazvin
Geographic characteristics: Latitude: 36° 15' Degrees (north)
Longitude: -50° 00' Degrees (east)
Altitude: 1377 metres
Azimuth angle of building: Azimuth: -20° 00' Degrees
Climate: Cold-Temperate (see chapter 2, Group 2 and subgroup 2-5)
Mean yearly temperature: 14.37^{oC}

This three-story primary school comprises twenty classrooms; four of them located at the ground floor, eight at the first floor and the remaining eight at the second floor. There is a large assembly hall with the height of 6 m located at the first floor.

The building is steel framed with brick walls and steel framed window. The construction of the walls is 40 mm stone cladding, 220 mm brick and 13 mm plaster. The ground and first floor roofs are composed of 50 mm floor tile, 50 mm concrete, 220 mm concrete block and 15 mm plaster. The second floor roof consists of 40 mm asphalt and insulation, 20 mm concrete, 80 mm expanded clay, and 50 mm concrete, 220 mm concrete block and 15 mm plaster.

The windows are single glazed and the glazing ratio of the ground floor is 27.8% in north wall, 28.5% in the south wall, 10% in the west & east wall. The glazing ratio of first and second floors are 29% in north, 55% in south, 24% in west and 25% in the east wall. The direction of the building is extended from east to west and has a nearly rectangular plan. The assembly hall is a hexagon located at the north part of the school.

Heating is provided by a central heating system with thermostatically controlled gas-fired units and conventional radiators. The indoor temperature must be set to 24^{oC} in the warm season and 20^{oC} in the cold one. The cooling system consists of electric water-based cooler.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.5: The amount of actual annual energy used

	Heating Kwhrs	**Cooling** Kwhrs	**Lighting** Kwhrs
Electricity	--	--	139,782*
Gas	225,423	--	--
Gasoline	--	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.6: The calculated annual energy consumption

	Heating Kwhrs	**Cooling** Kwhrs	**Lighting** Kwhrs	
With window control	263,742.6	38,552.4	114,664.98	**With Daylighting**
Non-window control	263,742.6	75,774.4	195,264.10	**Non Daylighting**
With shading	263,654.2	35,066.2	118,085.45	**With shading& Daylighting**

Figure 8.18: The plan of the ground floor of a primary school with 20 classrooms (Number 1)

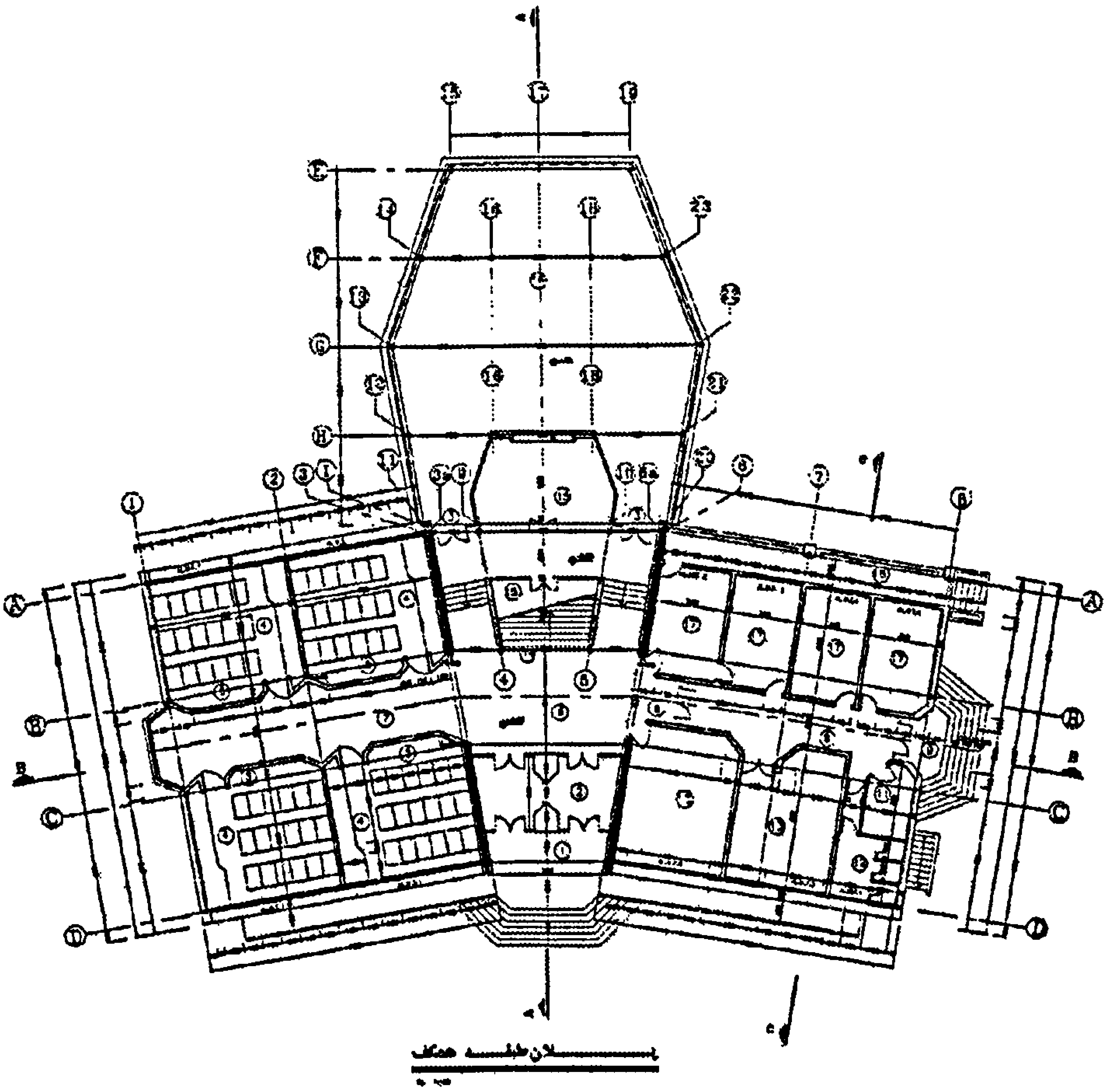


Figure 8.19: The plan of the low ground floor of a primary school with 20 classrooms (Number 1)

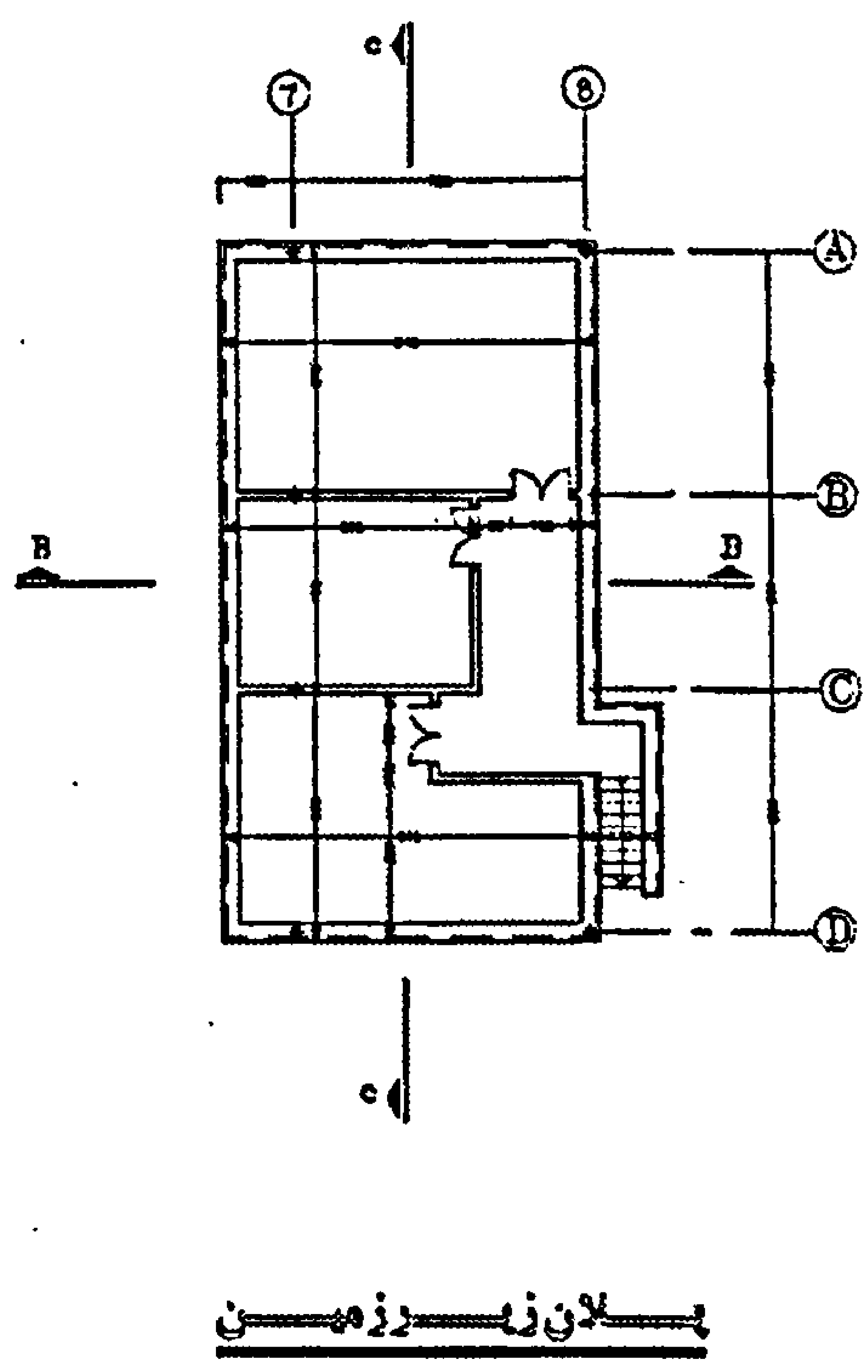


Figure 8.20: The plan of the first floor of a primary school with 20 classrooms (Number 1)

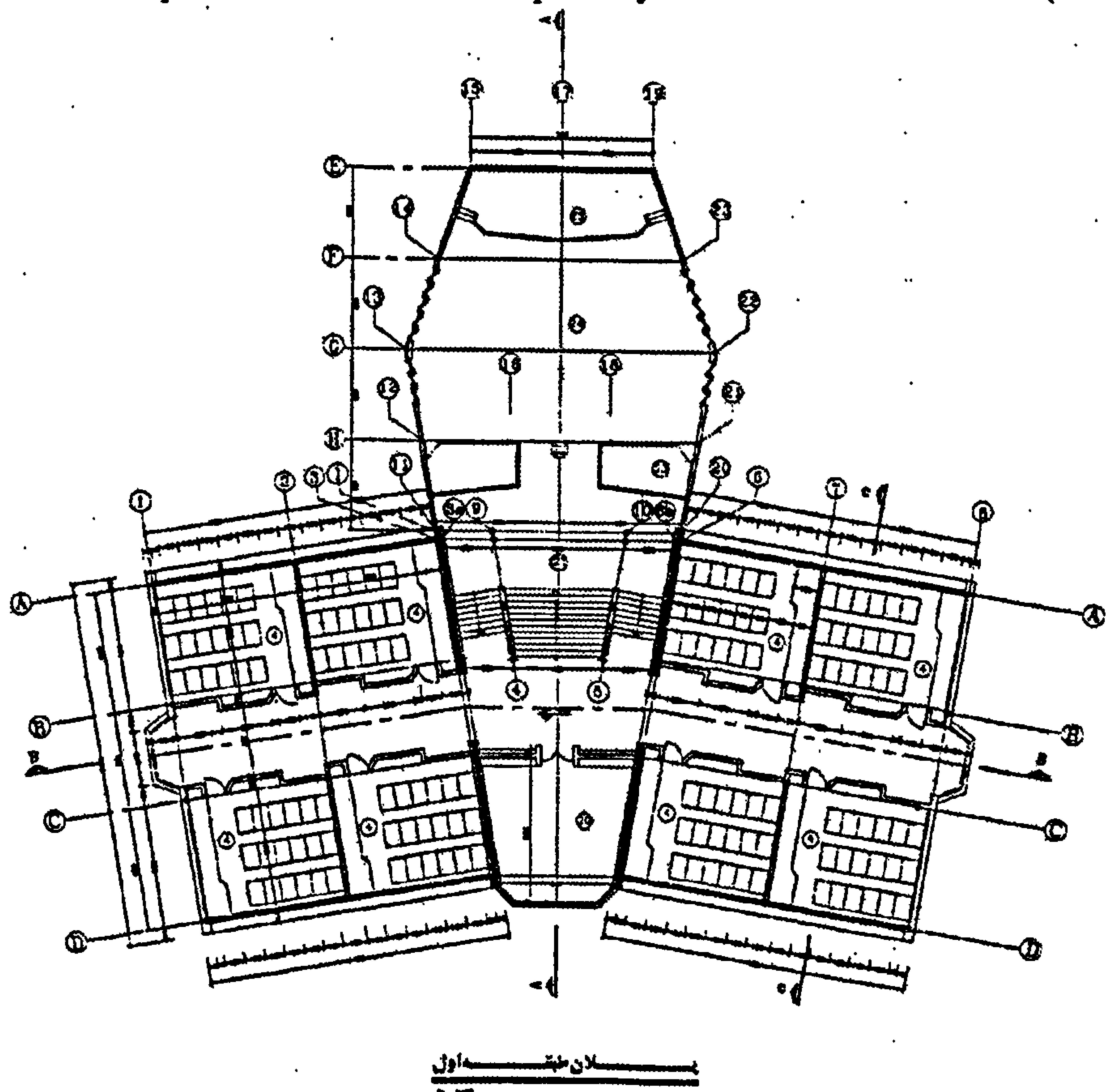


Figure 8.21: The plan of the second floor of a primary school with 20 classrooms (Number 1)

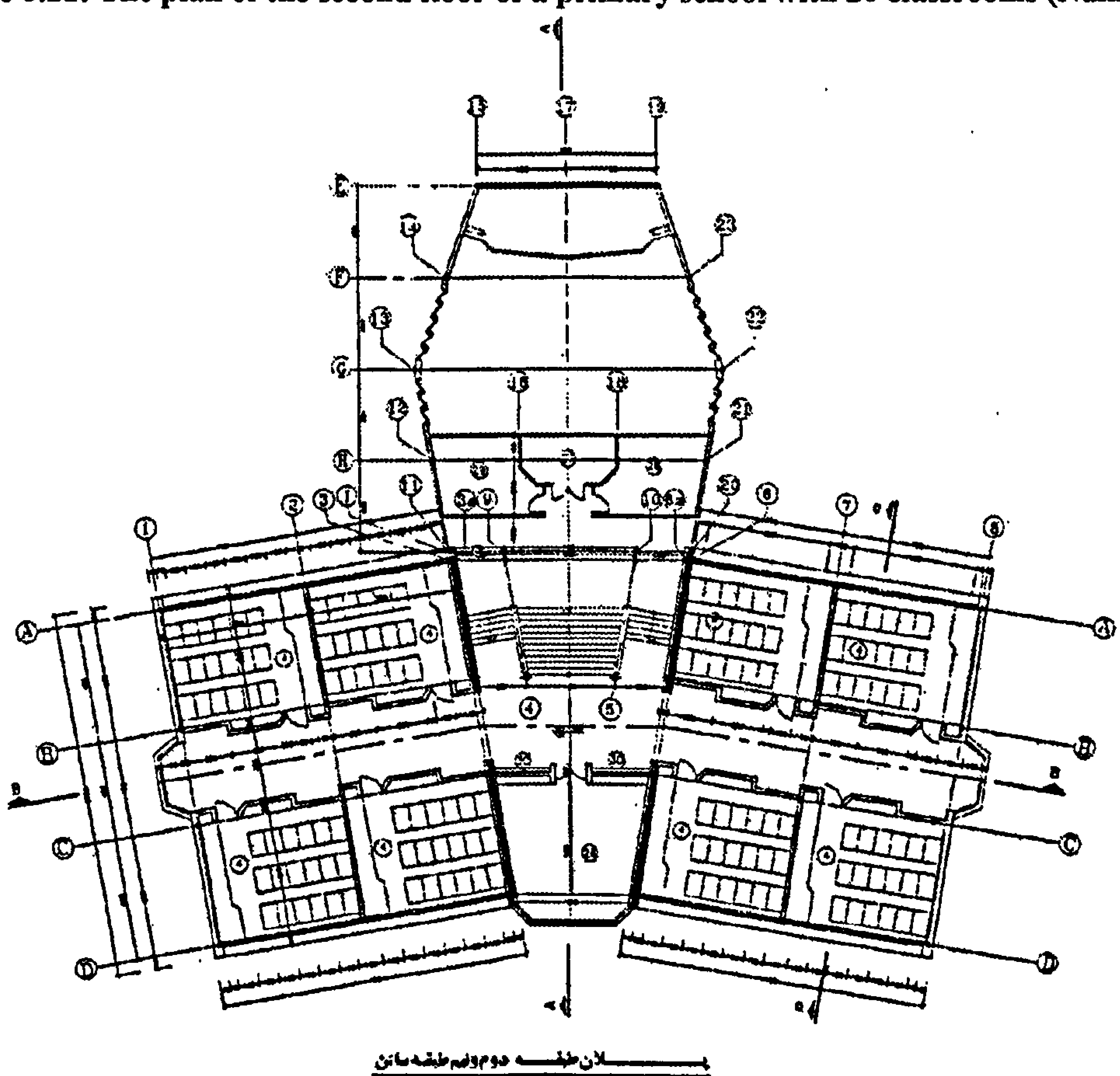


Figure 8.22: The south elevation of a primary school with 20 classrooms (Number 1)

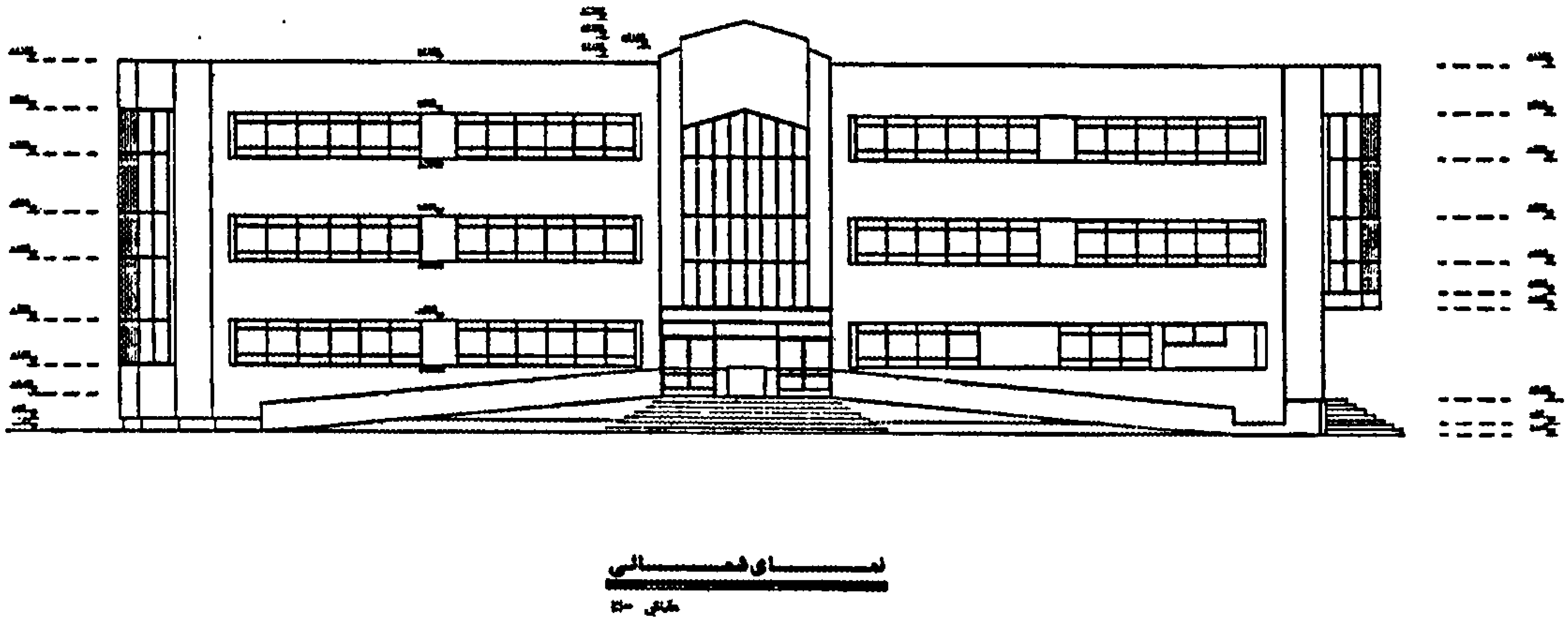


Figure 8.23: The north elevation of a primary school with 20 classrooms (Number 1)

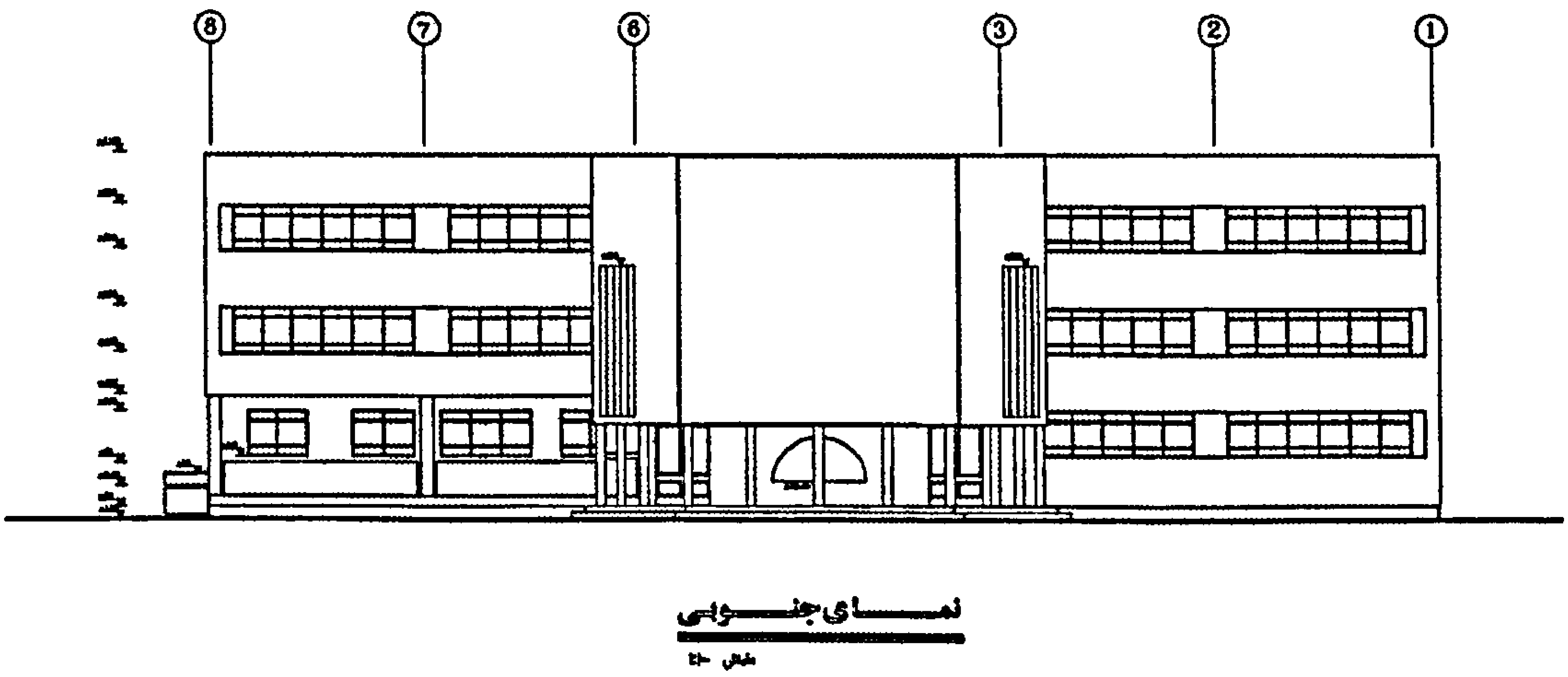


Figure 8.24: The west elevation of a primary school with 20 classrooms (Number 1)

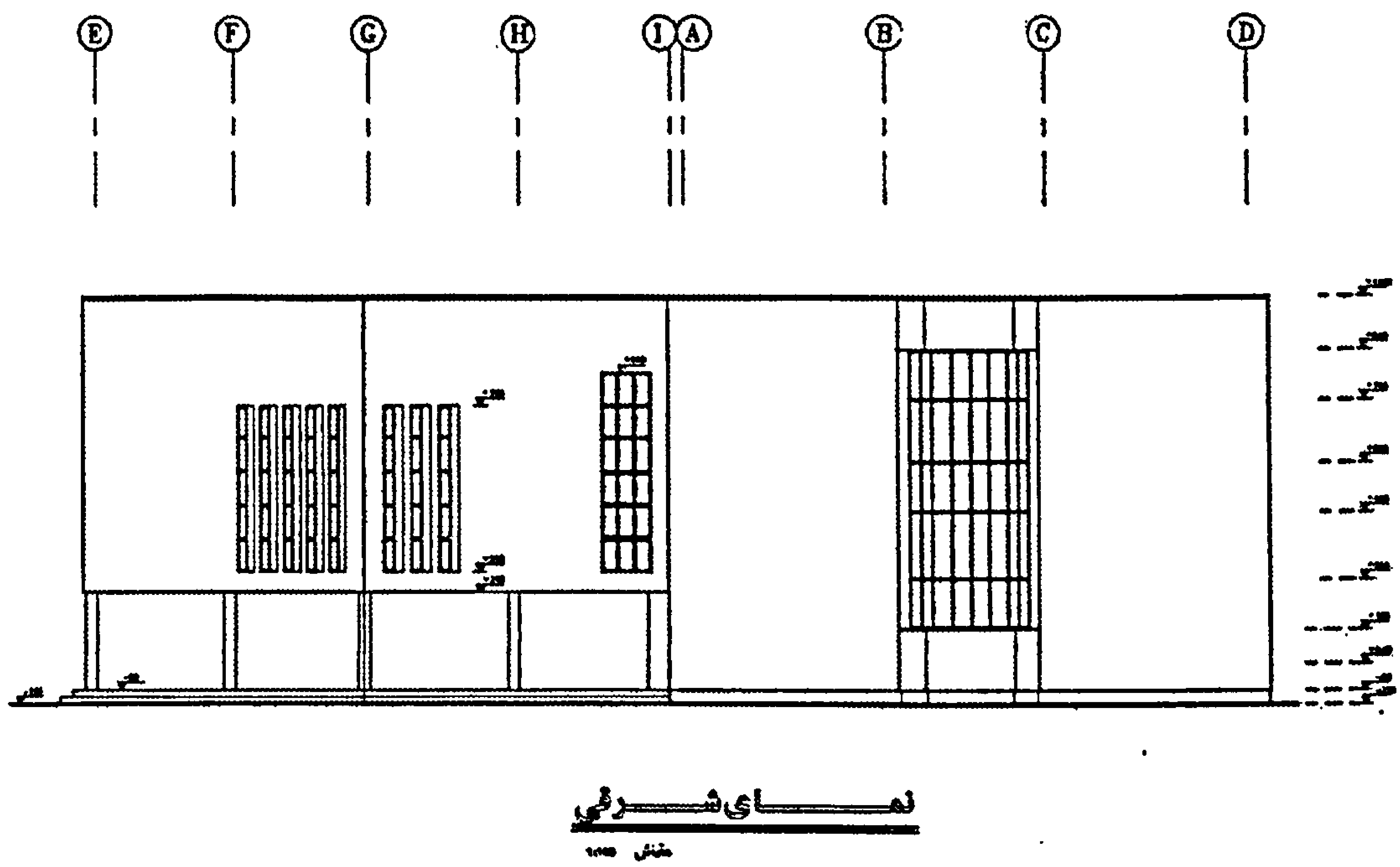


Figure 8.25: the east elevation of a primary school with 20 classrooms (Number 1)

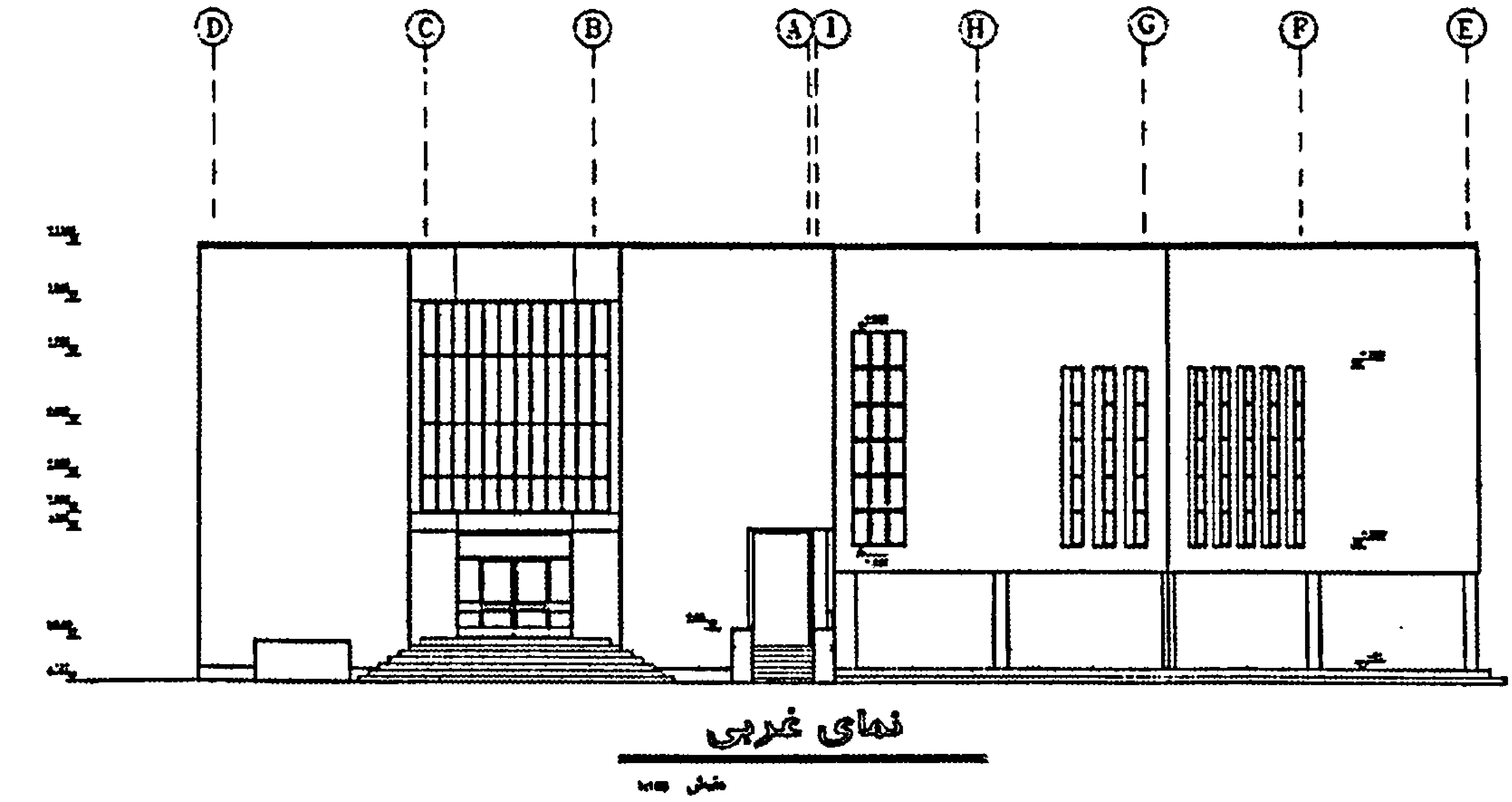


Figure 8.26: The section B-B of a primary school with 20 classrooms (Number 1)

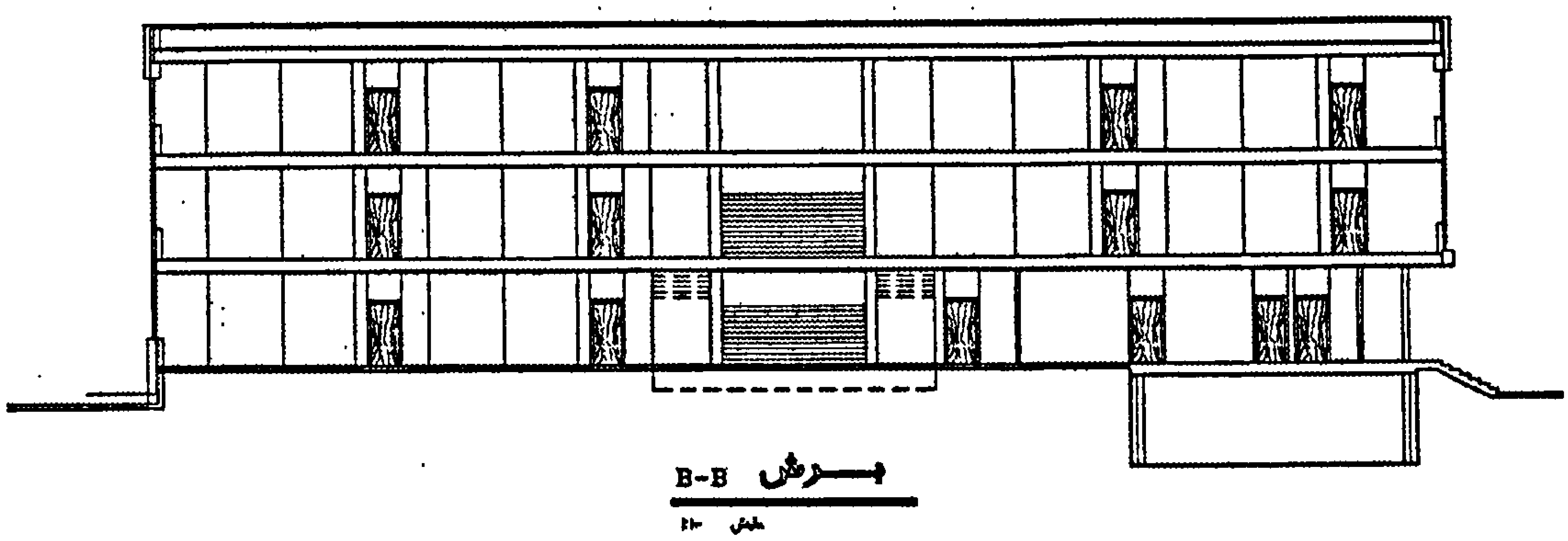
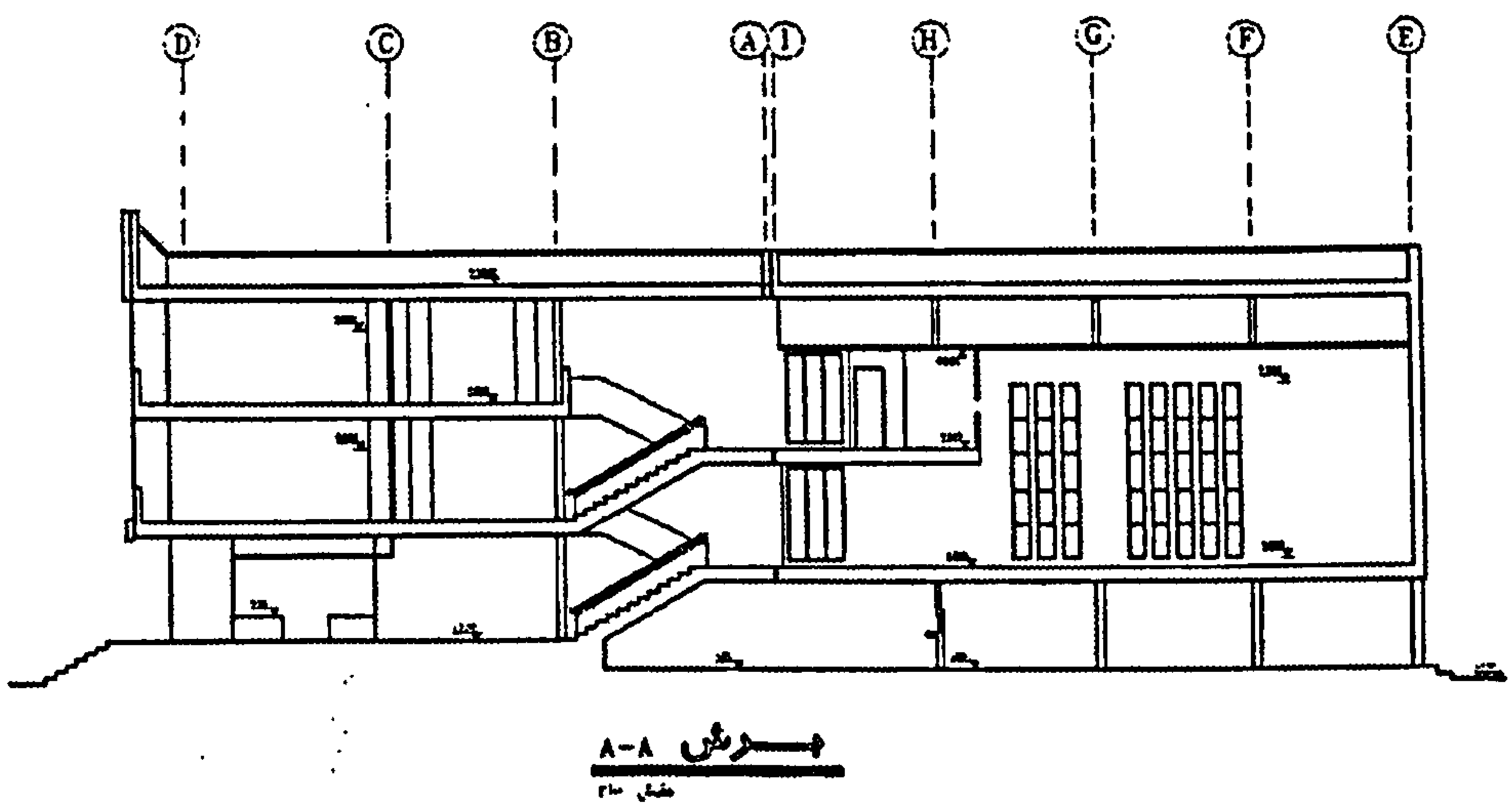


Figure 8.27: The section A-A of a primary school with 20 classrooms (Number 1)



8$_{7.2}$ * **Secondary School with 3 Classrooms** (School number 2)

Type: Secondary school
Usable area: 344 m^2
Pupils: 90
Location: Ghazvin (Mahmodabad)
Geographic characteristics: Latitude: 36° 15' Degrees (north)
Longitude: -50° 00' Degrees (east)
Altitude: 1377 metres
Azimuth angle of building: Azimuth: -13° 00' Degrees
Climate: Cold-Temperate (see chapter 2, Group 2 and subgroup 2-5)
Mean yearly temperature: 14.37^{oC}

This secondary school comprises three classrooms at the ground floor. It is located in the rural area of Ghazvin.

The building has masonry wall (brick) and steel framed window. The construction of the walls is 30 mm cement, 335 mm brickwork and 13 mm dense plaster. The roof consists of 20 mm cement, 40 mm expanded clay, 110 mm brick and 30 mm plaster. There is an additional sloped ceiling containing wood frame and asbestos sheet.

The windows are single glazed and the glazing ratio of the ground floor is 24% in north wall, 30% in the south wall, 10% in the west wall and 7% in the east wall.

The school has a rectangular plan with 25.50 m length and 13.50 m width and 4 m height and the direction is extended from east to west.

Heating is provided by oil stove. The indoor temperature must be set to 24^{oC} in the warm season and 20^{oC} in the cold one. This school did not use a cooling system.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.7: The amount of actual annual energy used

	Heating Kwhrs	**Cooling** Kwhrs	**Lighting** Kwhrs
Electricity	--	No cooling	27,890
Gas	--	--	--
Gasoline	3,000 litres	--	--

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.8: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	64,754.4	7,954.2	24,720.63	With Daylighting
Non-window control	64,754.4	13,155.7	43,588.37	Non Daylighting
With shading	64,624.2	7,104.1	25,579.23	With shading& Daylighting

Figure 8.28: The plan of a secondary school with 3 classrooms (Number 2)

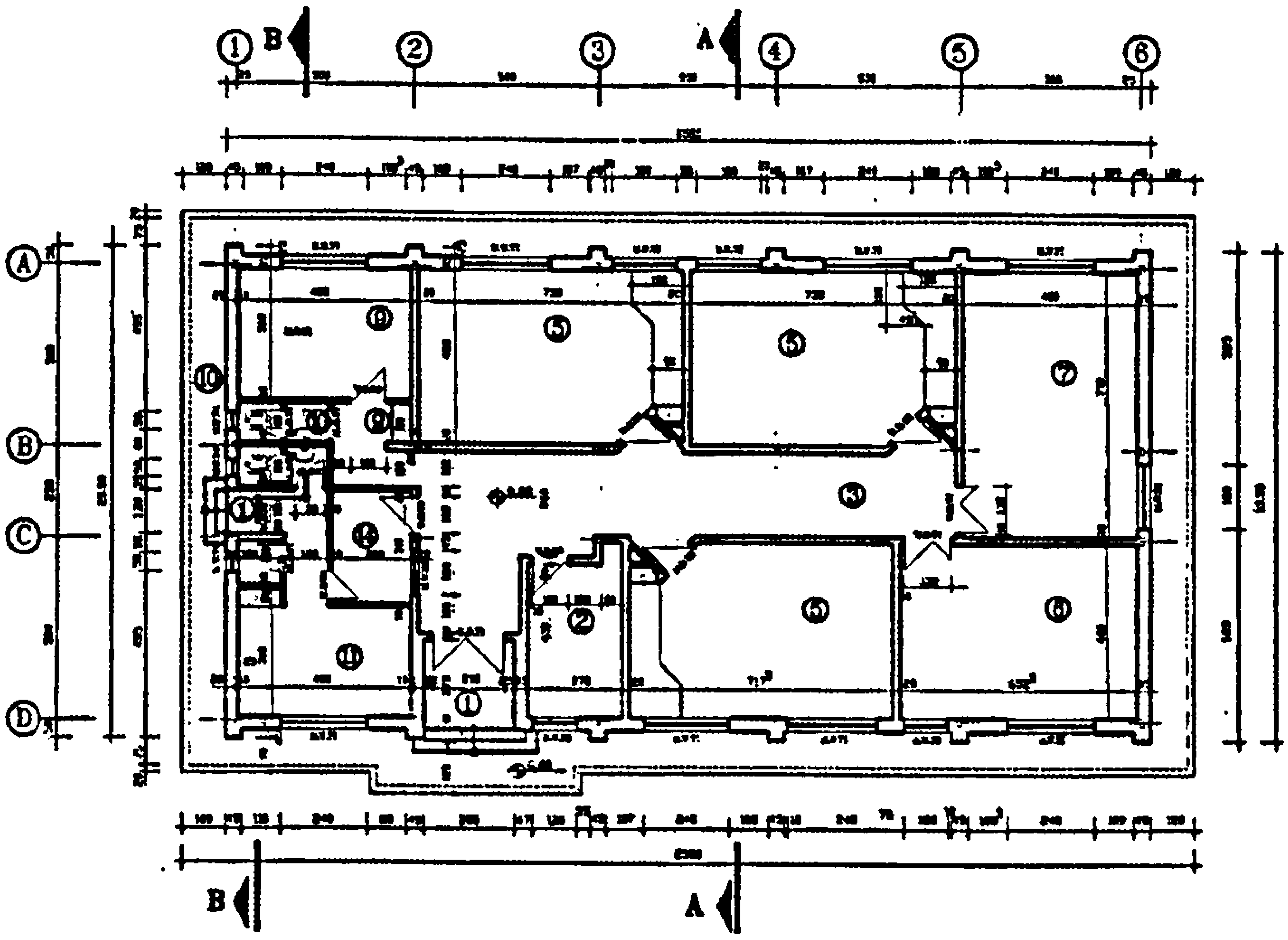


Figure 8.29: The section B-B

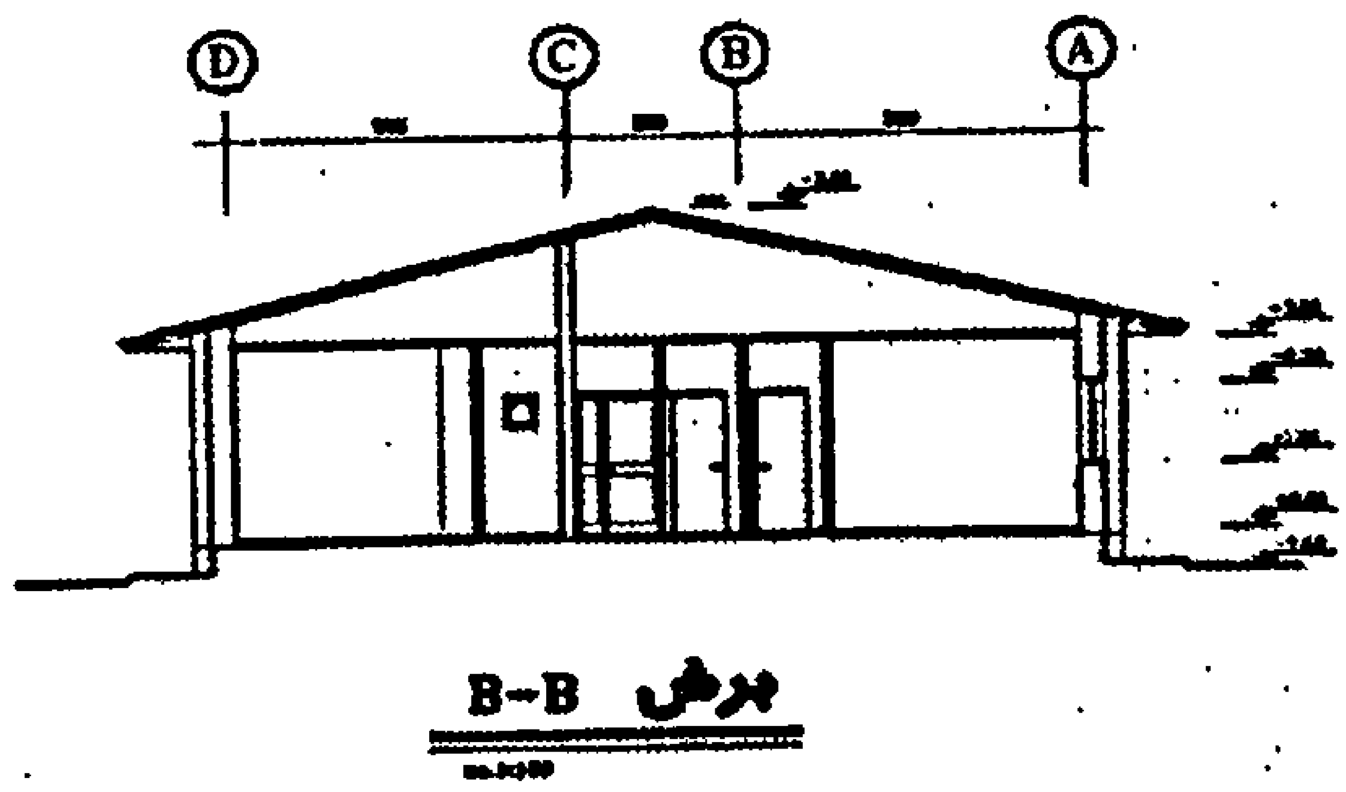


Figure 8.30: The east elevation

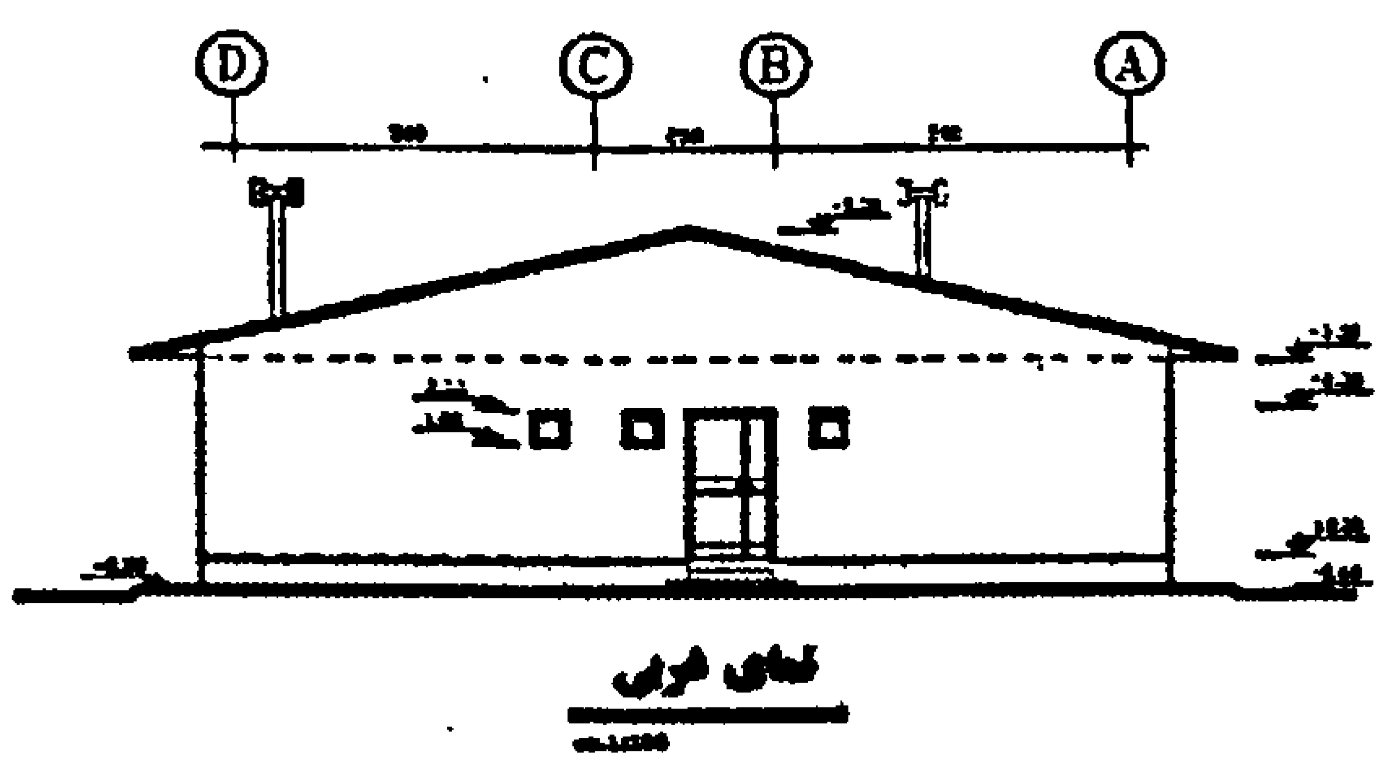


Figure 8.31: The south elevation of a secondary school with 3 classrooms (Number 2)

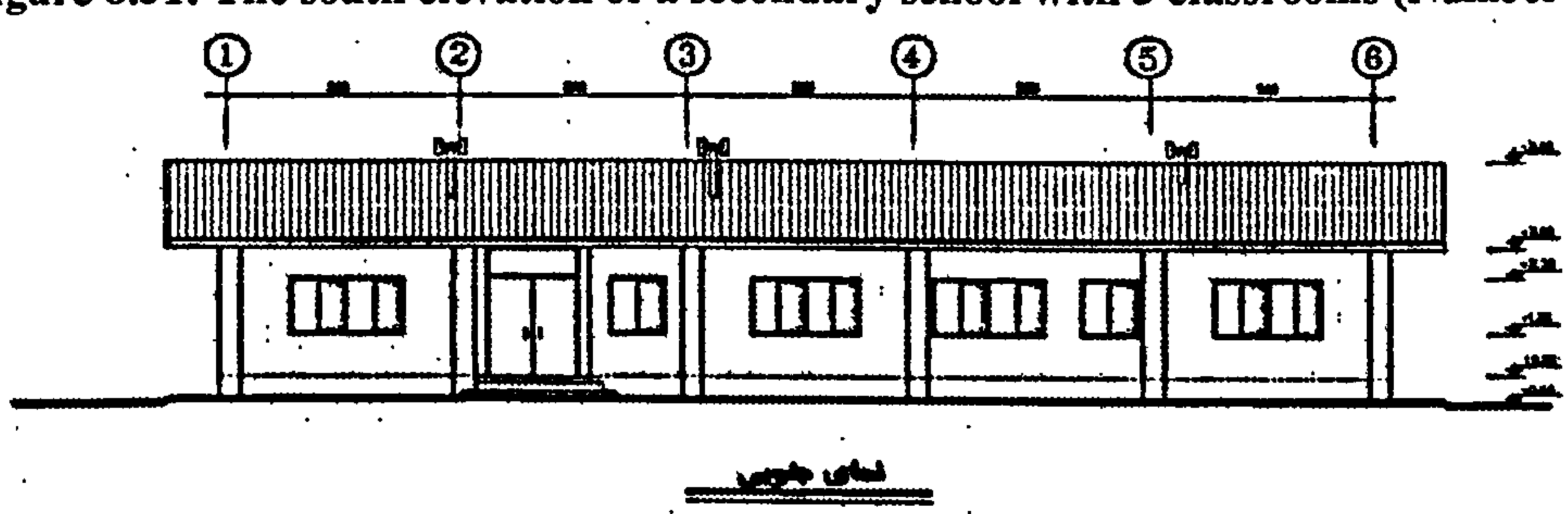
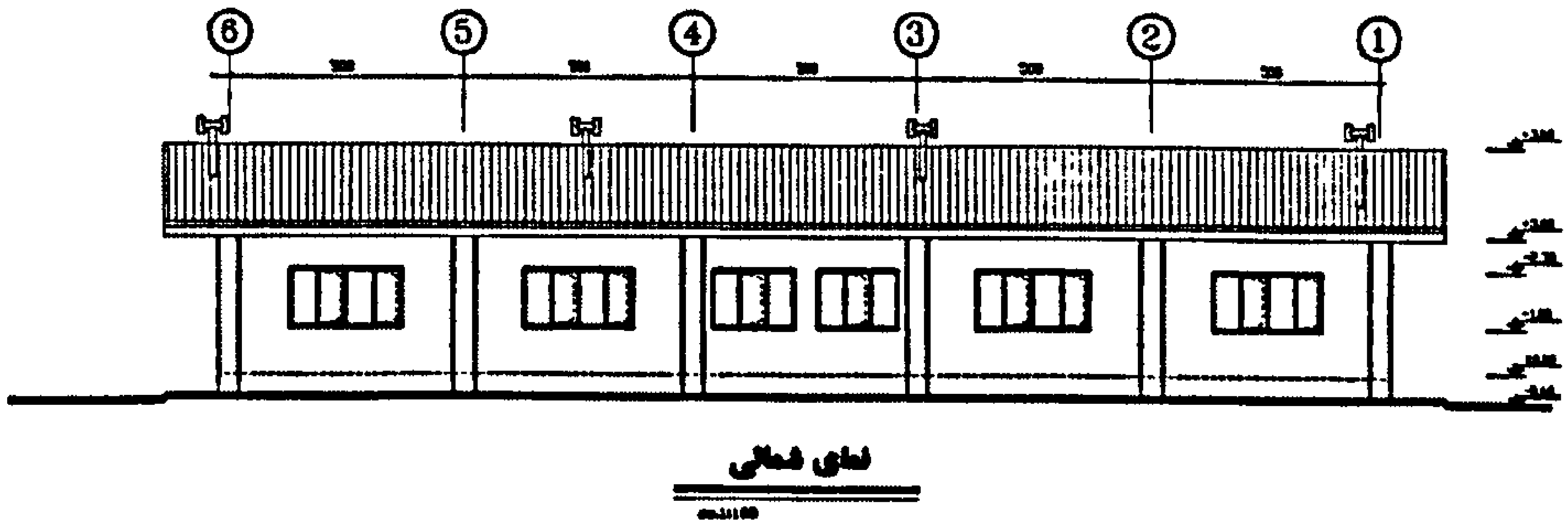


Figure 8.32: The north elevation of a secondary school with 3 classrooms (Number 2)



$8_{7.3}$ * **High School with 9 Classrooms** (School number 3)

Type: High school
Usable area: 1600 m^2
Pupils: 270
Location: Ghazvin
Geographic characteristics: Latitude: 36° 15' Degrees (north)
Longitude: -50° 00' Degrees (east)
Altitude: 1377 metres
Azimuth angle of building: Azimuth: +8° 00' Degrees
Climate: Cold-Temperate (see chapter 2, Group 2 and subgroup 2-5)
Mean yearly temperature: 14.37^{oC}

This two-story high school comprises nine classrooms, three of them located at the ground floor and the other six at the first floor.

The building is steel framed with brick walls and aluminium framed window. The construction of the walls is 40 mm stone cladding, 220 mm brickwork and 13 mm plaster. The Ground floor roof consists of 50 mm floor tile, 20 mm cement, 80 mm expanded clay, 110 mm brick and 40 mm plaster. The first floor roof composed of 40 mm asphalt and insulation, 20 mm cement, 150 mm expanded clay, 110 mm brick and 40 mm plaster.

The windows are single glazed and the glazing ratio of the ground floor is 34.7% in north wall, 35.4% in the south wall, 16.2% in the west & east wall. The glazing ratio of first floor is 33.45% in north, 34.35% in south, 16.2% in west and 19.75% in the east wall.

The school has a rectangular plan with 29.5 m length and 27.1 m width and 7 m height (the room height is 3 m at each floor) and the direction is expended from east to west.

Heating is provided by a central heating system with thermostatically controlled gas-fired units and conventional radiators. The indoor temperature must be set to 24^{oC} in the warm season and 20^{oC} in the cold one. The cooling system consists of electric water-based cooler.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.9: The amount of actual annual energy used

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs
Electricity	--	--	84,673*
Gas	145,092	--	--
Gasoline	--	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.10: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	186,026.1	22,078.1	73,974.06	With Daylighting
Non-window control	186,025.1	36,516.5	134,299.3	Non Daylighting
With shading	185,529.6	19,386.4	77,285.17	With shading& Daylighting

Figure 8.33: The plan of the ground floor of a high school with 9 classrooms (Number 3)

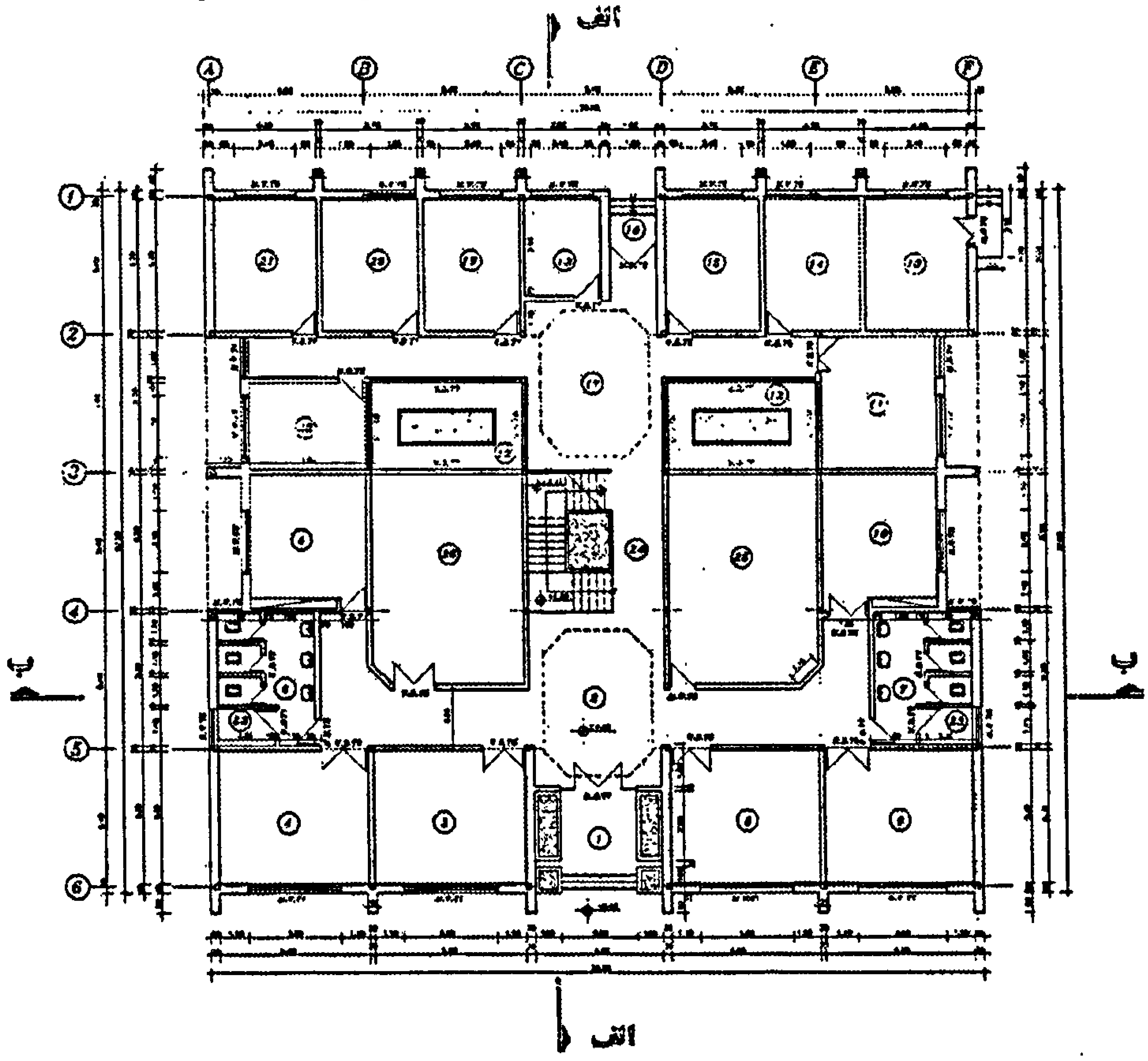


Figure 8.34: The plan of the first floor of a high school with 9 classrooms (Number 3)

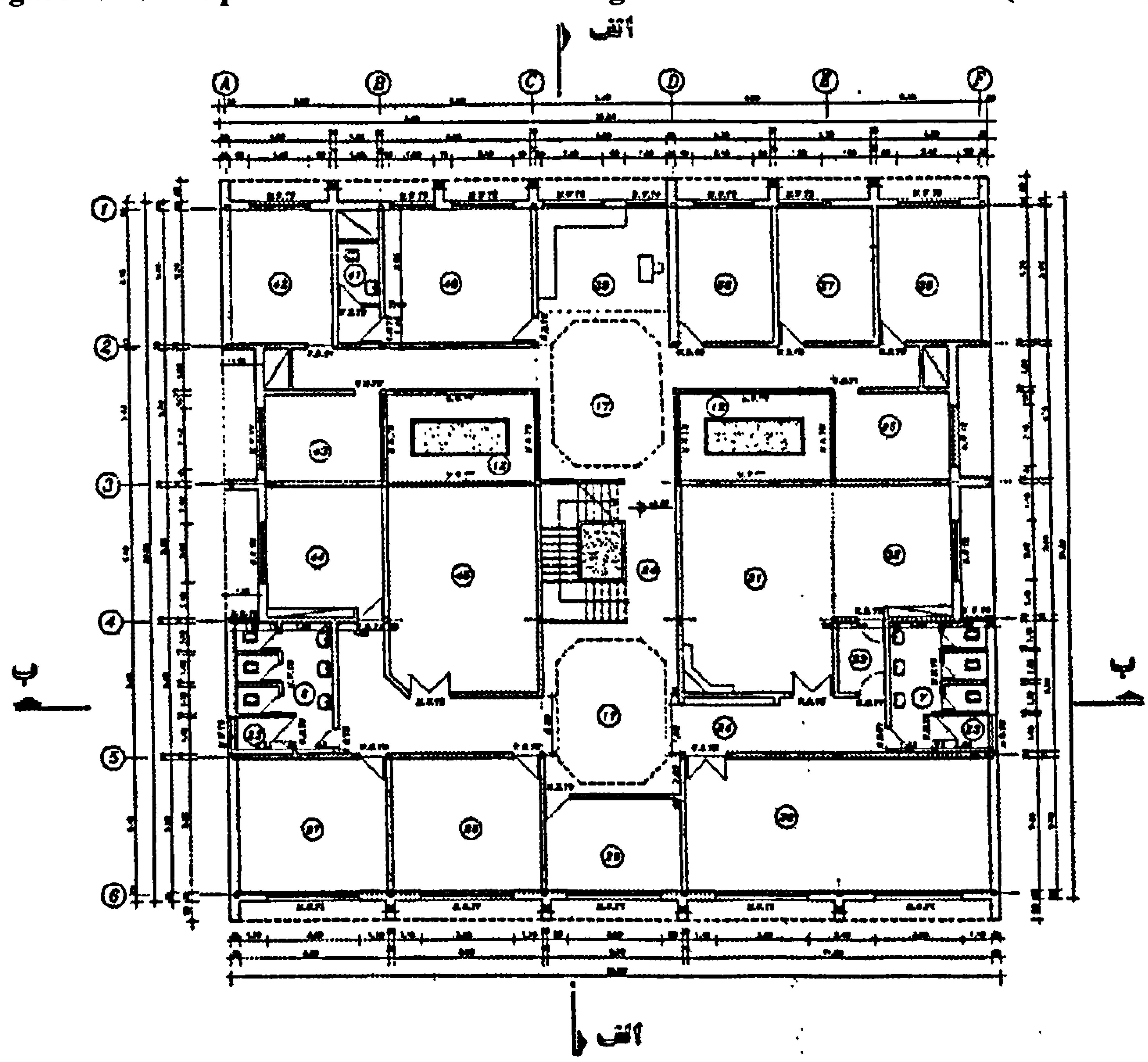


Figure 8.35: The south and north elevations of a high school with 9 classrooms (Number 3)

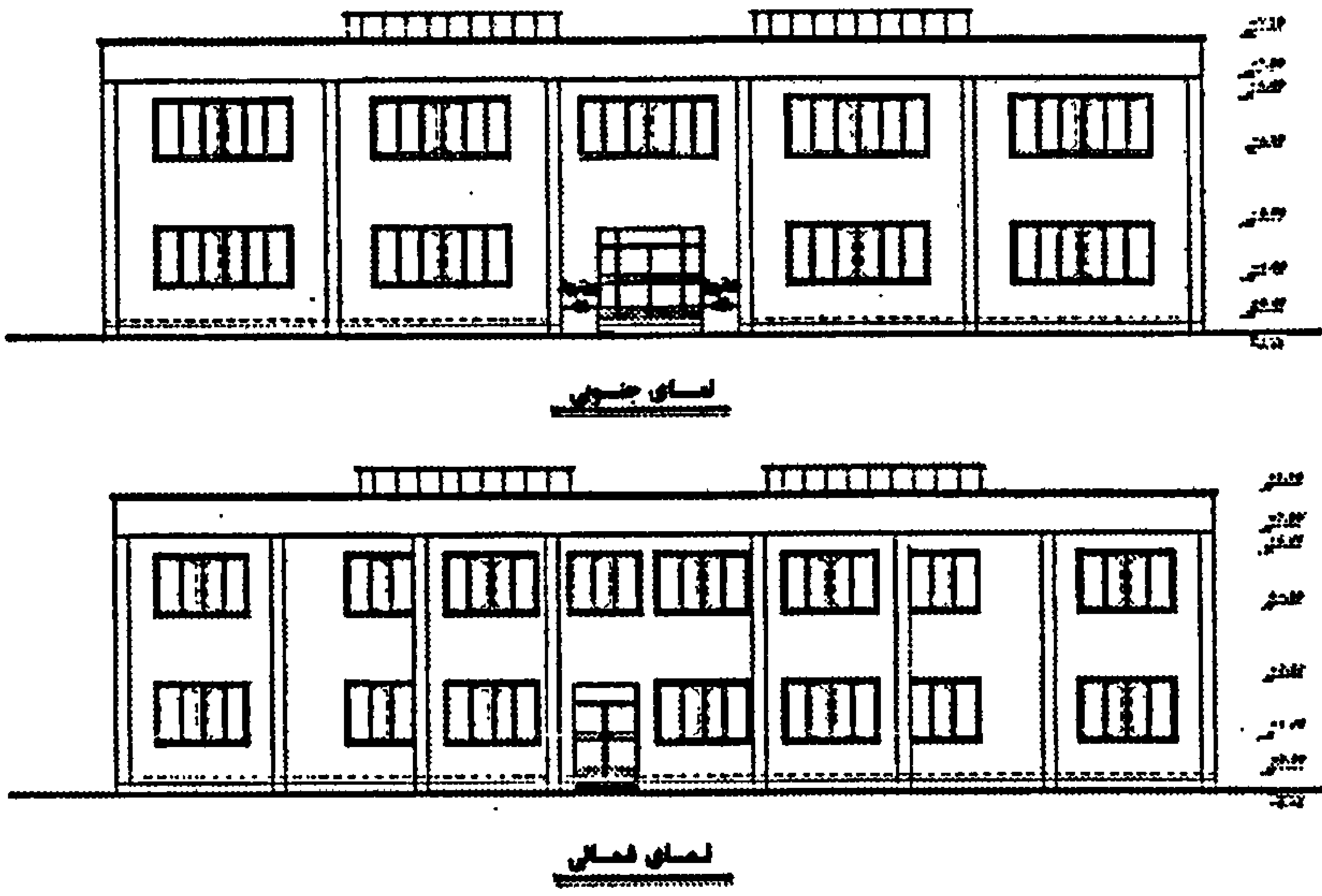


Figure 8.36: The west and east elevations of a high school with 9 classrooms (Number 3)

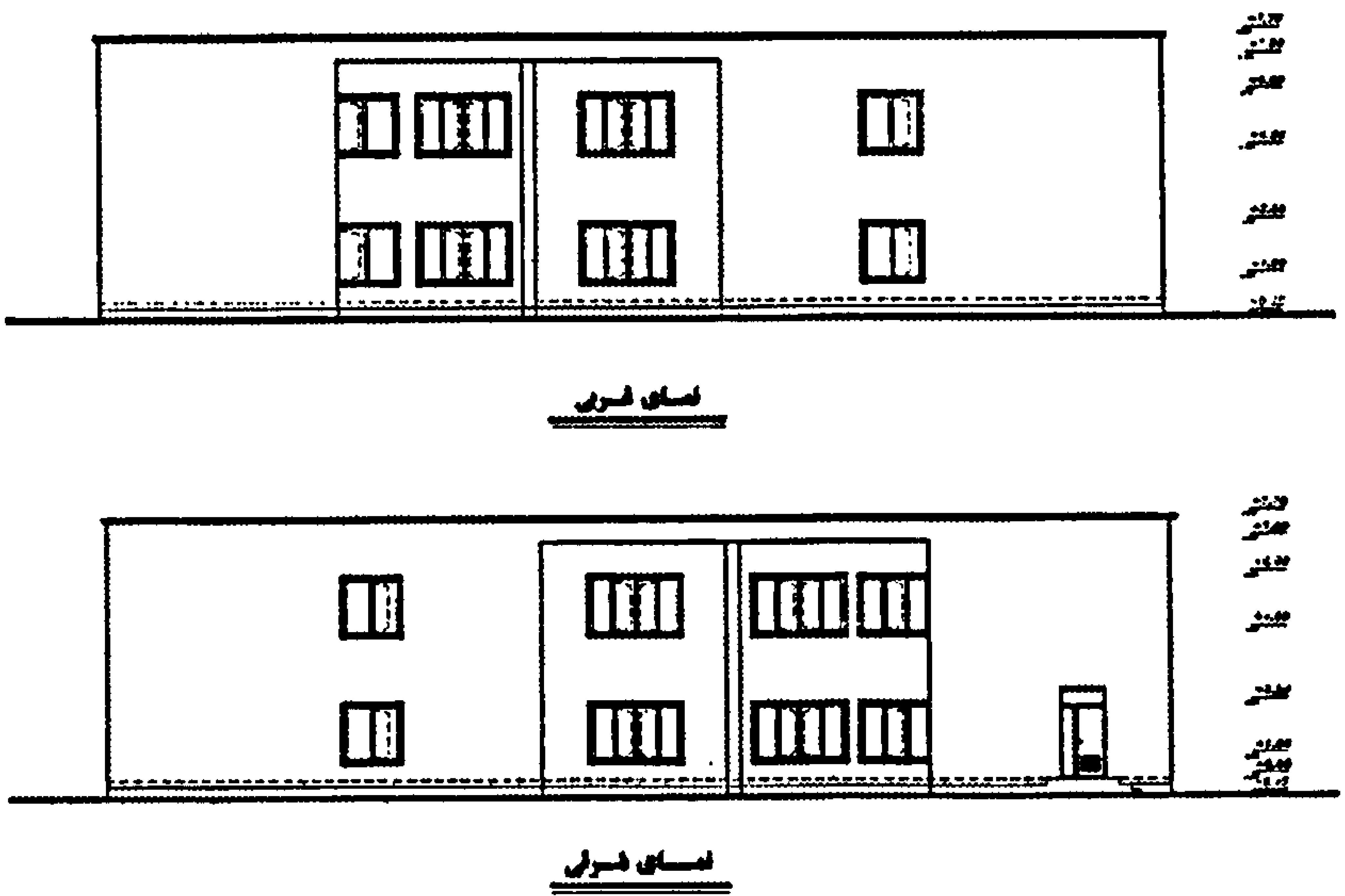
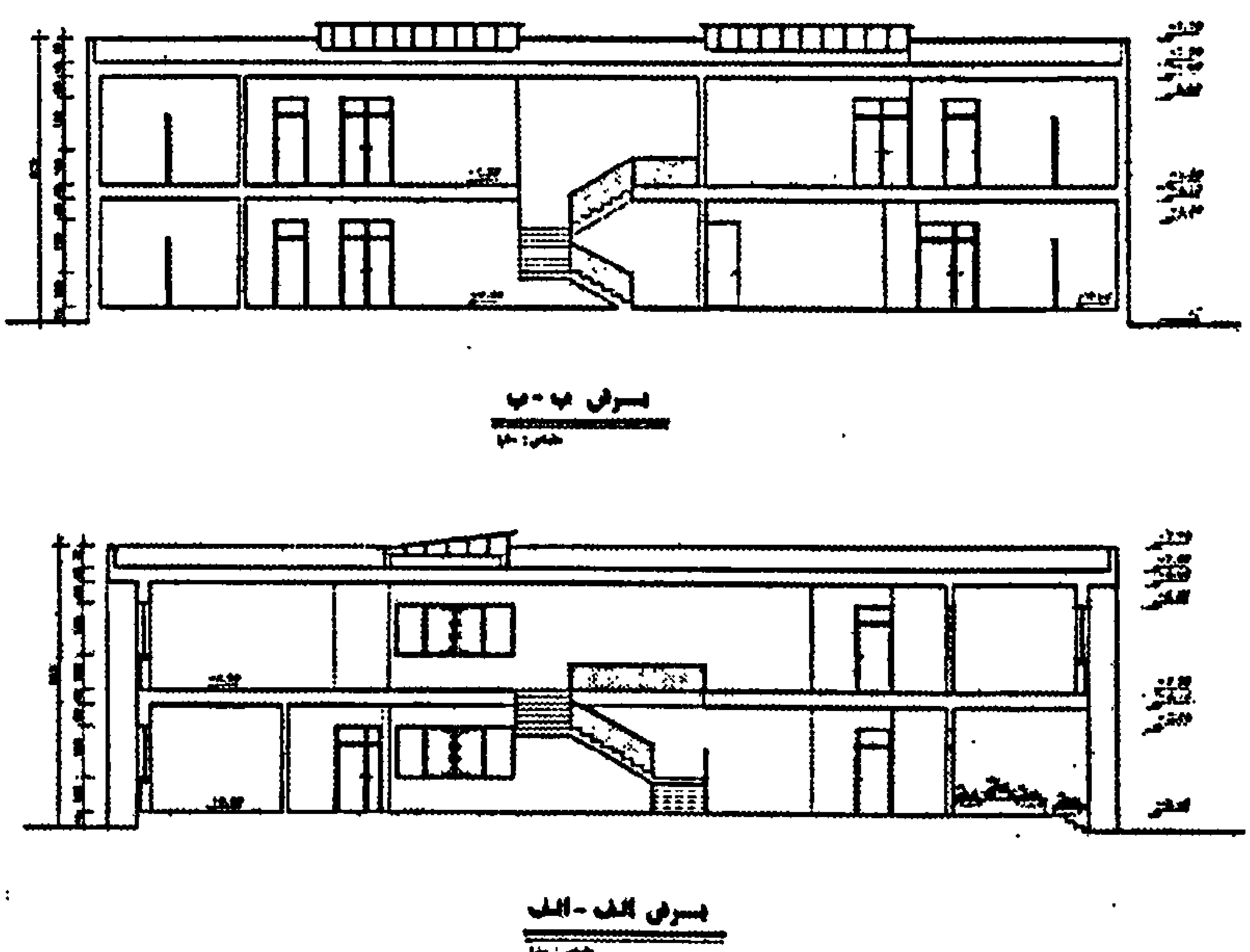


Figure 8.37: The sections B-B and A-A of a high school with 9 classrooms (Number 3)



8$_{7.4}$ * Special Primary School with 5 Classrooms (School number 4)

Type: Special primary school (for children with special need)
Usable area: 600m^2
Pupils: 50
Location: Ghom
Geographic characteristics: Latitude: 34° 38' Degrees (north)
Longitude: -50° 53' Degrees (east)
Altitude: 928 metres
Azimuth angle of building: Azimuth: +18° 00' Degrees
Climate: Relatively cold-Hot (see chapter 2, Group 5 and subgroup 5-3)
Mean yearly temperature: 17.58^{oC}

This two-story special primary school comprises five classrooms, three of them located at the ground floor and the other two at the first floor.

The building has masonry wall (brick) and steel framed window. The construction of the walls is 110 mm brickwork, 225 mm brick and 13 mm plaster. The Ground floor roof consists of 50 mm floor tile, 20 mm cement, 80 mm expanded clay, 110 mm brick and 40 mm plaster. The first floor roof composed of 40 mm asphalt and insulation, 20 mm cement, 150 mm expanded clay, 110 mm brick and 40 mm plaster.

The windows are single glazed and the glazing ratio of the ground floor is 15% in north wall, 24% in the south wall, 12% in the west wall and 5% in the east wall. The glazing ratio of first floor is 15% in north, 24% in south, 3% in west and 28% in the east wall.

The plan of the ground floor consists of two rectangles with the following dimensions: 26m x 14m and 8m x 7.3m. The first floor has a rectangular plan with 14 m length and 12.7 m width. The room height is 3 m at each floor and the direction is extended from east to west.

Heating is provided by a central heating system with thermostatically controlled gasoline-fired units and conventional radiators. The indoor temperature must be set to 24^{oC} in the warm season and 20^{oC} in the cold one. The cooling system consists of electric water-based cooler.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.11: The amount of actual annual energy used

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs
Electricity	--	--	81,792*
Gas	--	--	--
Gasoline	10900 litres	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.12: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	74,516.0	30,626.0	45,900.43	With Daylighting
Non-window control	74,516.0	39,089.3	75,396.1	Non Daylighting
With shading	74,503.6	28,482.6	47,106.36	With shading& Daylighting

Figure 8.38: The plan of the ground floor of a special primary school with 5 classrooms
(Number 4)

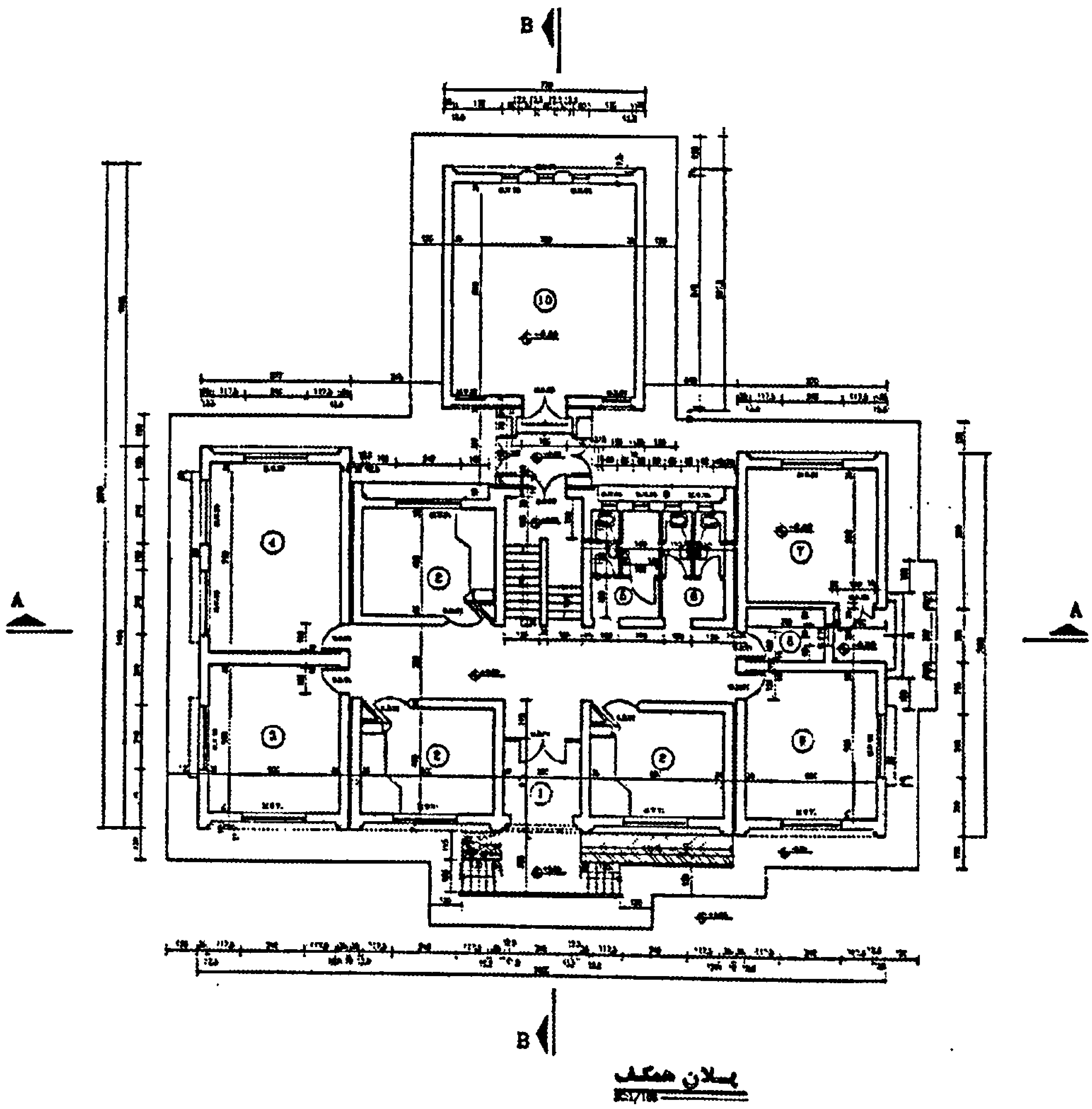


Figure 8.39: The plan of the first floor of a special primary school with 5 classrooms (Number 4)

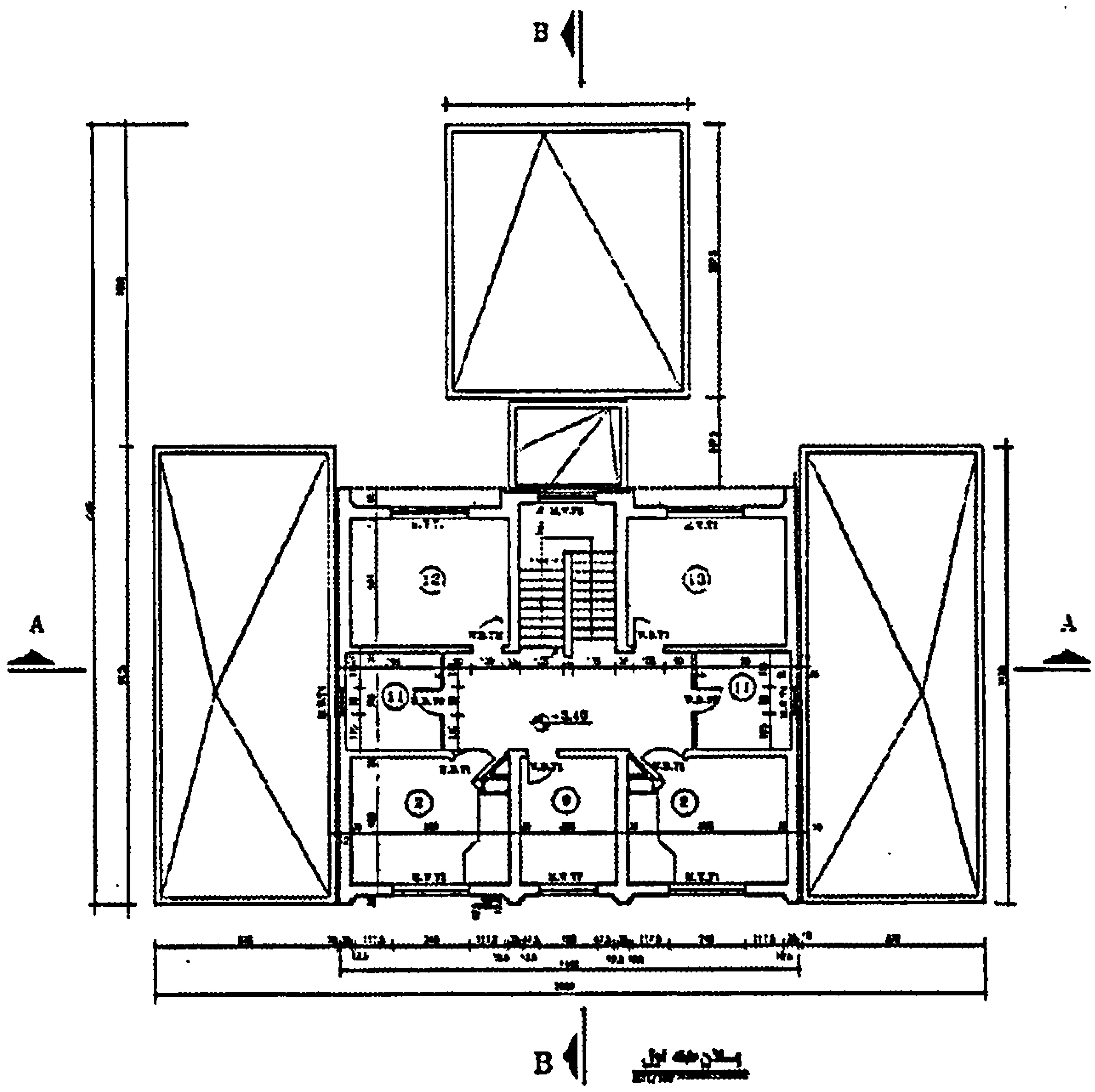


Figure 8.40: The west elevation of a special primary school with 5 classrooms (Number 4)

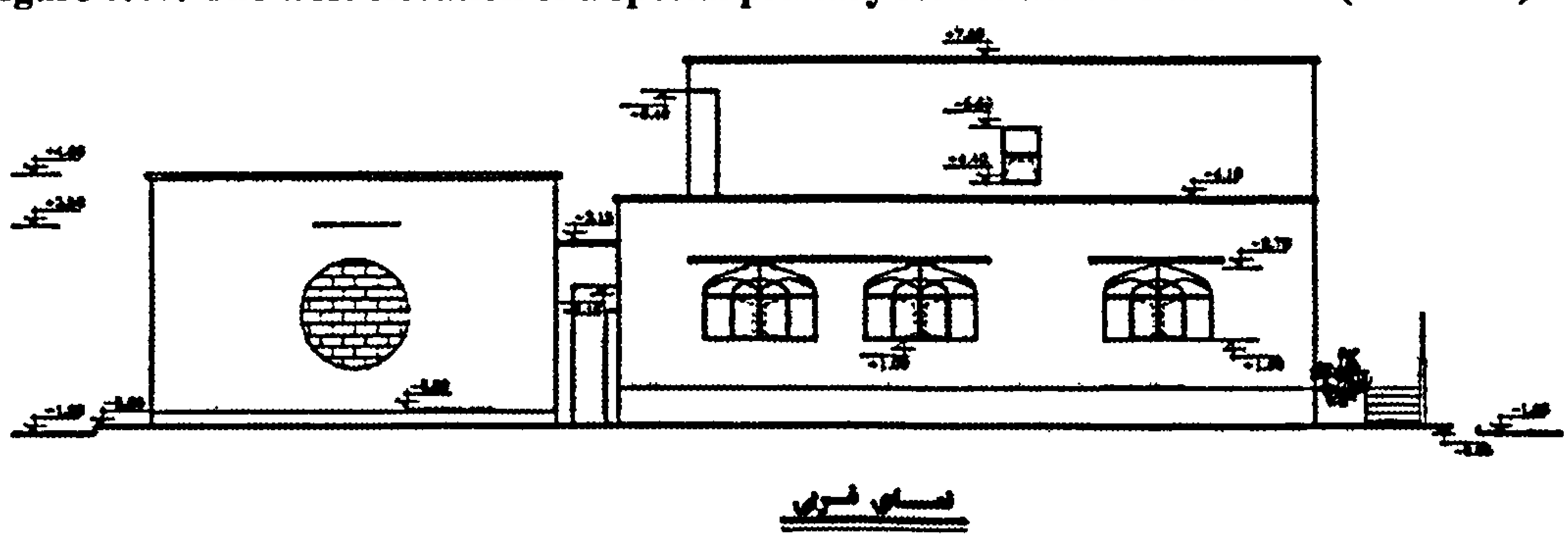


Figure 8.41: The east elevation of a special primary school with 5 classrooms (Number 4)

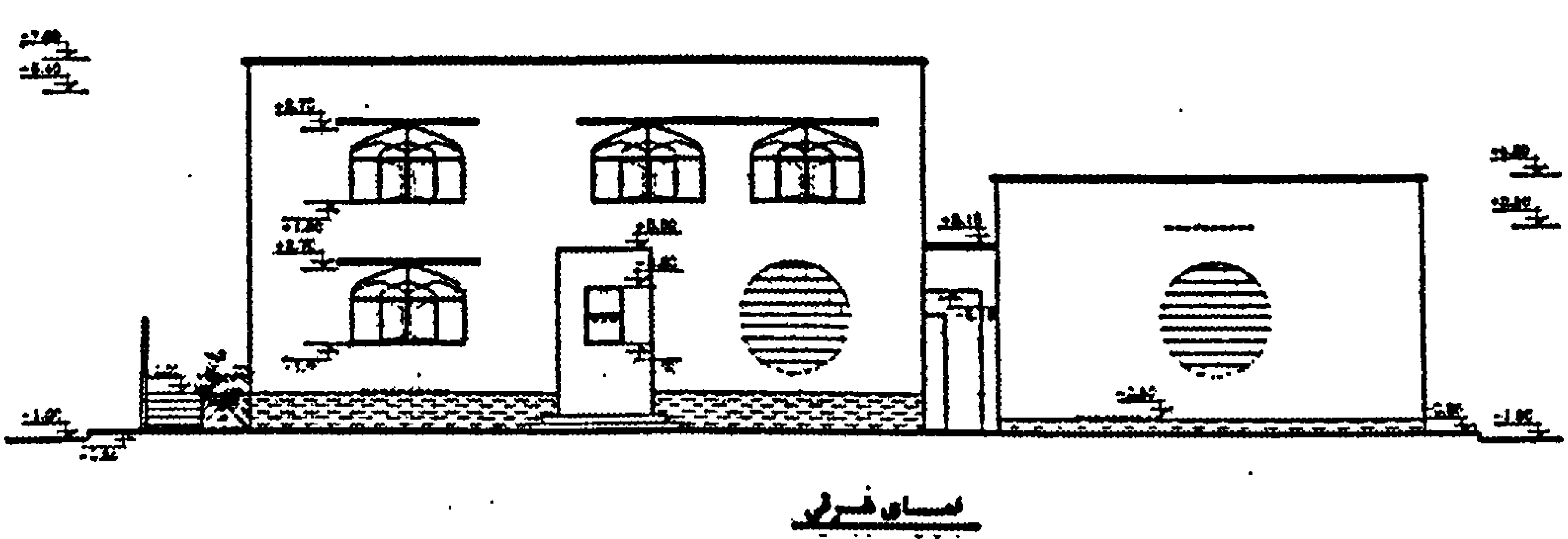
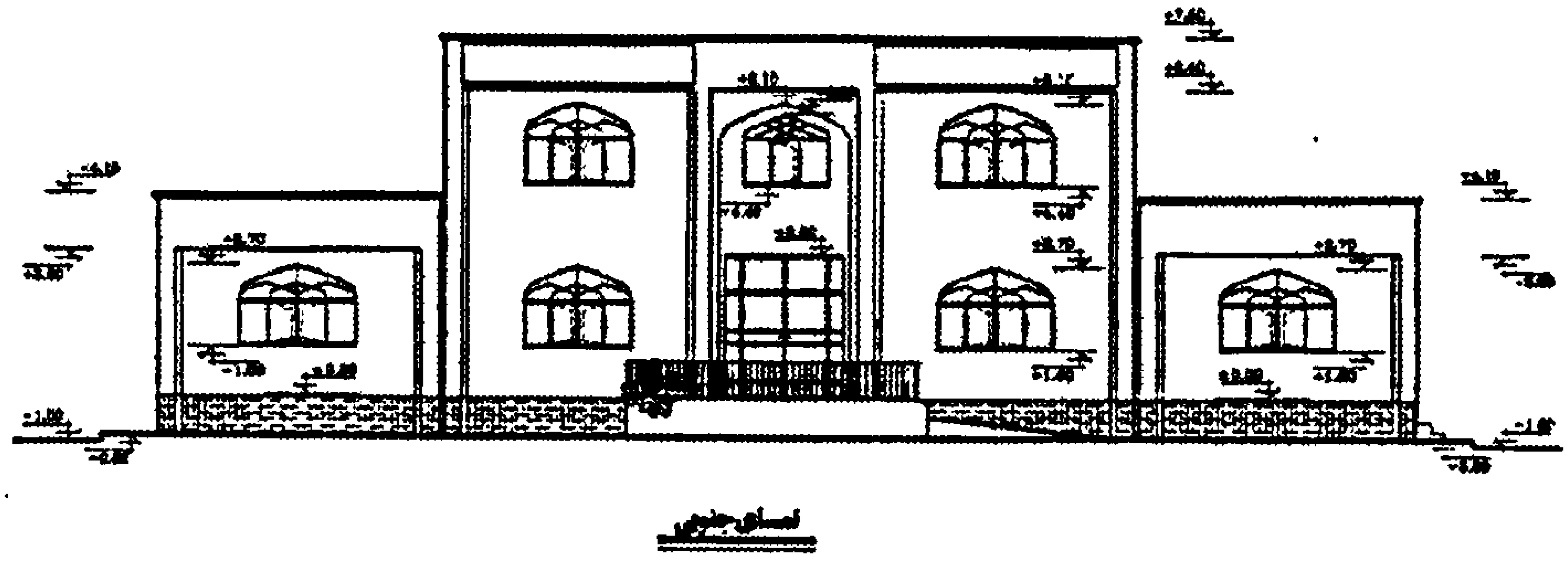


Figure 8.42: The south elevation & section A-A of a special primary school with 5 classrooms (Number 4)



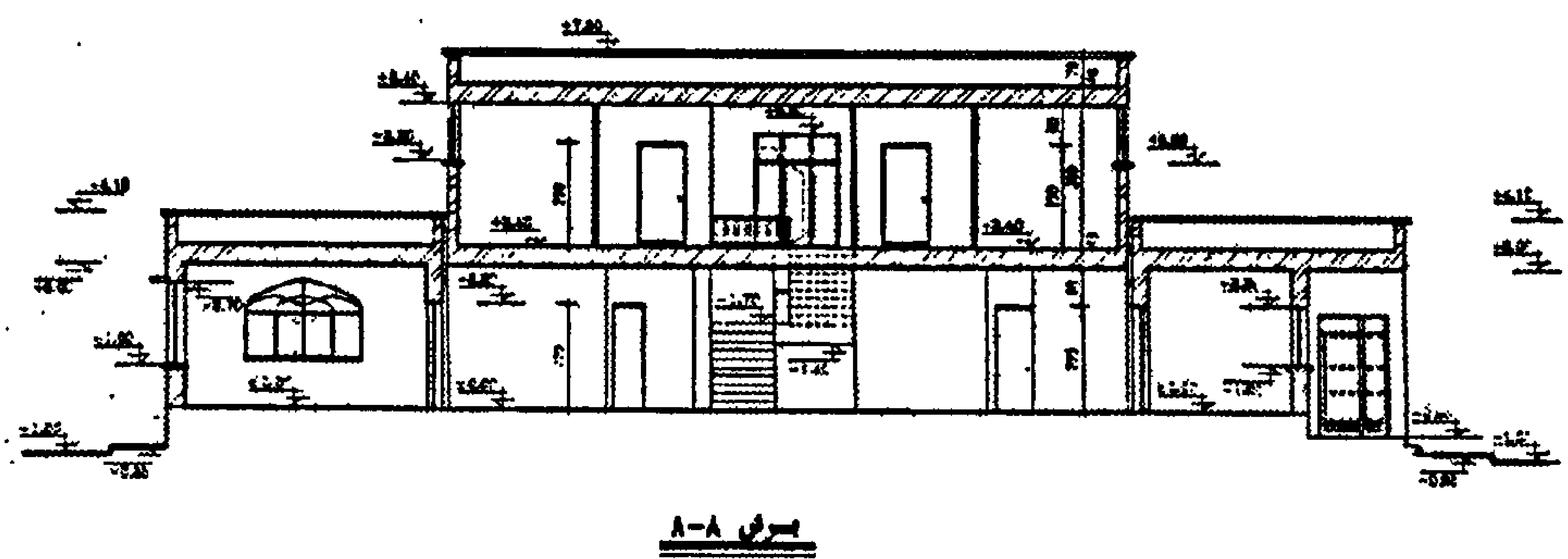
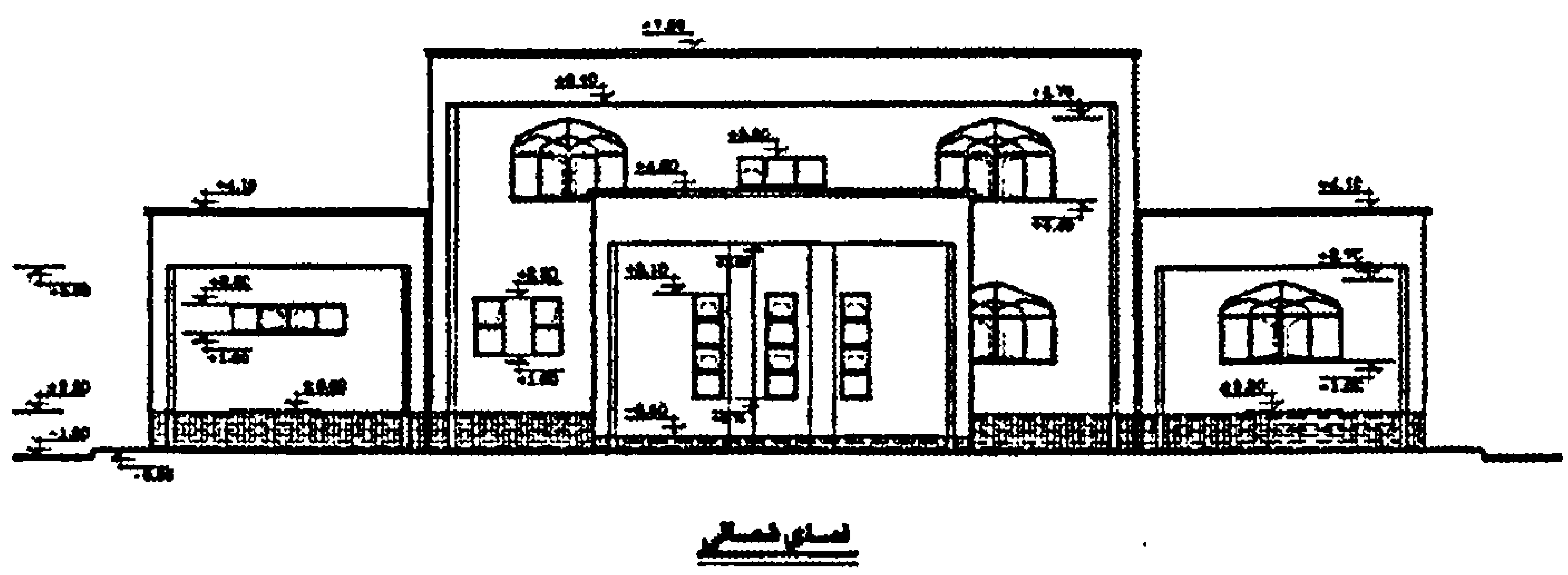
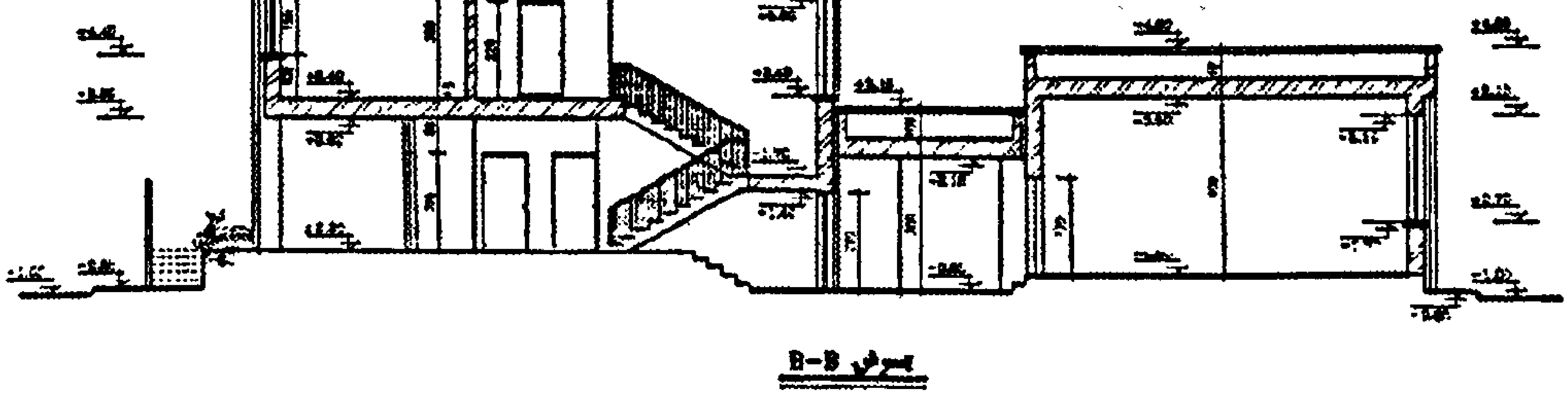


Figure 8.43: The north elevation & section B-B of a special primary school with 5 classrooms (Number 4)





$8_{7.5}$ * **Secondary School with 9 Classrooms** (School number 5)

Type: Secondary school
Usable area: 1400m²
Pupils: 270
Location: Ghom
Geographic characteristics: Latitude: 34° 38' Degrees (north)
Longitude: -50° 53' Degrees (east)
Altitude: 928 metres
Azimuth angle of building: Azimuth: +25° 00' Degrees
Climate: Relatively cold-Hot (see chapter 2, Group 5 and subgroup 5-3)
Mean yearly temperature: 17.58^{oC}

This two-story secondary school comprises nine classrooms, three of them located at the ground floor and the other six at the first floor.

The building is steel framed with brick walls and aluminium framed window. The construction of the walls is 30 mm cement, 225 mm brick and 13 mm plaster. The Ground floor roof consists of 50 mm floor tile, 20 mm cement, 80 mm expanded clay, 110 mm brick and 40 mm plaster. The first floor roof composed of 40 mm asphalt and insulation, 20 mm cement, 150 mm expanded clay, 110 mm brick and 40 mm plaster.

The windows are single glazed and the glazing ratio of the ground floor is 30% in north wall, 31% in the south wall, 26% in the west wall and 22% in the east wall. The glazing ratio of first floor is 34.5% in north, 43.2% in south, 9% in west and 9% in the east wall.

The school has a rectangular plan with 42 m length and 16 m width and 7 m height (the room height is 3 m at each floor) and the direction is expended from east to west.

Heating is provided by a central heating system with thermostatically controlled gas-fired units and conventional radiators. The indoor temperature must be set to 24^{oC} in the warm season and 20^{oC} in the cold one. The cooling system consists of electric water-based cooler.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.13: The amount of actual annual energy used

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs
Electricity	--	--	143,891*
Gas	108,179	--	--
Gasoline	--	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.14: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	131,926.2	81,309.5	73,419.96	With Daylighting
Non-window control	131,926.2	80,760.6	136,655.44	Non Daylighting
With shading	131,926.2	62,493.2	73,891.44	With shading& Daylighting

Figure 8.44: The plan of the ground floor of a secondary school with 9 classrooms (Number 5)

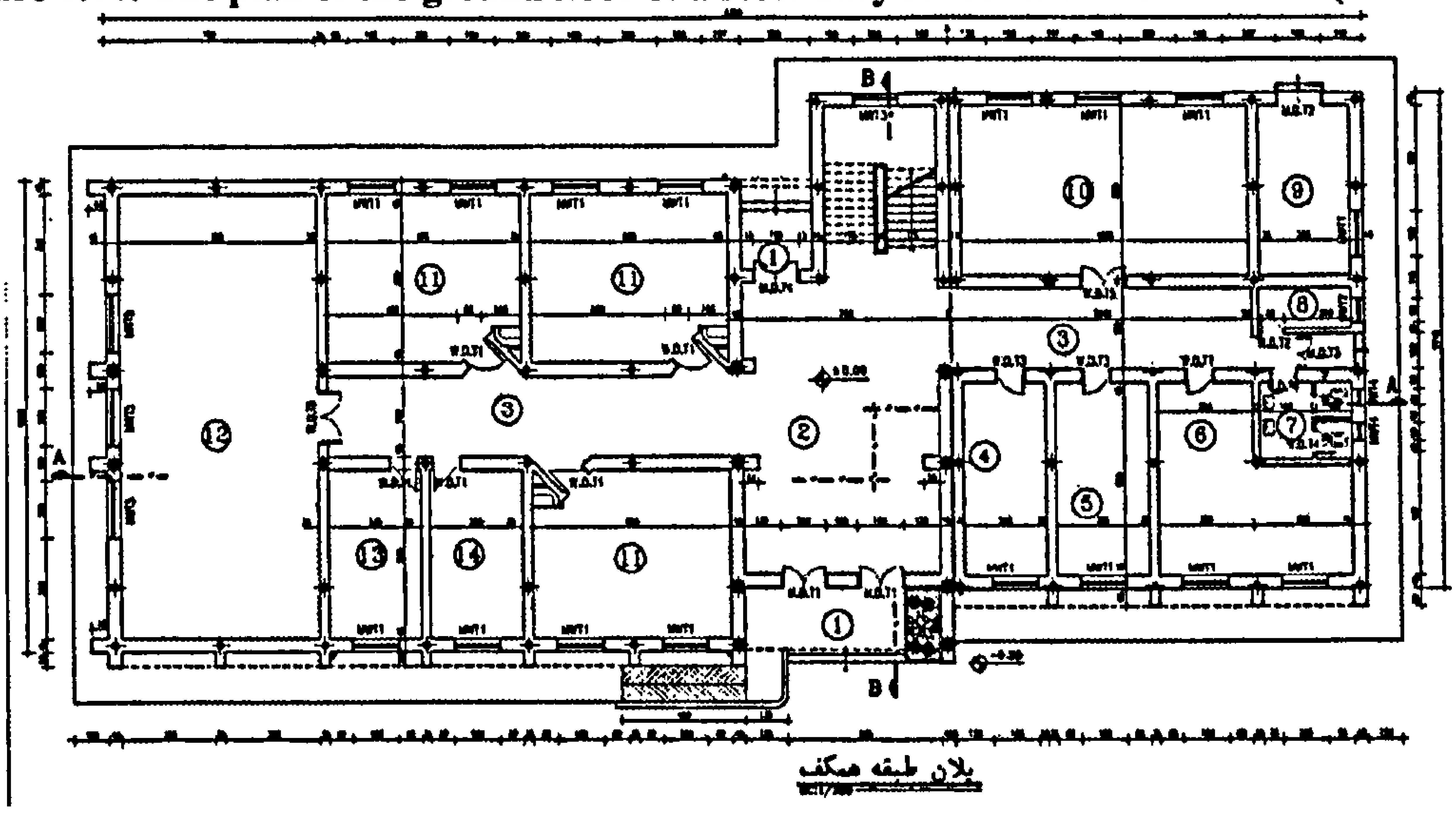


Figure 8.45: The plan of the first floor of a secondary school with 9 classrooms (Number 5)

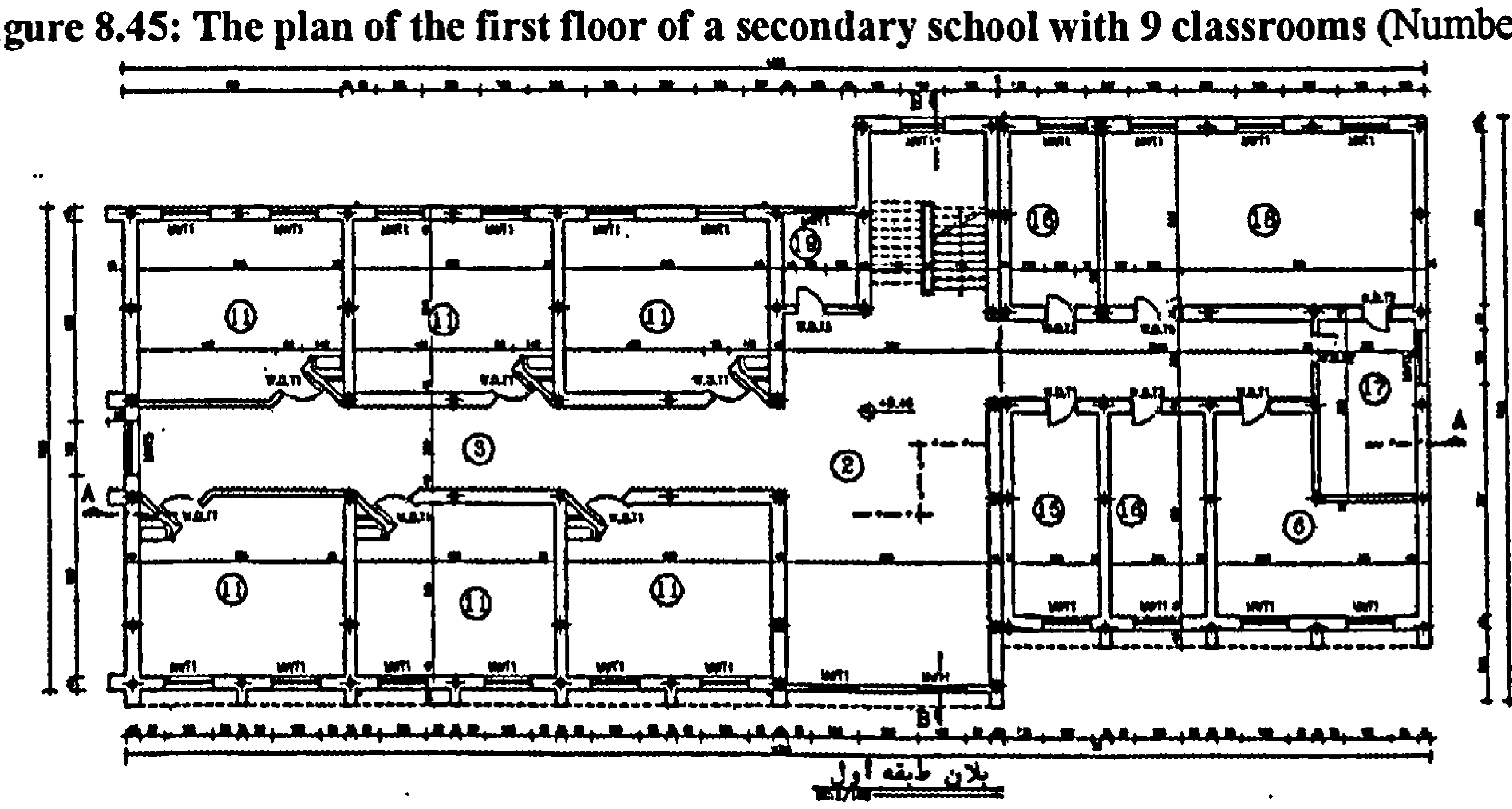


Figure 8.46: The west elevation of a secondary school with 9 classrooms (Number 5)

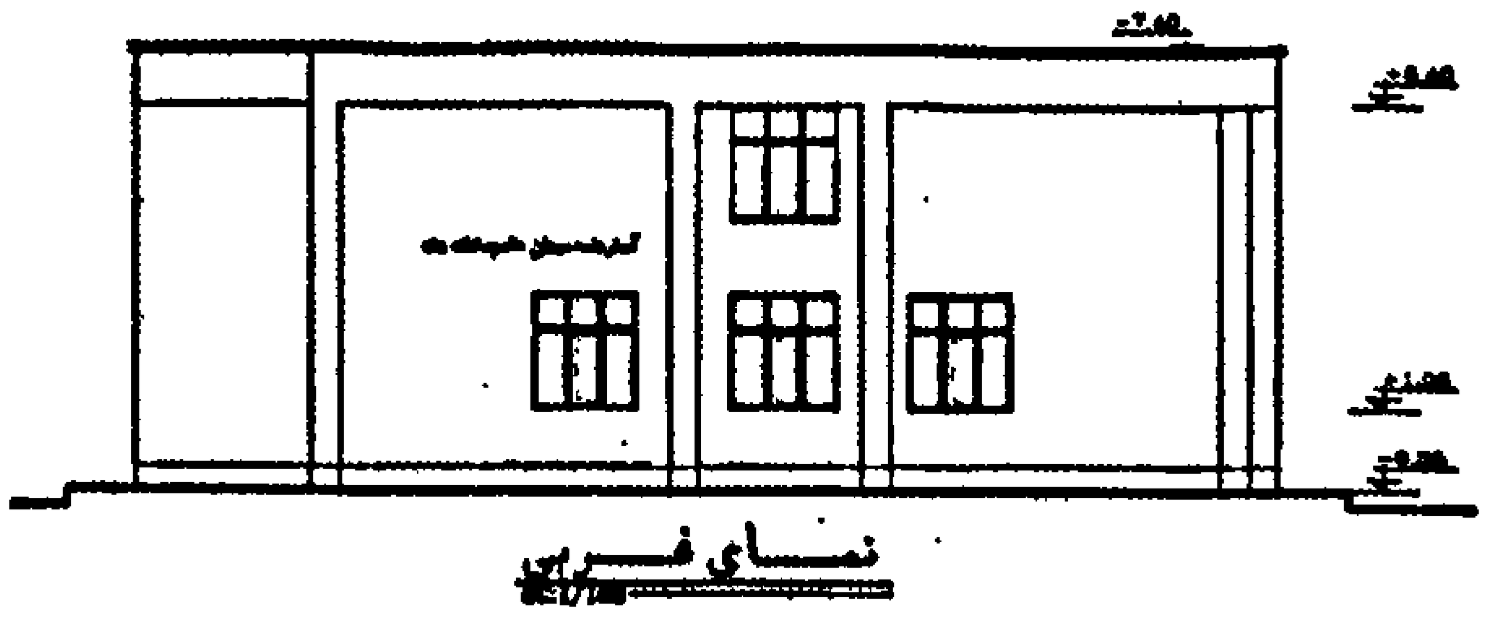


Figure 8.47: East elevation

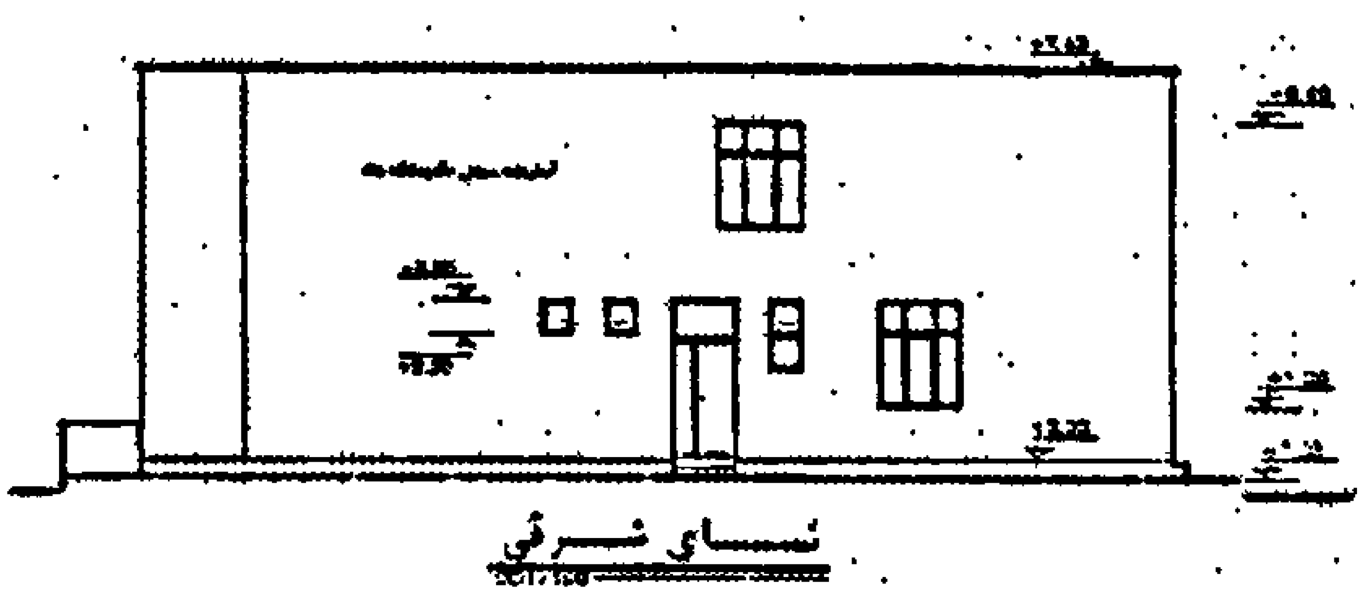


Figure 8.48: Section B-B

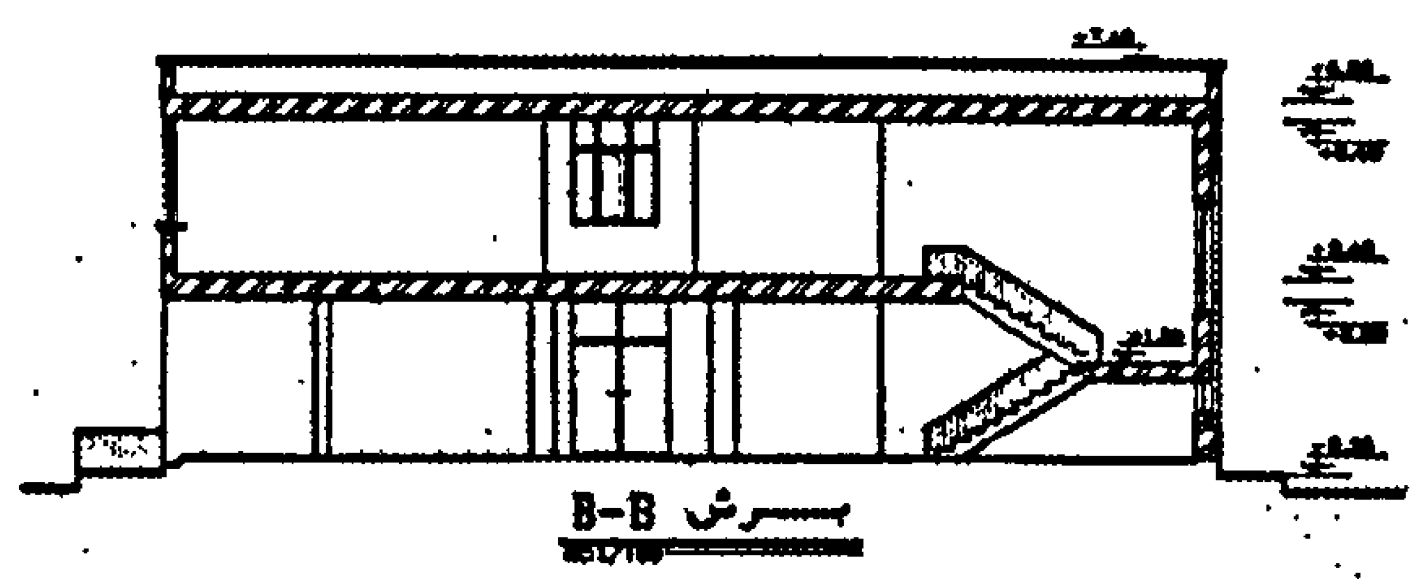
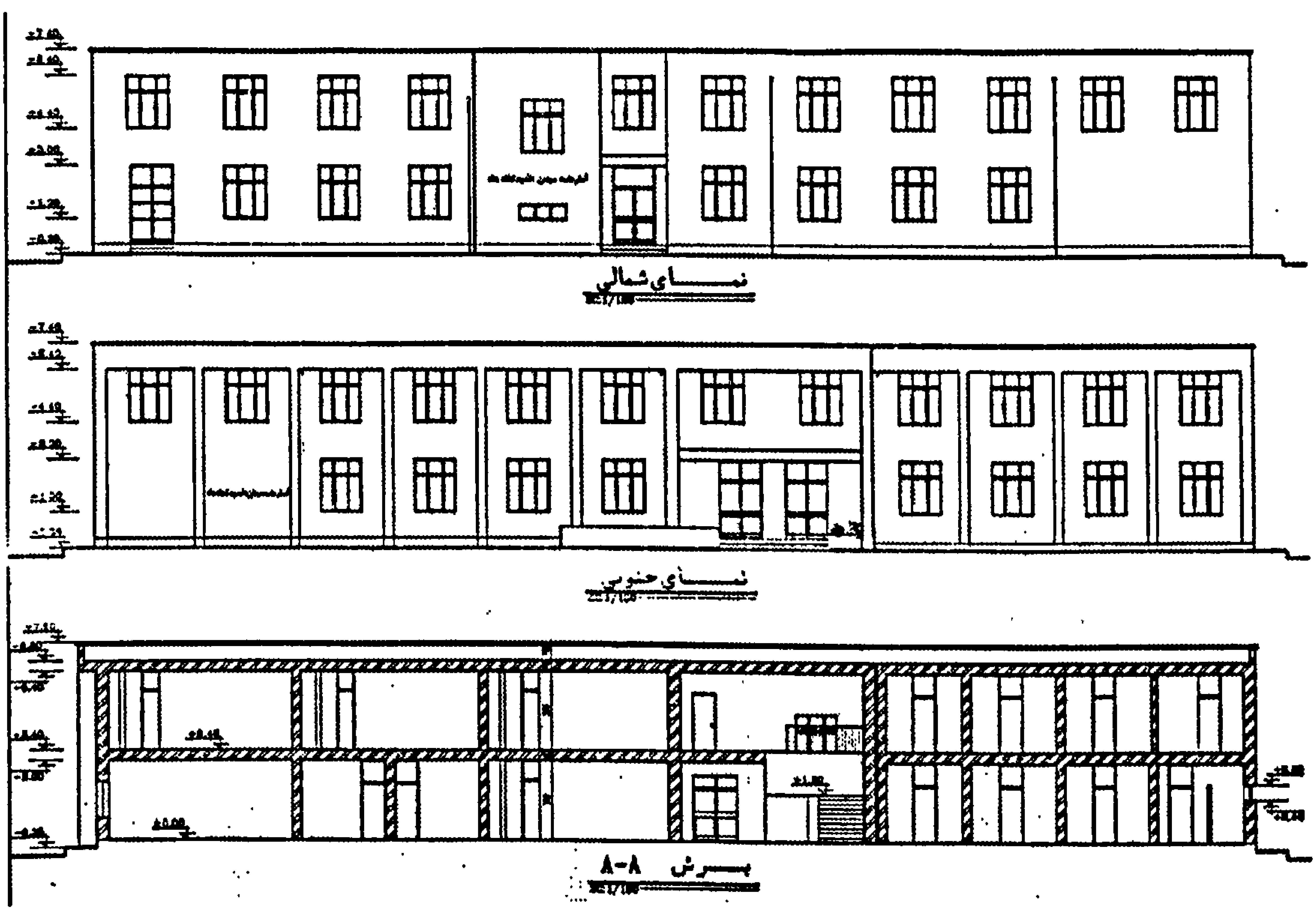


Figure 8.49: The north and south elevations & section A-A of a secondary school with 9 classrooms (Number 5)



8$_{7.6}$ * **Special Primary School with 9 Classrooms** (School number 6)

Type: Special primary school (for children with special need)
Usable area: 790 m^2
Pupils: 80
Location: Yazd

Geographic characteristics:	Latitude: 31° 54' Degrees (north) Longitude: -54° 24' Degrees (east) Altitude: 1230 metres
Azimuth angle of building:	Azimuth: -25° 00' Degrees

Climate: Relatively cold-Hot and arid (see chapter 2, Group 5 and subgroup 5-4)
Mean yearly temperature: 19°C

This two-story special primary school comprises nine classrooms, three of them located at the ground floor and the other six at the first floor.

The building has masonry wall (brick) and wood framed window. The construction of the walls is 110 mm brickwork, 225 mm brick and 13 mm plaster. The ground floor roofs are composed of 50 mm floor tile, 50 mm concrete, 220 mm concrete block and 15 mm plaster. The first floor roof consists of 30 mm tile & cement, 25 mm asphalt and insulation, 20 mm concrete, 80 mm expanded clay, and 50 mm concrete, 220 mm concrete block and 15 mm plaster.

The windows are single glazed and the glazing ratio of the ground floor is 15% in north wall, 24.64% in the south wall, 12% in the west wall and 5.1% in the east wall. The glazing ratio of first floor is 19.3% in north, 12% in south, 21% in west and 21% in the east wall.

The plan of the ground floor consists of two rectangles with the following dimensions: 26m* 14m and 8m* 7.3m. The first floor has a rectangular plan with 14 m length and 26 m width. The room height is 3 m at each floor and the direction is extended from east to west.

Heating is provided by a central heating system with thermostatically controlled gasoline-fired units and conventional radiators. The indoor temperature must be set to 24°C in the warm season and 20°C in the cold one. The cooling system consists of electric water-based cooler.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.15: The amount of actual annual energy used

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs
Electricity	--	--	81,570*
Gas	--	--	--
Gasoline	5,250 litres	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.16: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	75,758.2	49,504.2	53,670.6	With Daylighting
Non-window control	75,758.2	60,857.3	91,888.99	Non Daylighting
With shading	75,758.2	47,139.3	58,909.03	With shading& Daylighting

Figure 8.50: The plan of the ground floor of a special primary school with 9 classrooms (Number 6)

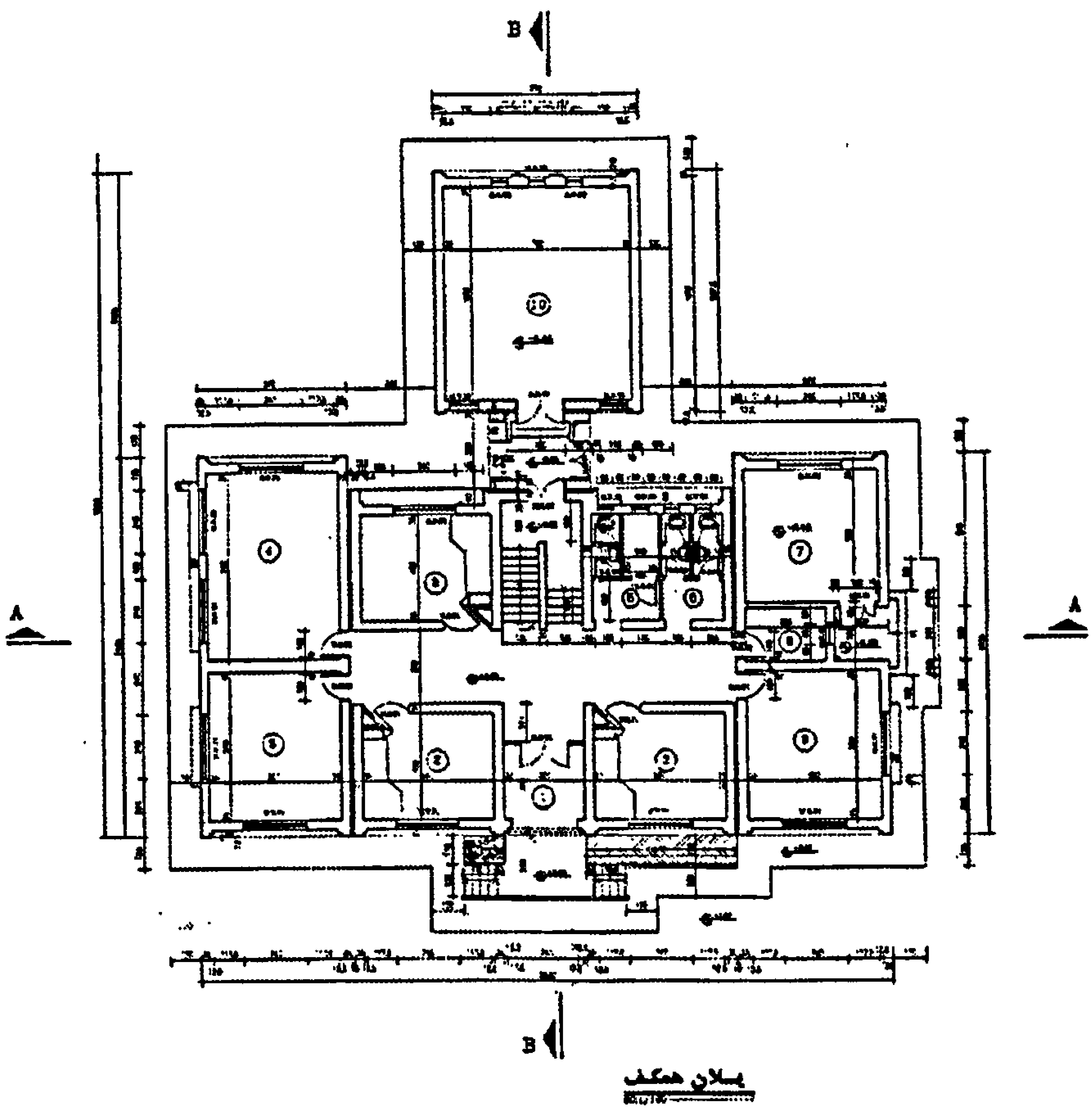


Figure 8.51: The plan of the first floor of a special primary school with 9 classrooms (Number 6)

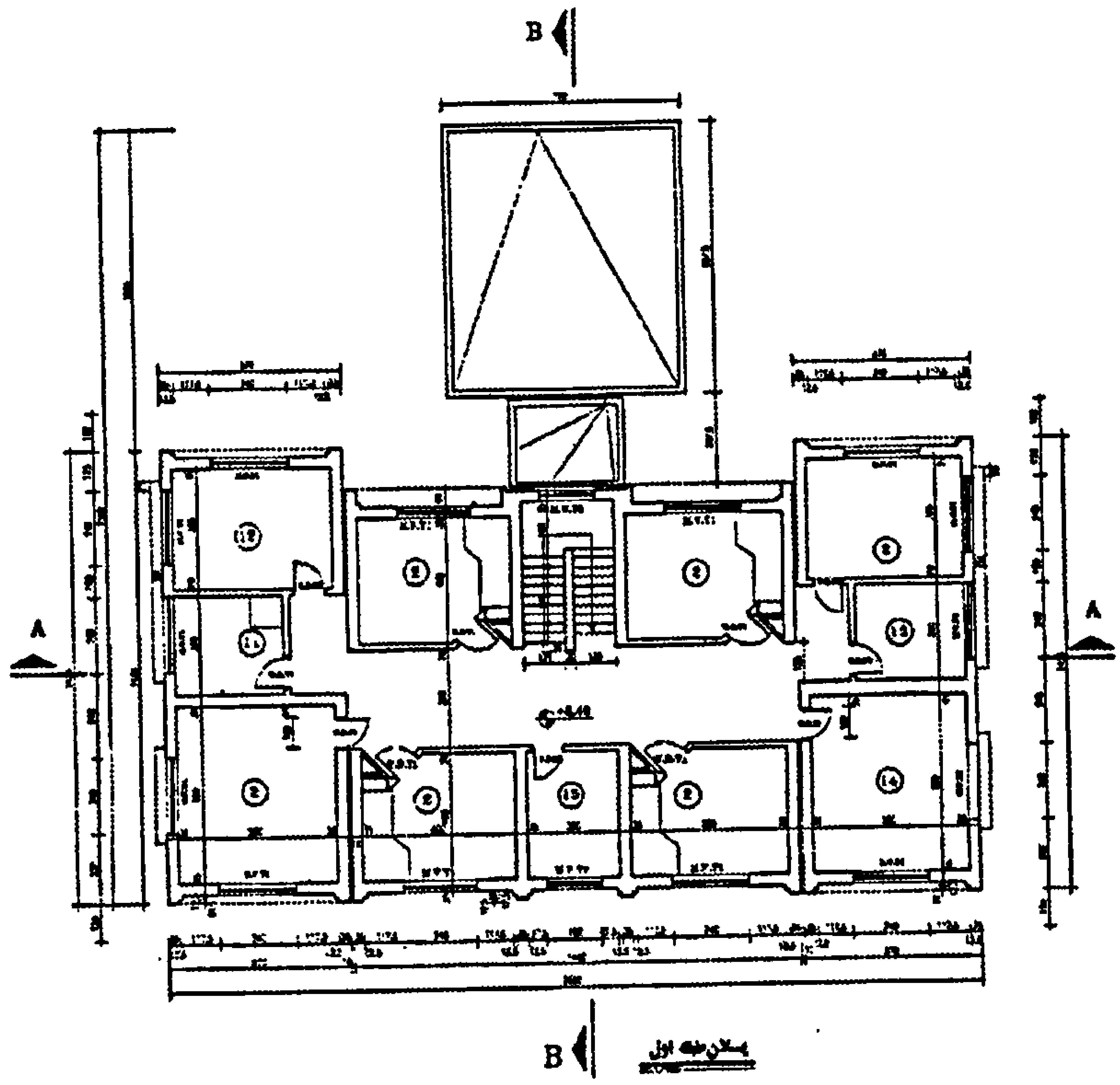


Figure 8.52: The sections A-A and B-B of a special primary school with 9 classrooms (Number 6)

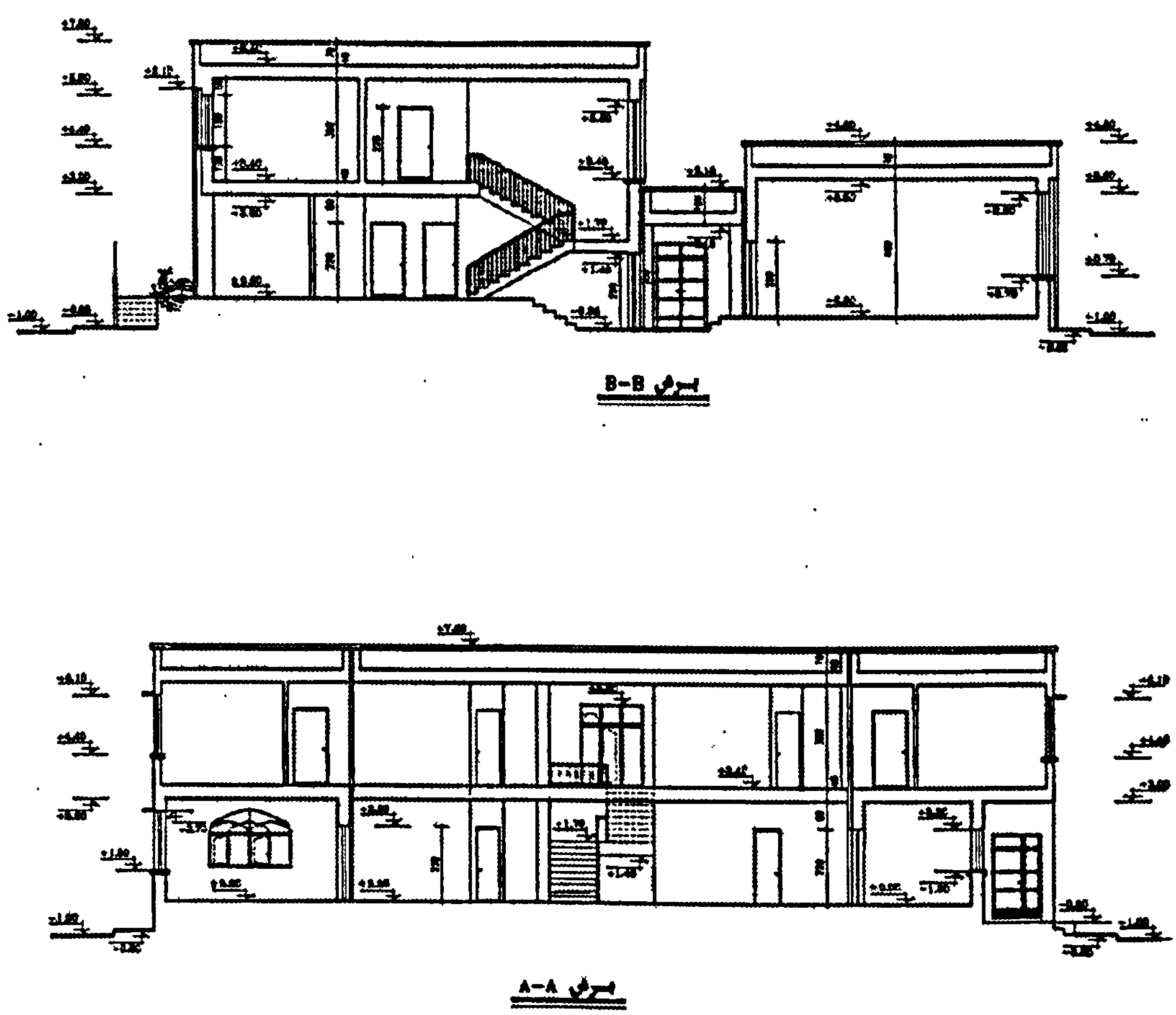
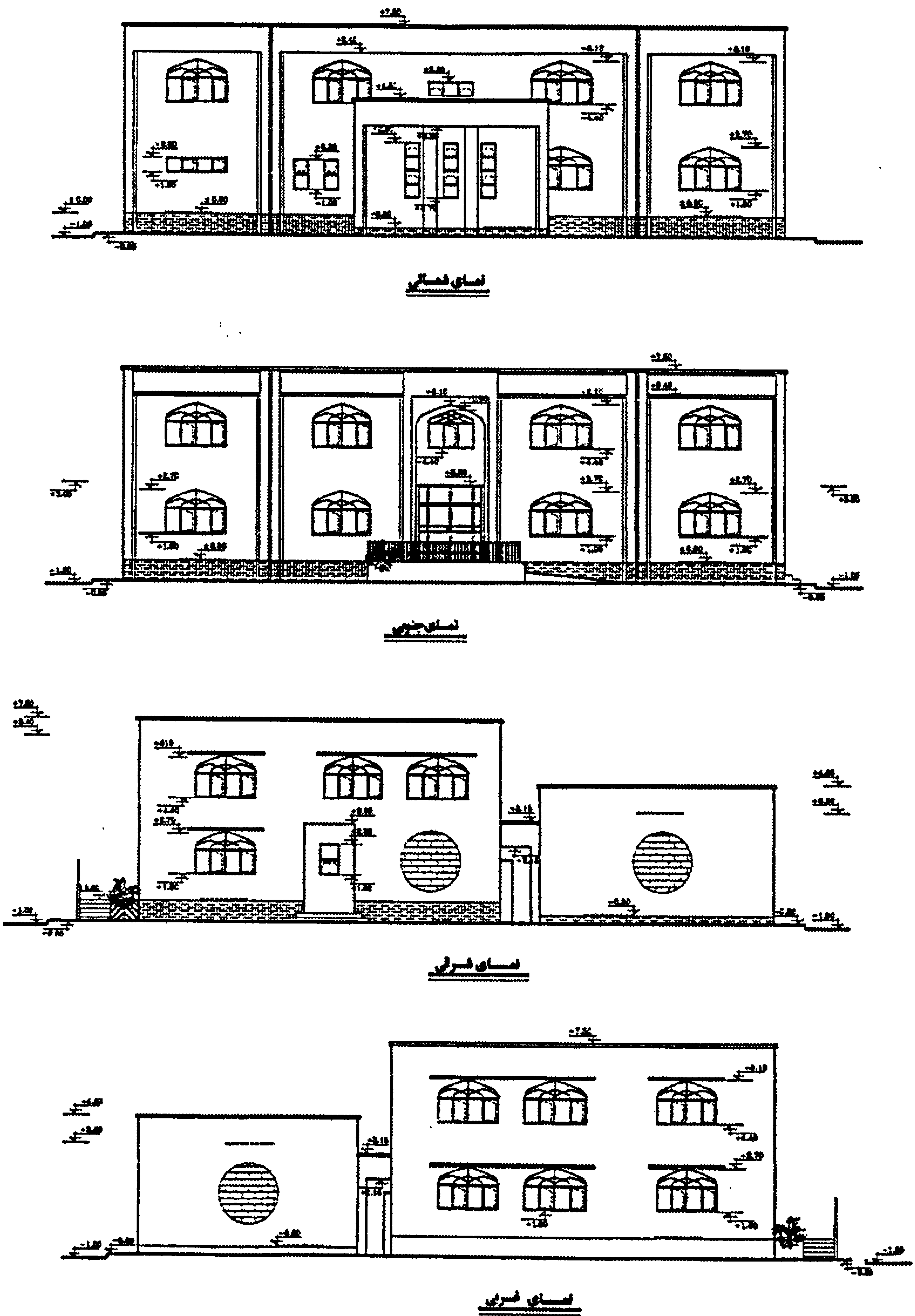


Figure 8.53: The north, south, east and west elevations of a special primary school with 9 classrooms (Number 6)



8$_{7.7}$ * **Secondary School with 12 Classrooms** (School number 7)

Type: Secondary school
Usable area: 2300 m^2
Pupils: 360
Location: Yazd
Geographic characteristics: Latitude: 31° 54' Degrees (north)
Longitude: -54° 24' Degrees (east)
Altitude: 1230 metres
Azimuth angle of building: Azimuth: -19° 00' Degrees
Climate: Relatively cold-Hot and arid (see chapter 2, Group 5 and subgroup 5-4)
Mean yearly temperature: 19°C

This two-story secondary school comprises twelve classrooms, three of them located at the ground floor and the other nine at the first floor.

The building is steel framed with brick walls and aluminium framed window. The construction of the walls is 110 mm brickwork, 225 mm brick and 13 mm plaster. The ground floor roofs are composed of 50 mm floor tile, 50 mm concrete, 220 mm concrete block and 15 mm plaster. The first floor roof consists of 30 mm tile & cement, 25 mm asphalt and insulation, 20 mm concrete, 80 mm expanded clay, and 50 mm concrete, 220 mm concrete block and 15 mm plaster.

The windows are single glazed and the glazing ratio of the ground floor is 30% in north wall, 31% in the south wall, 26% in the west wall and 22% in the east wall. The glazing ratio of first floor is 34.5% in north, 43.2% in south, 9% in west and 9% in the east wall.

Heating is provided by a central heating system with thermostatically controlled gas-fired units and conventional radiators. The indoor temperature must be set to 24°C in the warm season and 20°C in the cold one. The cooling system consists of electric water-based cooler.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.17: The amount of actual annual energy used

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs
Electricity	--	--	220,274
Gas	133,893	--	--
Gasoline	--	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.18: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	179,697.6	129,397.1	124,511.91	With Daylighting
Non-window control	179,697.6	165,476.1	223,832.16	Non Daylighting
With shading	179,697.6	122,099.3	66,988.46	With shading& Daylighting

Figure 8.54: The plan of the ground floor of a secondary school with 12 classrooms (Number 7)

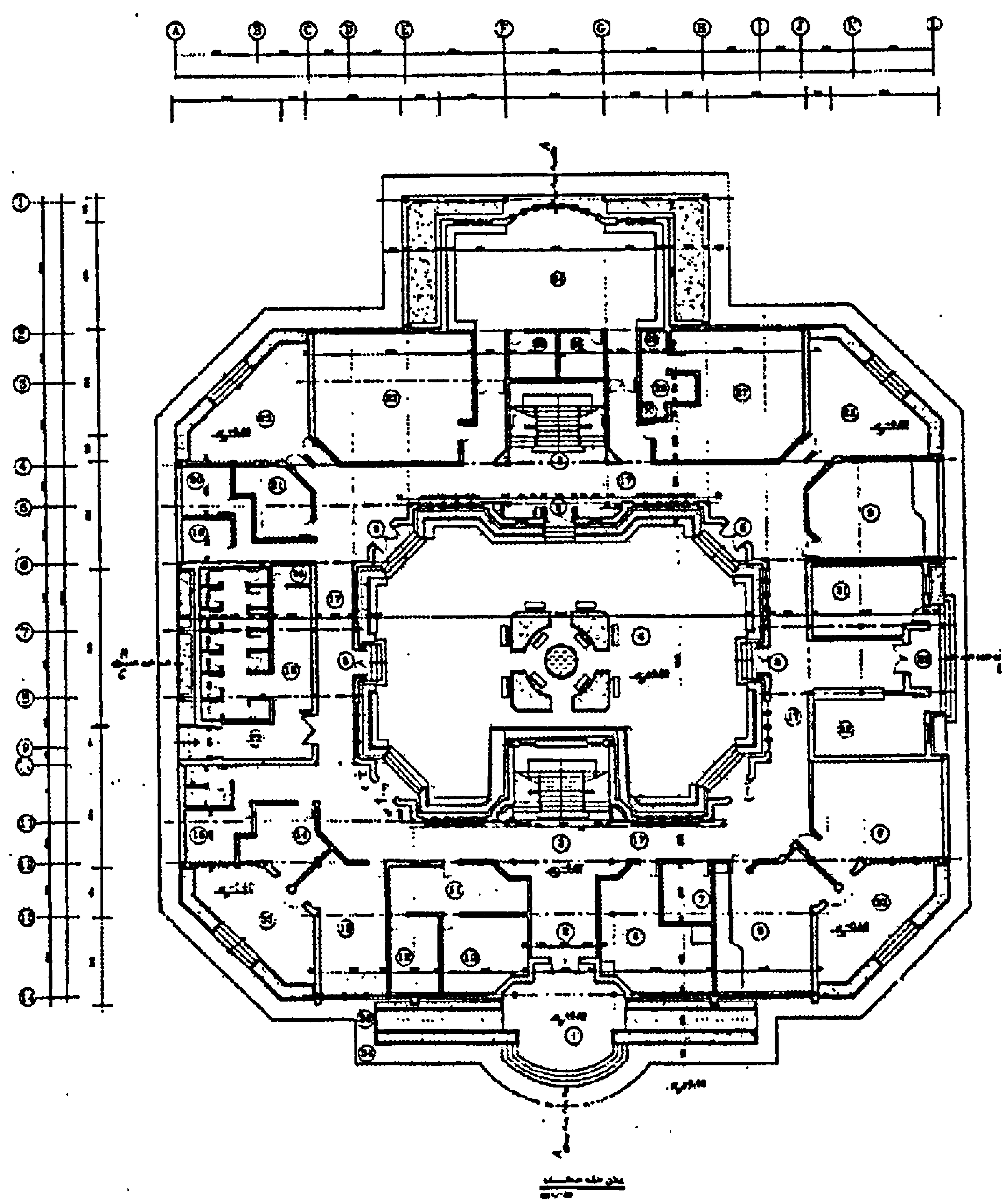


Figure 8.55: The plan of the first floor of a secondary school with 12 classrooms (Number 7)

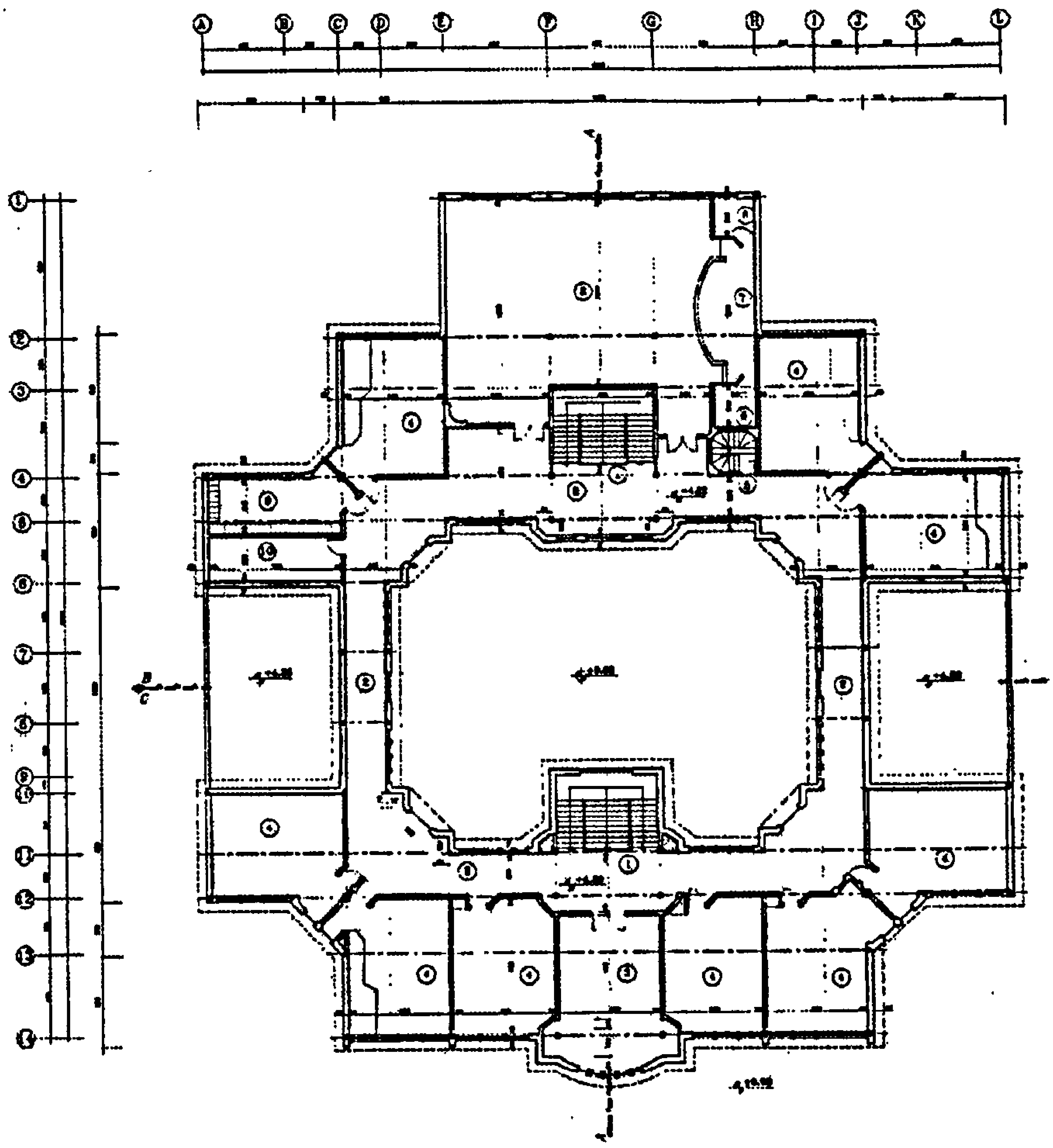


Figure 8.56: The sections A-A, B-B, C-C of a secondary school with 12 classrooms (Number 7)

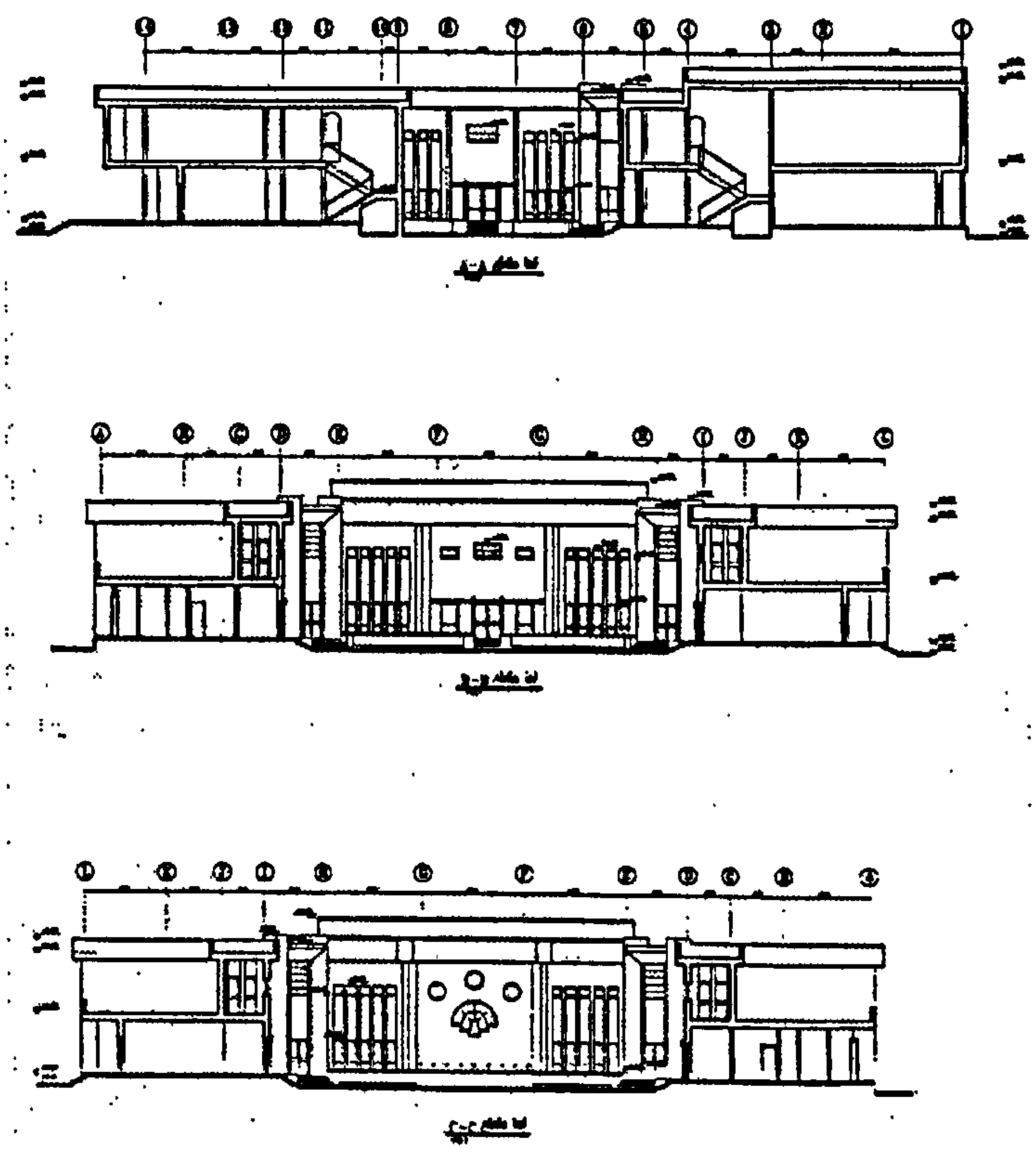
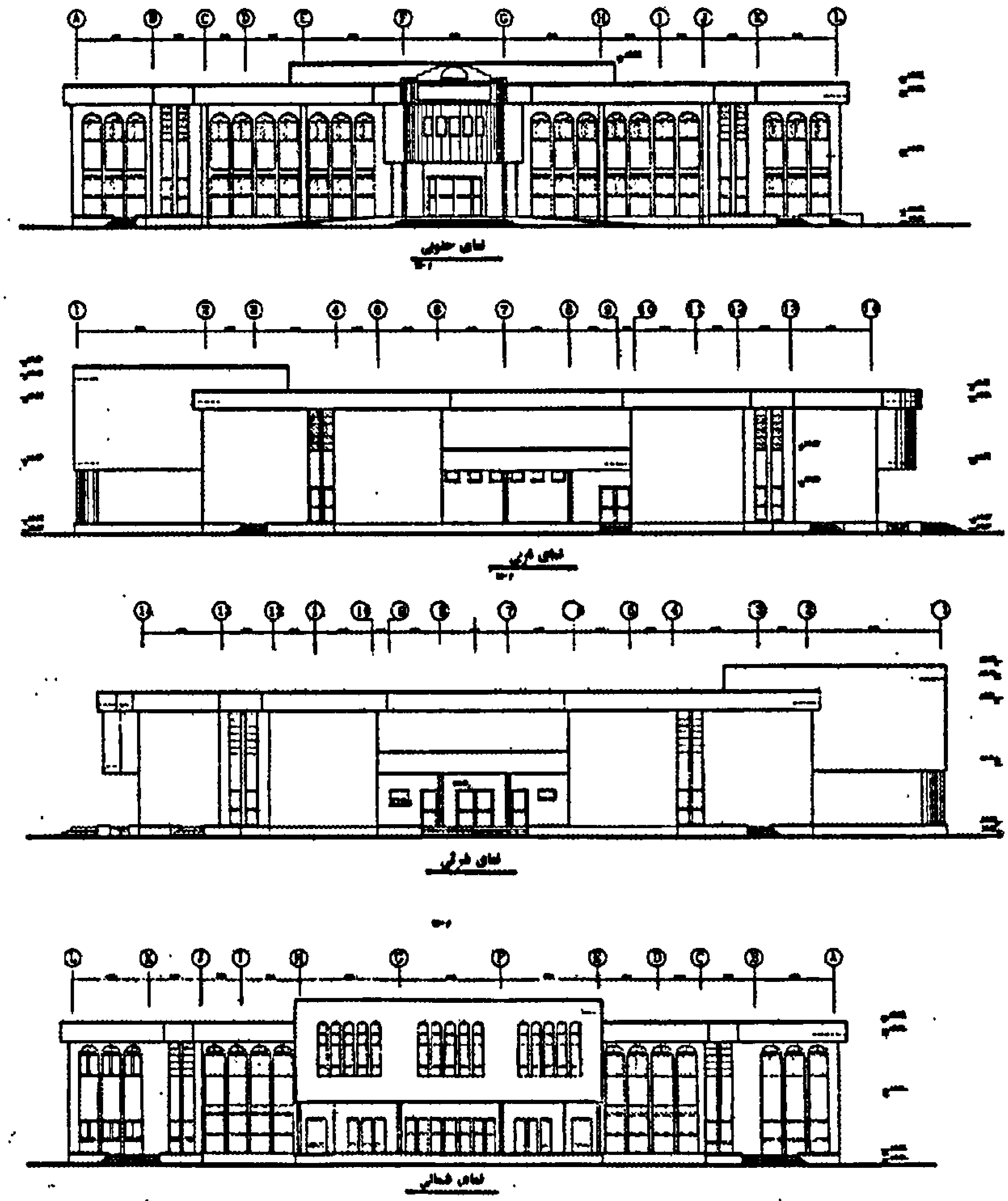


Figure 8.57: The south, west, east and north elevations of a secondary school with 12 classrooms (Number 7)



8$_{7.8}$ * High School with 9 Classrooms (School number 8)

Type: High school
Usable area: 1200m^2
Pupils: 270
Location: Yazd
Geographic characteristics: Latitude: 31° 54' Degrees (north)
Longitude: -54° 24' Degrees (east)
Altitude: 1230 metres
Azimuth angle of building: Azimuth: -27° 00' Degrees
Climate: Relatively cold-Hot and arid (see chapter 2, Group 5 and subgroup 5-4)
Mean yearly temperature: 19^{oC}

This two-story high school comprises nine classrooms, four of them located at the ground floor and the other five at the first floor.

The building is steel framed with brick walls and wood framed window. The construction of the walls is 110 mm brickwork, 225 mm brick and 13 mm plaster. The ground floor roofs are composed of 50 mm floor tile, 50 mm concrete, 220 mm concrete block and 15 mm plaster. The first floor roof consists of 30 mm tile & cement, 25 mm asphalt and insulation, 20 mm concrete, 80 mm expanded clay, and 50 mm concrete, 220 mm concrete block and 15 mm plaster.

The windows are single glazed and the glazing ratio of the ground floor is 29.8% in north wall, 54.8% in the south wall and 25.25% in the west & east wall. The glazing ratio of first floor is 28.1% in north, 30.7% in south and 21.7% in west & east wall.

The school has a rectangular plan with dimensions of 28m x 23.5m. There is a small central yard with is a rectangle with dimensions of 5.6m x 4.8m. The room height is 3 m at each floor and the direction is expended from east to west.

Heating is provided by a central heating system with thermostatically controlled gas-fired units and conventional radiators. The indoor temperature must be set to 24^{oC} in the warm season and 20^{oC} in the cold one. The cooling system consists of electric water-based cooler.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.19: The amount of actual annual energy used

	Heating Kwhrs	**Cooling** Kwhrs	**Lighting** Kwhrs
Electricity	--	--	136,998*
Gas	71802	--	--
Gasoline	--	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.20: The calculated annual energy consumption

	Heating Kwhrs	**Cooling** Kwhrs	**Lighting** Kwhrs	
With window control	98,359.2	78,747.5	82,428.68	**With Daylighting**
Non-window control	98,359.2	104,731.1	122,911.34	**Non Daylighting**
With shading	98,359.2	73,556.5	83175.39	**With shading& Daylighting**

Figure 8.58: The plan of the ground floor of a high school with 9 classrooms (Number 8)

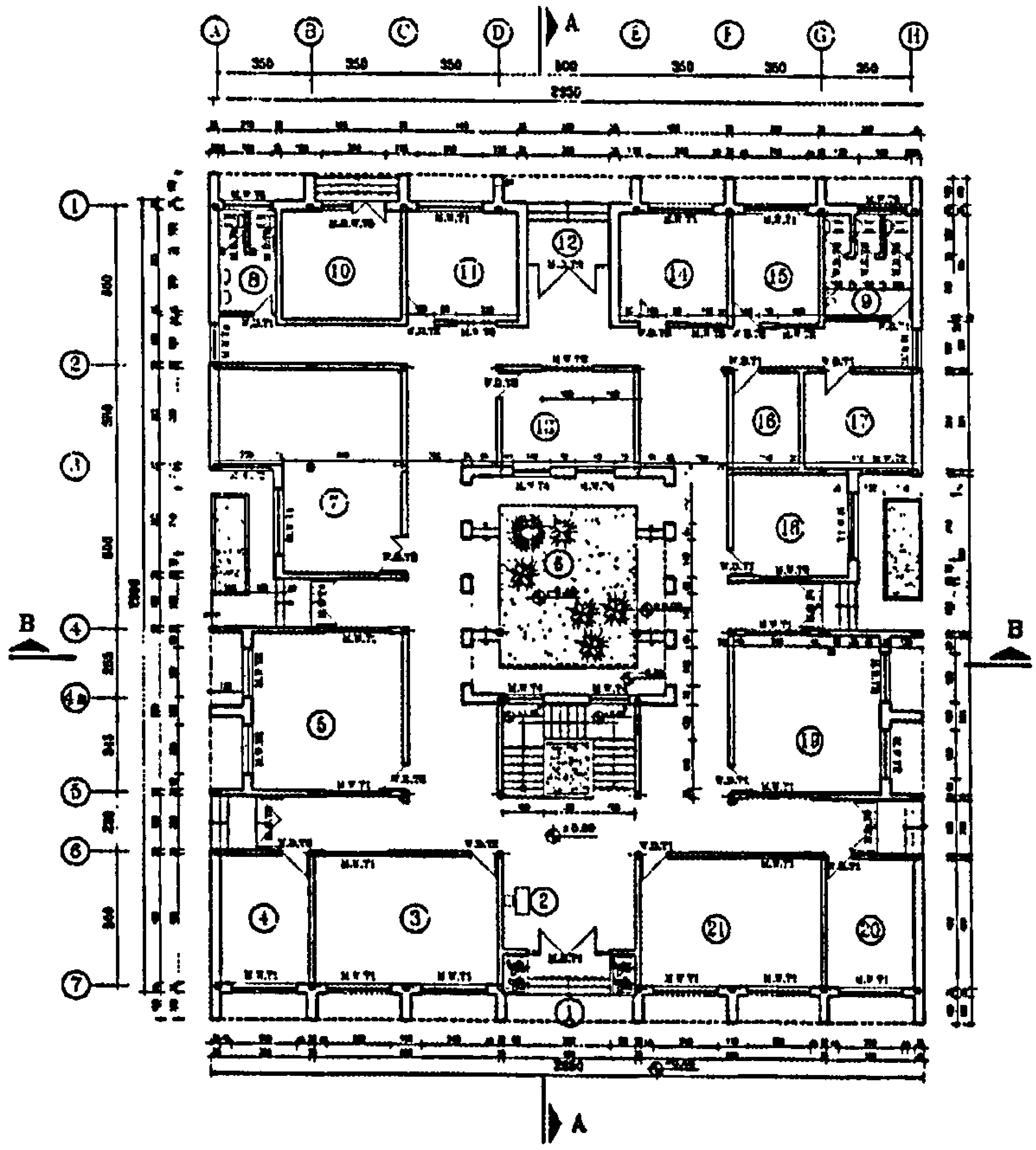


Figure 8.59: The plan of the first floor of a high school with 9 classrooms (Number 8)

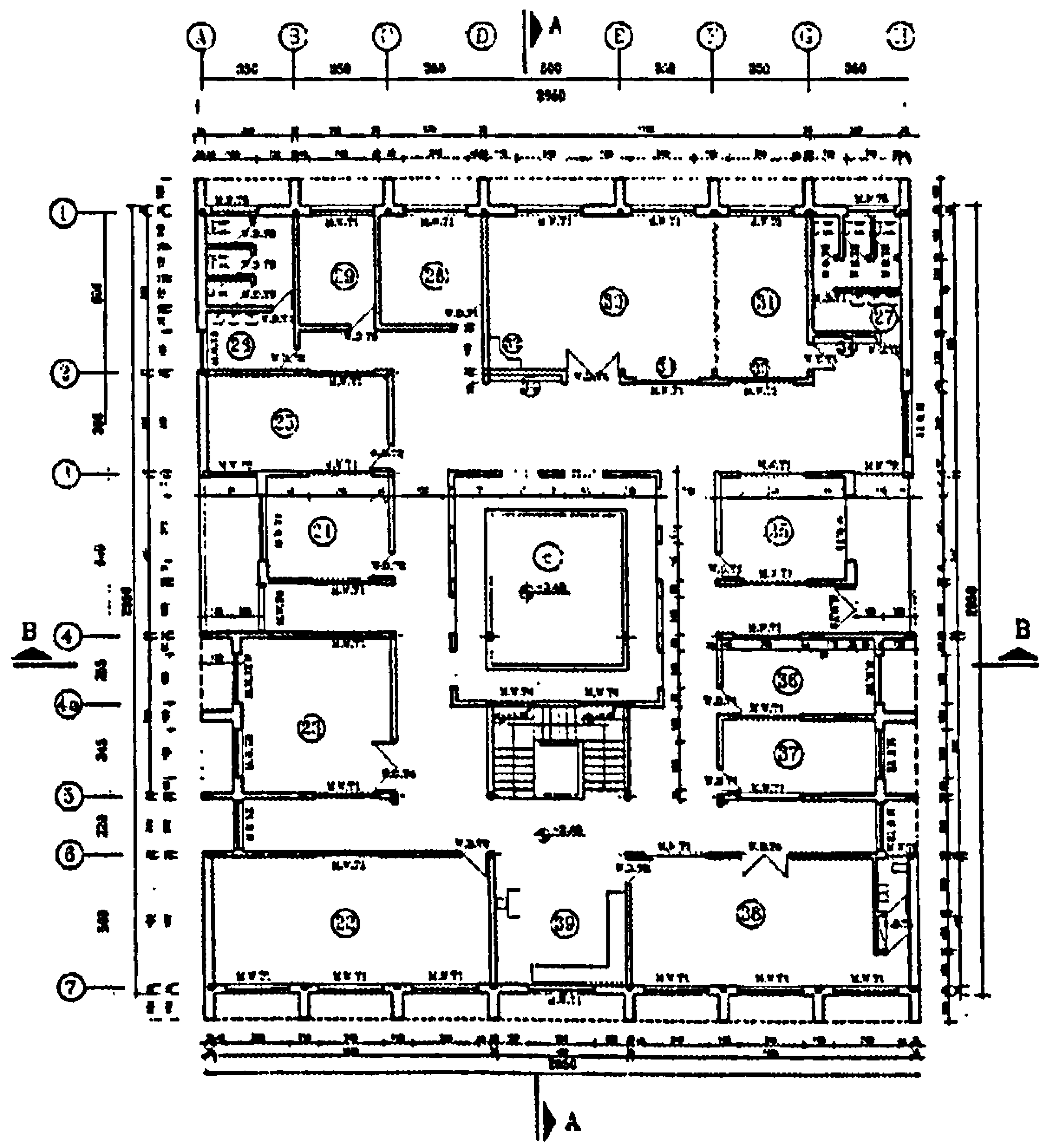


Figure 8.60: The north and south elevations of a high school with 9 classrooms (Number 8)

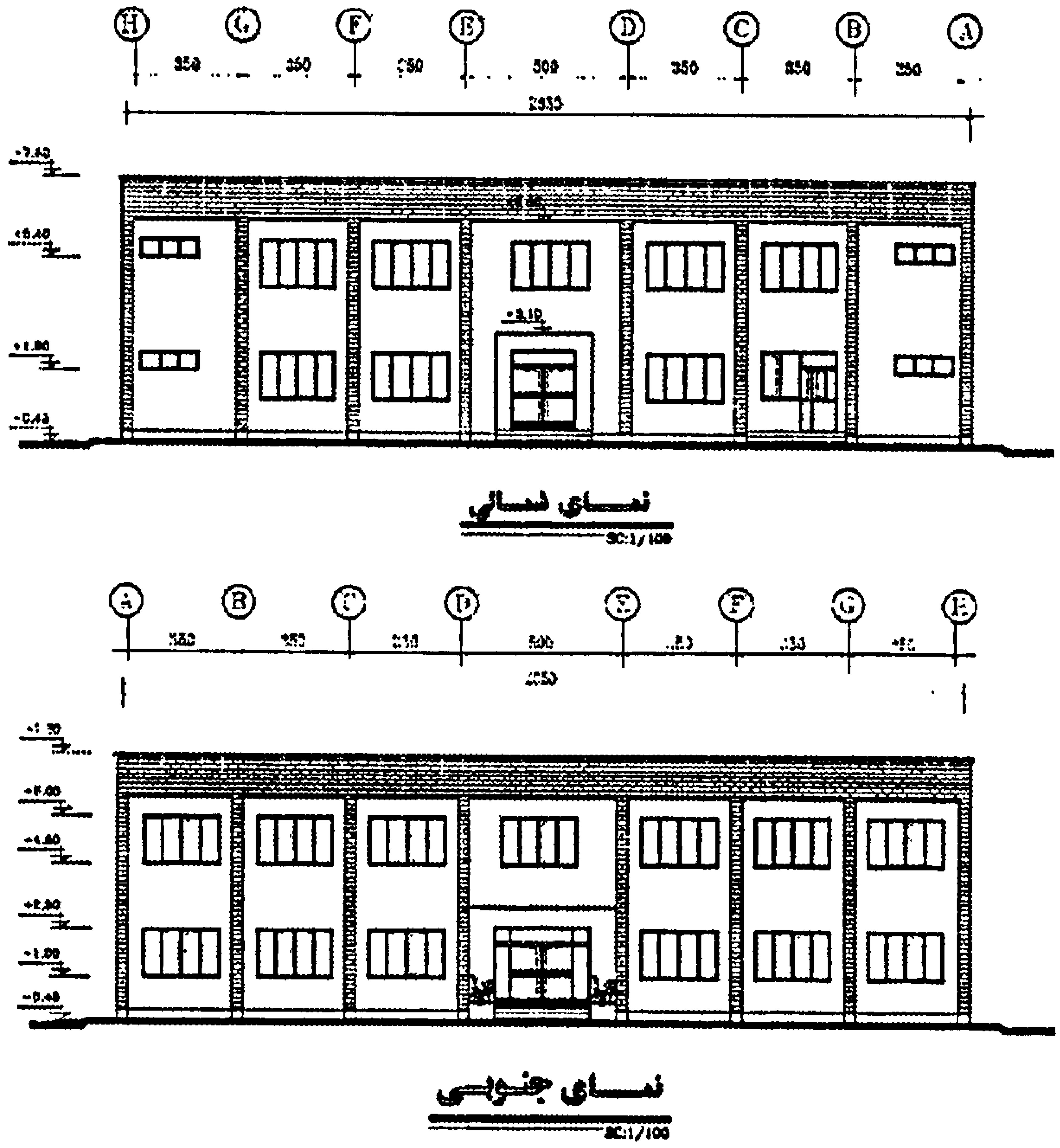


Figure 8.61: The sections A-A & B-B of a high school with 9 classrooms (Number 8)

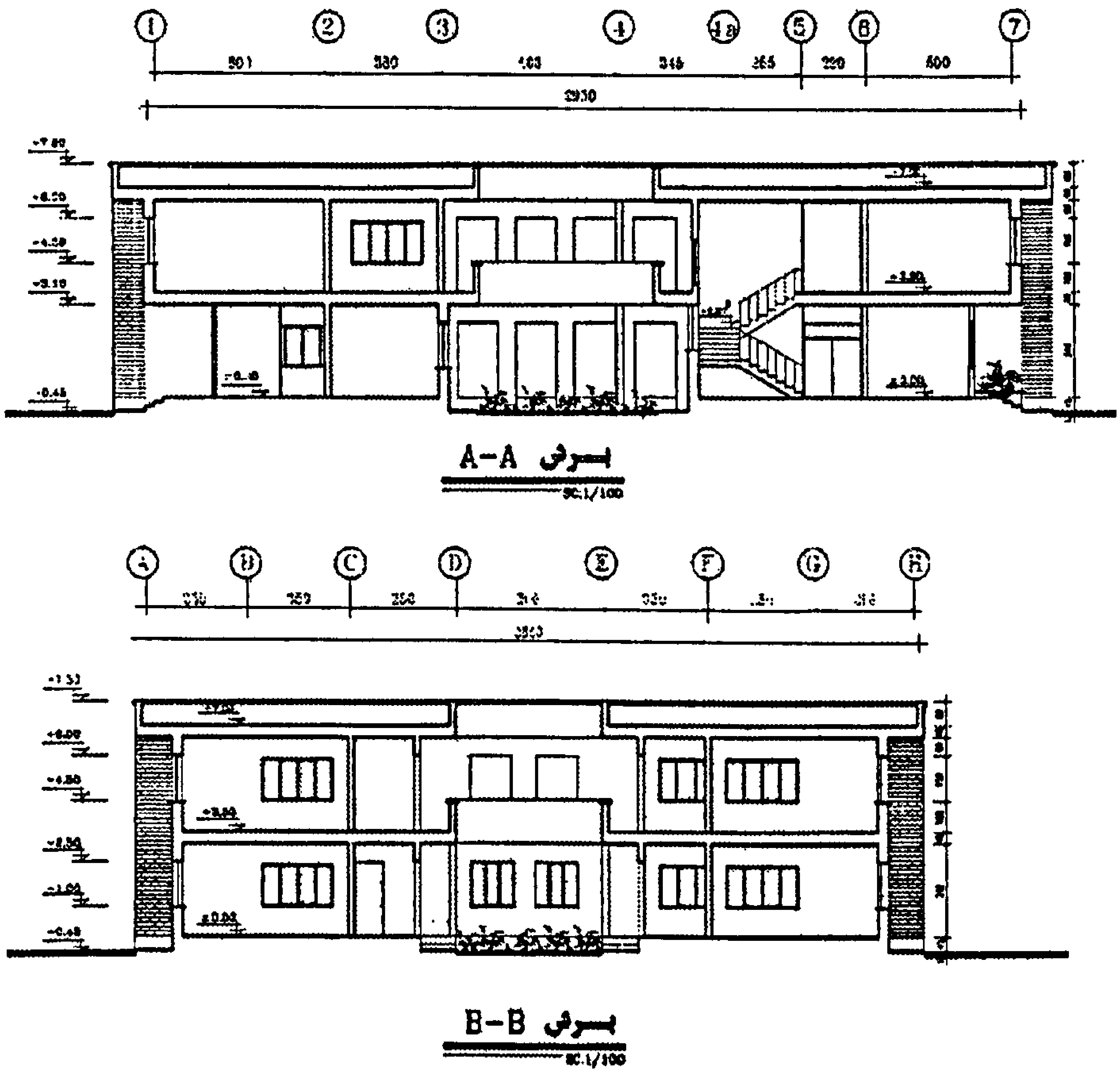
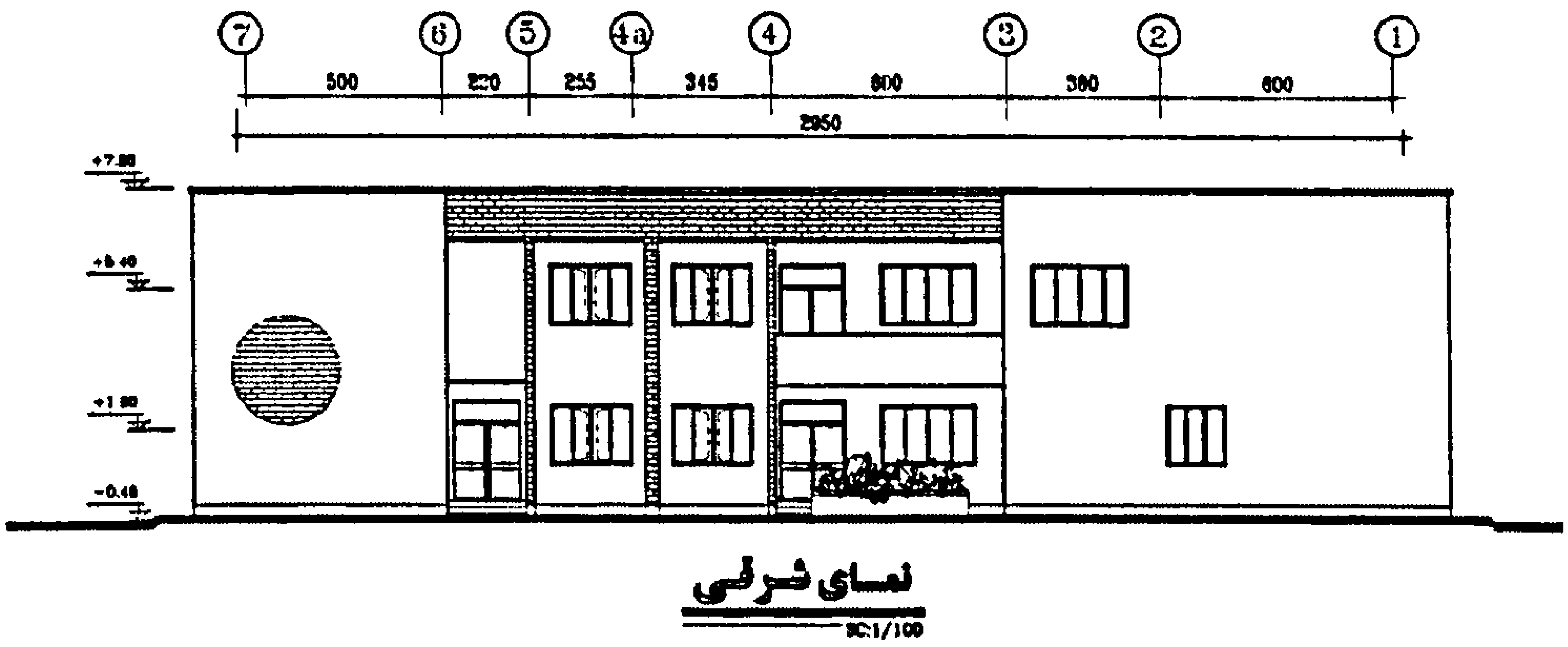


Figure 8.62: The east elevation of a high school with 9 classrooms (Number 8)



$8_{7.9}$ * Special Primary School with 13 Classrooms (School number 9)

Type: Special primary school (for children with special need)
Usable area: 1783 m^2
Pupils: 120
Location: Babolsar
Geographic characteristics: Latitude: 36° 43' Degrees (north)
Longitude: -52° 39' Degrees (east)
Altitude: -21 metres
Azimuth angle of building: Azimuth: -3° 00' Degrees
Climate: Cold-Humid (see chapter 2, Group 3 and subgroup 3-3)
Mean yearly temperature: 16.29^{oC}

This three-story special primary school comprises thirteen classrooms, one of them located at the ground floor six at the first floor and the remaining six at the second floor.

The building is steel framed with brick walls and steel framed window. The construction of the walls is 110 mm brickwork, 220 mm brick and 13 mm plaster. The ground and first floor roofs are composed of 50 mm floor tile, 50 mm concrete, 220 mm concrete block and 15 mm plaster. The second floor roof is sloped ceiling containing steel frame and asbestos sheet. There is additional 25 mm blanket insulation over purlins.

The windows are single glazed and the glazing ratio of the ground floor is 26% in north wall, 40% in the south wall, 14% in the west wall and 25.4% in the east wall. The glazing ratio of first floor is 33.55% in north, 35.77% in south, 15% in west and

20.4% in the east wall. Also the glazing ratio of second floor is 35.65% in north, 35.77% in south, 15.8% in west and 21.46% in the east wall.

This school has a L shaped plan consisting of three floors. The area of each floor is 595 m2, and the total height of the building is 10 metres, and the direction is expended from east to west.

Heating is provided by a central heating system with thermostatically controlled gasoline-fired units and conventional radiators. The indoor temperature must be set to 24^{oC} in the warm season and 20^{oC} in the cold one. The cooling system consists of electric gas-based cooler (only in the office).

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.21: The amount of actual annual energy used

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs
Electricity	--	No cooling	75,282*
Gas	--	--	--
Gasoline	12,500 litres	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and gas-based cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.22: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	136,097.4	49,269.9	73,133.90	With Daylighting
Non-window control	136,097.4	96,466.7	149,761.39	Non Daylighting
With shading	136,097.4	44,521.1	74,187.9	With shading& Daylighting

Figure 8.63: The plan of the ground floor of a special primary school with 13 classrooms
(Number 9)

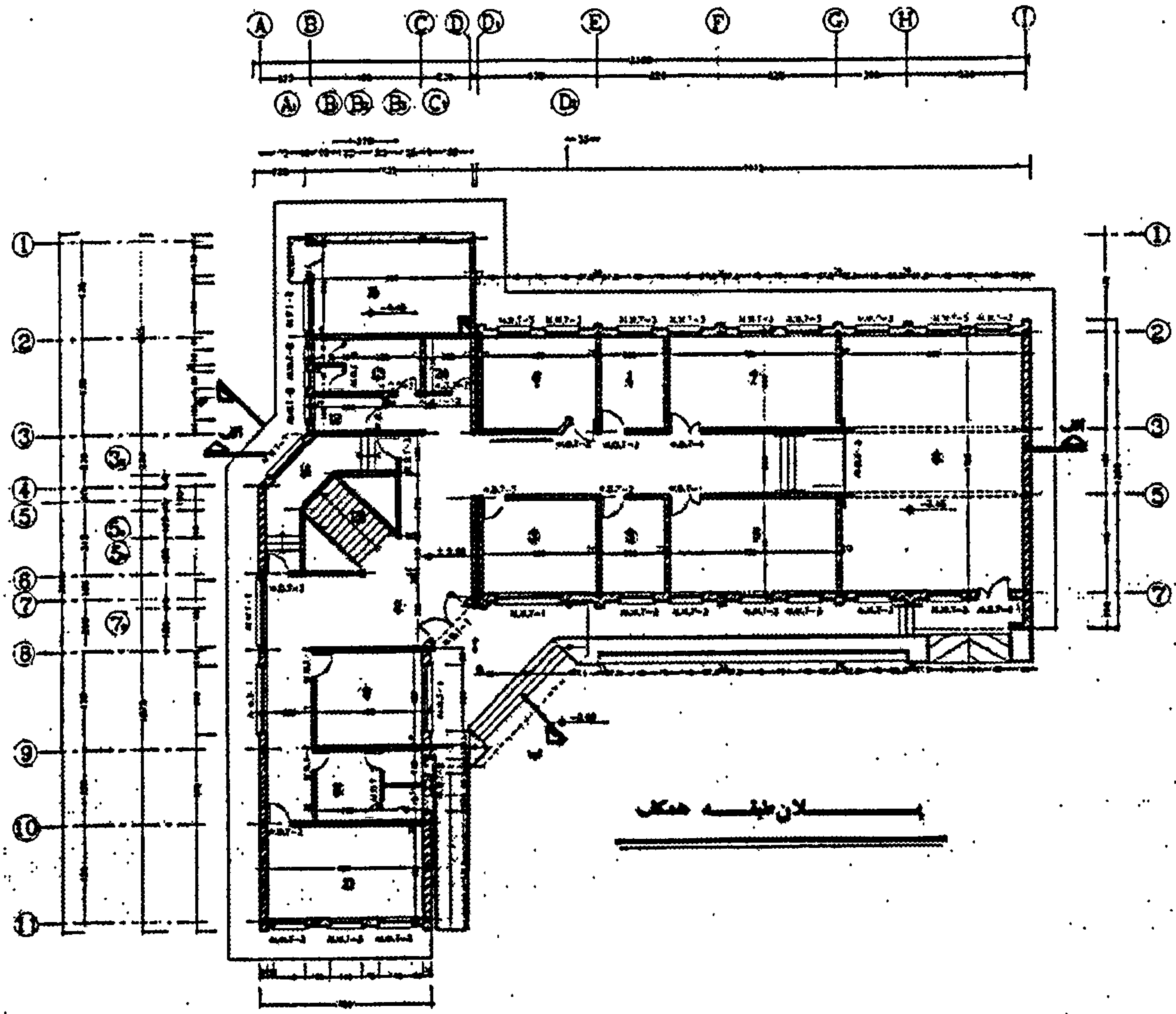


Figure 8.64: The plan of the first & second floors of a special primary school with 13 classrooms
(Number 9)

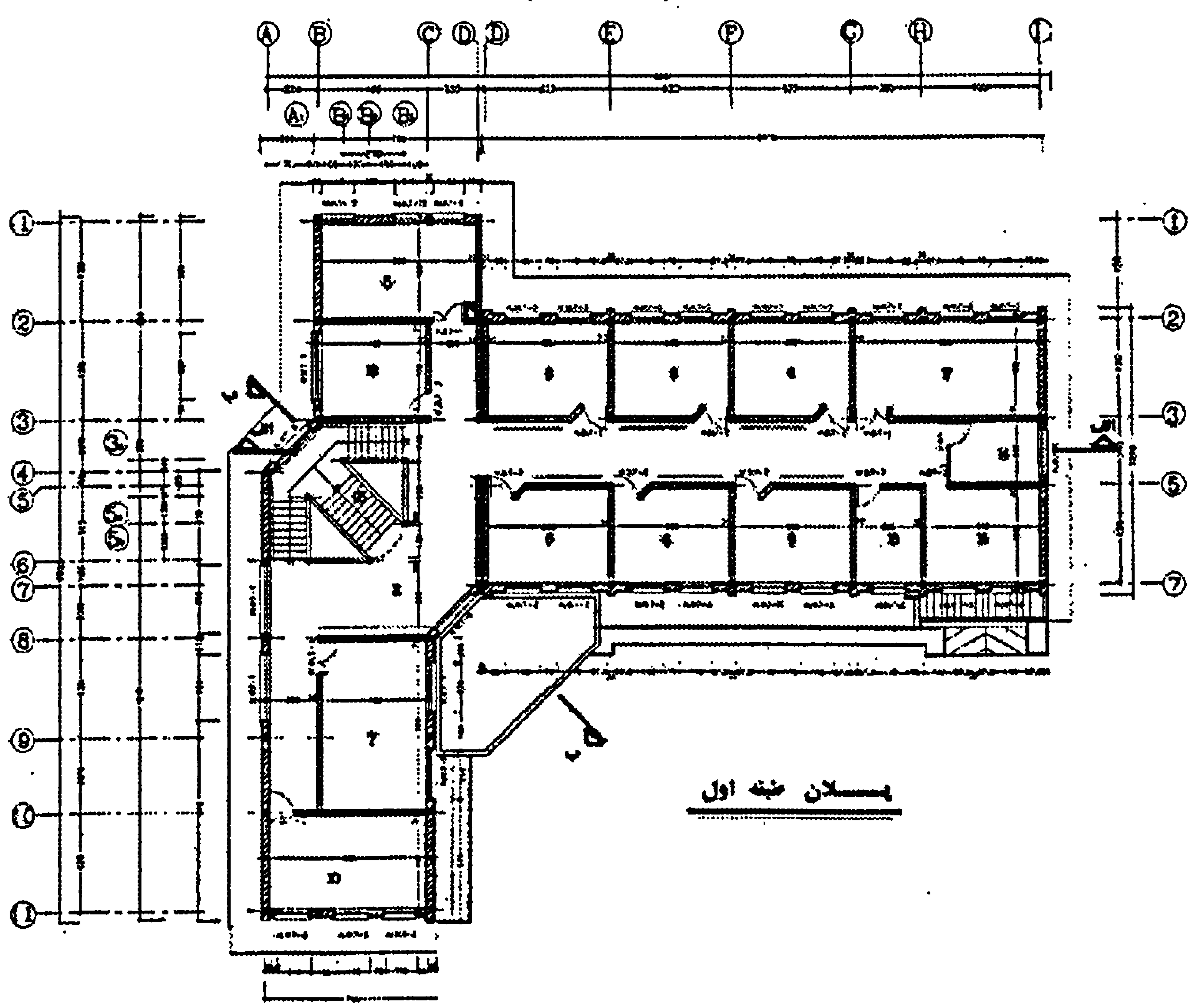


Figure 8.65: The south elevation of a special primary school with 13 classrooms (Number 9)

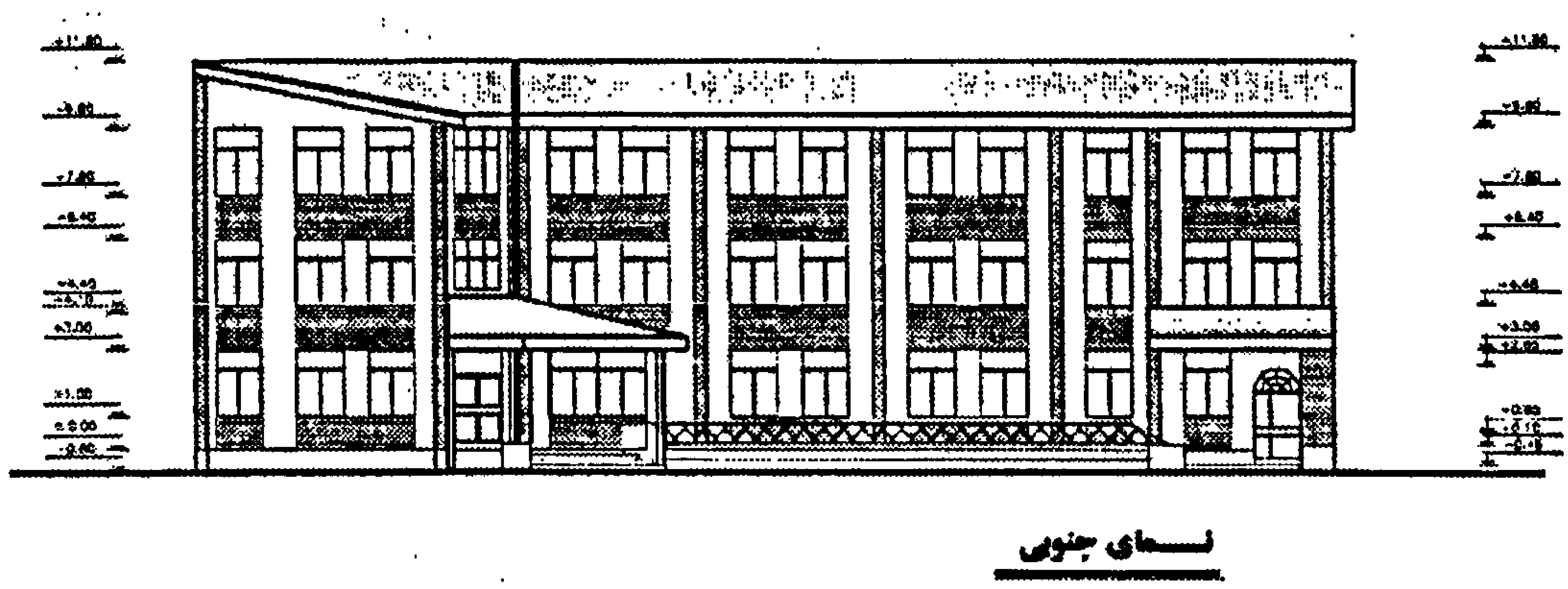


Figure 8.66: The north elevation of a special primary school with 13 classrooms (Number 9)

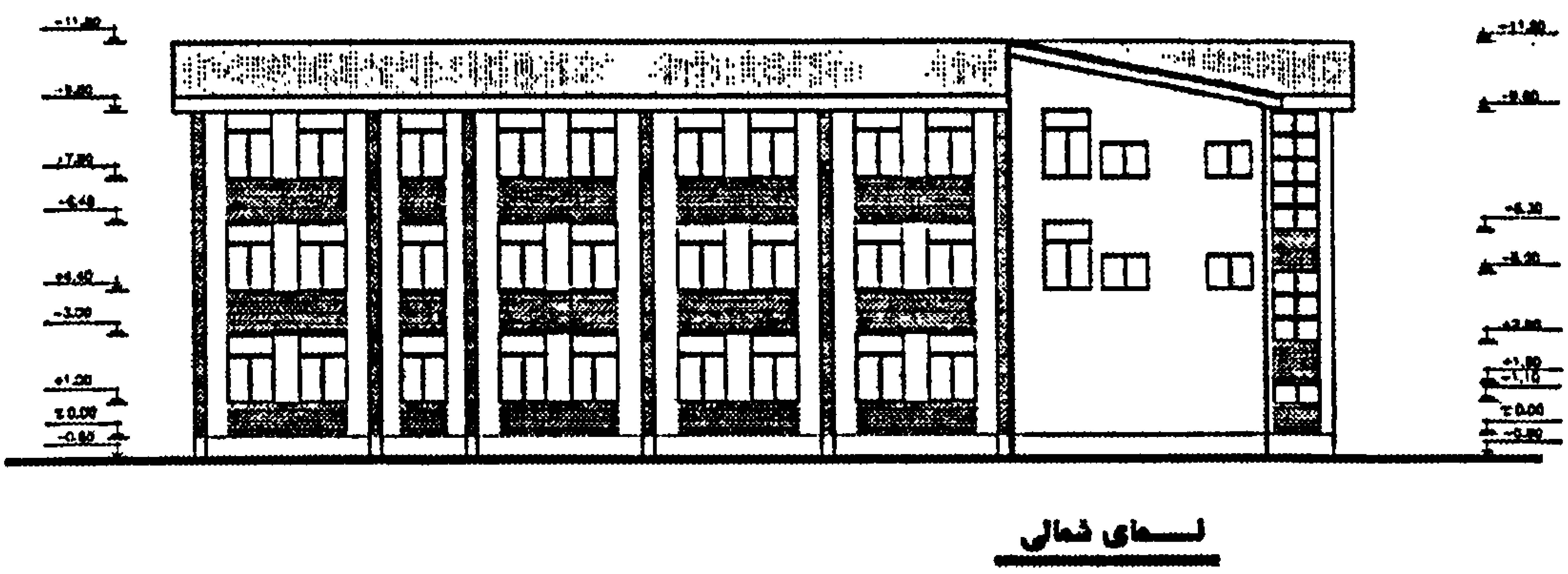


Figure 8.67: The west and east elevations of a special primary school with 13 classrooms (Number 9)

Figure 8.68: The section A-A of a special primary school with 13 classrooms (Number 9)

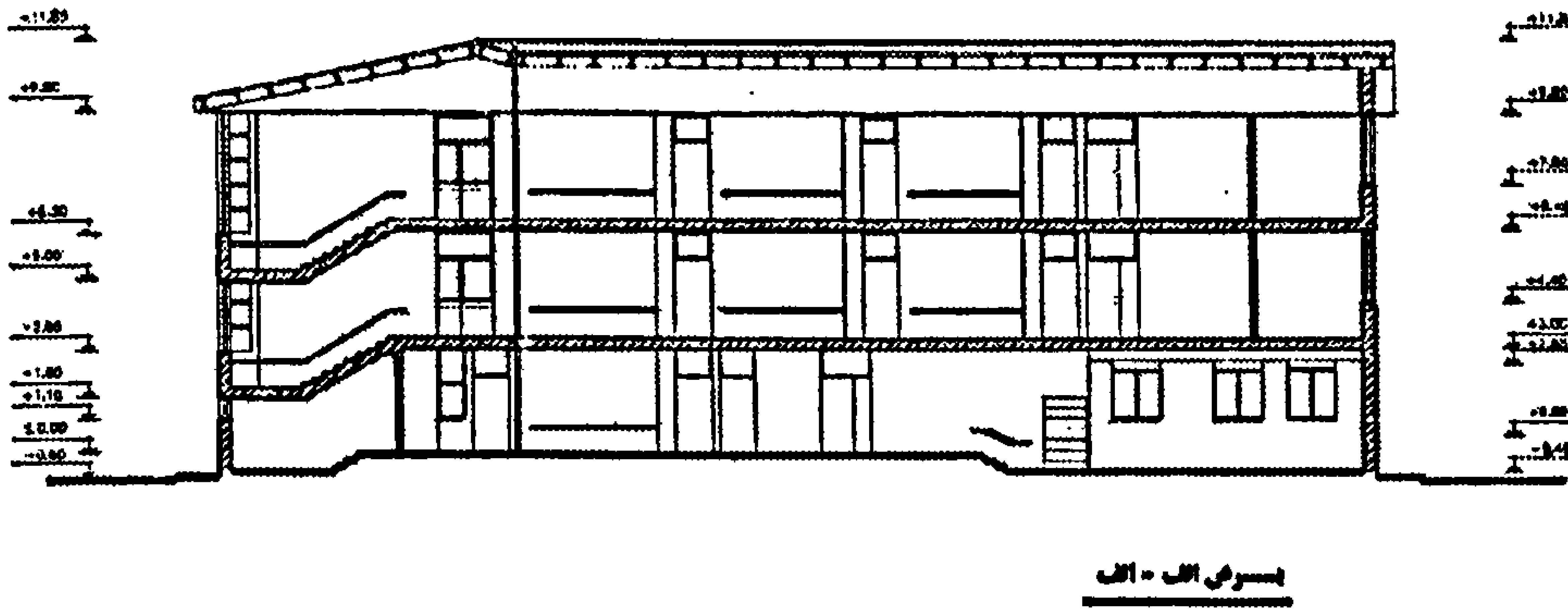
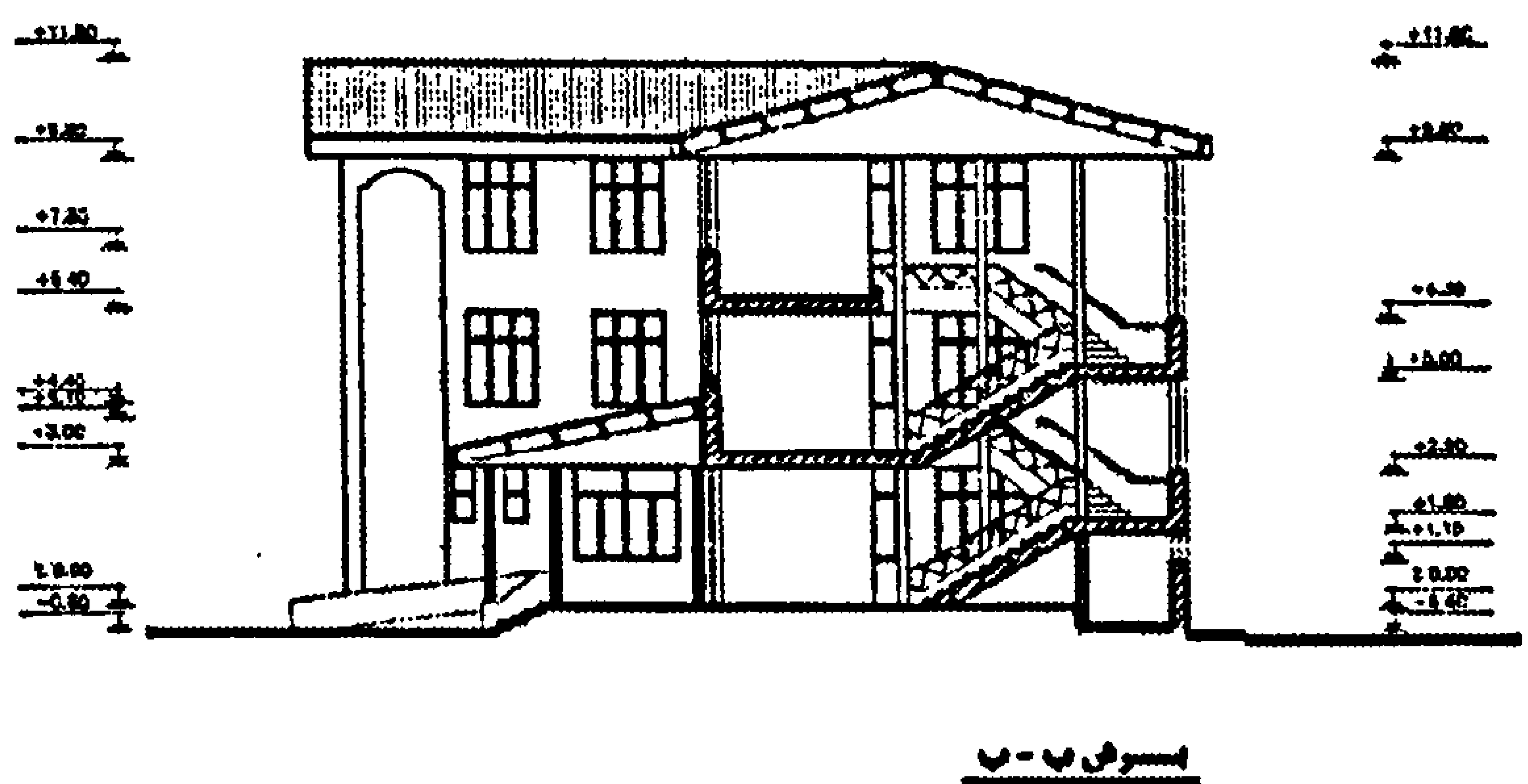


Figure 8.69: The section B-B of a special primary school with 13 classrooms (Number 9)



8$_{7.10}$ * Secondary School with 9 Classrooms (School number 10)

Type: Secondary school
Usable area: 1017 m^2
Pupils: 270
Location: Babolsar
Geographic characteristics: Latitude: 36° 43' Degrees (north)
Longitude: -52° 39' Degrees (east)
Altitude: -21 metres
Azimuth angle of building: Azimuth: +10° 00' Degrees
Climate: Cold-Humid (see chapter 2, Group 3 and subgroup 3-3)
Mean yearly temperature: 16.29^{oC}

This two-story secondary school comprises nine classrooms, three of them located at the ground floor and the other six at the first floor.

The building is concrete framed with brick walls and aluminium framed window. The construction of the walls is 30 mm cement, 220 mm brick and 13 mm plaster. The ground floor roof is composed of 50 mm floor tile, 50 mm concrete, 220 mm brick block and 15 mm plaster. The first floor roof is sloped ceiling containing wood frame and steel sheet and there is additional 25 mm blanket insulation over purlins.

The windows are single glazed and the glazing ratio of the ground & first floors are 29% in north wall, 37% in the south wall, 10.8% in the west wall and 12.6% in the east wall.

The school has a rectangular plan with 31.2 m length and 23.8 m width. At the north west and north east of building there are two play-grounds measuring 12.4 m* 7 m. The total height of the building is 7.5 m. The direction is expended from east to west.

Heating is provided by a central heating system with thermostatically controlled gasoline-fired units and conventional radiators. The indoor temperature must be set to 24^{oC} in the warm season and 20^{oC} in the cold one. The cooling system consists of electric gas-based cooler.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.23: The amount of actual annual energy used

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs
Electricity	--	No cooling	70,439*
Gas	--	--	--
Gasoline	9,000 litres	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and gas-based cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.24: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	79,734.4	36,592.1	59,509.86	**With Daylighting**
Non-window control	79,734.4	82,928.9	93,852.44	**Non Daylighting**
With shading	79,734.4	33,826.0	61,744.04	**With shading& Daylighting**

Figure 8.70: The plan of the ground floor of a secondary school with 9 classrooms (Number 10)

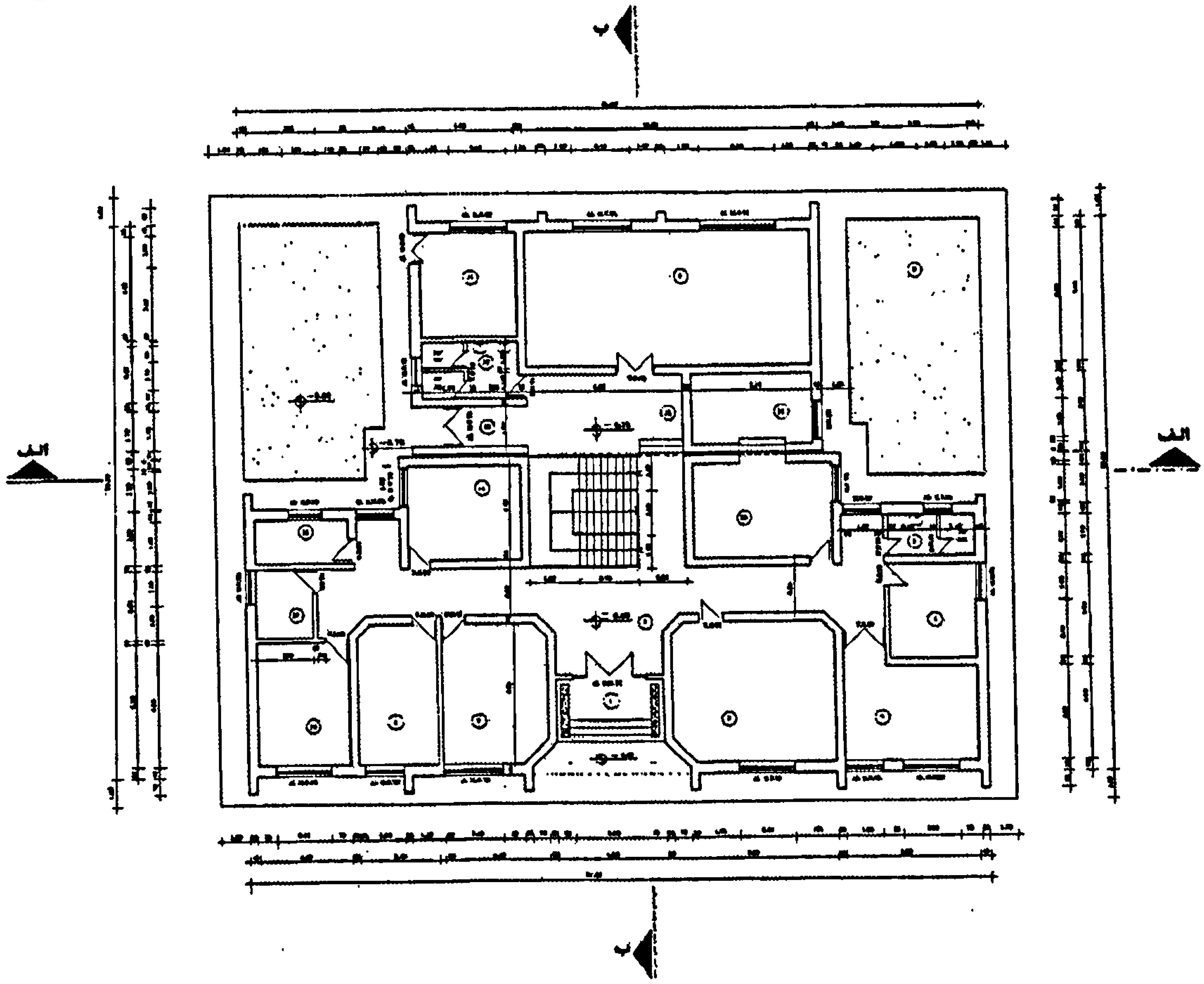


Figure 8.71: The plan of the first floor of a secondary school with 9 classrooms (Number 10)

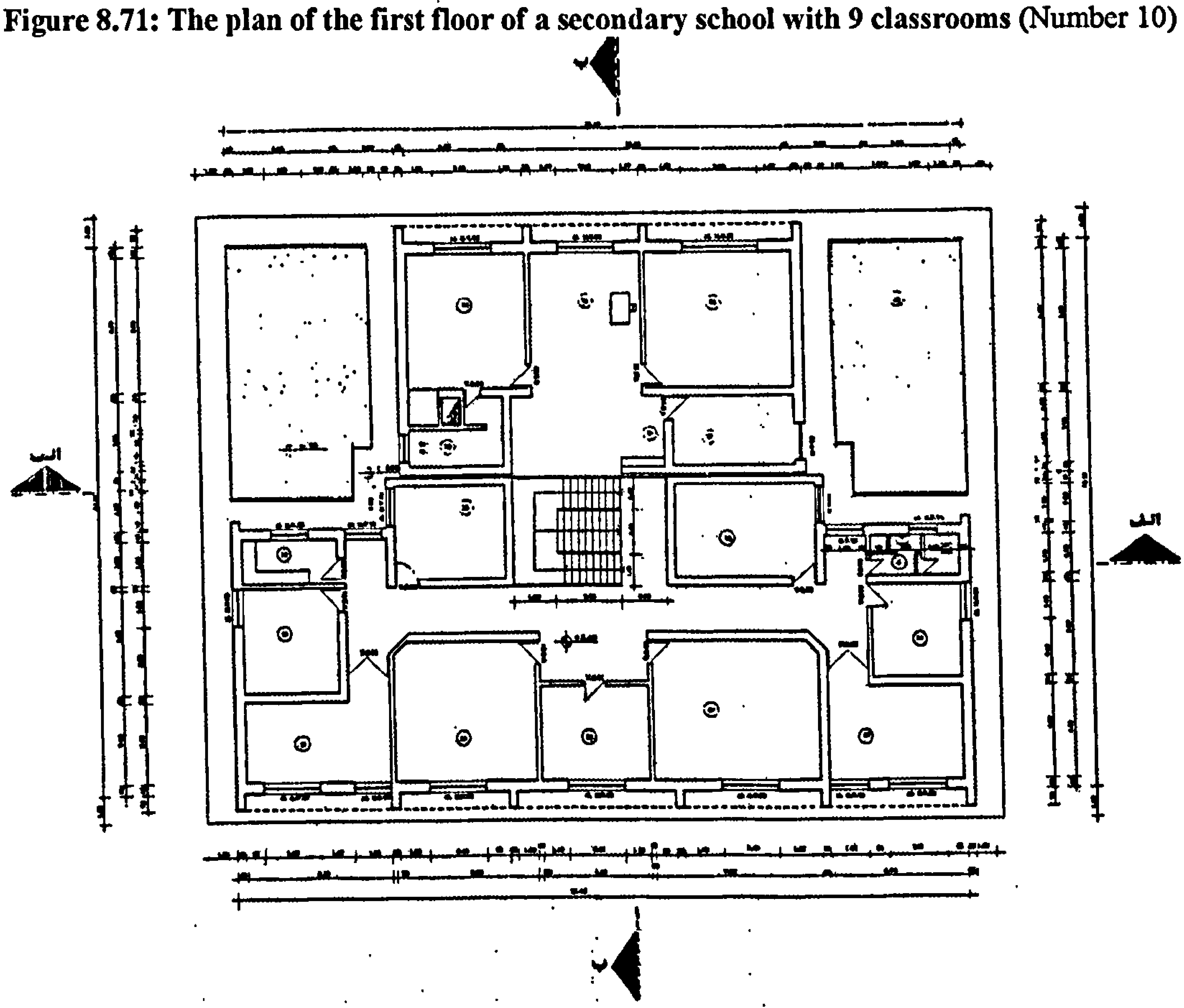


Figure 8.72: The north elevation & section A-A & south elevation of a secondary school with 9 classrooms (Number 10)

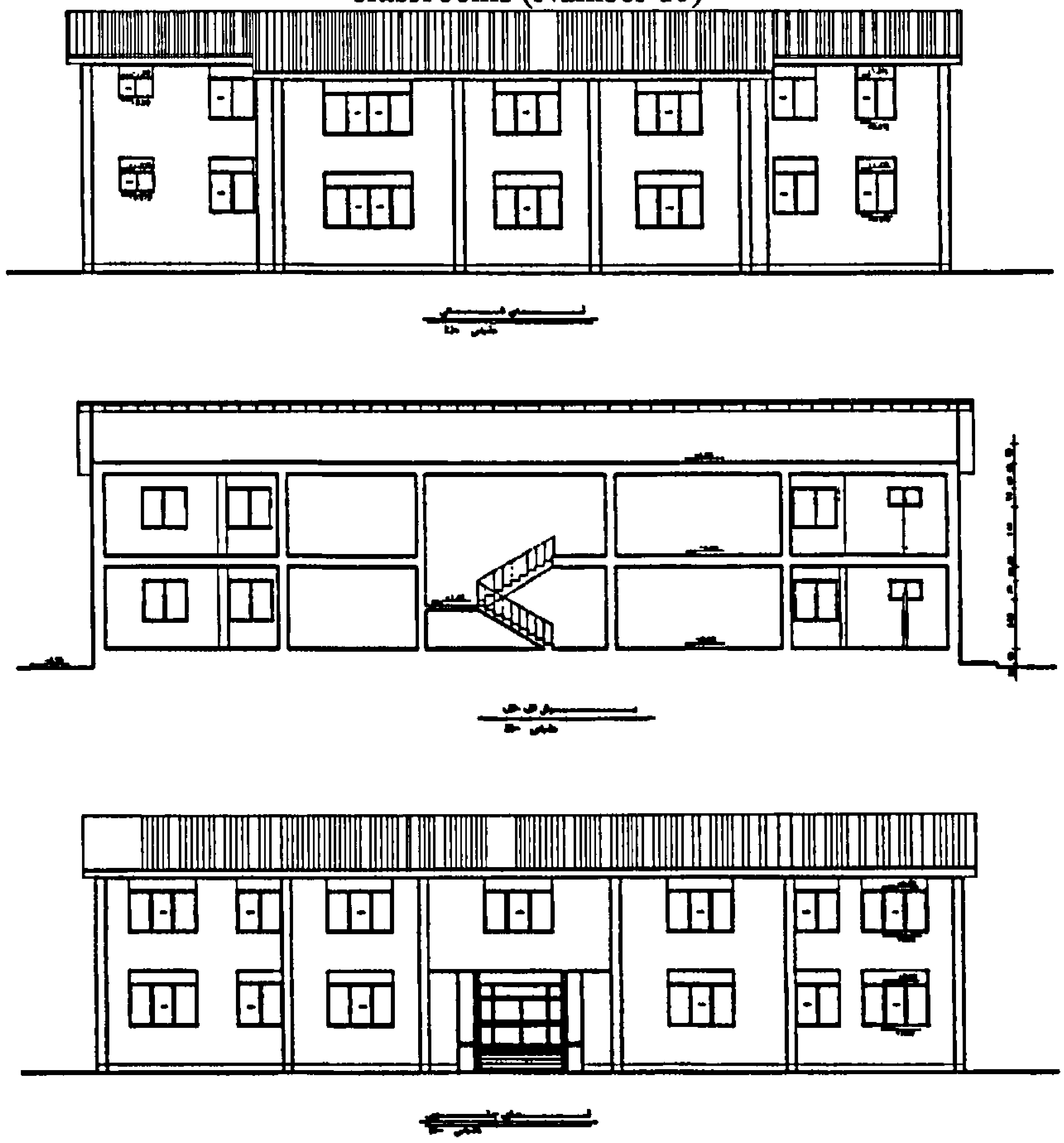
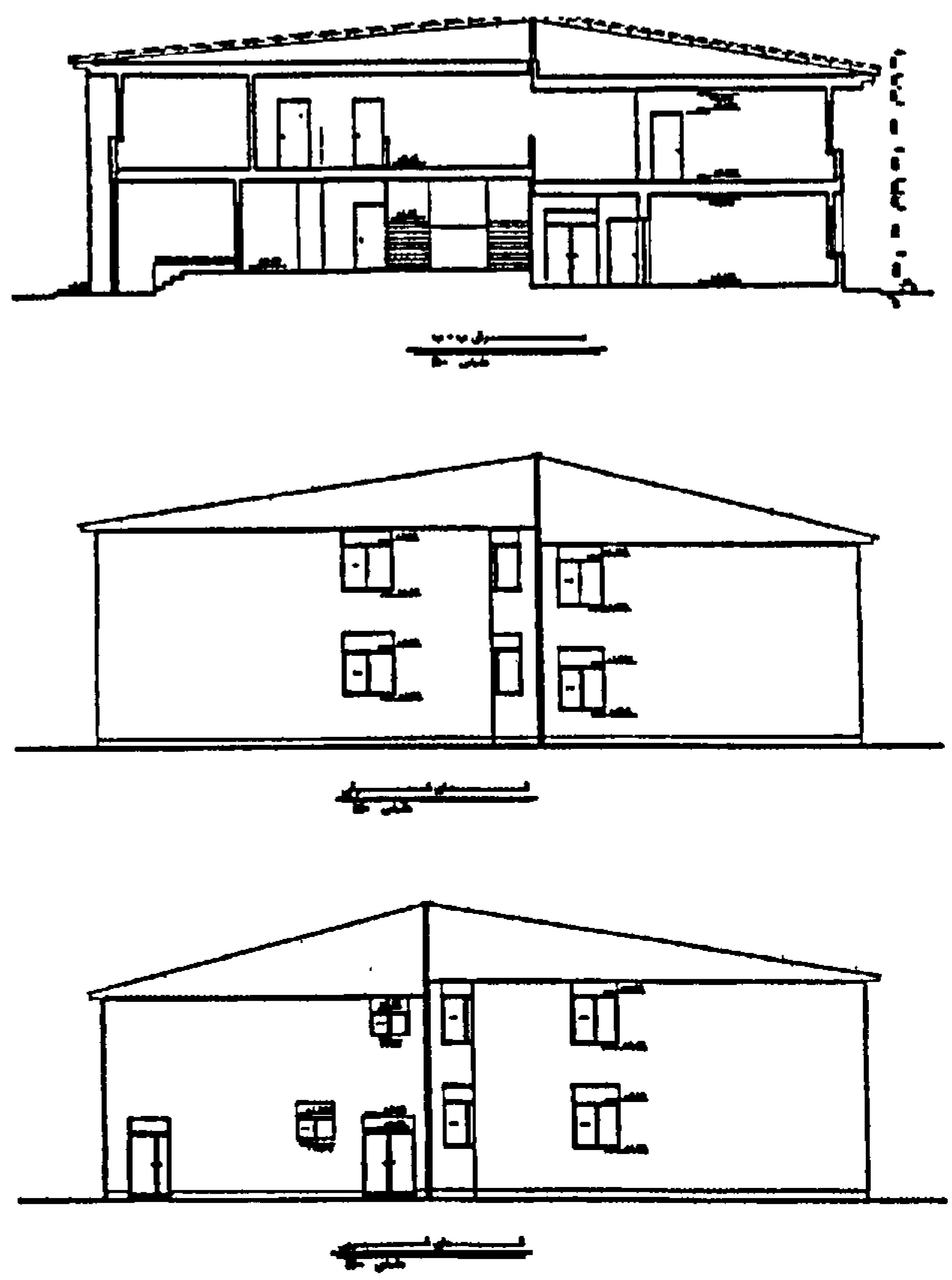


Figure 8.73: The section B-B & east and west elevations of a secondary school with 9 classrooms (Number 10)



8.7.11 * High School with 9 Classrooms (School number 11)

Type: High school (Kar danesh school)
Usable area: 1530 m^2
Pupils: 360
Location: Babolsar
Geographic characteristics: Latitude: 36° 43' Degrees (north)
Longitude: -52° 39' Degrees (east)
Altitude: -21 metres
Azimuth angle of building: Azimuth: +18° 00' Degrees
Climate: Cold-Humid (see chapter 2, Group 3 and subgroup 3-3)
Mean yearly temperature: 16.29^{oC}

This three-story high school comprises nine classrooms; five of them located at the first floor, and the other four at the first floor. Pupils learn different technical skills in this high school. Therefore, it is composed of different laboratories and workshops.

The building is concrete framed with brick walls and steel framed window. The construction of the walls is 110 mm brickwork, 220 mm brick and 13 mm plaster. The ground and first floor roofs are composed of 50 mm floor tile, 50 mm concrete, 220 mm brick block and 15 mm plaster. The second floor roof is sloped ceiling containing wood frame and steel sheet and there is additional 25 mm blanket insulation over purlins.

The windows are single glazed and the glazing ratio of the ground floor is 44.5% in north wall, 59% in the south wall, 12% in the west wall and 0% in the east wall. The glazing ratio of first floor is 51% in north & south, 4% in west and 4% in the east wall. Also the glazing ratio of second floor is 51% in north & south, 4% in west and 0% in the east wall.

The school has a rectangular plan with the dimensions of 33.5 m x 15 m. The height of each floor is 3 metres, and the direction is expended from east to west.

Heating is provided by a central heating system with thermostatically controlled gasoline-fired units and conventional radiators. The indoor temperature must be set to 24^{oC} in the warm season and 20^{oC} in the cold one. There is no cooling system in the classrooms. However, an electric gas-based cooler is used in the head teacher office.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.25: The amount of actual annual energy used

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs
Electricity	--	No cooling	95,382
Gas	--	--	--
Gasoline	14,230 litres	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and gas-based cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.26: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	146,055.0	63,116.9	85,779.81	With Daylighting
Non-window control	146,055.0	140,765.4	167,874.12	Non Daylighting
With shading	146,055.0	57,559.4	86,919.08	With shading& Daylighting

Figure 8.74: The plan of the ground floor of a high school with 9 classrooms (Number 11)

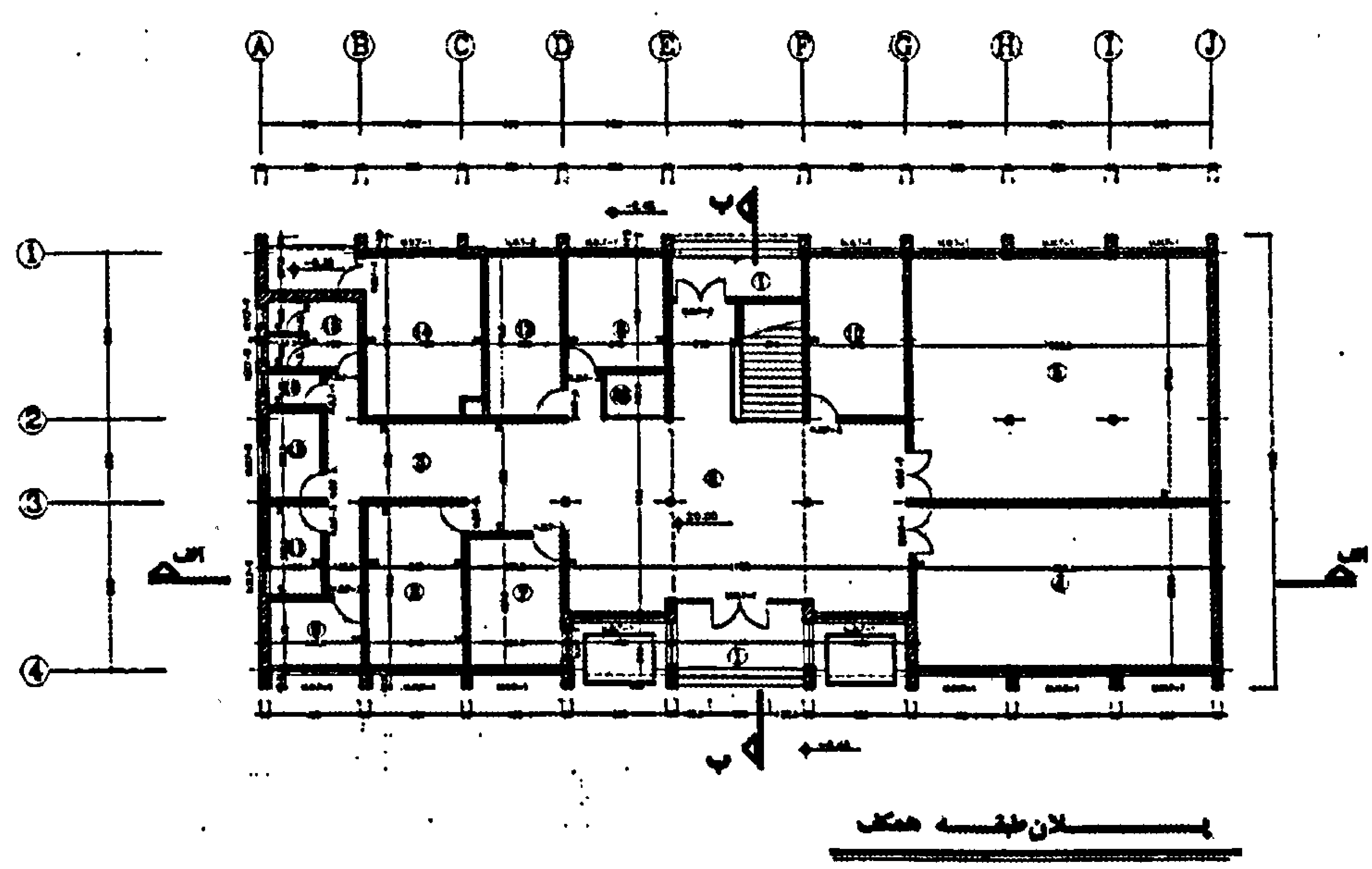


Figure 8.75: The plan of the first floor of a high school with 9 classrooms (Number 11)

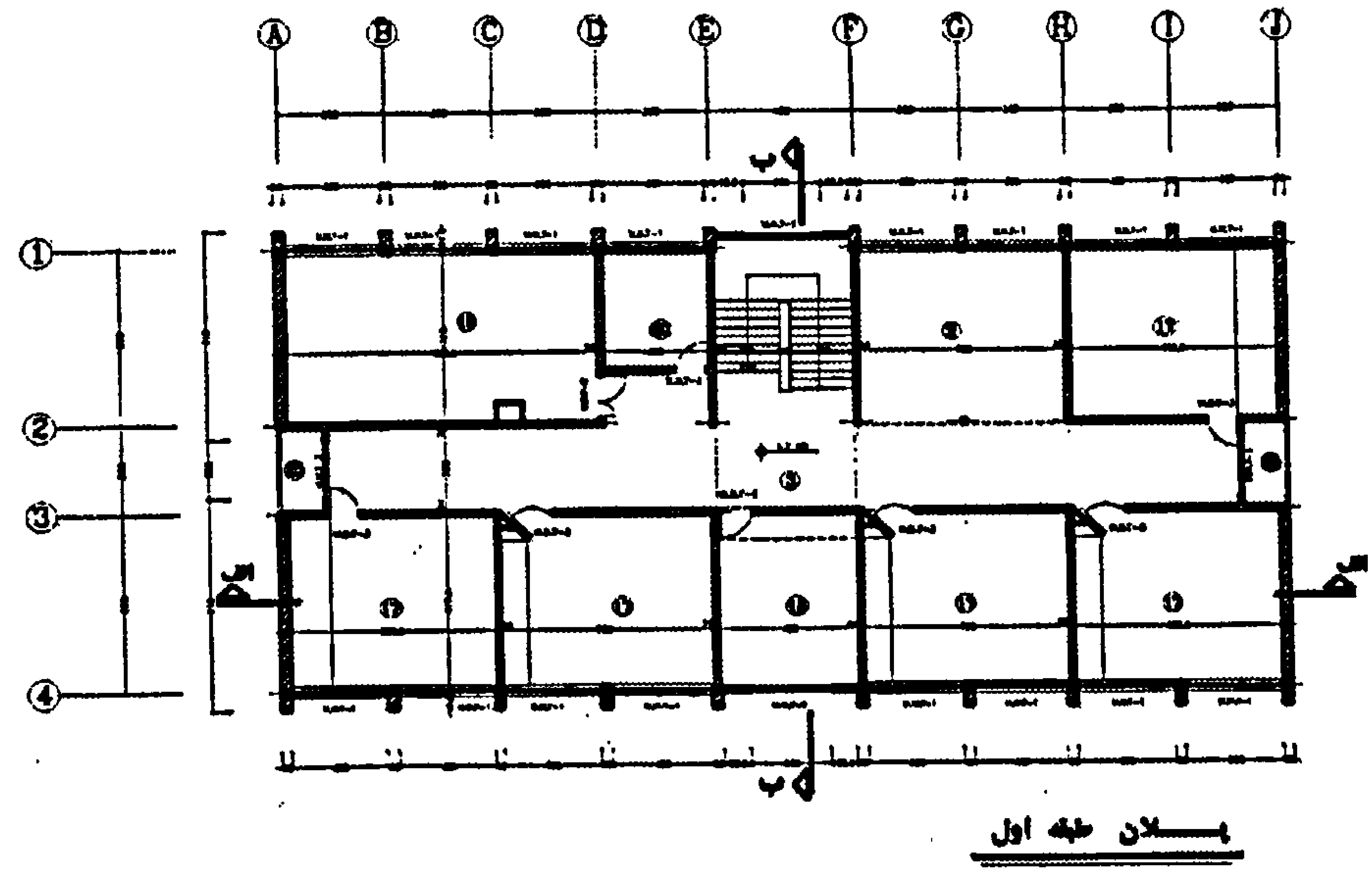


Figure 8.76: The plan of the second floor of a high school with 9 classrooms (Number 11)

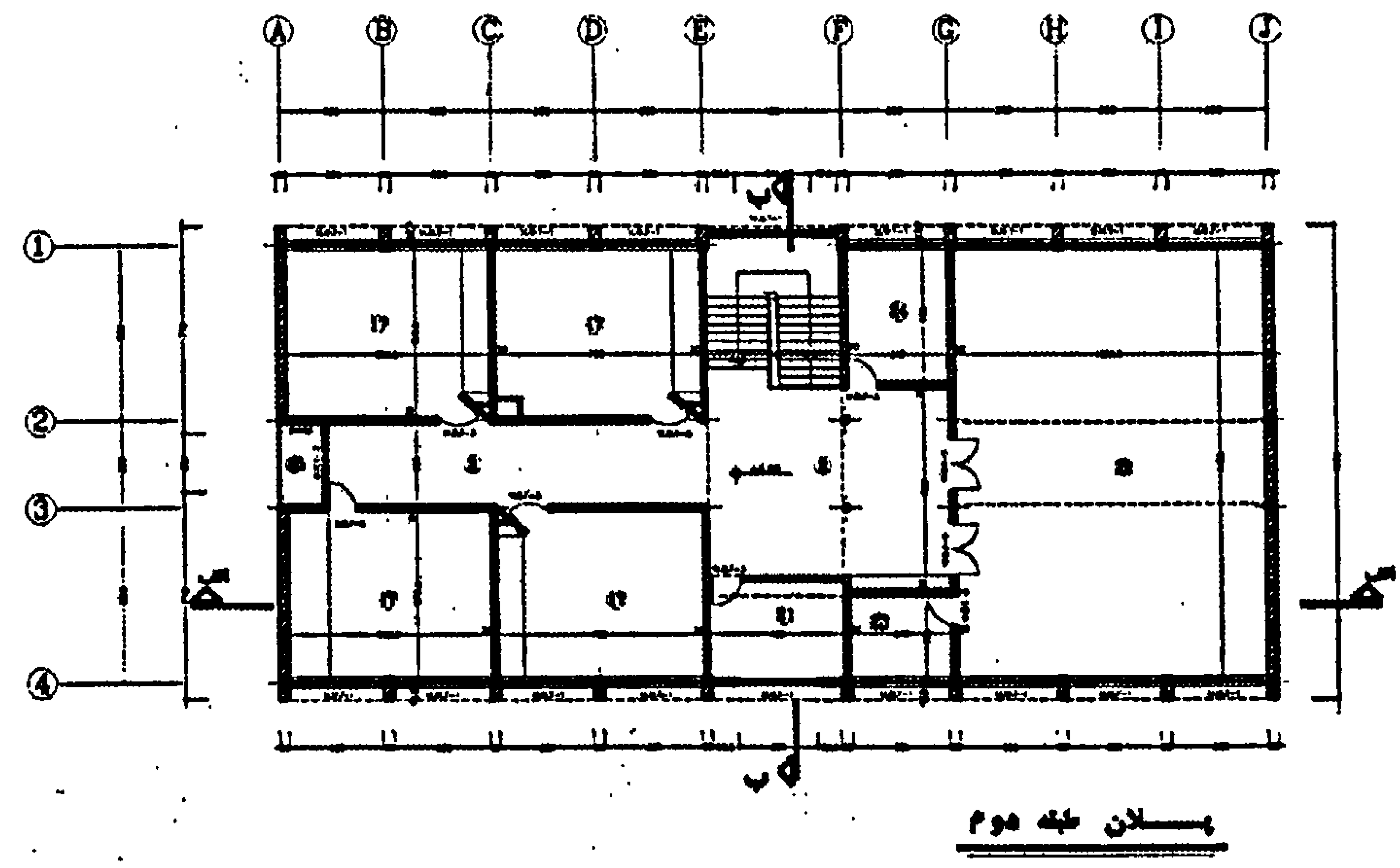


Figure 8.77: The north elevation of a high school with 9 classrooms (Number 11)

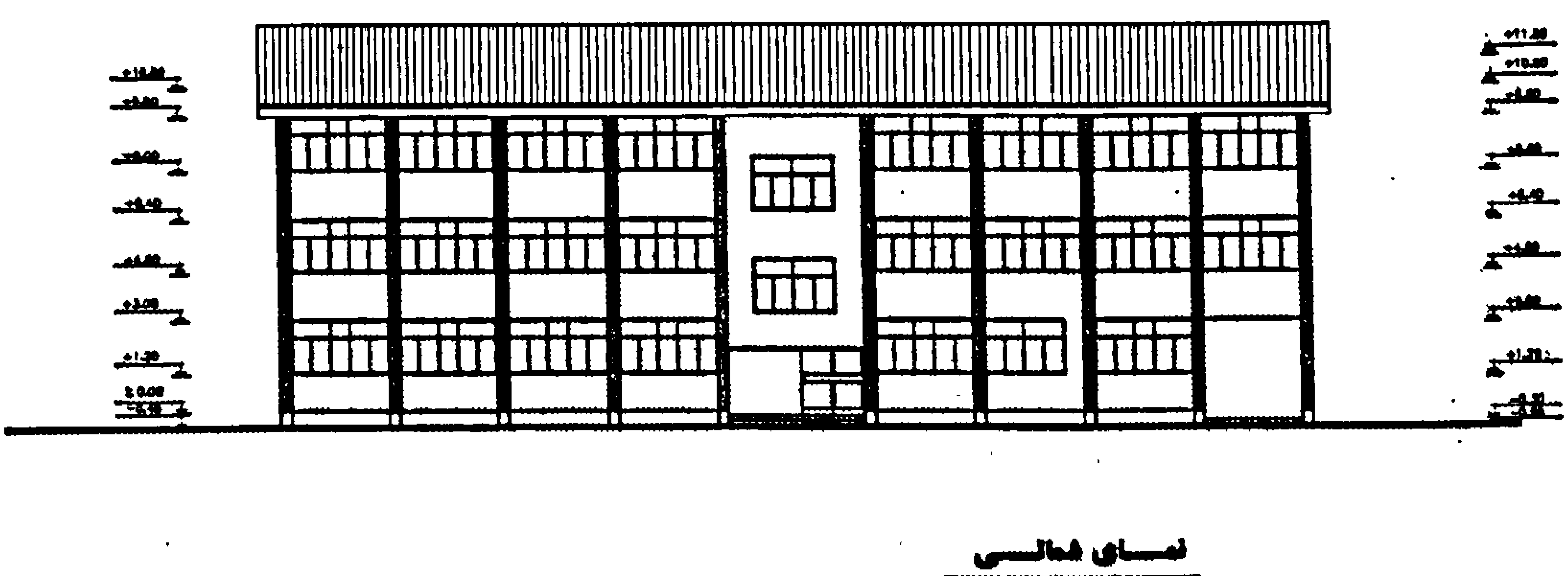


Figure 8.78: The south elevation of a high school with 9 classrooms (Number 11)

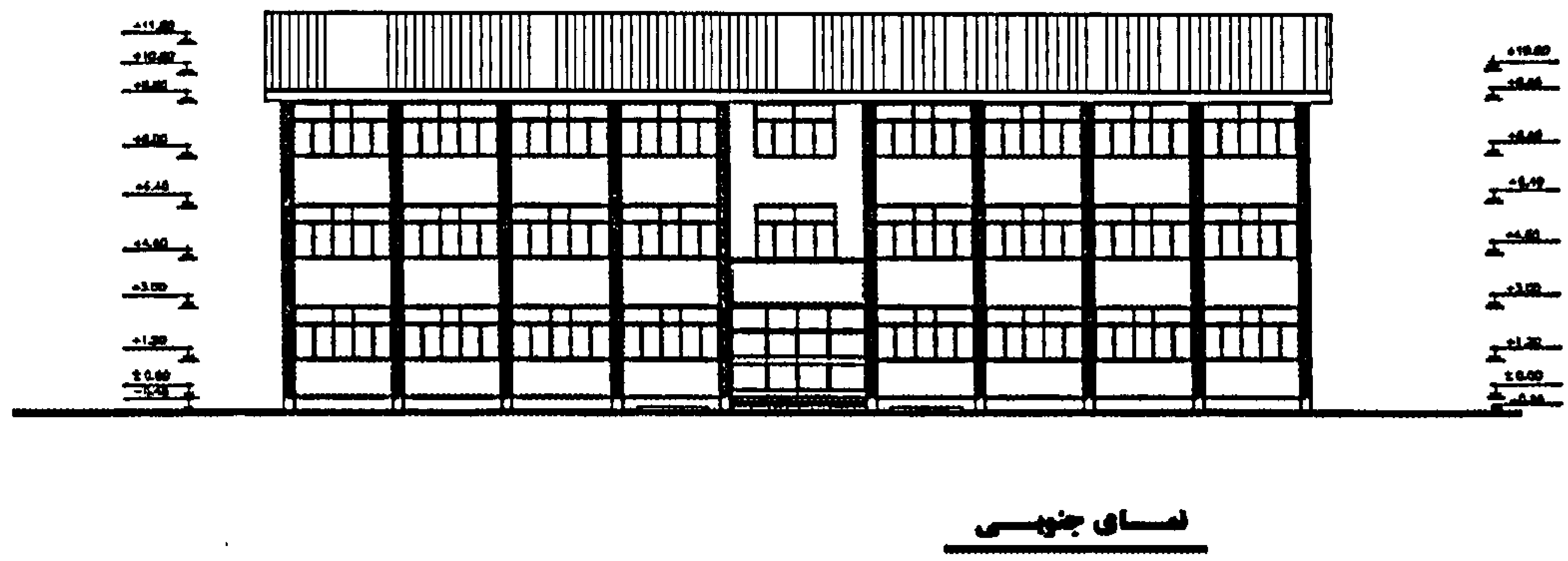


Figure 8.79: West elevation

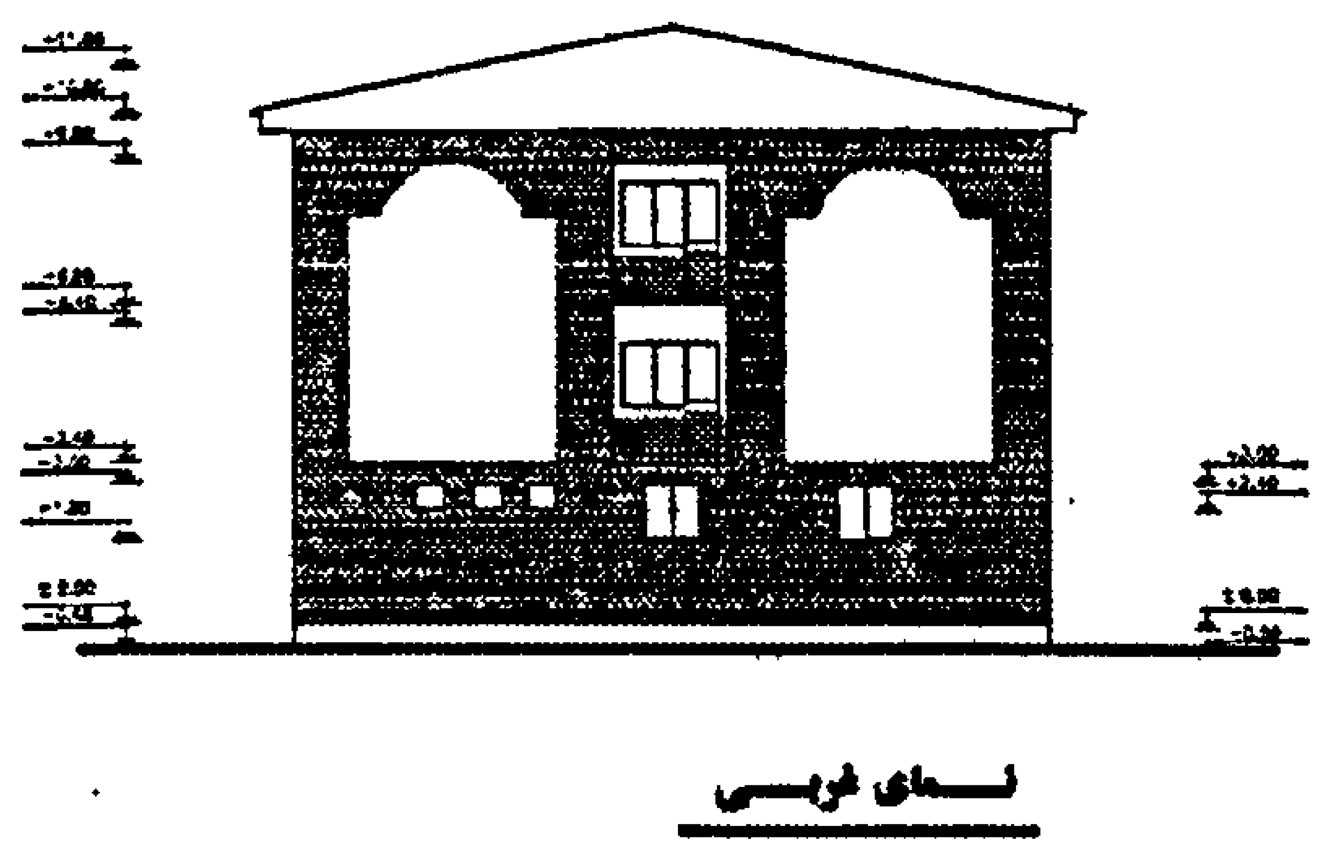


Figure 8.80:East elevation

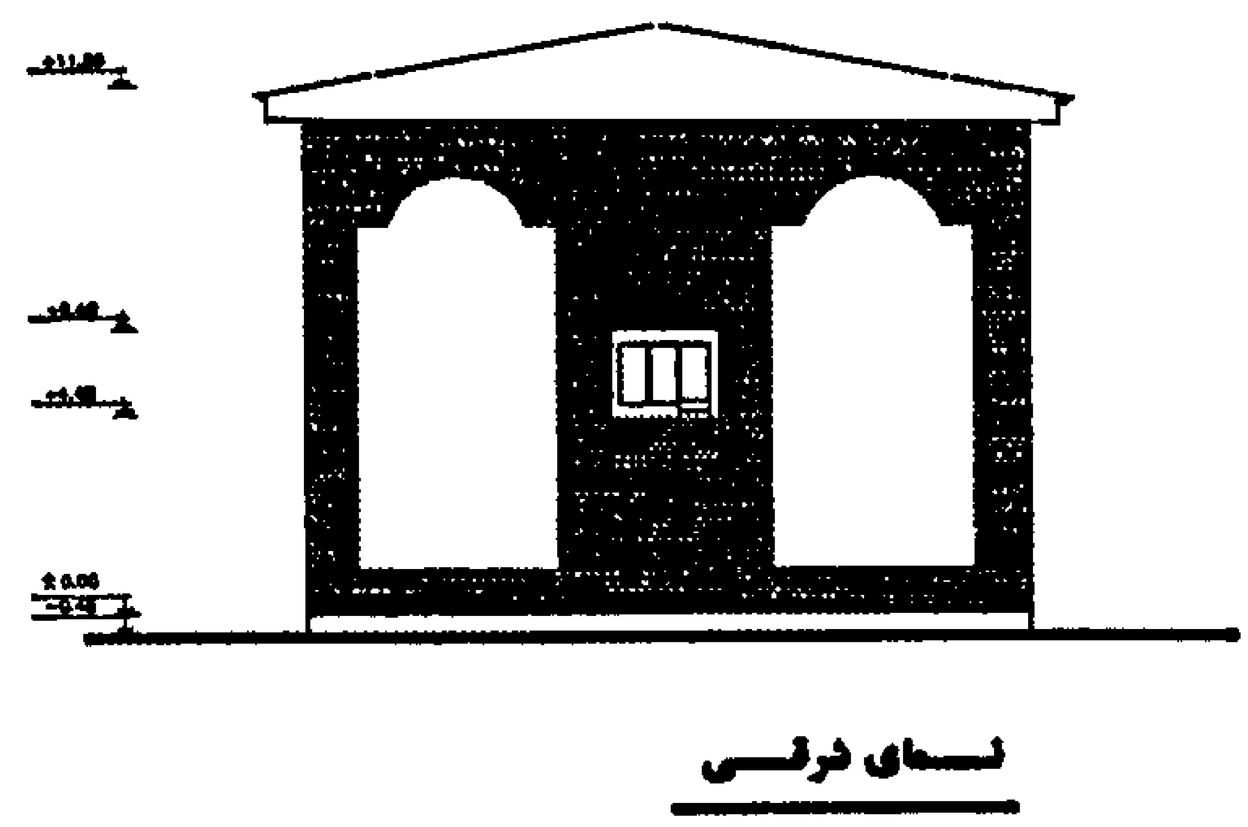


Figure 8.81: The section A-A of a high school with 9 classrooms (Number 11)

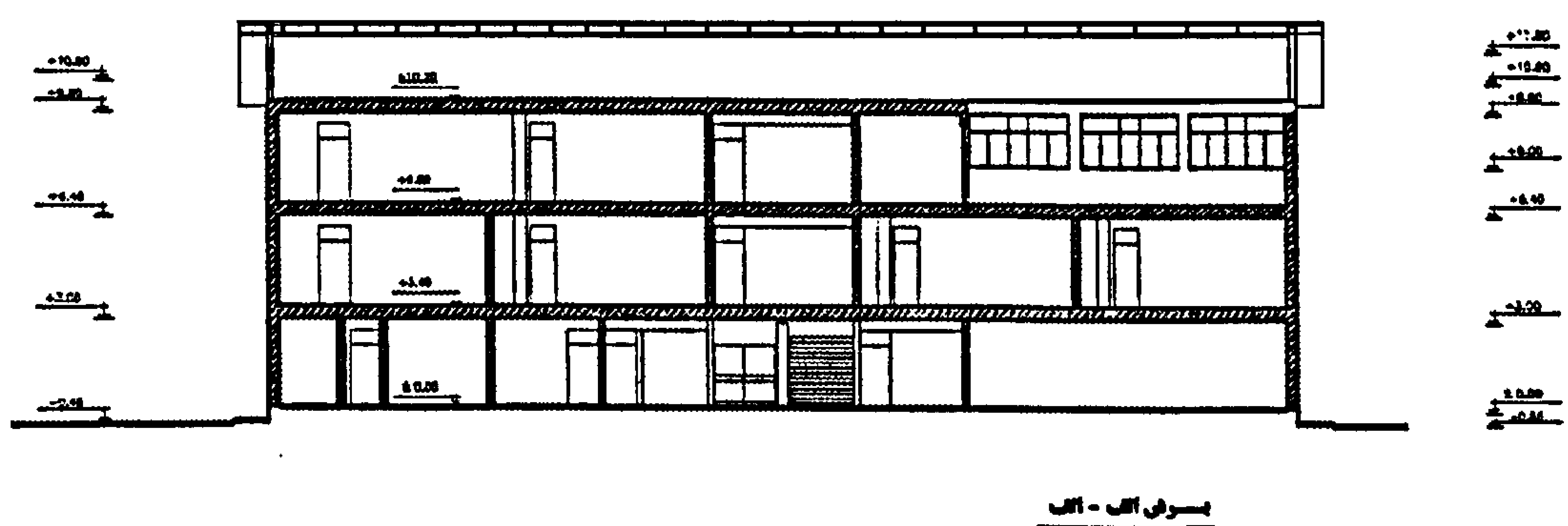
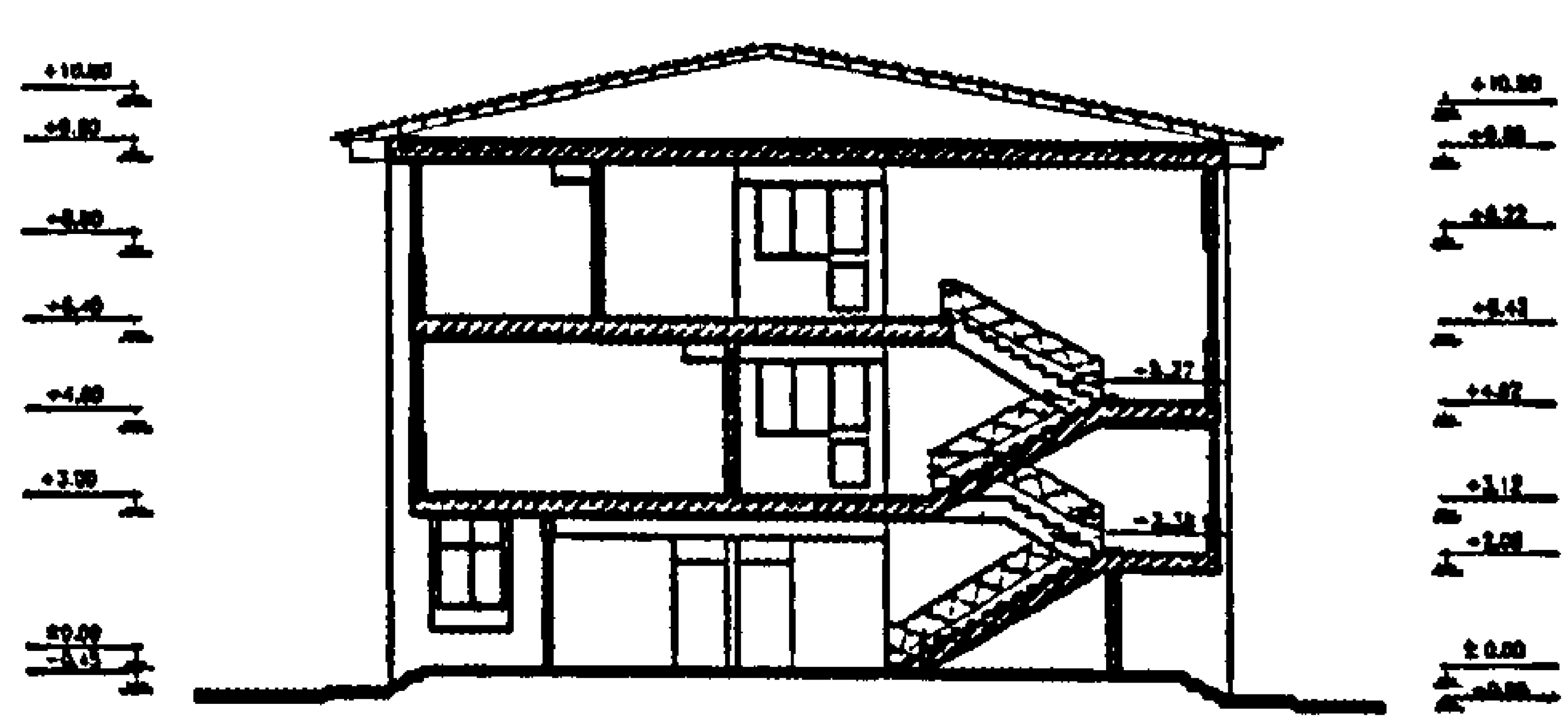


Figure 8.82: The section B-B of a high school with 9 classrooms (Number 11)



$8_{7.12}$ * **High School with 9 Classrooms** (School number 12)

Type: High school
Usable area: 1665 m^2
Pupils: 360
Location: Ardabil
Geographic characteristics: Latitude: 37° 32' Degrees (north)
Longitude: -48° 17' Degrees (east)
Altitude: 1372 metres
Azimuth angle of building: Azimuth: 00° 00' Degrees
Climate: Very cold-Temperate (see chapter 2, Group 2 and subgroup 2-2)
Mean yearly temperature: 8.88^{oC}

This four-story high school comprises nine classrooms, five of them located at the first floor and the other four at the second floor. Pupils learn different technical skills in this high school like school number 11. Therefore, it is composed of different laboratories and workshops.

The building is steel framed with brick walls and steel framed window. The low ground floor walls construction is 110 mm brick, 10 mm insulation, 335 mm brickwork and 30 mm stone cladding. The ground floor walls are 50 mm stone sheet, 335 mm brick and 15 mm plaster. The first &second floor walls construction is 50 mm stone sheet, 225 mm brick and 15 mm plaster. The low ground, ground and first floor roofs consists of 50 mm floor tile, 20 mm cement, 80 mm expanded clay, 300 mm brick block and 15 mm plaster. The second floor roof composed of 40 mm Tile, 20mm asphalt and insulation, 20 mm cement, 150 mm expanded clay 50 mm concrete, 15 mm plaster.

The windows are single glazed and the glazing ratio of the low ground floor is 9.6% in north wall, 14.5% in the south wall, 0% in the west &east wall. The ground floor is 53% in north wall, 48% in the south wall and 20% in the west &east wall. Also the glazing ratio of first and second floor is 50.5% in north, 59% in south and 20% in west & east wall.

The school has a rectangular plan with 26 m length and 16 m width. Each floor has 3 m height, and the direction is expended from east to west.

Heating is provided by a central heating system with thermostatically controlled gasoline-fired units and conventional radiators. The indoor temperature must be set to

24^{oC} in the warm season and 20^{oC} in the cold one. Since the weather is always cold during the opening periods of school there is no need for using a cooling system.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.27: The amount of actual annual energy used

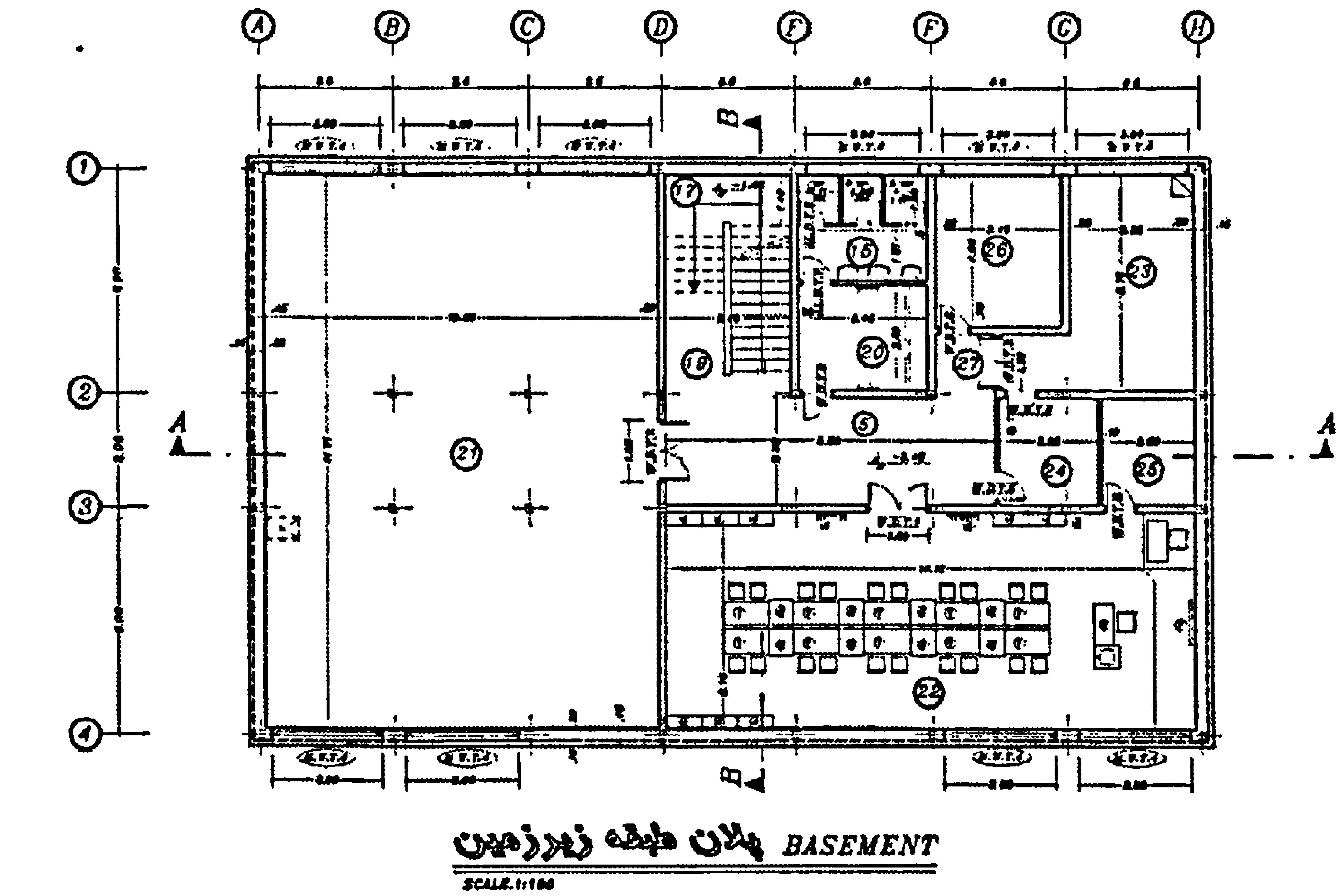
	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs
Electricity	--	No cooling	89,564
Gas	--	--	--
Gasoline	31,800 litres	--	--

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.28: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	414,363.6	0	103,899.5	**With Daylighting**
Non-window control	414,363.6	8,668.7	188,490.3	**Non Daylighting**
With shading	412,418.4	0	107,870.94	**With shading& Daylighting**

Figure 8.83: The plan of the Low ground floor & ground floor of a high school with 9 classrooms (Number 12)



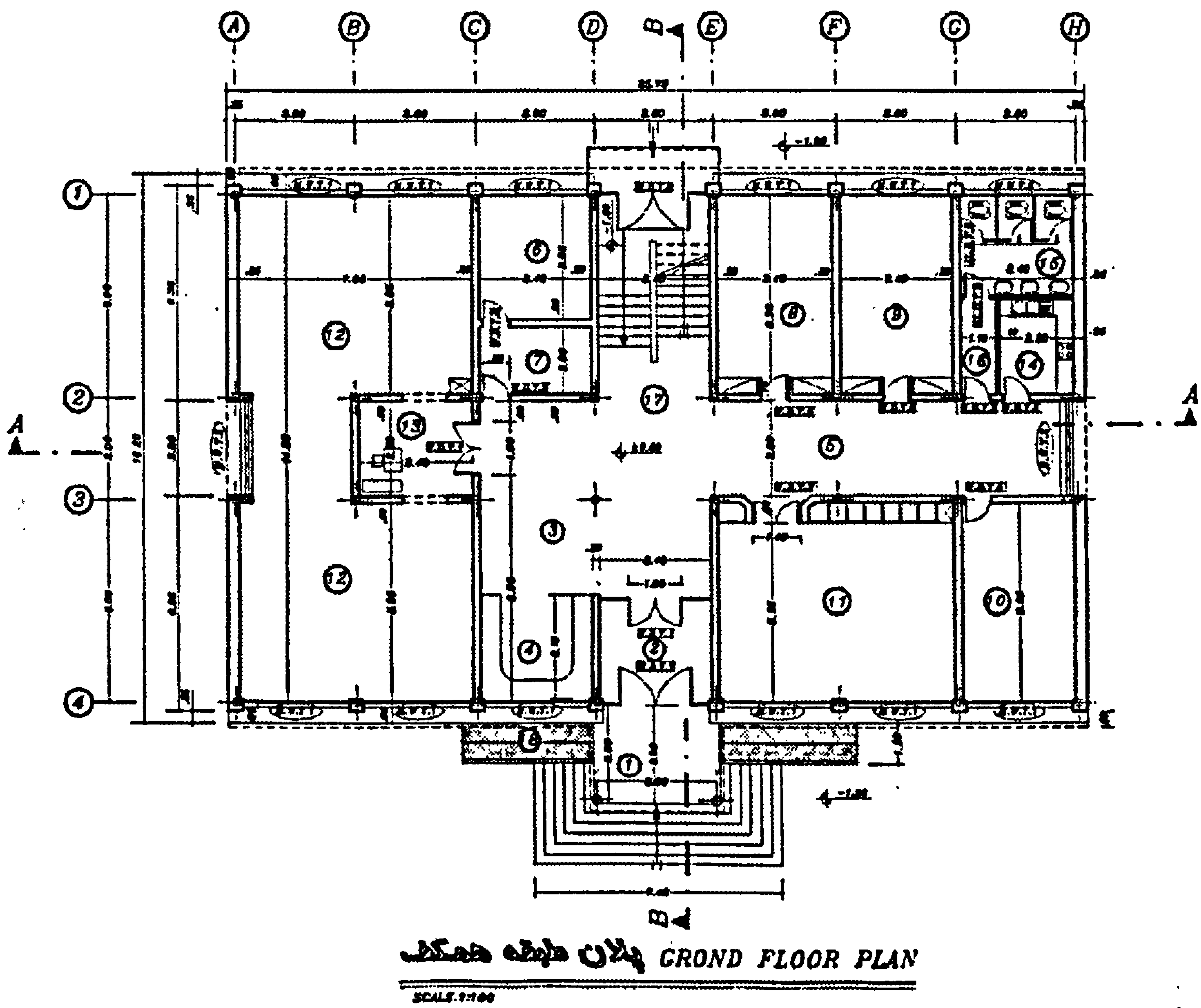
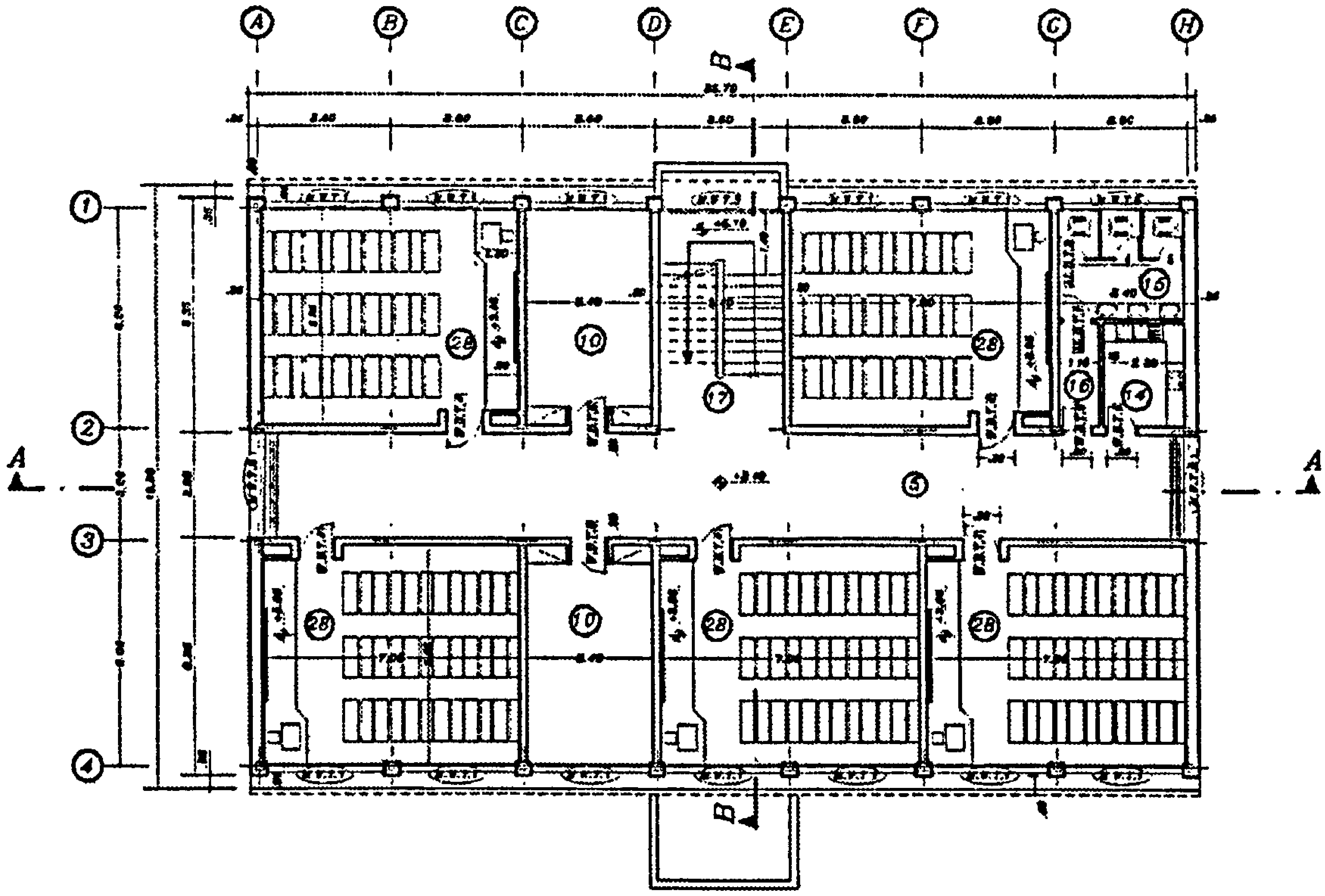
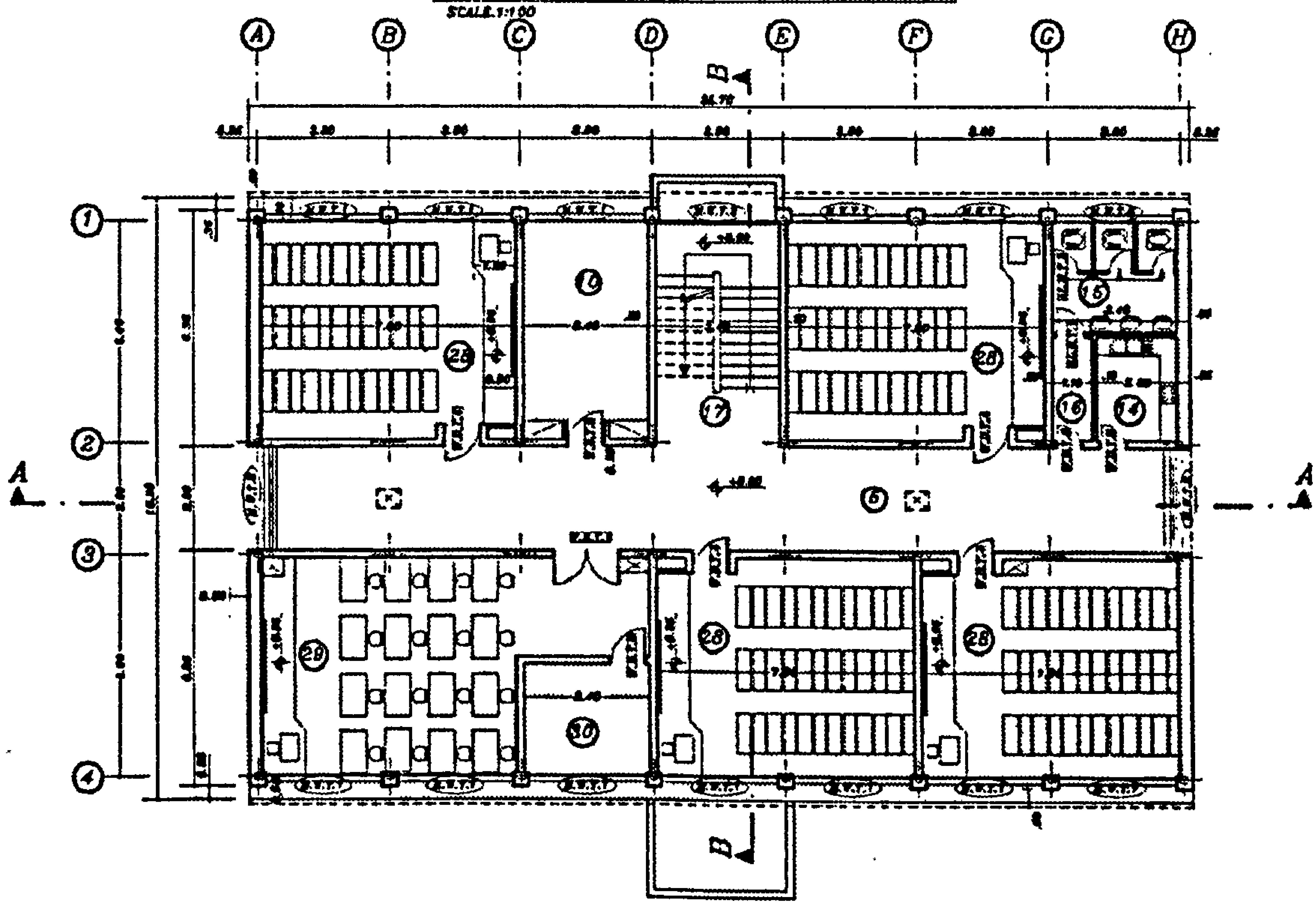


Figure 8.84: The plan of the first and second floor of a high school with 9 classrooms (Number 12)



پلان طبقه اول FIRST FLOOR PLAN

SCALE 1:100



پلان طبقه دوم SECOND FLOOR PLAN

SCALE 1:100

Figure 8.85: The north elevation of a high school with 9 classrooms (Number 12)

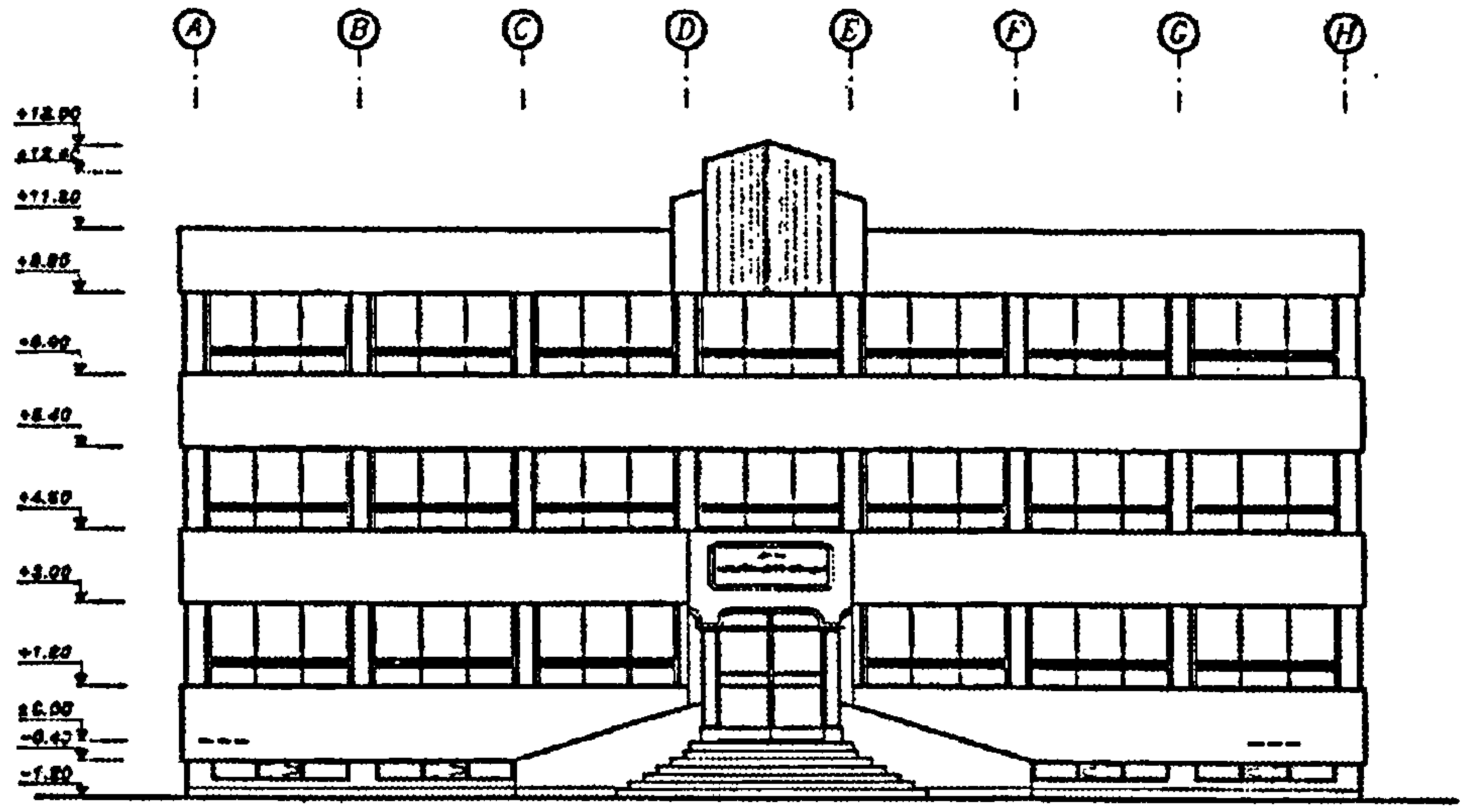


Figure 8.86: The south elevation of a high school with 9 classrooms (Number 12)

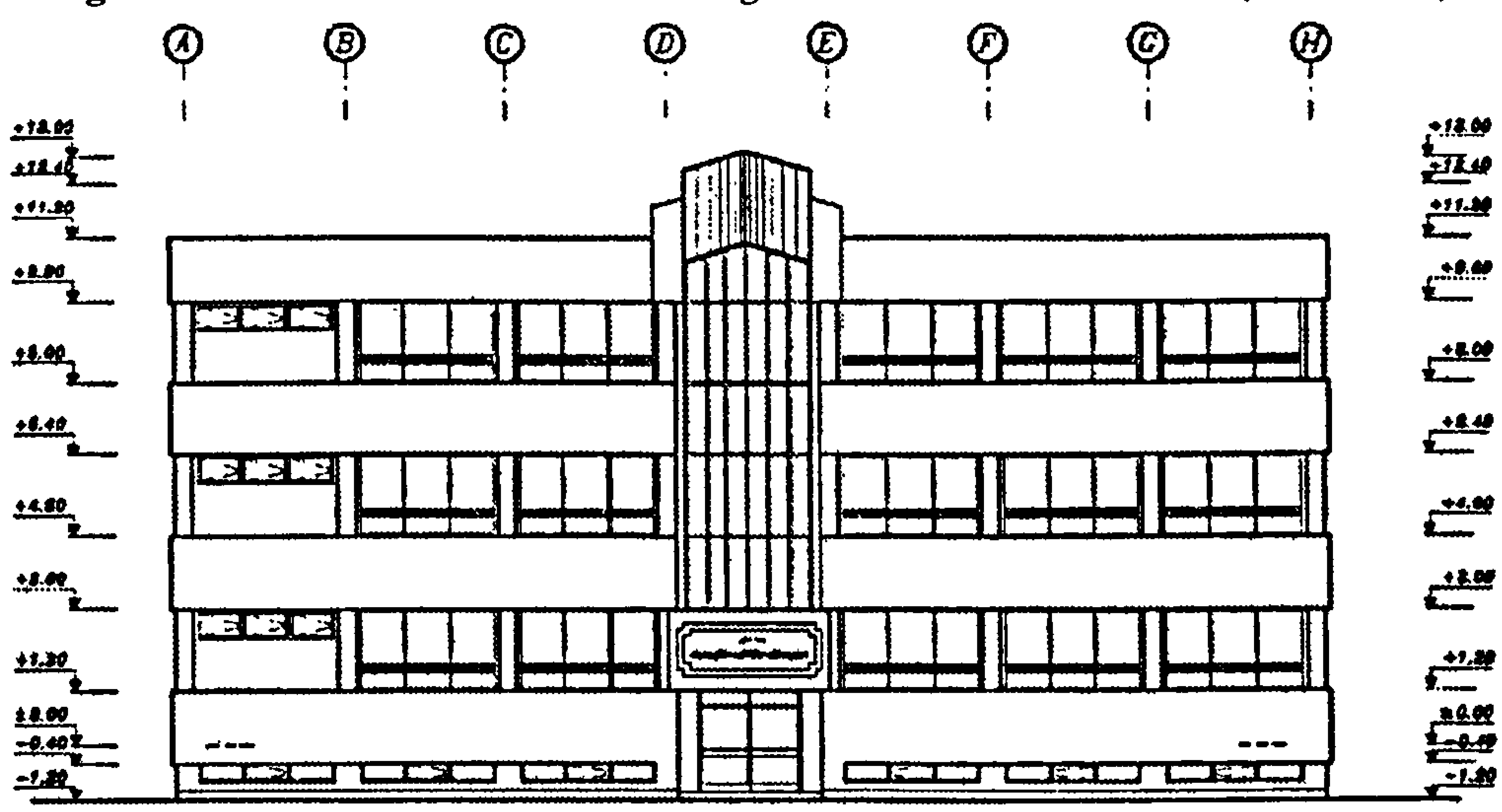


Figure 8.87: The east elevation of a high school with 9 classrooms (Number 12)

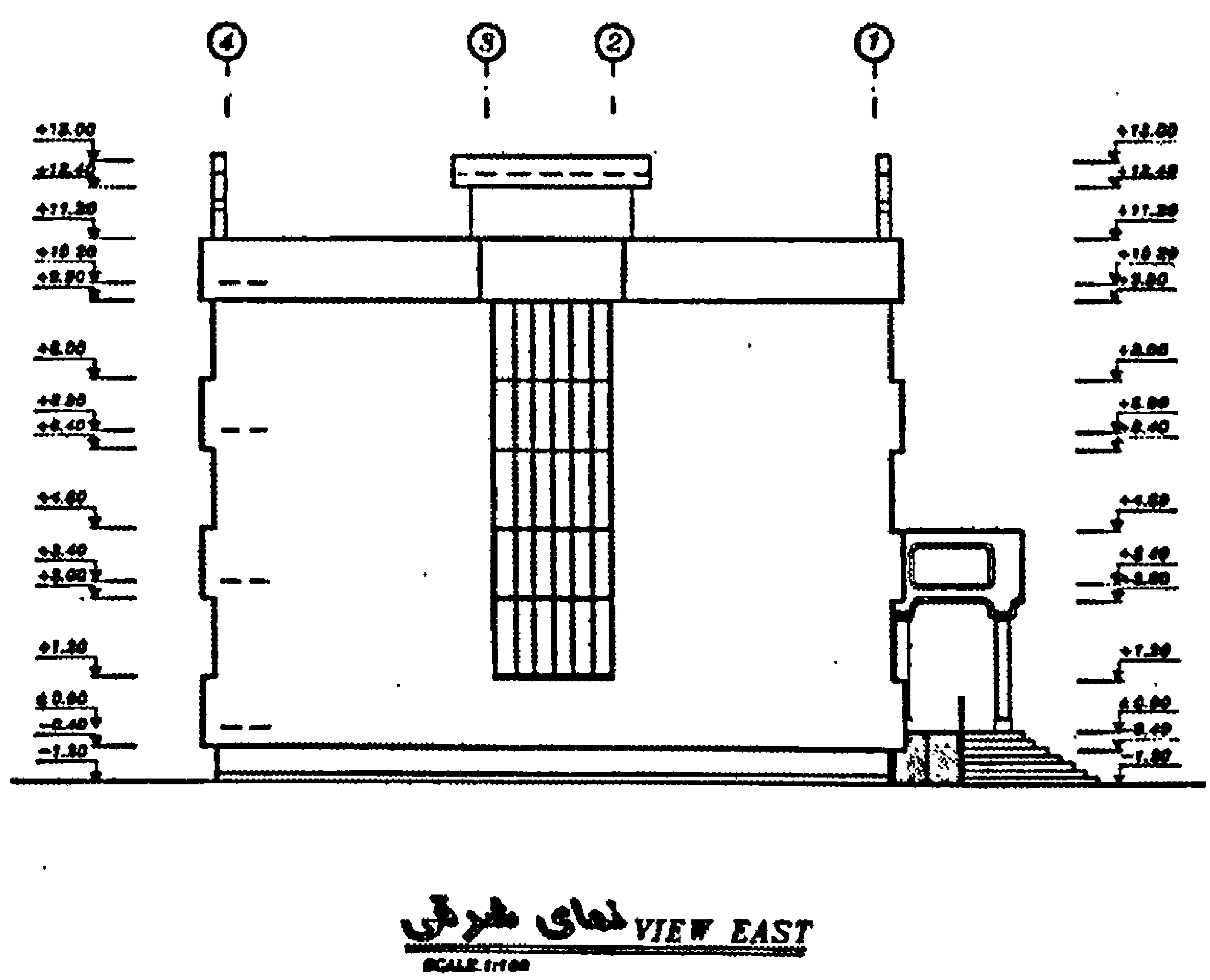


Figure 8.88: The west elevation of a high school with 9 classrooms (Number 12)

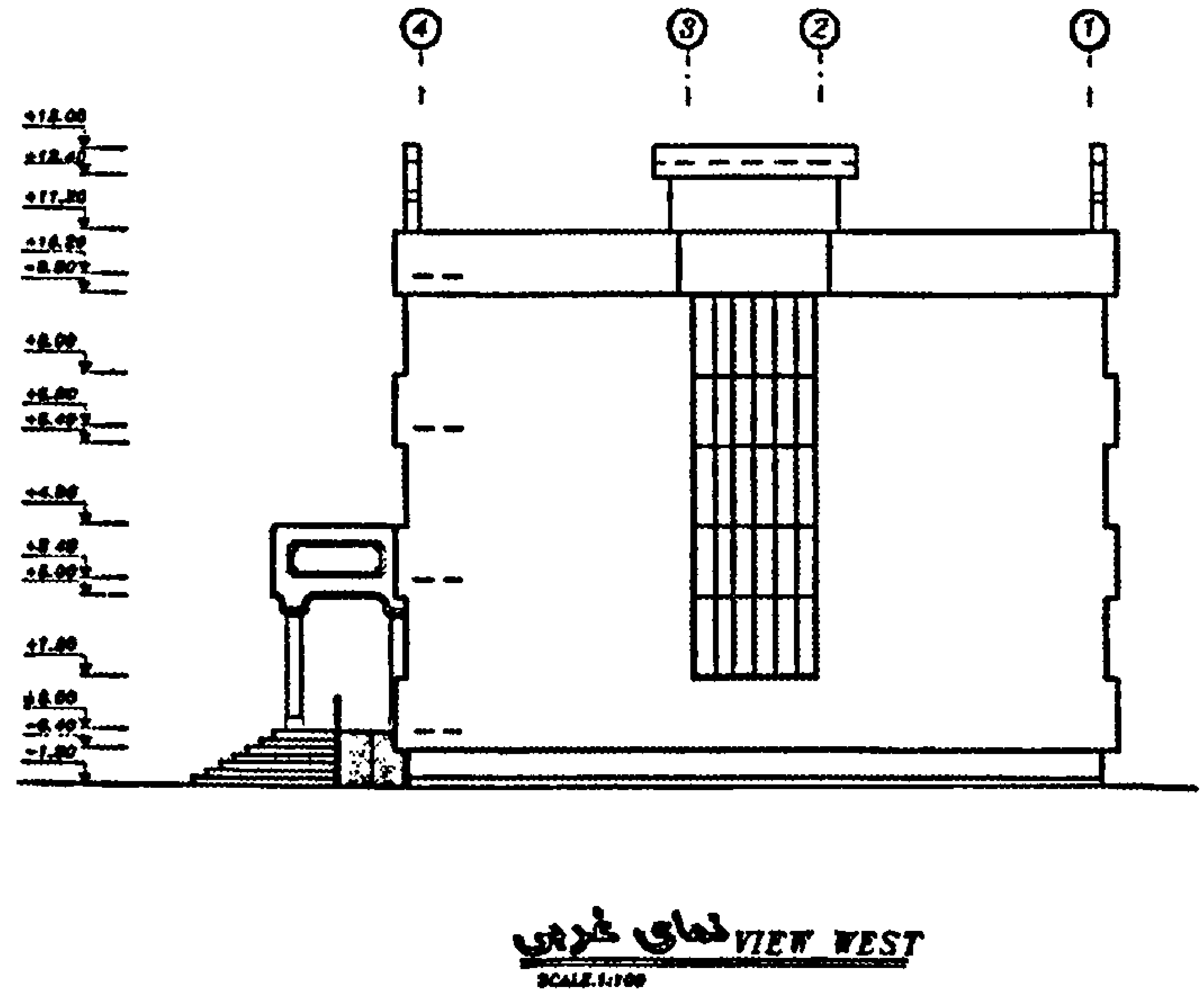


Figure 8.89: The section B-B of a high school with 9 classrooms (Number 12)

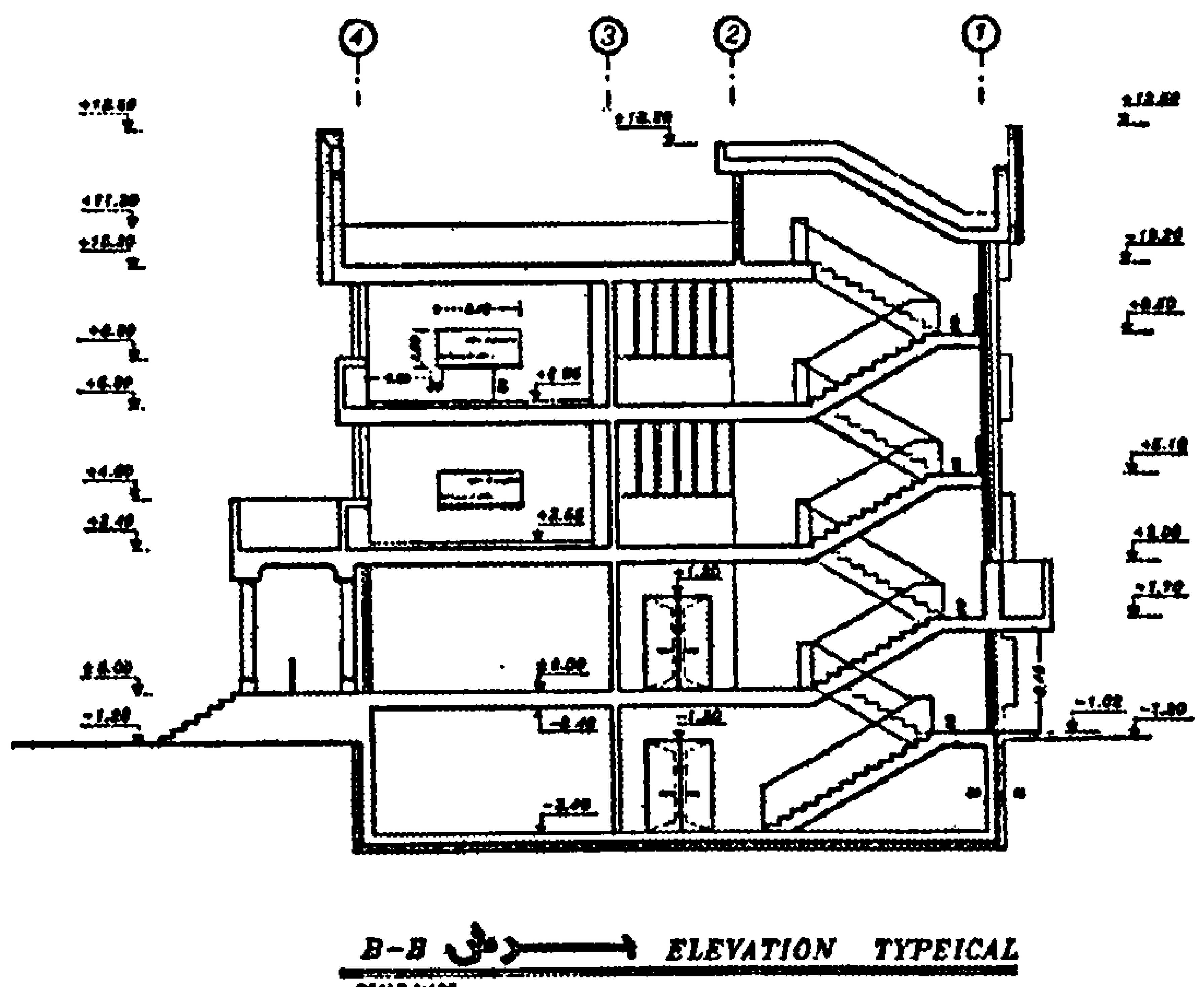
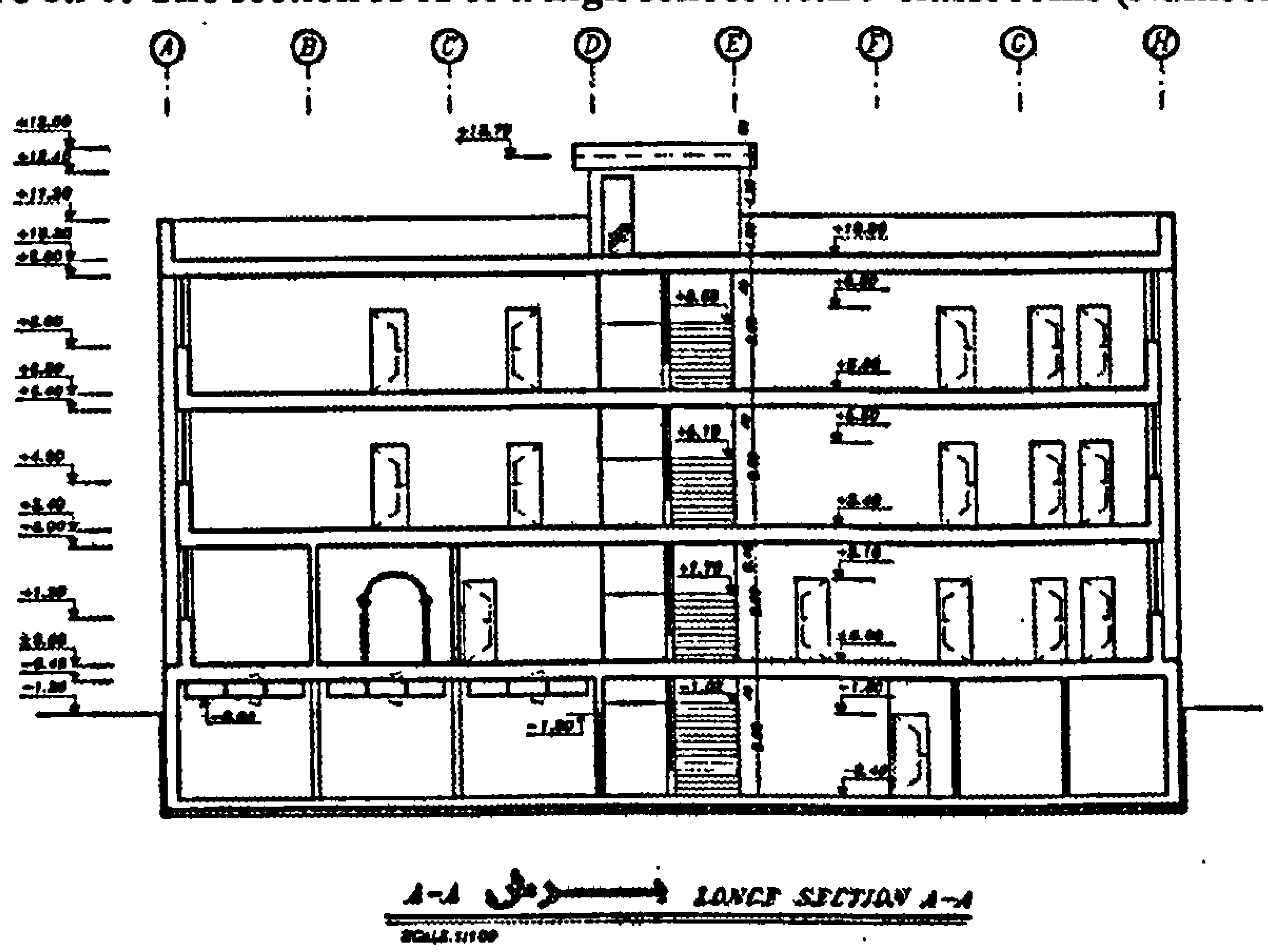


Figure 8.90: The section A-A of a high school with 9 classrooms (Number 12)



8$_{7.13}$ * High School with 12 Classrooms (School number 13)

Type: High school
Usable area: 1550m^2
Pupils: 360
Location: Bandar-Abbas
Geographic characteristics: Latitude: 27° 13' Degrees (north)
Longitude: 56° 22' Degrees (east)
Altitude: 10 metres
Azimuth angle of building: Azimuth: -5° 00' Degrees
Climate: Temperate-Very Hot and Humid (see chapter 2, Group 8 and subgroup 8-2)
Mean yearly temperature: 27.98^{oC}

This two-story high school comprises twelve classrooms, six of them located at the ground floor and the other six at the first floor.

The building has masonry wall (brick) and steel framed window. The construction of the walls is 110 mm brickwork, 335 mm brick and 13 mm plaster. The ground floor roof is composed of 50 mm floor tile, 50 mm concrete, 250 mm concrete block and 15 mm plaster. The first floor roof consists of 30 mm tile & cement, 25 mm asphalt and insulation, 20 mm cement, 80 mm expanded clay, and 50 mm concrete, 250 mm concrete block and 15 mm plaster.

The windows are single glazed and the glazing ratio of the ground floor is 17.7% in north wall, 29.4% in the south wall and 20% in the west & east wall. The glazing ratio of first floor is 18.1% in north, 18.5% in south and 18.6% in west & east wall.

The plan of this school is a rectangular with 32.4 m length and 27 m width and a central yard measuring 9m * 11 m. Each floor has 3 m height and the direction is expended from north to south. There are three entrances located at the east, west and south.

Since the weather is always hot no heating system has been used and the cooling system is electric gas-based cooler. The indoor temperature must be set to 24^{oC} in the warm season and 20^{oC} in the cold one.

The holiday period starts from mid-June until mid-September. The number of air changes per hour is considered to be 1.2 during the active period of school and 0.5 during the inactive period. Also the illuminance design is 300 lux.

The amount of actual annual energy used is:

Table 8.29: The amount of actual annual energy used

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs
Electricity	--	--	387,788*
Gas	--	--	--
Gasoline	No heating	--	--

*Note: The amount of energy mentioned in the lighting part is the total amount of energy used by lighting and cooling.

The calculated annual energy consumption (My dynamic excel sheet program) is:

Table 8.30: The calculated annual energy consumption

	Heating Kwhrs	Cooling Kwhrs	Lighting Kwhrs	
With window control	34,900.6	359,606.5	99,780.26	**With Daylighting**
Non-window control	34,900.6	368,845.9	148,141.54	**Non Daylighting**
With shading	34,900.6	352,454.8	103081.78	**With shading& Daylighting**

Figure 8.91: The plan of the ground floor of a high school with 12 classrooms (Number 13)

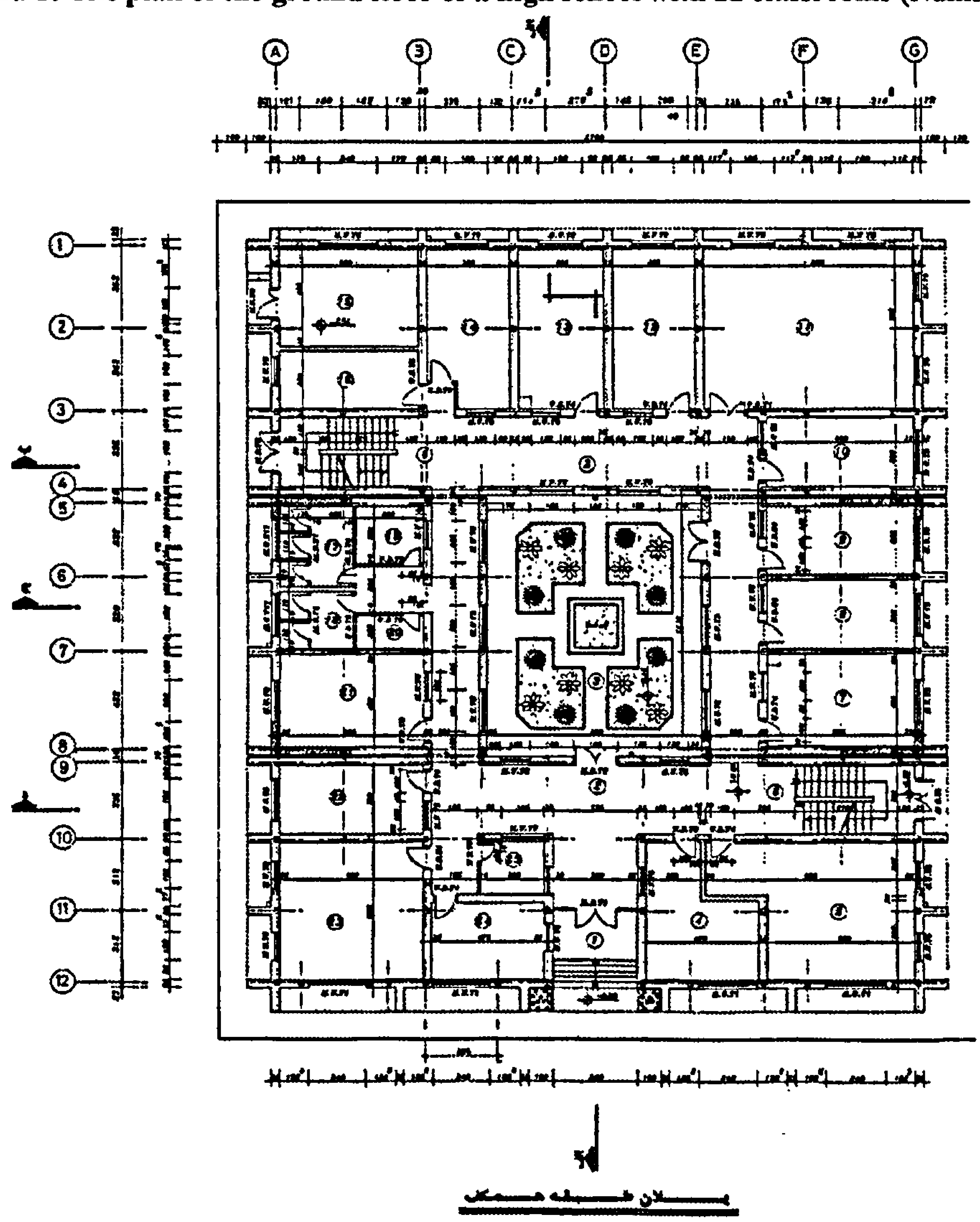


Figure 8.92: The plan of the first floor of a high school with 12 classrooms (Number 13)

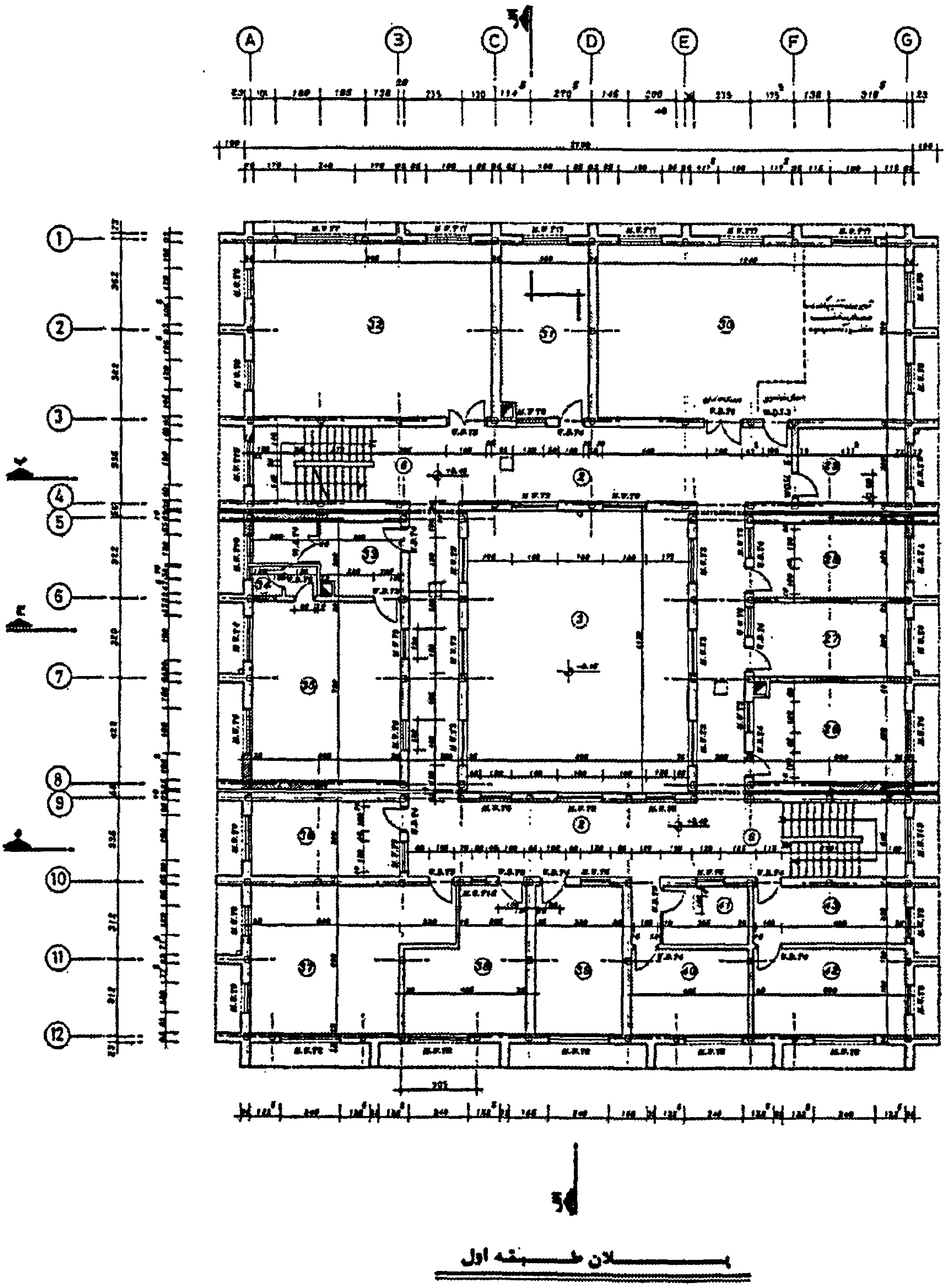
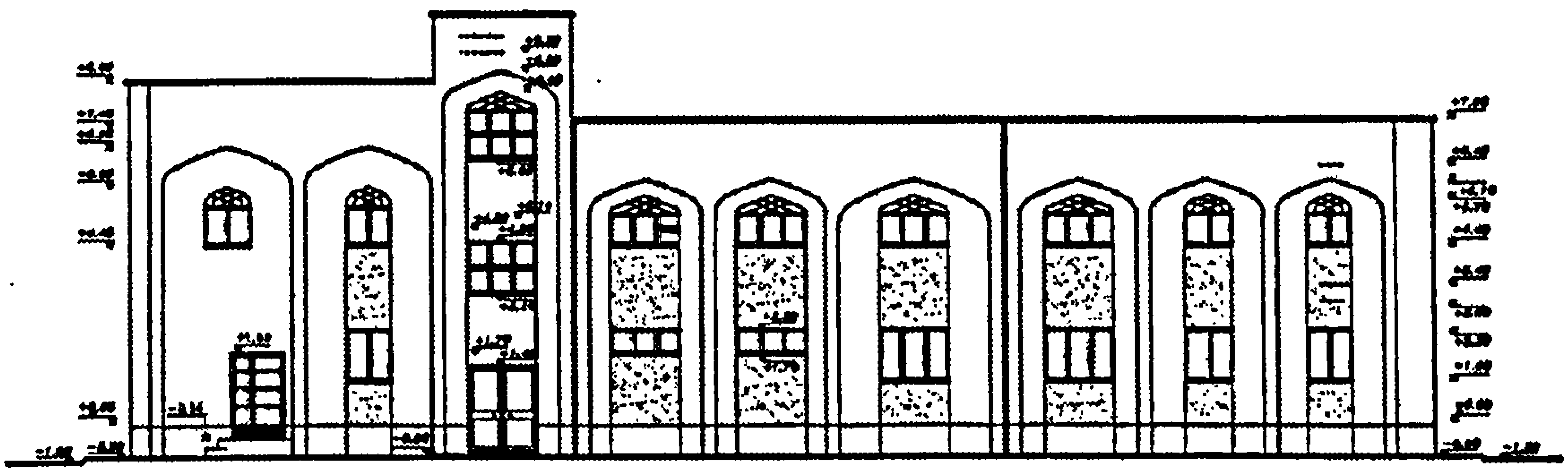
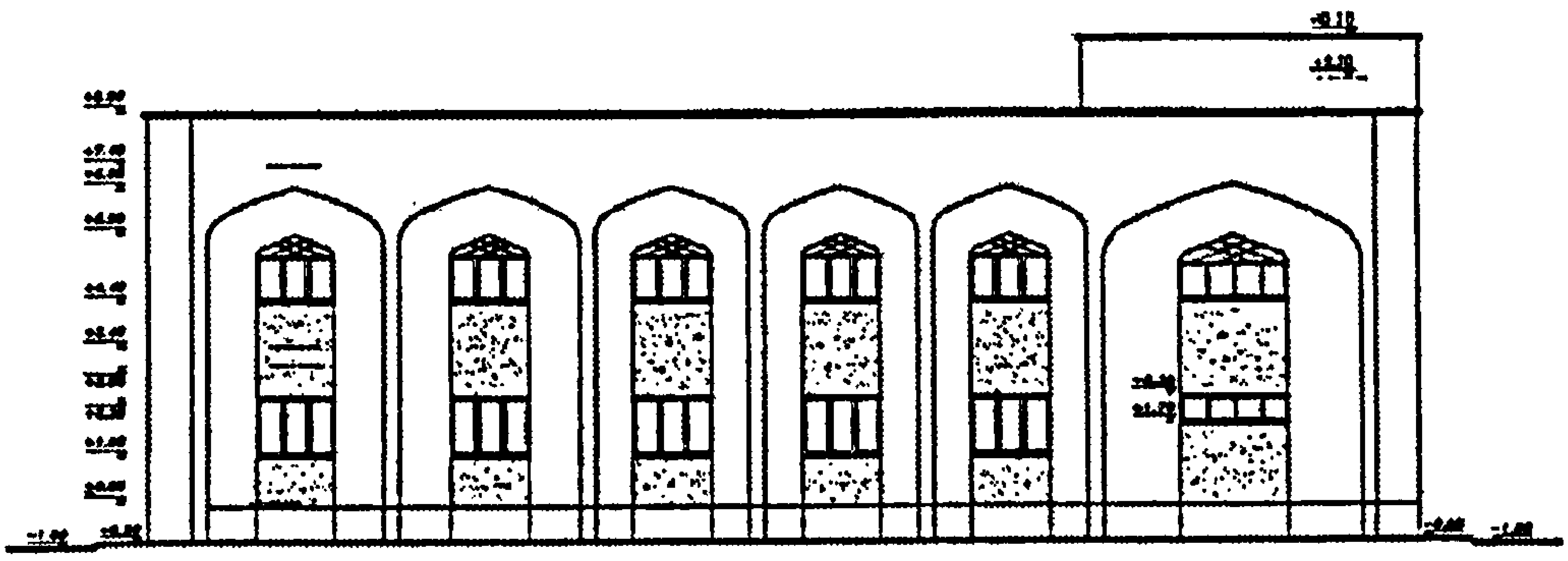


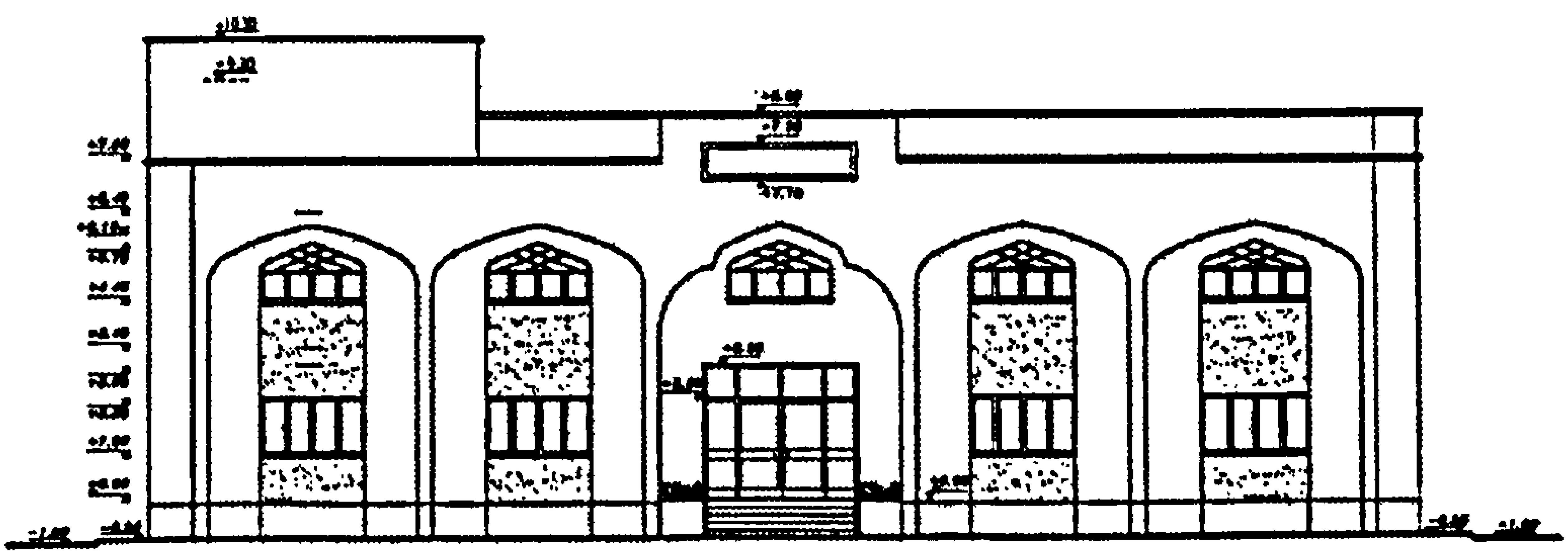
Figure 8.93: The west, north and south elevations of a high school with 12 classrooms (Number 13)



نمای غربی

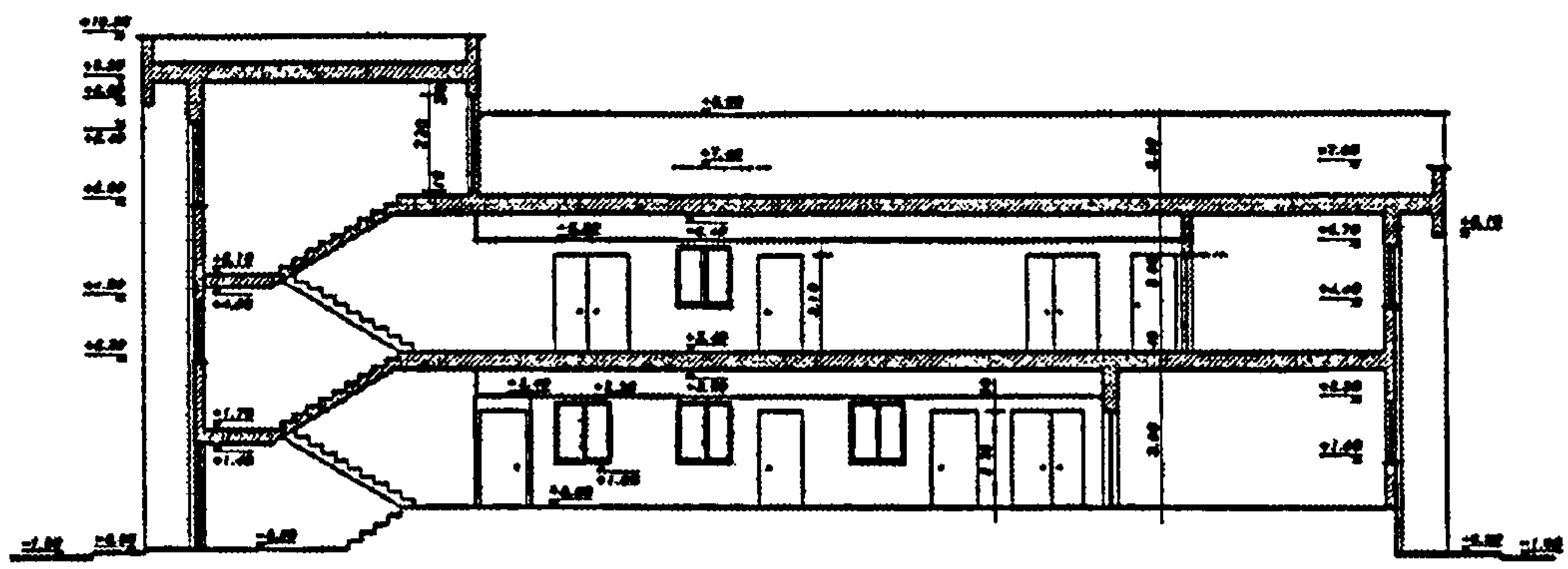


نمای شمالی



نمای جنوبی

Figure 8.94: The sections B-B, C-C and D-D of a high school with 12 classrooms (Number 13)



مقطع ب - ب

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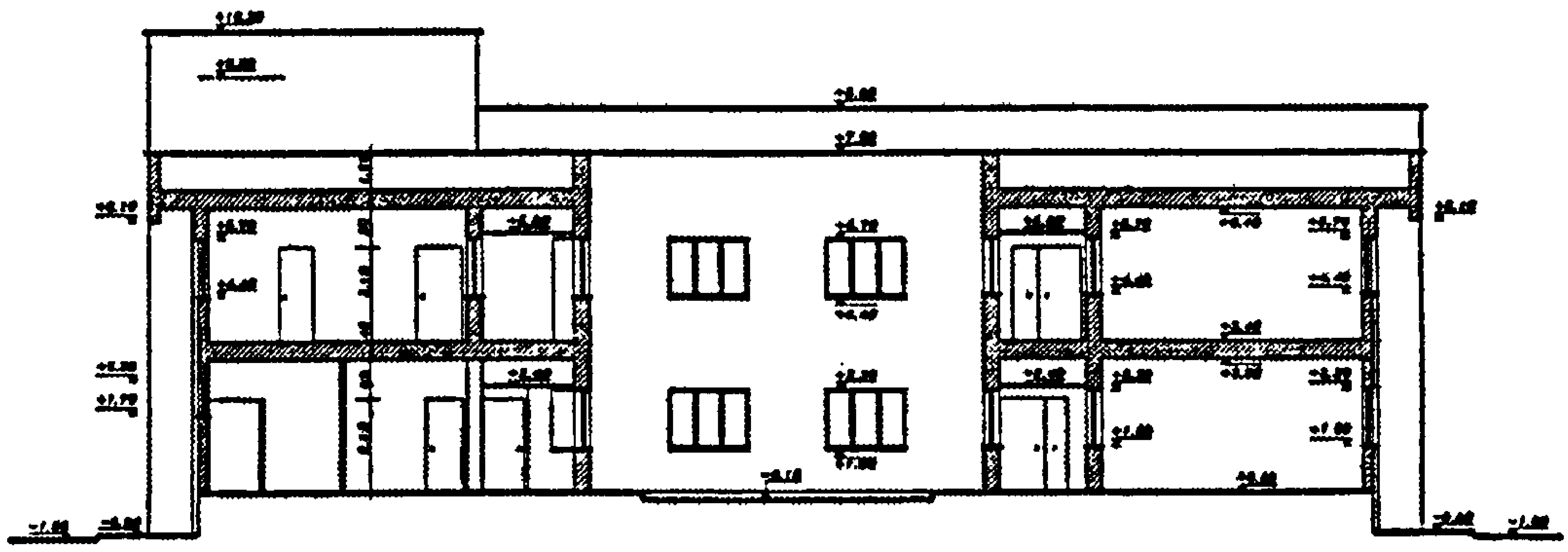

مقطع ج - ج

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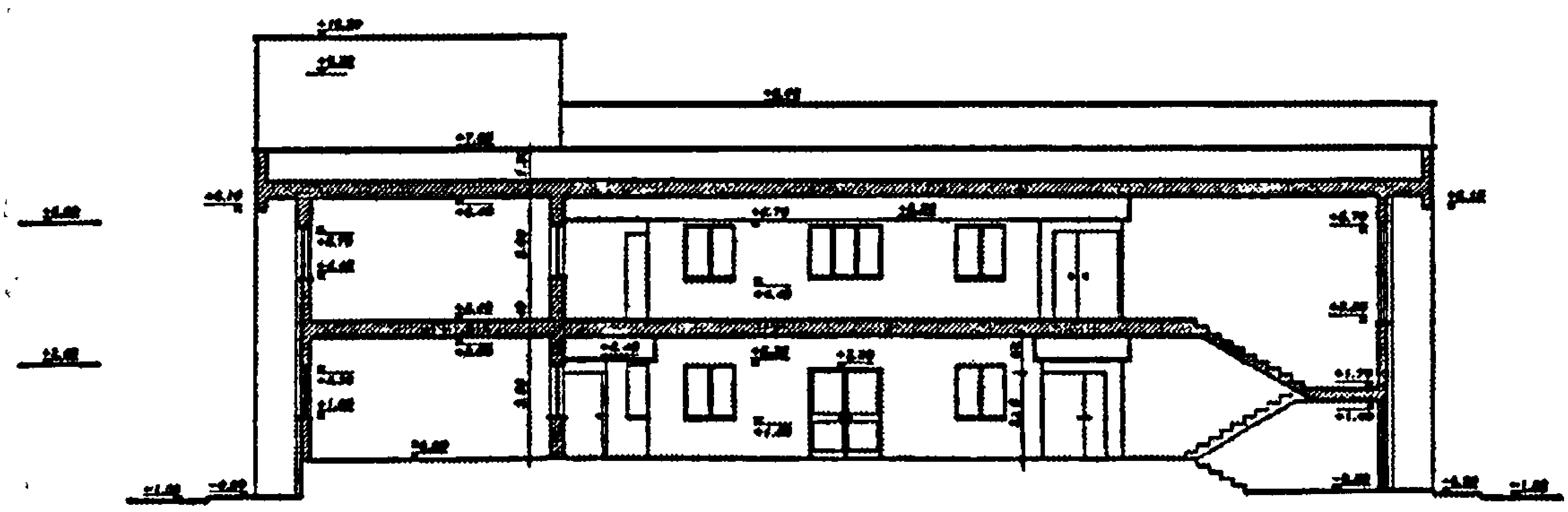

مقطع د - د

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8₈ * Average Annual Heating, Cooling and Lighting Energy Used and Requirements

For the thirteen schools for which energy data was available the annual heating, cooling and lighting energy used was normalised to consumptions per sq. metre floor area. Using the excel spreadsheets the theoretical energy usage for each of the schools was established and again normalised to a consumption per sq. metre floor area. The results of this analysis are shown in Table 8.31.

Table 8.31: The average annual heating, cooling and lighting energy used and requirements

Units: Kwhrs/year.m^2

Schools	Actual Annual Energy Used			Calculated Annual Energy Usage		
	Heating	Cooling	Lighting	Heating	Cooling	Lighting
School Number 1	121.85	Cooling + Lighting = 75.56		142.56	20.84	61.98
School Number 2	113.37	No cooling	81.08	188.24	23.12	71.86
School Number 3	90.68	Cooling + Lighting = 52.92		116.27	13.80	46.23
School Number 4	236.17	Cooling + Lighting = 136.32		124.19	51.04	76.50
School Number 5	77.27	Cooling + Lighting = 102.78		94.23	58.08	52.44
School Number 6	86.39	Cooling + Lighting = 103.25		95.90	62.66	67.94
School Number 7	58.21	Cooling + Lighting = 95.77		78.13	56.26	54.14
School Number 8	59.84	Cooling + Lighting = 114.17		82.00	65.62	68.69
School Number 9	91.14	No cooling	42.22	76.33	27.63	41.02
School Number 10	115.04	No cooling	69.26	78.40	35.98	58.52
School Number 11	120.91	Cooling + Lighting = 62.34		95.46	41.25	56.07
School Number 12	248.29	No cooling	53.79	248.72	0.00	62.37
School Number 13	No Heating	Cooling + Lighting = 250.19		22.52	232.00	64.37

8₉ * Results

A comparison has been made between the amount of actual annual energy used and calculated annual energy consumption in 13 different types of schools in various climatic regions of Iran (table 8.32).

The main objective of this comparison was to evaluate the robustness of the excel spreadsheet programmes over a range of climate zones in Iran. This was important as the excel spreadsheet programmes were to be used to generate a new design code for school buildings in different parts of Iran and therefore the excel programmes had to be able to simulate the likely energy performance to a reasonable degree of accuracy. It is recognised that one year's data from the thirteen schools is not perhaps the best set of data but it was all that was available. As can be seen from table 8.33 and figure

8.95 the difference between the actual annual energy used and the calculated annual energy consumption ranges from a few percentage points to over 30%. This degree of difference is not uncommon in buildings as many assumptions had to be made in the running of the excel spreadsheet. For example we had little or no actual information on the exact occupancy patterns, time of occupancy, internal loads or indeed actual temperatures both inside and outside. Without such information it was necessary to use likely values for the following variables:

Occupancy patterns based on normal school days in Iran

Internal air temperatures of 20C in winter 24C in summer

Internal loadings of 27 W/m^2

Solar radiation values established from the simulation programme outlined in Chapter 4

External air temperature data from the Iranian Metrological Office.

Table 8.32: Comparison between amounts of actual energy used and calculated annual energy consumption

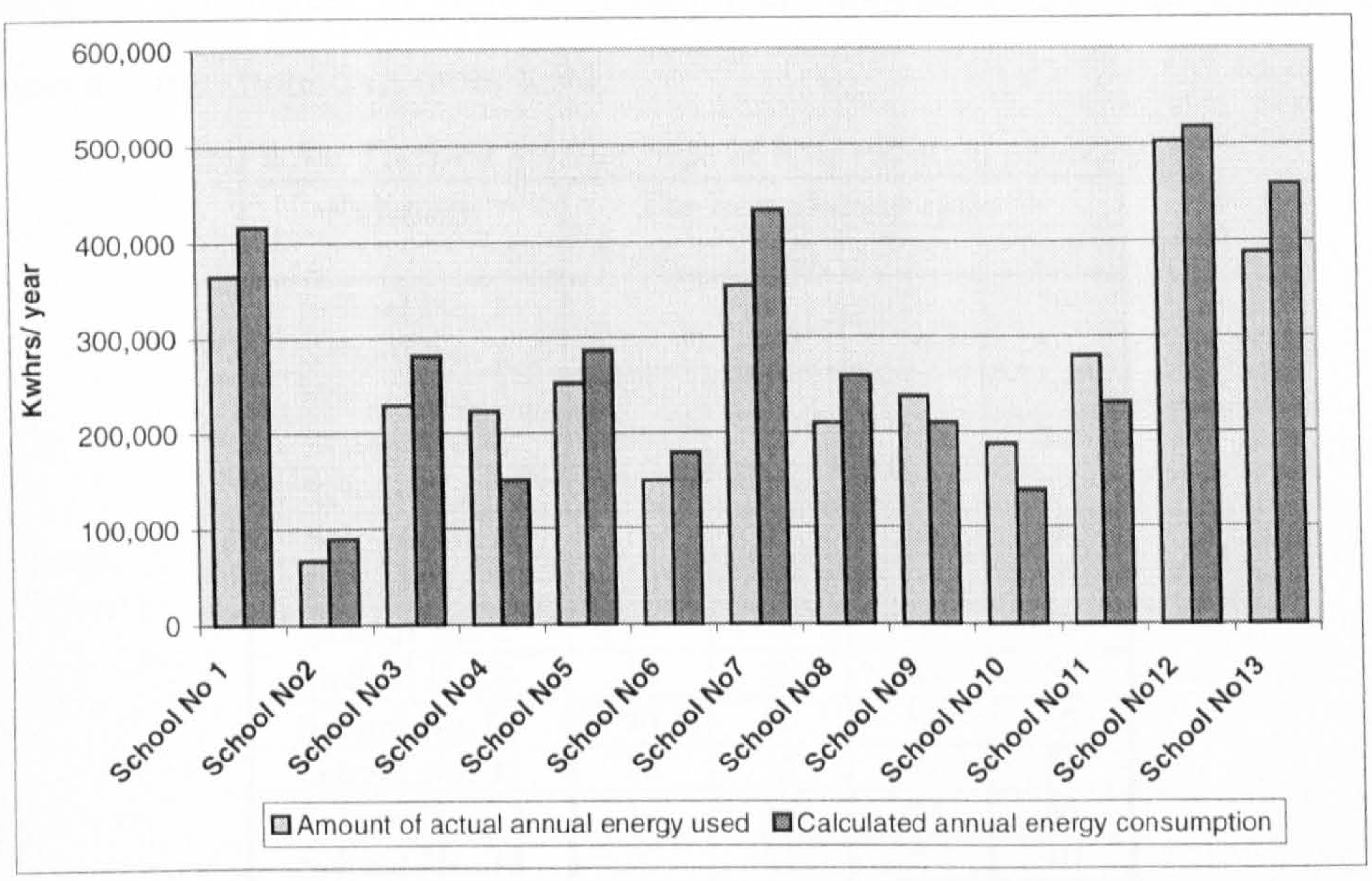
Schools		Amount of actual annual energy used (Kwhrs)			Calculated annual energy consumption (Kwhrs)		
		Heating	Cooling	Lighting	Heating	Cooling	Lighting
School Number 1	Electricity	---	---	139,782	263,742.60	38,552.40	114,664.98
	Gas& gasoline	225,423	---	---	---	---	---
School Number 2	Electricity	---	---	27,890	64,754.40	7,954.20	24,720.63
	Gas& gasoline	3,000 litres	---	---	---	---	---
School Number 3	Electricity	---	---	84,673	186,026.10	22,078.10	73,974.06
	Gas& gasoline	145,092	---	---	---	---	---
School Number 4	Electricity	---	---	81,792	74,516.00	30,626.00	45,900.43
	Gas& gasoline	10,900litres	---	---	---	---	---
School Number 5	Electricity	---	---	143,891	131,926.20	81,309.50	73,419.96
	Gas& gasoline	108,179	---	---	---	---	---
School Number 6	Electricity	---	---	81,570	75,758.20	49,504.20	53,670.60
	Gas& gasoline	5,250litres	---	---	---	---	---
School Number 7	Electricity	---	---	220,274	179,697.60	129,397.10	124,511.91
	Gas& gasoline	133,893	---	---	---	---	---
School Number 8	Electricity	---	---	136,998	98,359.20	78,747.50	82,428.68
	Gas& gasoline	71802	---	---	---	---	---
School Number 9	Electricity	---	No cooling	75,282	136,097.40	49,269.90	73,133.90
	Gas& gasoline	12,500 litre	---	---	---	---	---
School Number 10	Electricity	---	No cooling	70,439	79,734.40	36,592.10	59,509.86
	Gas& gasoline	9,000 litre	---	---	---	---	---
School Number 11	Electricity	---	No cooling	95,382	146,055.00	63,116.90	85,779.81
	Gas& gasoline	14,230 litre	---	---	---	---	---
School Number 12	Electricity	---	No cooling	89,564	414,363.60	0	103,899.50
	Gas& gasoline	31,800 litre	---	---	---	---	---
School Number 13	Electricity	---	---	387,788	34,900.60	359,606.50	99,780.26
	Gas& gasoline	No Heating	---	---	---	---	---

It is recognised that in using the above assumptions that there will be some variations between the predicted energy use and the actual use but without a full monitoring programme of the schools considered it is difficult to see how such differences can be accounted for. However given that the average difference is 23.46% it was felt that this was good enough to allow the model to be used in parametric studies. It is also recognised that the results obtained from the excel spreadsheet programme are only indicative of the energy performance and could not be used as an actual indication of the real energy usage. These arguments are also used in the justification of the new LT for Europe simulation package developed by Dr. N Baker and others at the Martin Centre, Cambridge University.

Table 8.33: Comparison between amounts of actual energy used and calculated annual energy consumption

Schools	Amount of actual annual energy used (Kwh)*	Calculated annual energy consumption (Kwh)*	Difference %
School No 1	365,205	416,959.98	14.17
School No2	66,890	89,475.03	33.76
School No3	229,765	282,078.26	22.77
School No4	223492	151,042.43	-32.42
School No5	252,070	286,655.66	13.72
School No6	149820	178,933.00	19.43
School No7	354,167	433,606.61	22.43
School No8	208,800	259,535.38	24.30
School No9	237783	209,231.30	-12.01
School No10	187439	139,244.26	-25.71
School No11	280372	294,951.71	-17.31
School No12	502964	518,263.10	3.04
School No13	387,788	459,386.76	18.46

Figure 8.95: Comparison between amounts of actual energy used and calculated annual energy consumption



In order to examine the effect of window size and its orientation on energy demands of spaces, 13 schools are considered. It is assumed that there is no heat flow through internal partitions. Window design of these schools is changed. Different areas of glazing are obtained by changing the window width whilst keeping the height at a constant 1.5 metres. In all cases windows are located centrally on the external walls with a constant window sill height of 1.20 metres. The occupancy is assumed zero in all schools. By changing the width of windows different glazing ratios of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 percent are obtained respectively.

The annual cooling, heating and lighting requirements of schools having different glazing ratio are calculated (see appendix C). In terms of economics, changes in loads need to be considered with respect to their ultimate on purchasing energy. The designer of a school and its ultimate occupier will be concerned with running costs and the cost effectiveness of any modification in the design of building. It is of use, therefore, if the energy consequences of changing the window design can be expressed in terms of cost.

Annual heating, cooling and lighting loads together with the annual cost factors of all 13 schools with different glazing ratios are calculated under scenario 1 (equation 7.8, chapter 7) and are shown in figures 10.96. The best glazing ratios are as follow:

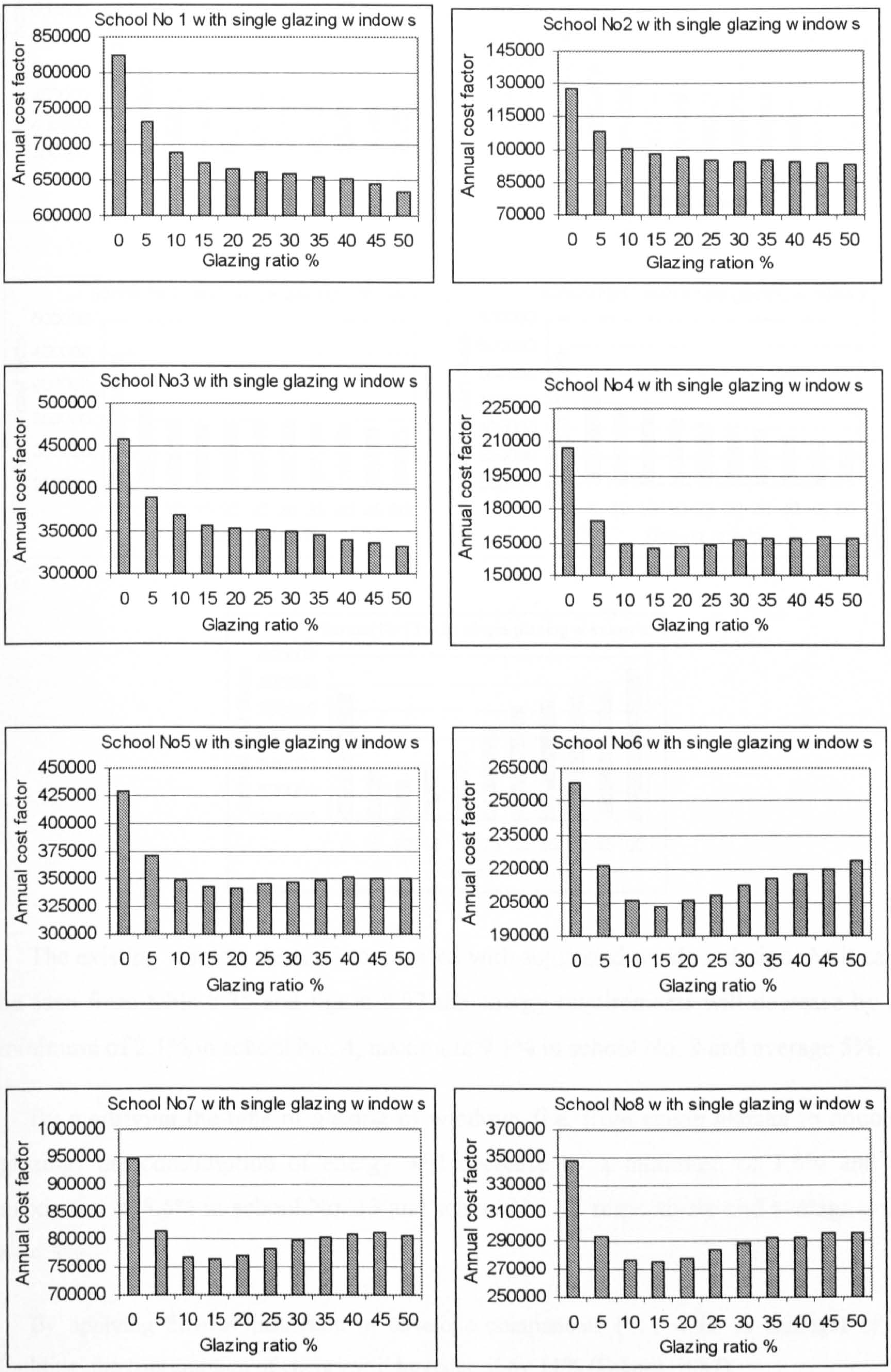
Schools No. 1,2,3,9,10,11,12: 50%
School No. 5: 20%
Schools No. 4,6,7,8: 15%
School No. 13: 10%

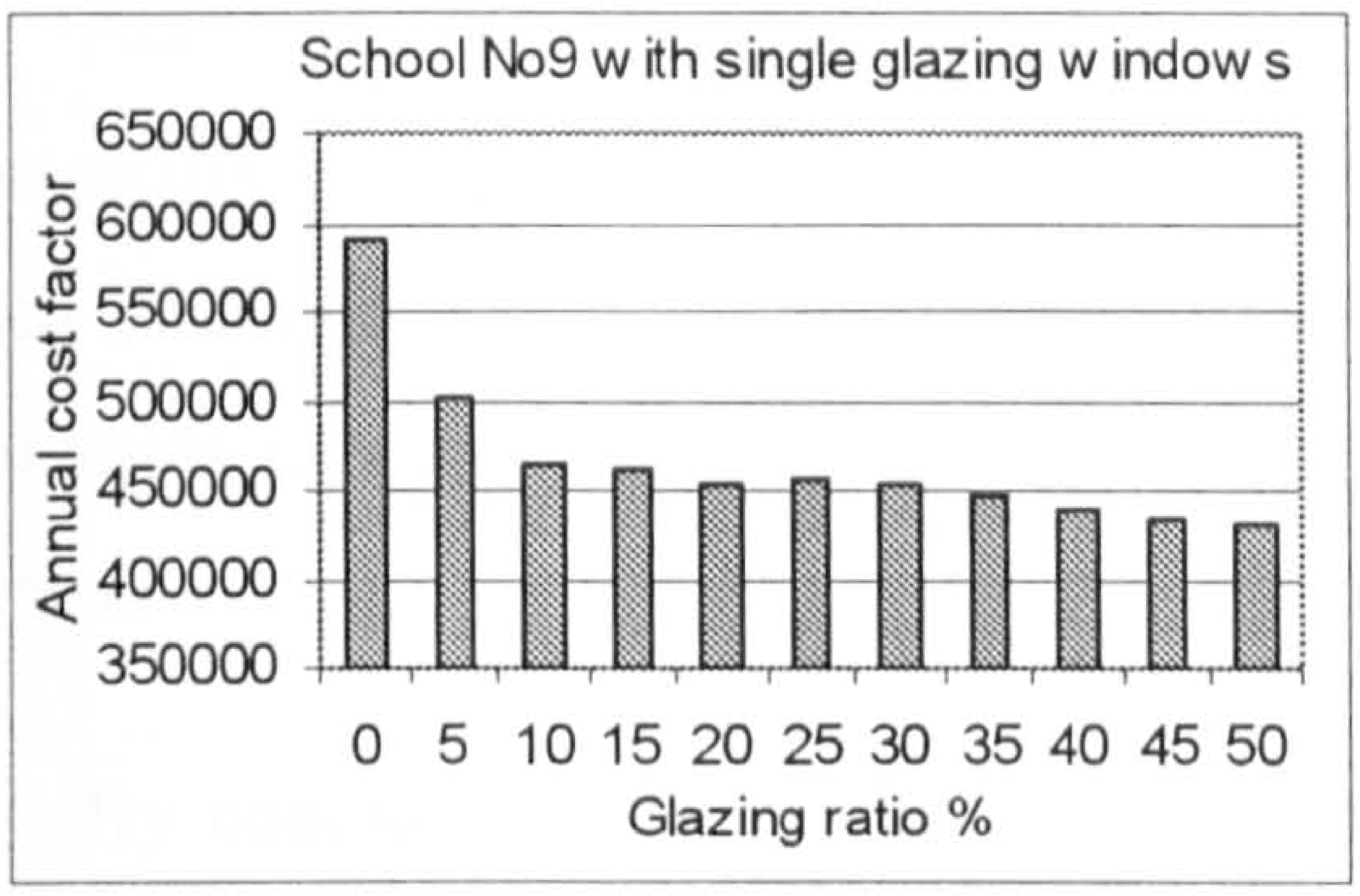
In order to choose the best glazing ratio of four cardinal orientations the annual cost factor is calculated in our 13 cases (see appendix C). The details of this calculation are mentioned in table 8.34.

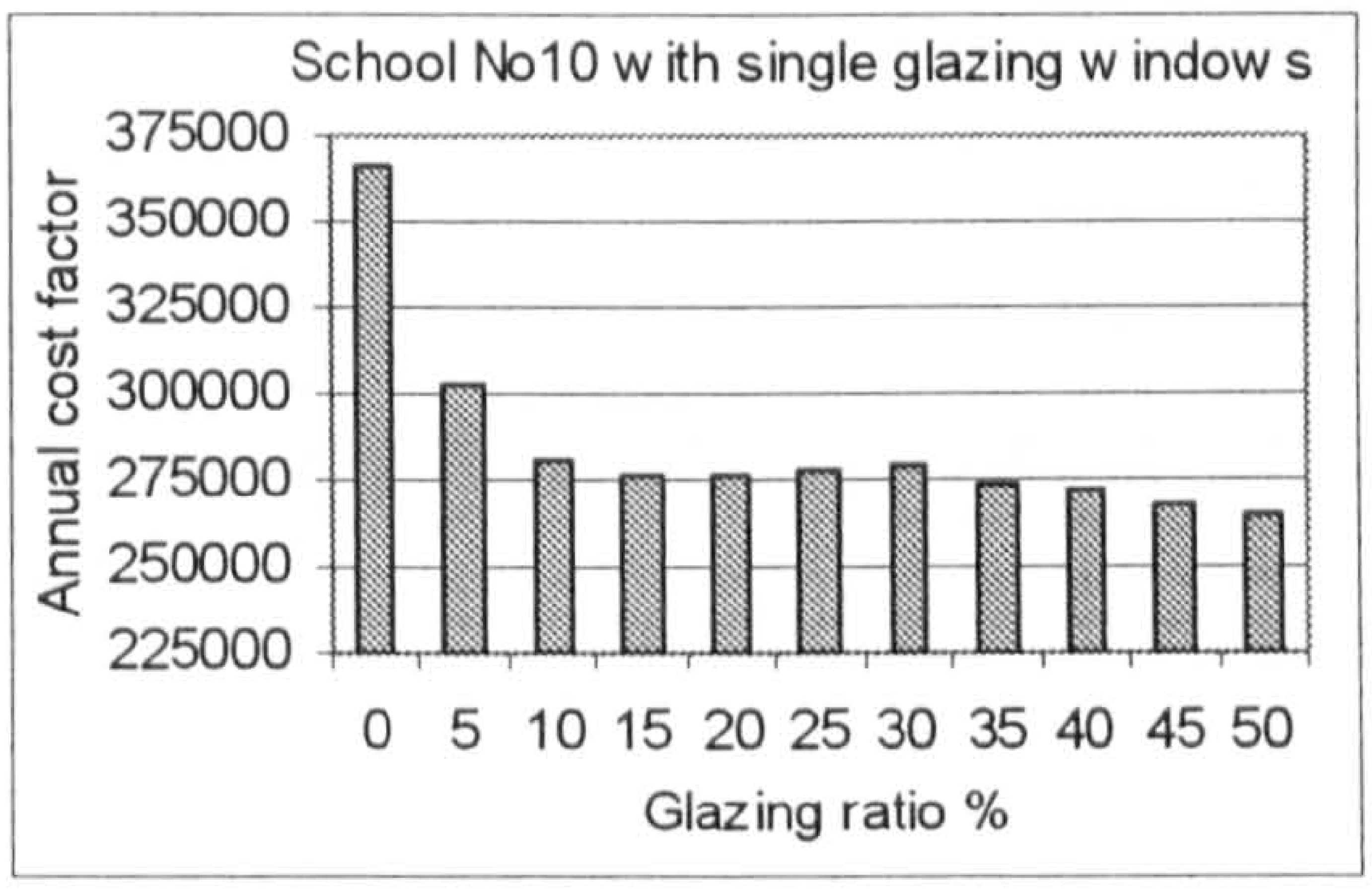
Table 8.34: The best glazing ratio of four cardinal orientations

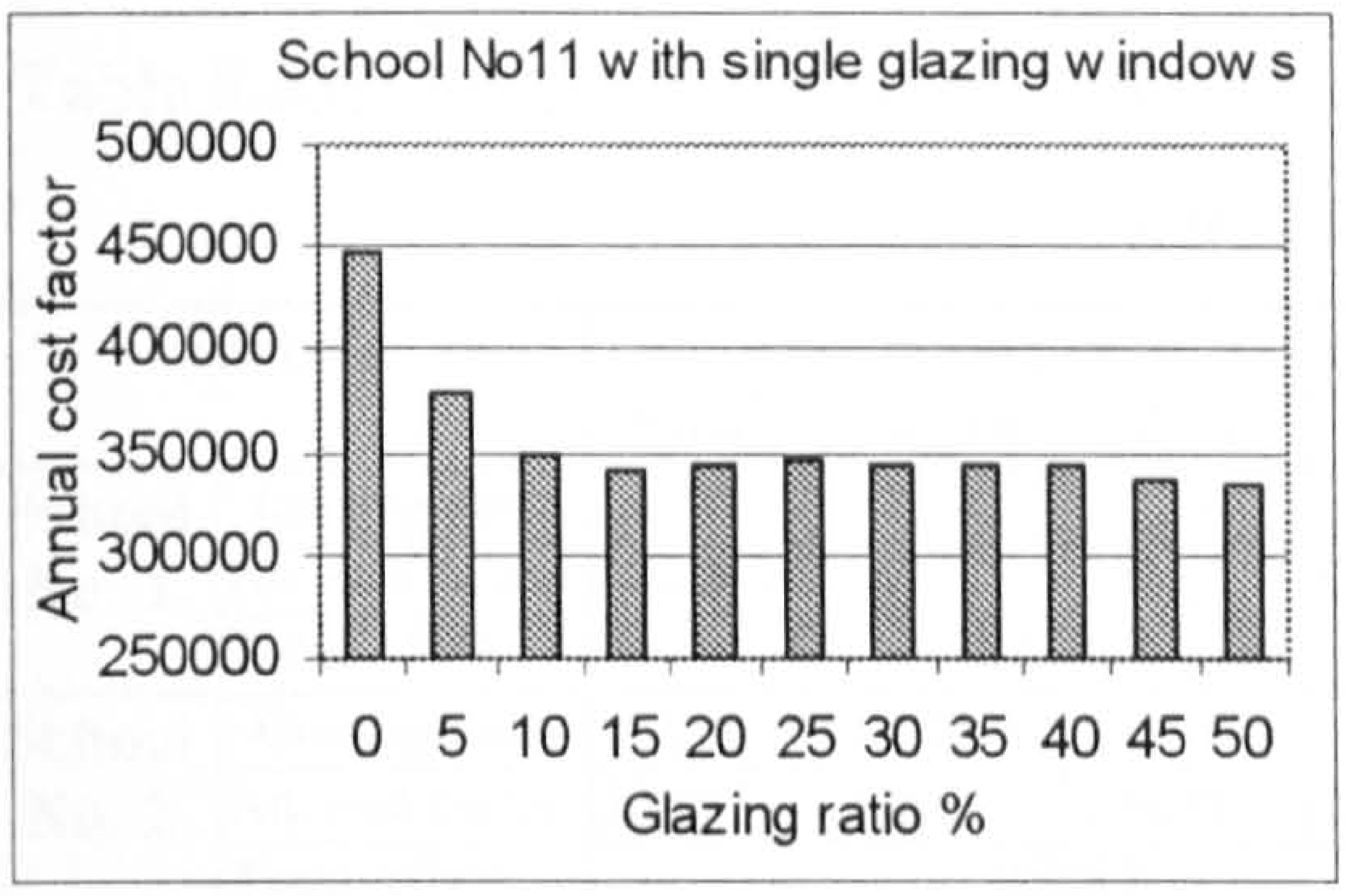
Schools	The best glazing ratio %			
	North	South	West	East
School No. 1	50	40	20	50
School No. 2	10	45	20	50
School No. 3	50	45	50	50
School No. 4	50	20	10	50
School No. 5	50	20	50	50
School No. 6	15	15	10	50
School No. 7	50	15	10	50
School No. 8	15	20	10	50
School No. 9	50	20	20	50
School No. 10	50	15	50	25
School No. 11	50	15	50	50
School No. 12	50	50	50	50
School No. 13	50	15	5	10

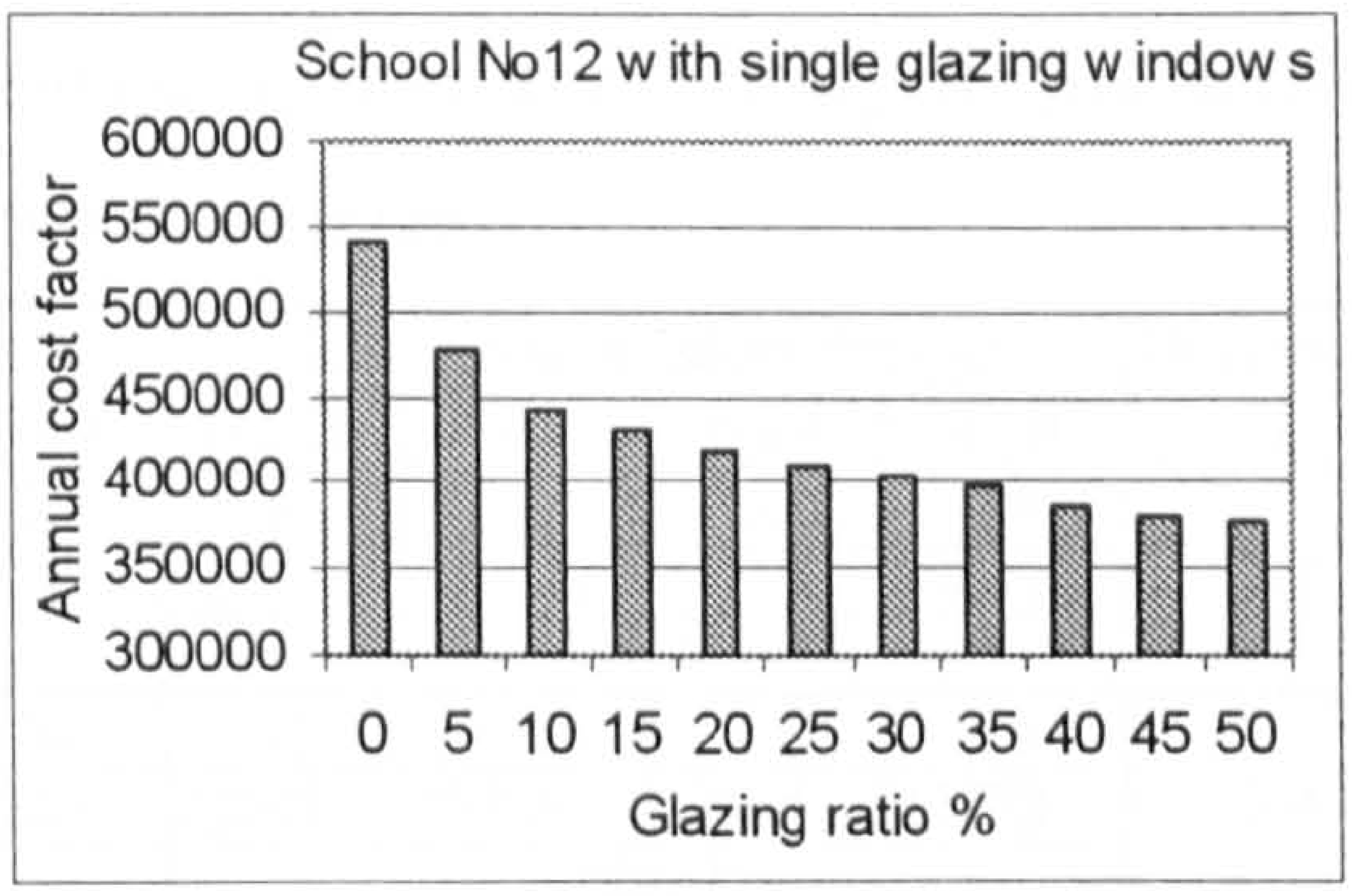
Figures 8.96: The calculated annual energy consumption by different glazing ratio

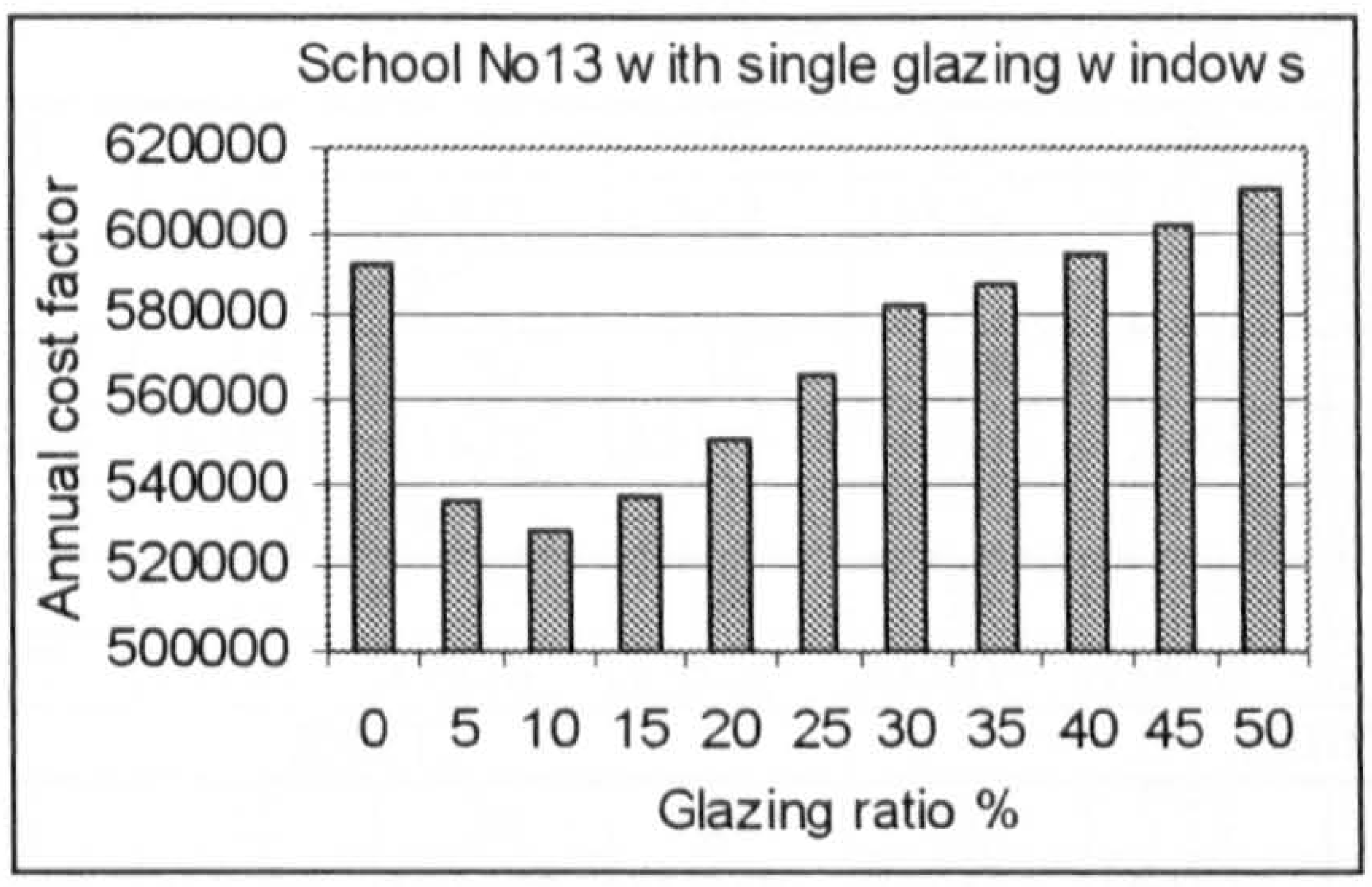












The existing window design is compared with suggested window design. As it can be seen from table 8.35 and figure 8.97 the energy requirements will decrease by a minimum of 2.1% in school No. 4, maximum 9.1% in school No. 9 and average 5%.

By modifying the type of glazing of windows (i.e. from single glazing to double glazing) the consumption of energy will decrease by a minimum of 1.6% and a maximum of 8.6% in school No. 13 and school No. 12 respectively and average will be 4.5%.

By applying thermal insulation in envelope components (i.e., walls & ceilings) of a building, the consumption of energy will be reduced by 11% (Eslami, 1987).

According to the results of this case study, if a suitable window design is selected in existing schools, the cost of energy consumption of 12521 new school buildings (by adding 5% to 4.5% and then multiplying to 133,210 which is the total number of schools in Iran) can be provided by the substantial savings in the annual running costs.

By conclusion, substantial savings in the annual running cost of school buildings can be achieved under the new design strategy.

Table 8.35: Comparison annual cost of energy use in cases with existing window design and suggested window design

Schools		Existing window design				Suggested window design				Difference
		North	South	West	East	North	South	West	East	%
School No. 1	Glazing ratio	30	50	25	25	50	40	20	50	-3.7
	An. cost factor	340767	157017	75523	82075	329675	155761	74953	70699	
	Total ACF*	655382				631088				
School No. 2	Glazing ratio	25	30	10	10	10	45	20	50	-3.4
	An. cost factor	32687	34894	13477	14223	32292	33799	13164	12772	
	Total ACF*	95281				92027				
School No. 3	Glazing ratio	35	35	15	20	50	45	50	50	-4.4
	An. cost factor	91545	83860	90810	81676	88481	83976	87845	72127	
	Total ACF*	347891				332429				
School No. 4	Glazing ratio	15	25	10	30	50	20	10	50	-2.1
	An. cost factor	45171	61384	28547	27825	43379	60507	28547	27006	
	Total ACF*	162927				159439				
School No. 5	Glazing ratio	35	45	10	10	50	20	50	50	-6.5
	An. cost factor	136047	142675	41632	35449	128440	129445	41320	33509	
	Total ACF*	355803				332714				
School No. 6	Glazing ratio	20	25	20	20	15	15	10	50	-2.8
	An. cost factor	69287	74494	29358	33678	68559	72432	28016	32003	
	Total ACF*	206817				201010				
School No. 7	Glazing ratio	35	45	20	20	50	15	10	50	-7.5
	An. cost factor	262658	219026	161078	157929	251427	194512	151317	143187	
	Total ACF*	800691				740443				
School No. 8	Glazing ratio	30	50	25	25	15	20	10	50	-9.0
	An. cost factor	50700	74857	83159	82715	49170	66475	76130	73383	
	Total ACF*	291431				265158				
School No. 9	Glazing ratio	35	40	15	20	50	20	20	50	-9.1
	An. cost factor	143833	105616	108367	99964	128468	102242	105997	79431	
	Total ACF*	457780				416138				
School No. 10	Glazing ratio	30	40	10	10	50	15	50	25	-8.6
	An. cost factor	79785	87265	60484	54617	70620	82929	58832	45393	
	Total ACF*	282151				257774				
School No. 11	Glazing ratio	50	50	5	5	50	15	50	50	-8.2
	An. cost factor	114574	142657	48901	42260	114574	127308	43263	34631	
	Total ACF*	348392				319776				
School No. 12	Glazing ratio	50	50	20	20	50	50	50	50	-3.4
	An. cost factor	127492	118855	71421	71664	127492	118855	65384	64374	
	Total ACF*	389432				376105				
School No. 13	Glazing ratio	20	25	20	20	50	15	5	10	-6.0
	An. cost factor	124654	142661	143390	144011	120468	134657	132483	134035	
	Total ACF*	554716				521643				

ACF = Annual Cost Factor

Figure 8.97: Comparison of energy use in cases with existing and suggested window design

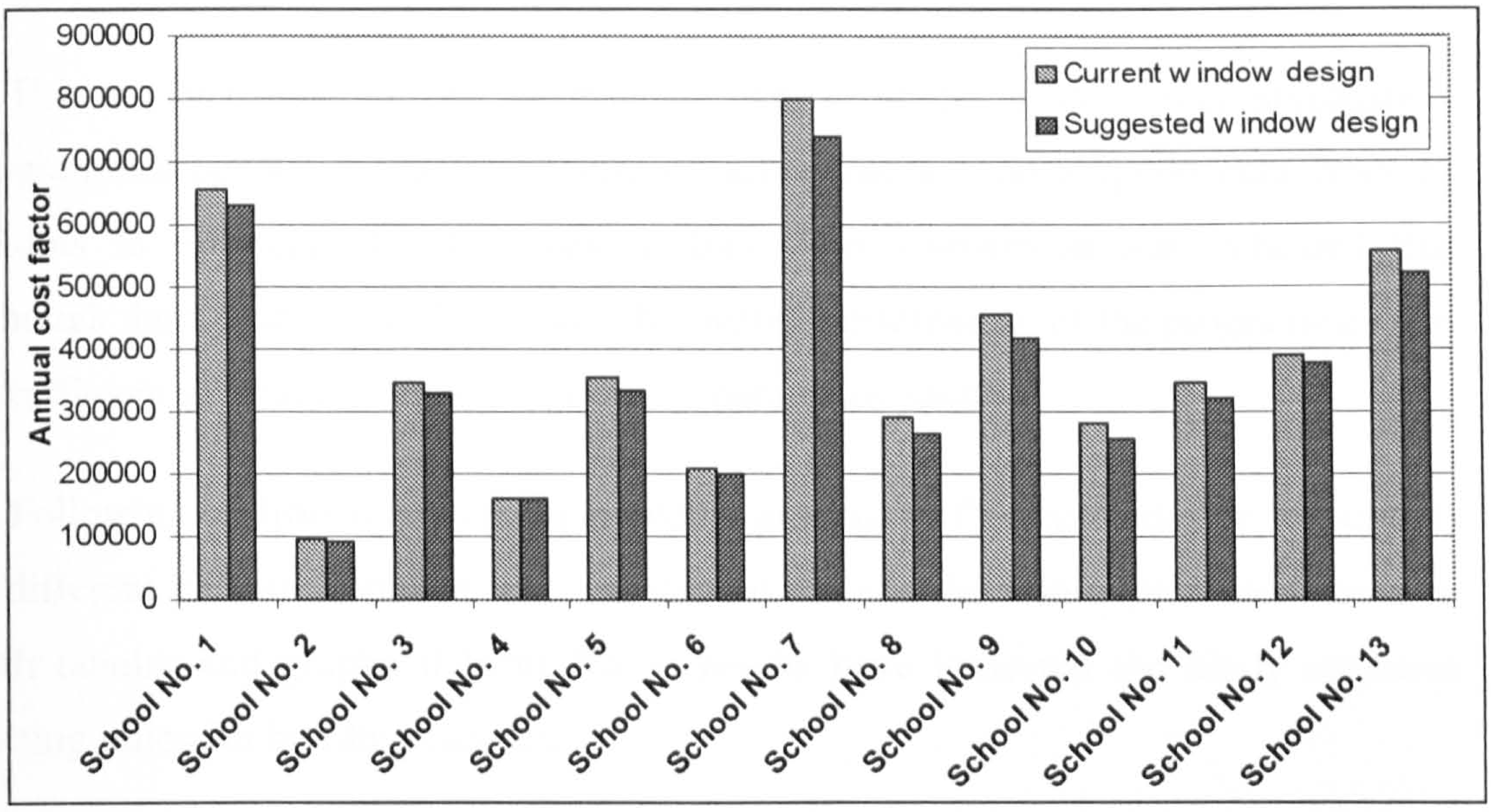
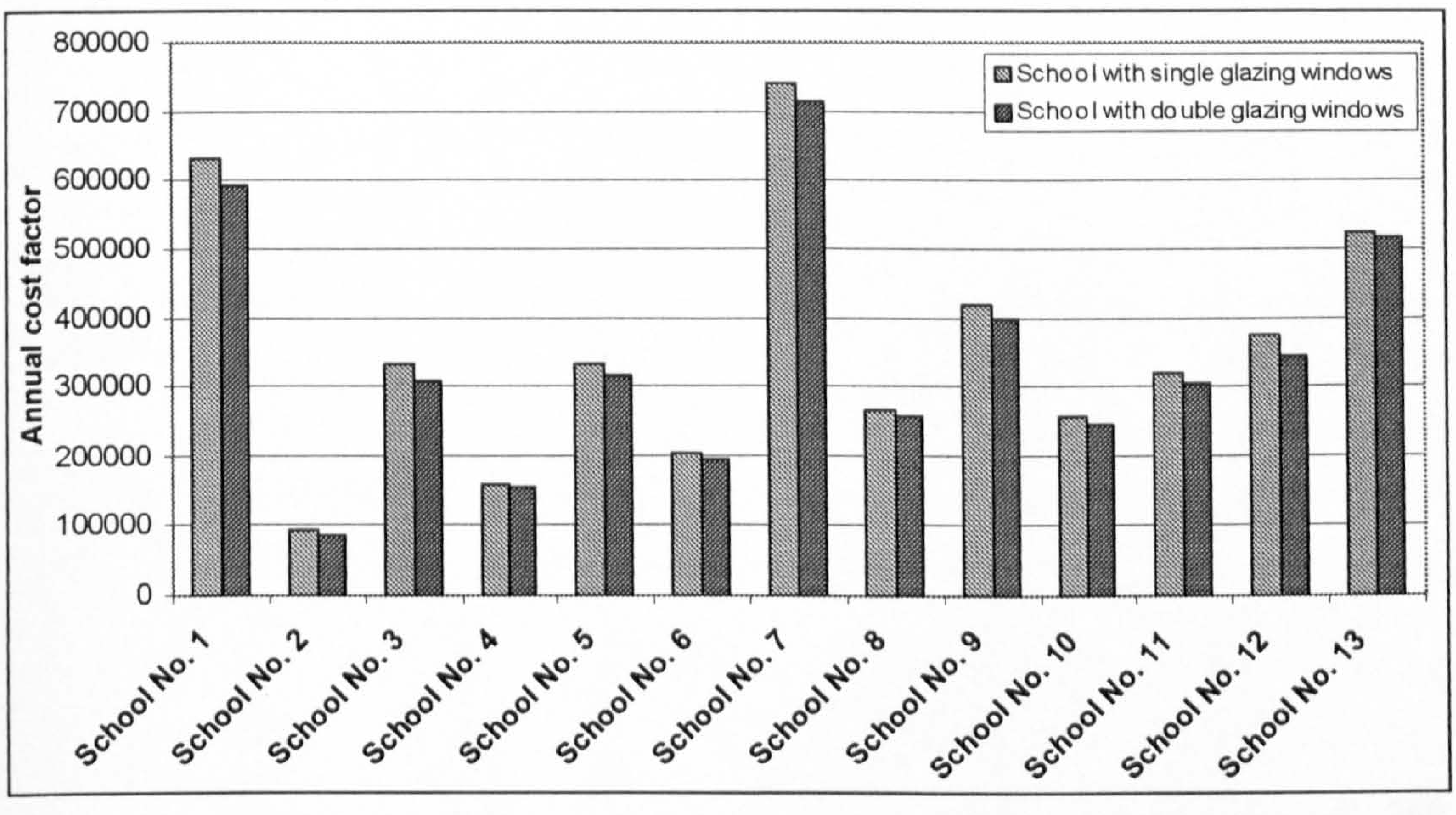


Table 8.36: Comparison of energy use in cases with single and double-glazing windows

	School with single glazing windows	School with double glazing windows	Different
	Annual cost factor	Annual cost factor	%
School No. 1	631088	593005.24	-6.0
School No. 2	92027	87400.09	-5.0
School No. 3	332429	309507.62	-6.9
School No. 4	159439	155259.19	-2.6
School No. 5	332714	317963.24	-4.4
School No. 6	201010	196177.74	-2.4
School No. 7	740443	714830.34	-3.5
School No. 8	265158	257822.08	-2.8
School No. 9	416138	397238.58	-4.5
School No. 10	257774	245305.78	-4.8
School No. 11	319776	305460.15	-4.5
School No. 12	376105	343724.28	-8.6
School No. 13	521643	513516.2	-1.6

Figure 8.98: Comparison of energy use in cases with single and double-glazing windows



8_{10} * Summary

This chapter has set out to evaluate the accuracy of the excel spreadsheet programmes against a limited amount of actual energy consumption data from 13 schools in different climate zones in Iran. This comparison has indicated that although there were some differences the overall performance of the programmes was of sufficient accuracy to justify their use in parametric studies.

Following on from this work a parametric analysis of the façade design for schools in different climatic zones in Iran was carried out and the results presented above in both tabular and graphical form. These results have indicated the likely optimum glazing ratios for building facades.

The value of this work was to enable an understanding of the role which façade design plays in the optimisation of the façade design of school buildings in Iran and as an introduction to the development of a new Design Code for both better energy efficiency and space planning.

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Chapter 9

Conclusion

9 * Conclusion

9_1 * Conclusion

The amount of solar radiation in Iran is great enough to meet a part of our heating and lighting needs in school buildings. Many different technologies can be used to convert sunlight into useful forms of energy. The best time to incorporate passive solar technologies in a building is during the initial design. Passive solar features if properly used can provide an energy saving of up to 40%. Therefore it is one of the least expensive and most environmentally friendly methods of providing our energy needs. Because of their form and use (mostly during daytime), new school buildings represent the most favourable category of non-domestic buildings in which passive solar design techniques could be employed to pursue energy efficiency.

This work has investigated several aspects of school design in Iran, including the need to have a more accurate model of solar radiation.

- The work carried out by the author was:

1- Because there is little actual information on the amount of solar radiation available in Iran a new and tested model for the prediction of solar radiation on any surface anywhere in Iran was developed from first principals.

2- The development of an excel based spreadsheet thermal admittance model which uses solar radiation data (developed in conclusion 1) to calculate the energy performance of a school design.

3- The development of an excel based daylight model which used solar radiation data from solar radiation programme (designed in chapter 4) to calculate the lighting requirements in school building.

4- Using the models (2 and 3) testing them against actual schools in Iran to determine their accuracy. These tests indicated that the models were of sufficient accuracy to allow them to be used for parametric studies.

- **Conclusions drawn from the work outlined above:**

The main conclusions, which can be drawn from this work, are:

According to the results of solar radiation computation in Iranian cities and the separate excel sheet programme, the passive solar features considered in the design of school buildings are the absorption and transmission of solar radiation through walls and windows and the use of sunlight for daylighting. A parametric study of the energy performance of a suggested model on fenestration design in hot climate of Iran was carried out. The Excel computer programme was used to analyse the variations in heating, cooling and lighting loads due to changes in orientation, size and shading of windows. The results were that a substantial saving in the annual running cost of school buildings as much as 14% could be achieved under appropriate glazing ratios. From the studies carried out the best glazing ratios were found to be as follows:

I. West facing windows is 10%.

II. For the six different climate zones are:

Table 9.1: The best glazing ratio in six different cities of Iran

Cities	Best Glazing Ratio %				
	North	South	West	East	Roof
Ghazvin	50	40	10	50	10
Ghom	50	20	10	50	5
Yazd	45	15	10	50	5
Babolsar	50	20	10	50	5
Ardebil	10	50	50	50	20
Bandar-Abbas	45	15	10	10	5

It can also be concluded that in hot humid climate regions of Iran it is necessary to consider the application of shading in the school design and in hot dry climate regions to consider other solutions such as verandas, colonnades and small enclosed courtyards, in order to obtain the maximum amount of shade and coolness. Therefore, these results may encourage the adoption of passive solar measures in future school design in Iran.

It can be concluded from the effect of roof design on the thermal performance of school building that roofs in the hot and humid climate region (especially in the climate zone 8 in chapter 2) should be finished in light colours, particularly when the insulating materials are incorporated in their construction. The most effective method is to construct a second roof over the first.

A case study was performed on 13 schools in different climatic regions of Iran in order to explore the problems of current design from the energy point of view. The results of this study can be used in a new energy efficient design of school buildings in the future. The disadvantages of current design are as follow:

a - The standard of educational spaces has not been observed in the design of school buildings.

b - The type of windows is single glazed and the glazing ratio is high.

c - No thermal insulation has been installed in walls and roofs.

After selecting the appropriate glazing ratio in the case studies the energy requirements decreased by up to 9.1%. Also, by replacing existing windows (not optimised) by double-glazed windows the energy consumption was decreased by up to 8.6%.

It can also be concluded that:

1- The south facing glazing ratio should be increased to 50% in cold climatic regions and to 15% in hot climate.

2- With the aim of reducing the energy used for cooling in the warm season in warm humid climates specially in south of Iran designers must ensure that the windows are shaded in the mid period of the day (10:00 – 14:00 hrs). It is also recognised that in hot humid and hot dry climates that to promote natural ventilation high ceilings are helpful as they allow warm air to rise above head height and also provide sufficient buoyancy forces to move the air.

3- With the aim of reducing the energy used for lighting, the glazing ratio of the roof should be at least 5%. Care should be taken in providing roof lighting as the strong sun could result in an increased cooling requirement or an increase on thermal discomfort. Roof lights, which do not face south, should therefore be considered. This means designers must only use diffuse lighting in the roof in hot and hot dry climate.

4- Daylighting strategies in the hot dry climates in Iran must consider the sunlight reflected from adjacent roofs and building surfaces as this is an important component of sky lighting (see figure 9.1) and properly designed skylighting devices can function as windcatchers (Badgir) and/or vents for convective air currents (see figure 9.2).

Figure 9.1: Sun reflects

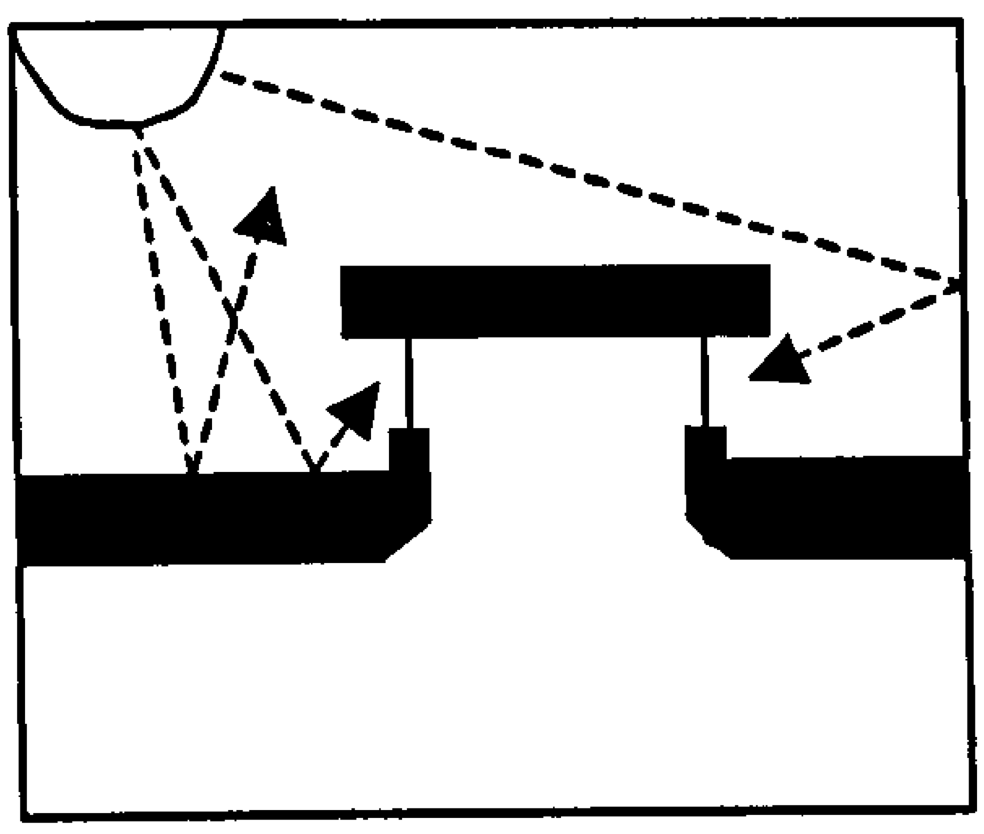
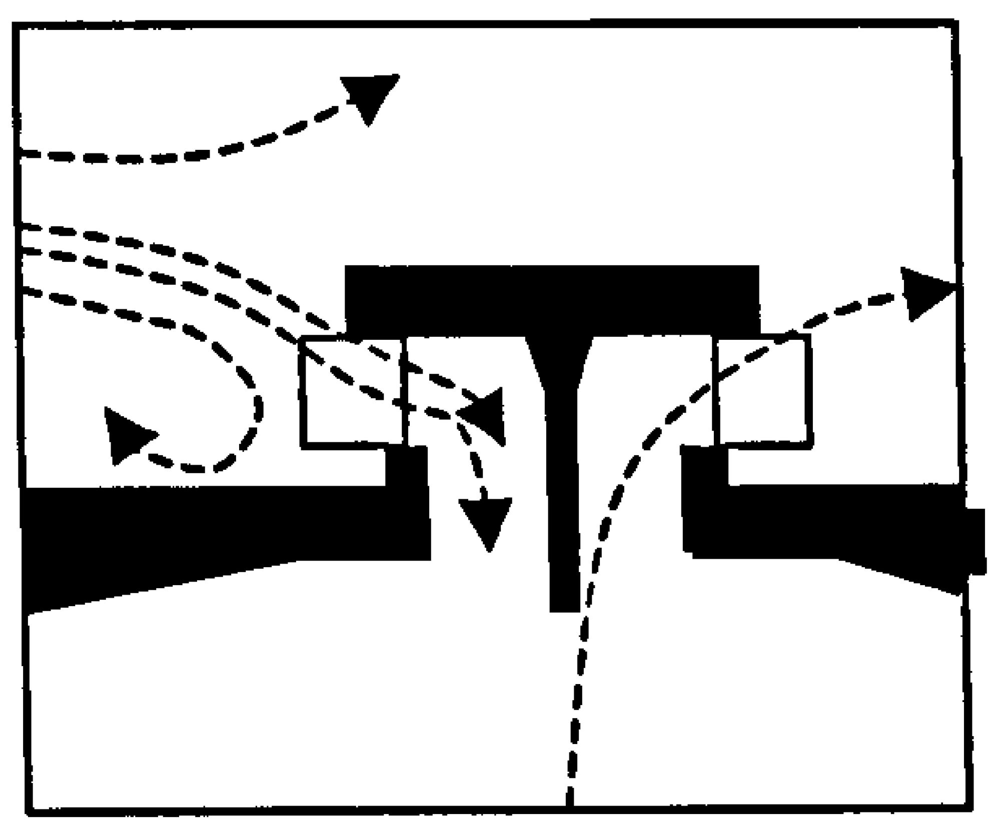


Figure 9.2: Windcatcher as a ventilator



9_2 * Discussion

The study of present school buildings in Iran indicates that these buildings in most climates are neither energy efficient nor can they provide the desired physical comfort. The results of this study performed on different climatic regions in Iran and the consequences of solar radiation computation in most cities showed that solar energy can make a very useful contribution to the heating and lighting of school buildings. Furthermore, solar radiation is abundant in most climatic regions of Iran, as a cheap and clean source of energy and its effective application will help in reducing the consumption of fossil fuels, saving energy and conserving it for future generations. Also, its impact on reducing the air pollution, which is a great problem in Iran, should not be underestimated.

The case study performed on the energy consumption of 13 schools in different climatic regions of Iran showed that thermal insulation and window type (double glazing windows with appropriate glazing ratio), if properly used and designed, can result in substantial savings in the annual running cost of school buildings and considerable reduction in the consumption of fossil fuels.

In the investigation of the effect of roof design on the thermal performance of buildings a reference school located in hot climate in Iran was studied and concluded that in hot humid climates the roofs should be finished in light colours (for example in Bandar-abbas) and a roof with more shade like a Dome form in the hot dry climate (for example in Yazd). Also, the thermal resistance of roofs have important impact on their surface temperatures.

We can design passive solar schools to reduce the energy requirements for heating only in the cold climate regions in Iran, Although some problems may arise with the passive solar designed schools such as glare from the direct sun, overheating in summer and excessive heat loss in winter, these schools need cost no more than ordinary schools. Other benefits are the availability of extra usable place, improvement in the amenity value and reduction of energy consumption in school buildings. However in a hot dry climate such as Yazd, other solution such as verandaz and colonnades should be considered. These solutions will promote more ventilation Thus lowering the temperature of the building surfaces, which results in a reduction in the radiant heat emission from the surfaces. A lower radiant temperature will aid in the reduction in the cooling energy requirement. Other ways are to use small-enclosed courtyards with a water pool in order to the maximum the amount of shade and coolness from the evaporation of the water.

The design features of passive solar schools in the developed countries with similar climates (such as the UK) are very useful in suggesting a general guideline for energy efficient school design in the cold climate regions in Iran. Such features include the use of passive cooling/ heating by the use of thermal mass, the use of atrium spaces to provide passive heating and daylight penetration. School building design is influenced by the prevalent climate, social factors, philosophy of education and technical advances in construction techniques and materials. Unfortunately in

Iran and many other developing countries the relationship between educationalists, architects and those engaged in educational activities is relatively absent, which obstructs the mechanism of school building innovation. Therefore, firstly a strong relationship has to be built between different people engaged in educational activities in Iran. Concerning to the progressive need in providing new school building in Iran, and in order to solve the problem of providing the cost of energy use for heating, lighting and cooling of current school building, the application of advanced technologies for the improvement of energy performance of school building is now necessary. By using the experiences of developed countries and the transmission of their technologies in the design and construction of energy efficient buildings, the quality of the internal environment i.e. lighting, heating, ventilation and energy consumption could be improved and be brought to the required standards in Iran.

Solar energy usage can be improved by incorporating passive solar features like atria and conservatories. Therefore, it is necessary to consider these concepts in the new design of energy efficient school building specially in the cold climate regions in Iran.

Generally, we have to realise that for providing a rational and energy efficient school design in Iran a balance between educational, economical, environmental and social needs should be considered in the design process. Flexibility and adaptability are also crucial in this design.

9_3 * Recommendations

An important incentive to the use of daylight in buildings is the need to reduce the energy costs of lighting. In school buildings the electricity used by lighting can be a significant proportion of the total energy use. When daylight is planned from early design stages of a building, there can be a large saving in its lifetime use of energy.

But daylighting is not free. Large areas of glazing can cause unacceptable heat gain and loss through the building fabric and can also increase both construction costs and maintenance costs.

The following guidelines are useful to the designer:

1- The optimum use of daylighting for energy saving in large school buildings usually comes with a combination of well-controlled electric lighting during daytime hours and windows of optimum size. Costs tend to increase when windows are either very big or very small, or when ceilings are very high.

2- Daylighting must be assessed in the early design stages in conjunction with the thermal performance of the building.

3- Electric lighting to be used during daytime hours must be designed in conjunction with the windows, considering both the layout of luminaries and the electric lighting control system.

The effectiveness of any energy-saving programme depends crucially on the management of the building on all staff and teachers having the knowledge and motivation to avoid unnecessary energy use. This applies not only to staff and teachers occupying the building during normal working hours but also to maintenance and cleaning personnel who may work early in the morning or during the evening.

The flow of thermal energy through the windows of a building can be greater than through any other part of the external cladding. When in winter the exterior air temperature is low there can be significant heat loss. When direct sunlight falls on a window, there can be rapid heat gain.

Natural ventilation is an important function of windows in a designed to minimise energy use, In most cases the requirements of window location for air movement are compatible with the requirements of good daylight distribution, but conflicts can arise when users attempt to screen windows to reduce sunlight or glare in hot weather.

Decisions about the form of windows for good lighting are inseparable from other requirements of environmental control. These can determine the basic form of the buildings, its orientation and its mass; they also affect window size, the use of shading devices and the choice of glazing. Daylighting cannot be considered in isolation; its quality and integration with the thermal and acoustic environment are determined above all by decisions made in the early design stages of a building.

9_4 * Further Study and Research

Work in this area may be expanded in a number of different ways. Some suggestions for further research emerge from this study.

♦ The focus of this study was on school buildings. The extension of the study for developing standards and suggesting guidelines for other types of buildings (residential, industrial and commercial) are also important. Parameters such as building operating conditions, window types, building operating hours and sometimes construction systems are different for these types of buildings.

♦ In this study the energy use of heating, cooling and lighting of designed models with different glazing ratio was calculated in only six climatic subgroups (out of 32 subgroups) of Iran. Therefore, further research is needed in all climatic subgroups of Iran in order to provide a general and perfect guideline in this area of work.

♦ In this research a dynamic excel sheet program was designed for calculation of solar radiation in all cities of Iran. It is important to complete this work i.e., providing a general program for the calculation of solar radiation in Iran.

♦ Further development of the LT method as an energy design tool to provides an output of annual primary energy for lighting, heating, cooling and ventilation

♦ More detailed studies into daylighting as a means of offsetting fossil fuel consumption.

♦ More detailed studies into the effects of thermal insulation on the energy performance of buildings.

Glossary, Abbreviation and Symbol

GLOSSARY:

Absorptance The ratio of radiation absorbed at a surface to the radiation on that surface. The absorptance varies with radiation wavelength and angle of incidence.

Absorption Transformation of radiant energy to a different form of energy by the intervention of matter

Access A route such as a road that allows people or goods to reach a destination

Air Changes Per Hour (ac/h), Number of times in an hour a volume of air equal to the volume of a room or building is renewed with outside air.

Air Leakage The uncontrolled flow of air through the building envelope.

Air Mass Number A measure of the path length of sunlight through the atmosphere: expressed in comparison with unit path length where the sun is directly overhead: used to define the intensity and spectral distribution of sunlight.

Altitude Angle The angular height of a point above the horizon.

Astronomical Day Length Astronomical day length is the time during which the centre of the solar disc is above an altitude of zero degrees (without any allowance for atmospheric refraction).

Atmosphere A mixture of gases surrounding the Earth. Earth's atmosphere consists of 79.1% nitrogen (by volume), 20.9% oxygen and 0.03% carbon dioxide and trace amounts of other gases. It can be divided into number of layers according to thermal properties (temperature). The layer nearest the earth is the troposphere (up to about 10-15 km above the surface), next is the stratosphere (up to about 50 km) followed by the mesosphere (up to 80-90 km) and finally the thermosphere or ionosphere which extends into space. There is little mixing of gasses between layers.

Atrium Partially open-roofed courtyard.

Average Daylight Factor The process, which takes place as the human visual system adjusts itself to the brightness or the colour of the visual field.

Axis Imaginary straight line around which symmetry can be established, or objects in respect with each other can be interrelated.

Azimuth Angle The angular distance between true south and a point on the horizontal plane: negative to the east, positive to the west.

Barrel of Oil A common unit of capacity for petroleum and its products. 1 barrel (bbl) = 158.987 Litres = 42 US gallons.

Base Temperature A temperature datum taken as a base for the calculation of heating degree days; for example, the setting on the main thermostat controlling the heating appliances, or a volume-weighted mean whole-house temperature; or the balance point temperature.

Biofuels Nonfossil biomass energy source and biomass-derived fuels, which together encompass all energy sources from recent-term organic (plant and animal) matter.

Biomass The living weight of an animal or plant population: more generally, plant and tree material on the earth's surface. Carbon dioxide is a bi-product of Biomass burning.

Clear Sky In any month, the sky conditions producing the mean maximum daily global radiation on a horizontal surface.

Climate System The Earth's climate is determined by the interactive behaviour of the atmosphere, the oceans, the biosphere, the cryosphere and the geosphere, which all make up the climate system.

Climate The prevalent long term weather conditions in a particular area.

Climatology Climatology, like meteorology, is a science of the atmosphere. Meteorology is primarily concerned with atmospheric process; climatology deals chiefly with the results of those processes.

Comfort Zone The range of values of the environmental variables, sometimes expressed in the form of a temperature equivalent, the combined effect of which is perceived as comfortable or acceptable.

Condensation The deposition of moisture held by the air in a room onto an internal surface. This occurs when the temperature of a surface is below saturation point relative to the water vapour content of the air, i.e. too low to hold the moisture in vapour form.

Conduction Mode of heat transfers within or between materials at different temperature involving transmission of kinetic energy at molecule level; the rate of heat transfer depends on the thermal conductivity.

Contrast Subjectively this term describes the difference in appearance of two parts of a visual field seen simultaneously or successively. The difference may be one of brightness or colour or both.

Convection Mode of heat transfer in fluids (air or water) or between a surface and adjacent fluid due to difference in temperature.

Cryosphere That part of the earth's surface consisting of ice masses and snow deposits.

Day Angle (J') The day angle J' expresses the day number J as an angle from 1200 hours on the 31st December. A year length of 365.25 days is used.

Day Number (J) The day number J represents the number of days which have elapsed since the beginning of a year. For example, 1st January has J=1 whilst 1st February has J = 31 + 1 = 32. A year is normally

	taken as 365 days (i.e. not a leap year with 366 days) for solar calculations
Daylight	The light from the sun and sky.
Daylight Factor	The illuminance received at a point indoors, from a sky of known or assumed luminance distribution, expressed as a percentage of the horizontal illuminance outdoors from an unobstructed hemisphere of the same sky.
Diffuse Radiation	Solar radiation scattered by the atmosphere.
Direct Glare	Glare caused when excessively bright parts of the visual field are seen directly, e.g., lamps which are inadequately shielded.
Direct Radiation	Solar radiation transmitted directly through the atmosphere. For an opaque: surface + reflectance=1 For glazing: absorptance+ reflectance+ transmittance=1
Energy Consumption	The gross input of all commercial forms of primary energy at a given time. The use of energy as a source of heat or power, or as an input in the manufacturing process.
Energy Efficiency	The ratio of the desired energy conversion actually obtained and the theoretical maximum of desired energy conversion given the same energy input.
Energy Resources	Global aggregate of energy-bearing non-renewable minerals and renewable energy forms (such as solar energy).
Energy Source	A substance, such as petroleum, natural gas, or coal that supplies heat or power. Generally, electricity and renewable forms of energy, such as biomass, geothermal, wind, and solar, are considered to be energy sources.
Energy Supply	The net output of all commercial forms of primary energy at a given time.
Environment	The sum of all external conditions, both natural and artificial, affecting the life, development and survival of an organism or system.
Fossil Fuel	Any hydrocarbon deposit that can be burned for heat or power such as coal, oil or natural gas.
Geosphere	The soils, sediments and rock layers of the Earth's crust, both continental and beneath the ocean floors.
Geothermal Energy	The thermal energy transferred to water or steam from molten underground rock.
Glare	The discomfort or impairment of vision experienced when parts of the visual field are excessively bright in relation to the general surroundings.

Global Irradiance The total irradiance (sunlight intensity) falling on a surface: the sum of the direct and diffuse irradiance

Global Warming A theory that increased concentrations of greenhouse gases are causing an elevation in the Earth's surface temperature. See also greenhouse gases.

Greenhouse Effect A term used to describe the effect where greenhouse gases trap re-emitted infrared radiation, so heating up the atmosphere. This is a natural phenomenon and increases the Earth's average surface temperature from -18^{oC} (the effective radiation temperature) to $+15^{oC}$.

Greenhouse Gases These include water vapour, carbon dioxide, tropospheric ozone, nitrous oxide, methane and other lesser gases. They allow short-wave ultra-violet (UV) radiation to pass through unimpeded but trap long wave infrared radiation re-emitted from the Earth. Water vapour is the most important greenhouse gas but it is thought that concentrations in the atmosphere are being little affected by human activity. This is not the case with carbon dioxide, methane and nitrous oxide where human activity is leading to increased levels of these gases in the atmosphere and enhancing the natural greenhouse effect.

Heating Load (KWh) The amount of useful heat required to maintain spaces in a building at their design temperatures over a given period.

Illuminance The luminous flux density at a surface, i.e., the luminous flux incident per unit area (lumens per square metre (lm/m^2) or lux).

Illumination The process of lighting an object or surface.

Insolation Radiant energy from the sun that strikes the earth.

Internal Heat Gains (KWh) Heat generated inside a building by occupant activities (body heat, household appliances, artificial lighting).

Irradiance The intensity of solar radiation on a surface (w/m^2).

Irradiation The amount of solar energy received on a surface (KWh/m^2)

Kilowatt (KW) Unit of power equal to 1000W.

Kilowatt-hour (KWh) Unit of power equal to 1000Wh.

Latitude The angular distance north or south of the equator.

Load Any device or appliance (or set of devices or appliances), which is using electrical power.

Local Restricted to a nearby area.

Location Where a settlement is situated.

Long-wave Radiation	Radiation emitted between 5 and 30 μm wavelength; for example, the radiation emitted from surfaces in a room, or from the outside surfaces of external building elements.
Luminaire	An apparatus which controls the distribution of light given by a lamp or lamps and which includes all the components necessary for fixing and protecting the lamps and for connecting them to the supply circuit. Luminaires has superseded the term lighting fitting.
Luminance	The physical measure of the stimulus, which produces the sensation of brightness, measured by the luminous intensity of the light emitted or reflected in a given direction from a surface element in the same direction. The SI unit of luminance is the candela per square metre (cd/m^2).
Lux (lx)	Illuminance produced on a surface of unit area by a unit of luminous flux of 1 lumen uniformly distributed over the surface.
Megawatt (MW)	Unit of energy equal to 1,000,000W.
Megawatt-hour (MWh)	Unit of energy equal to 1,000,000Wh.
Meteorology	The science of weather-related phenomena (vid. Climatology).
Paleoclimatology	The study of climate and climate change during the geological past.
Photovoltaics (PV) Cell	Semiconductor device that converts light to electricity using the photovoltaic effect.
Primary Energy (KWh)	The total amount of energy drawn from primary source (oilfield, coalmine, etc.) to extract, process, transport and distribute the fuels used for domestic and other purposes; it is a quantity that is higher than the calorific value of those fuels (delivered energy) by an amount representing the energy cost of extraction, processing, transportation and distribution of fuels.
Radiation	Energy emitted in the form of electromagnetic waves. Radiation has differing characteristics depending upon the wavelength. Radiation from the Sun has a short wavelength (Ultra-violet) whilst energy re-radiated from the Earth's surface and the atmosphere has a long wavelength (infra-red).
Reflectance	The ratio of the luminous flux reflected from a surface to the luminous flux incident on it.
Relative Humidity	The mass of vapour contained by air at a given temperature expressed as a percentage of the mass of vapour that would cause saturation at the same temperature.
Renewable Energy	Energy obtained from sources that are essentially inexhaustible. Includes wood, waste, geothermal, wind, photovoltaic and solar thermal energy.
Rural	Belonging to the countryside rather than the city.

Settlement Any permanent place of residence of people.

Site The actual piece of land where a settlement is situated.

Solar Altitude (degrees) Solar Altitude is the Angle Between the Centre of the Solar Disc and the Horizontal Plane

Solar Collector Equipment that actively concentrates thermal energy from the sun. The energy is usually used for space heating, for water heating, or for heating swimming pools. Either air or liquid is the working fluid.

Solar Declination (degrees) Solar declination is the angle between the sun's rays and the earth's equatorial plane. Declination values are positive when the sun is north of the equator (March 21 to September 23) and negative when the sun is south of equator. Maximum and minimum values of δ are $+23^{0}\,27'$ and $-23^{\circ}\,27'$

Solar Energy The radiant energy of the Sun that can be converted into other forms of energy, such as heat or electricity.

Solar Hour Angle (degrees) The solar hour angle ω expresses the time of day in terms of the angle of rotation of the earth about its axis from its solar noon position at a specific place. As the earth rotates 360° about its axis in 24 hours, in one hour the rotation is 15°. By convention the hour angle is negative before noon and positive after noon, i.e. 09.00 LAT represents an hour angle of -45° and 15.00 LAT represents an hour angle of $+45^{\circ}$

Solar-thermal Energy Conversion: Use of impinging solar radiation as a heat source.

Solar Transmission (Or solar transmittance). The ratio of global solar radiation transmitted by a glazing material to the radiation incident on the outside surface of the material.

Station Height Correction (P/P_o) The station height correction is the ratio of mean atmospheric pressure (P) at the elevation of the site to mean atmospheric pressure at sea level (P_o). The ratio (P/P_o) is used to correct the path length to take account of station height.

Surface Azimuth Angle Surface azimuth angle measured from due south in Northern hemisphere and for due north in Southern hemisphere (Easterly values -ve) (Degrees)

Tilt The angle between a surface and the horizontal plane.

Transmittance The ratio of luminous flux transmitted by a material to the incident luminous flux.

Troposphere The lowest layer of the atmosphere. The altitude of the troposphere varies with latitude, from about 16 km at the equator to only 8 km at the poles. Normally there is a decrease in temperature with height. This layer contains 75% of the total gaseous mass of the atmosphere and virtually all the water vapour and aerosols. This

	zone is responsible for most of the weather phenomena experienced and where atmospheric turbulence is most marked.
Useful Energy (KWh)	The final amount of heat or work for which fuels were used; the actual demand for energy and the purpose for its use. Useful energy is the product of delivered energy by the efficiency of the appliance used for the task.
U-value ($W/m^2.^oC$)	(or thermal transmittance). A thermal conductance that includes the thermal exchanges at surfaces and in cavities; the reciprocal of the sum of the thermal resistances of the constituent layers of a composite element plus the surface resistances at the external and internal surfaces. The U-value decreases with thermal insulation.
Ventilation	The process of supplying fresh air to a space.
Wall Solar Azimuth Angle	The wall solar azimuth angle is the angle between the vertical plane containing the normal to the surface and the vertical plane passing through the centre of the solar disc, i.e. it is the resolved angle on the horizontal plane between the direction of the sun and the normal to the surface. The values lie between -180^o and $+180^o$
Watt (W)	Unit of power.
Watt-hour (Wh)	Unity of energy; one Wh is consumed when one watt of power is used for a period of one hour.
World Meteorological Organisation (WMO):	A specialised UN agency responsible for establishment of meteorological stations and networks, and the monitoring of meteorological observations.
Zone	An area or region, which can be identified by a special feature. A town zone is an area of the town where one particular activity, such as housing or industry, is dominated.

ABBREVIATION:

ACF	Annual Cost Factor
ac/h	Air Changes per Hour
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ATI	The Atmospheric Turbidity Index
BTU	British Thermal Unit
CEC	Commission of the European Communities
C.F.	Correction Factor
CIBSE	Chartered Institution of Building Services Engineers

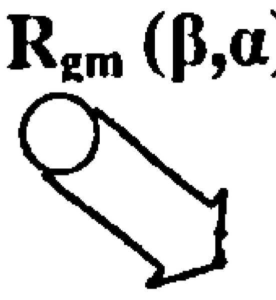
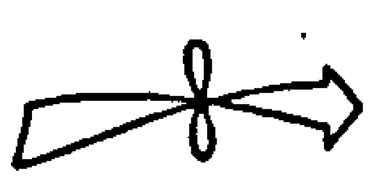
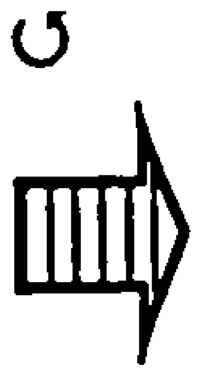
CLASP	Consortium of Local Authorities Special Programme
cm	Centimetre
EEC	European Economy Communities
DES	Department of Education and Science
DFE	Department for Education
DFEE	Department of Education and Employment
EFL	Educational Facilities Laboratories
ET	Equation of Time
ETSU	Energy Technical Support Unit
HMSO	Her Majesty's Stationery Office
IEA	International Energy Agency
ICLEI	International Council for Local Environmental Initiatives
IPCC	Intergovernmental Panel on Climate Change
IRIMO	Islamic Republic of Iran Meteorological Organisation
IRNA	Islamic Republic News Agency (Iran)
ISO	International Standardisation Organisation
KW	Kilowatt
KWh	Kilowatt-hour
LAT	Local Apparent Time
LDCs	The Less Developed Countries
LMT	Local Mean Time
M	Basic Module = 100 mm = 10 cm = 1 dm
m	Metre = 100 cm
m^2	Square Metre
MWh	Megawatt-hour
NAHP	North Atlantic High Pressure
NHBC	National House Building Council
NPI	National Performance Indicator

N.T.P	Normal Temperature and Atmospheric Pressure
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of Petroleum Exporting Countries
PSA	Property Service Agency
PV	Photovoltaic
R&D	Research and Development
RIBA	Royal Institute of British Architects
RNIB	Royal National Institute for the Blind
SCSD	School Construction Systems Development
SH	Size of Teacher
sh	Size of Pupil
SHP	The Siberian High Pressure
SO_2	Sulphur Dioxide
STHP	The Subtropical High Pressure
UN	United Nation
UNCED	The United Nations Conference on Environment and Development
UNEP	The United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
W	Watt
WCED	World Commission for Environment and Development
Wh	Watt-hour
WMO	The World Meteorological Organisation
YMO	Yazd Meteorological Organisation

SYMBOL:

I_O	The Solar Constant = 1367 Wm^{-2}
I_{OJ} (Wm^{-2})	Extraterrestrial Irradiance at Normal Incidence on Day J
J'	Day Angle
J	Day Number

γ	Solar Altitude
ϕ (degrees)	Latitude of the site (N +ve, S -ve)
δ (degrees)	Declination Angle of the Sun with Respect to Earth's Equator
ω (degrees)	Solar Hour Angle
ψ	Solar Azimuth
N_o	Astronomical Day Length
λ (degrees)	Longitude of Site (Positive to the East of Greenwich)
λ_R (degrees)	Reference Longitude of the Time Zone (Positive to the East of Greenwich)
t_r	The Times of Sunrise
t_s	The Times of Sunset
t	Local Apparent Time (LAT)
ν (degrees)	Angle of Incidence of Solar Beam on Surface
β	Inclination of Surface from Horizontal
α_f	Wall Solar Azimuth Angle
α (degrees)	Surface Azimuth Angle
$I_c (\beta,\alpha)$ (Wm^{-2})	Clear Sky Direct Irradiance on a Horizontal or Inclined Surface
I_c (Wm^{-2})	Clear Sky Direct Beam Irradiance Normal to Surface
$\cos\nu (\beta,\alpha)$	Cosine of Angle of Incidence
m	Relative Air Mass
δ_R	Rayleigh Optical Thickness at Given Air Mass
T_L	Linke Turbidity Factor
P/P_o	Altitude Correction to Air Mass
Z	Height Site Above Sea Level
E	Vapour Pressure
t_d	Dew Point Temperature (°F)
F	Fraction of Possible Sunshine in that Particular Hour
F_1	Forward Scattering Correction Factor

R	Reyleigh Optical Thickness at Given Air Mass m
I_c (Wm^{-2})	Direct Beam Irradiance Normal to Surface
q_a^m	Atmospheric Transmittance Coefficient Due to Absorption Only (Per Unit Air Mass)
D_c (Wm^{-2})	Diffuse Irradiance on a Horizontal Surface
${}_bD_c$	Background Diffuse Irradiance one a Horizontal Surface
${}_cD_c$	The Circumsolar Diffuse Irradiance on a Horizontal Surface Fore a Cloudless Day
α'_f	Wall Solar Azimuth Angle (Absolute Value in Degrees, i.e. If $\alpha_f <$ 0° then $\alpha'_f = -\alpha_f$)
K_d	Correction Factor for Sun Earth Distance
N (hours)	Monthly Mean Daily Recorded Bright Sunshine
σ_{4m}	Monthly Mean Relative Sunshine Duration Calculated Using a 4° Horizon for Sunrise
$_{4m}$	Monthly Mean Relative Sunshine Duration on a 4° sunrise basis
D_m (Wm^{-2})	Monthly Mean Diffuse Irradiance on a Horizontal Surface at a Given Solar Altitude
R_g (β,α) (Wm^{-2})	Ground Reflected Irradiance on Inclined Surfaces
I_m (β,α) (Wm^{-2})	Monthly Mean Direct Beam Irradiance on Inclined Plane
D_{ms} (β,α) (Wm^{-2})	Monthly Mean Sky Diffuse Irradiance
R_{gm} (β,α) (Wm^{-2})	Monthly Mean Ground Reflected Irradiance on Inclined Plane
	Solar Radiation Including Both the Components of Short Wave and Long Wave Radiation
	Long Wave Radiation
	Natural Ventilation
	Mechanical Ventilation
	Convection
	Thermal Conduction

Appendix A

The Data of Meteorology Stations & Cities of Iran

Station No.: 1 **Station Type:** Sinoptice **Longitude:** 48° 15' E
Station Name: Abadan **Latitude:** 30° 22' N **Altitude:** 11 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	18.2	20.3	25.6	31.6	38.3	42.6	44.2	43.8	42.3	35.5	26.6	20.0	32.4
T min (C)	7.4	8.6	12.8	17.4	22.9	26.2	27.6	26.6	23.3	18.7	12.9	8.4	17.7
T ave (C)	12.8	14.4	19.2	24.5	30.6	34.4	35.9	35.2	32.8	27.1	19.8	14.2	25.1
T rng (C)	10.8	11.7	12.8	14.2	15.4	16.4	16.6	17.2	19.0	16.8	13.7	11.6	14.7
RHmax (%)	84.0	79.0	71.0	67.0	54.0	43.0	43.0	44.0	55.0	64.0	75.0	82.0	63.4
RHmin (%)	57.0	46.0	35.0	30.0	22.0	16.0	18.0	19.0	20.0	27.0	40.0	53.0	31.9
Rain (mm)	42.7	31.0	21.4	16.8	6.2	0.0	0.0	0.0	0.0	3.5	17.2	35.4	174.2

Station No.: 2 **Station Type:** Climatological **Longitude:** 50° 41' E
Station Name: . Abadchi-Faridan **Latitude:** 32° 43' N **Altitude:** 2100 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.9	6.3	10.6	14.0	22.0	30.0	34.7	31.9	27.6	20.5	13.8	8.7	18.7
T min (C)	-12.1	-10.5	-4.7	1.7	7.6	11.4	13.5	10.9	7.5	3.6	-2.0	-6.9	1.7
T ave (C)	-4.1	-2.1	3.0	7.8	14.8	20.7	24.1	21.4	17.5	12.1	5.9	0.9	10.2
T rng (C)	16.0	16.8	15.3	12.3	14.4	18.6	21.2	21.0	20.1	16.9	15.8	15.6	17.0
RHmax (%)	76.0	82.0	62.0	66.0	54.0	40.0	43.0	45.0	51.0	59.0	58.0	66.0	58.5
RHmin (%)	52.0	52.0	49.0	43.0	35.0	23.0	22.0	22.0	22.0	30.0	38.0	51.0	36.6
Rain (mm)	105.4	48.3	41.2	80.9	27.9	0.0	1.8	0.8	0.0	24.9	44.0	39.7	414.9

Station No.: 3 **Station Type:** Sinoptice **Longitude:** 52° 40' E
Station Name: Abadeh **Latitude:** 31° 11' N **Altitude:** 2004 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.7	10.2	14.6	19.1	24.9	31.4	33.2	32.3	28.1	23.6	16.2	11.6	21.2
T min (C)	-2.6	-1.9	1.8	5.0	8.3	11.9	14.2	13.0	9.3	5.5	0.8	-1.7	5.3
T ave (C)	3.5	4.2	8.2	12.1	16.6	21.6	23.7	22.6	18.7	14.6	8.5	5.0	13.3
T rng (C)	12.3	12.1	12.8	14.1	16.6	19.5	19.0	19.3	18.8	18.1	15.4	13.3	15.9
RHmax (%)	68.0	66.0	67.0	59.0	49.0	37.0	38.0	39.0	38.0	49.0	67.0	67.0	48.6
RHmin (%)	38.0	37.0	32.0	30.0	23.0	18.0	18.0	19.0	20.0	23.0	31.0	35.0	27.0
Rain (mm)	34.5	19.0	22.0	26.4	12.2	0.7	0.1	1.6	0.0	6.5	9.5	24.0	156.5

Station No.: 4 **Station Type:** Climatological **Longitude:** 51° 59' E
Station Name: Abali **Latitude:** 35° 46' N **Altitude:** 2450 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	0.7	0.5	4.8	10.0	15.8	22.2	26.0	24.8	20.7	13.3	7.3	2.4	12.4
T min (C)	-8.6	-8.7	-3.4	1.7	6.5	11.2	15.1	14.0	10.3	4.3	-1.0	-5.3	3.0
T ave (C)	-4.0	-4.1	0.7	5.8	11.1	16.7	20.5	19.4	15.5	8.8	3.2	-1.5	7.7
T rng (C)	9.3	9.2	8.2	8.3	9.3	11.0	10.9	10.8	10.4	9.0	8.3	7.7	9.4
RHmax (%)	71.0	65.0	70.0	63.0	57.0	44.0	40.0	40.0	41.0	59.0	67.0	67.0	57.0
RHmin (%)	64.0	65.0	59.0	48.0	41.0	28.0	26.0	25.0	25.0	41.0	50.0	59.0	44.3
Rain (mm)	64.2	76.4	98.9	70.1	70.4	18.9	5.1	10.5	3.4	48.2	41.3	59.0	566.0

Station No.: 5 **Station Type:** Climatological **Longitude:** 46° 24' E
Station Name: Ajichaie **Latitude:** 38° 07' N **Altitude:** 1400 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	-0.5	3.1	8.4	15.7	21.5	26.7	31.7	32.0	26.3	17.5	11.6	4.2	16.5
T min (C)	-9.8	-6.0	-1.3	3.2	7.7	11.0	14.5	12.5	9.8	3.9	-0.4	-5.9	3.3
T ave (C)	-5.2	-1.5	3.5	9.4	14.6	18.9	23.1	22.3	18.0	10.7	5.6	-0.9	9.9
T rng (C)	9.3	9.1	9.7	12.5	13.8	15.7	17.2	19.5	16.5	13.6	12.0	10.1	13.3
RHmax (%)	78.0	82.0	84.0	78.0	77.0	72.0	61.0	60.0	67.0	75.0	84.0	83.0	75.1
RHmin (%)	80.0	76.0	63.0	49.0	47.0	38.0	28.0	27.0	33.0	51.0	60.0	74.0	52.2
Rain (mm)	20.0	21.2	47.2	50.9	41.9	16.3	1.2	0.9	8.7	20.0	22.4	26.0	276.7

Station No.: 6 **Station Type:** Climatological **Longitude:** 55° 10' E
Station Name: Azadshahr **Latitude:** 37° 05' N **Altitude:** 6 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.9	12.8	16.3	21.8	26.9	32.1	33.6	33.9	31.0	25.2	20.1	14.9	23.5
T min (C)	1.6	1.7	4.4	8.9	14.2	17.7	19.9	19.9	17.3	12.0	7.3	3.7	10.7
T ave (C)	7.3	7.3	10.3	15.3	20.5	24.9	26.8	26.9	24.1	18.6	13.7	9.3	17.1
T rng (C)	11.3	11.1	11.9	12.9	12.7	14.4	13.7	14.0	13.7	13.2	12.8	11.2	12.7
RHmax (%)	82.0	85.0	82.0	78.0	76.0	76.0	76.0	77.0	78.0	84.0	79.0	83.0	79.7
RHmin (%)	68.0	70.0	65.0	64.0	57.0	51.0	53.0	53.0	57.0	61.0	61.0	71.0	60.9
Rain (mm)	72 6	70.7	131.7	84.8	36.8	20.8	20.0	19.8	29.8	63.3	63.2	70.4	683.9

Station No.:	7		**Station Type:**		Climatological		**Longitude:**		48° 52' E			
Station Name:	Astara		**Latitude:**		38° 26' N		**Altitude:**		-25 m			

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.8	8.6	11.5	16.8	22.8	27.9	31.4	30.2	26.4	20.3	15.7	11.4	19.3
T min (C)	1.6	1.7	4.4	9.0	14.0	17.7	20.5	20.2	17.4	12.8	8.4	4.2	11.0
T ave (C)	5.2	5.2	7.9	12.9	18.4	22.8	26.0	25.2	21.9	16.5	12.0	7.8	15.2
T rng (C)	7.2	6.9	7.1	7.8	8.8	10.2	10.9	10.0	9.0	7.5	7.3	7.2	8.3
RHmax (%)	89.0	90.0	91.0	90.0	87.0	81.0	75.0	82.0	89.0	93.0	93.0	89.0	87.4
RHmin (%)	81.0	81.0	82.0	78.0	72.0	66.0	61.0	66.0	74.0	81.0	83.0	81.0	75.5
Rain (mm)	96.4	85.0	117.7	65.8	55.0	48.5	20.5	60.6	246.1	261.9	137.9	82.1	1277.5

Station No.:	8		**Station Type:**		Climatological		**Longitude:**		49° 48' E			
Station Name:	Aghajari		**Latitude:**		30° 42' N		**Altitude:**		29 m			

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	18.3	20.4	26.3	32.2	40.2	45.1	46.5	45.5	42.7	36.0	26.9	19.8	33.3
T min (C)	6.8	7.8	12.0	16.5	21.8	23.6	26.1	24.9	21.2	16.6	11.6	7.9	16.4
T ave (C)	12.5	14.1	19.1	24.4	31.0	34.3	36.3	35.2	32.0	26.3	19.3	13.8	24.9
T rng (C)	11.5	12.6	14.3	15.7	18.4	21.5	20.4	20.6	21.5	19.4	15.3	11.9	16.9
RHmax (%)	85.0	82.0	67.0	61.0	41.0	32.0	37.0	42.0	45.0	50.0	67.0	83.0	57.7
RHmin (%)	61.0	53.0	33.0	26.0	16.0	10.0	13.0	15.0	16.0	22.0	38.0	58.0	30.1
Rain (mm)	72.9	38.7	33.2	21.9	3.0	0.0	0.0	0.1	0.0	6.7	36.9	85.7	299.1

Station No.:	9		**Station Type:**		Climatological		**Longitude:**		52° 23' E			
Station Name:	Amol		**Latitude:**		36° 28' N		**Altitude:**		29 m			

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.5	11.2	13.6	19.5	24.3	27.5	29.8	29.8	27.7	23.1	18.0	14.1	20.9
T min (C)	3.3	2.6	4.8	9.3	13.2	18.5	21.1	20.8	18.9	13.1	8.2	5.2	11.6
T ave (C)	7.9	6.9	9.2	14.4	18.8	23.0	25.5	25.3	23.3	18.1	13.1	9.6	16.3
T rng (C)	9.2	8.6	8.8	10.2	11.1	9.0	8.7	9.0	8.8	10.0	9.8	8.9	9.3
RHmax (%)	89.0	90.0	91.0	90.0	88.0	85.0	87.0	90.0	90.0	89.0	91.0	90.0	89.2
RHmin (%)	75.0	77.0	77.0	74.0	74.0	74.0	73.0	73.0	72.0	73.0	73.0	76.0	74.3
Rain (mm)	67.2	89.3	82.1	53.5	33.4	28.1	22.3	43.7	68.3	116.2	85.6	127.3	817.0

Station No.:	10		**Station Type:**		Climatological		**Longitude:**		49° 13' E			
Station Name:	Avaj		**Latitude:**		35° 38' N		**Altitude:**		1894 m			

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	1.9	3.6	8.8	15.5	20.2	26.7	31.1	30.7	25.9	19.8	11.3	5.0	16.7
T min (C)	-8.1	-8.1	-2.8	2.5	6.0	9.2	12.6	11.9	9.1	5.1	0.0	-4.3	2.8
T ave (C)	-3.1	-2.3	3.0	9.0	13.1	18.0	21.9	21.3	17.5	12.4	5.7	0.3	9.7
T rng (C)	10.0	11.7	11.6	13.0	14.2	17.5	18.5	18.8	16.8	14.7	11.3	9.3	14.0
RHmax (%)	66.0	67.0	72.0	66.0	61.0	50.0	48.0	47.0	45.0	59.0	67.0	65.0	59.4
RHmin (%)	58.0	61.0	54.0	46.0	40.0	27.0	25.0	23.0	24.0	37.0	50.0	57.0	41.8
Rain (mm)	46.9	37.7	60.3	57.2	55.9	5.0	3.2	1.7	0.0	25.1	33.8	37.2	364.0

Station No.:	11		**Station Type:**		Climatological		**Longitude:**		52° 27' E			
Station Name:	Ahmadabad-Doroudzan		**Latitude:**		30° 12' N		**Altitude:**		1800 m			

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.6	10.8	16.3	21.6	27.5	33.2	35.9	35.2	31.6	26.0	18.3	12.7	23.1
T min (C)	-2.7	-1.7	2.7	7.7	12.4	16.6	18.3	17.9	15.1	10.1	4.8	0.4	8.5
T ave (C)	3.0	4.6	9.5	14.6	20.0	24.9	27.1	26.5	23.4	18.0	11.5	6.5	15.8
T rng (C)	11.3	12.5	13.6	13.9	15.1	16.6	17.6	17.3	16.5	15.9	13.5	12.3	14.7
RHmax (%)	77.0	82.0	76.0	74.0	66.0	57.0	56.0	54.0	55.0	59.0	72.0	80.0	67.3
RHmin (%)	69.0	63.0	60.0	55.0	50.0	47.0	44.0	43.0	44.0	47.0	56.0	63.0	53.4
Rain (mm)	113.2	88.3	87.8	35.3	8.5	0.0	3.3	0.2	0.0	17.2	21.9	105.0	480.7

Station No.:	12		**Station Type:**		Climatological		**Longitude:**		47° 03' E			
Station Name:	Ahmadvand		**Latitude:**		34° 28' N		**Altitude:**		1400 m			

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.5	8.9	13.4	18.9	25.7	30.9	35.4	35.0	32.0	26.8	18.5	11.5	22.0
T min (C)	-5.6	-3.7	0.8	5.4	8.6	10.9	15.6	15.5	10.5	7.1	3.1	-0.8	5.6
T ave (C)	1.0	2.6	7.1	12.1	17.2	20.9	25.5	25.3	21.3	16.9	10.8	5.3	13.8
T rng (C)	13.1	12.6	12.6	13.5	17.1	20.0	19.8	19.5	21.5	19.7	15.4	12.3	16.4
RHmax (%)	85.0	83.0	70.0	60.0	49.0	38.0	37.0	40.0	44.0	56.0	66.0	79.0	58.9
RHmin (%)	61.0	61.0	45.0	37.0	33.0	24.0	27.0	35.0	27.0	32.0	41.0	56.0	39.9
Rain (mm)	77.3	81.3	96.8	92.5	40.7	8.6	0.0	0.0	0.1	20.5	48.1	54.2	520.1

Station No.: 13 **Station Type:** Climatological **Longitude:** 50° 05' E
Station Name: Golpayegan **Latitude:** 33° 24' N **Altitude:** 2000 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.5	7.5	11.7	17.1	22.1	29.3	33.8	32.1	28.5	22.3	14.7	8.3	19.5
T min (C)	-6.3	-4.3	1.0	5.7	9.5	13.6	16.7	15.2	11.3	6.5	1.0	-3.4	5.5
T ave (C)	0.0	1.6	6.3	11.4	15.8	21.5	25.3	23.6	19.9	14.4	7.8	2.5	12.5
T rng (C)	12.8	11.8	10.7	11.4	12.6	15.7	17.1	16.9	17.2	15.8	13.7	11.7	13.9
RHmax (%)	67.0	67.0	66.0	59.0	53.0	43.0	43.0	44.0	43.0	54.0	67.0	72.0	56.5
RHmin (%)	50.0	52.0	46.0	37.0	37.0	29.0	25.0	21.0	26.0	33.0	42.0	52.0	37.5
Rain (mm)	42.1	37.6	44.9	37.8	29.6	1.0	1.5	1.8	0.0	17.8	27.6	44.5	286.2

Station No.: 14 **Station Type:** Sinoptice **Longitude:** 49° 42' E
Station Name: Arak **Latitude:** 34° 06' N **Altitude:** 1754 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.0	6.7	13.7	20.2	25.3	32.4	36.1	35.2	30.8	22.9	14.3	7.6	20.9
T min (C)	-4.2	-3.7	2.3	7.5	11.0	15.2	18.7	17.5	13.1	8.2	2.5	-1.2	7.2
T ave (C)	0.4	1.5	8.0	13.9	18.1	23.8	27.4	26.4	22.0	15.5	8.4	3.2	14.0
T rng (C)	9.2	10.4	11.4	12.7	14.3	17.2	17.4	17.7	17.7	14.7	11.8	8.8	13.6
RHmax (%)	78.0	76.0	67.0	59.0	60.0	41.0	37.0	37.0	37.0	54.0	68.0	74.0	57.3
RHmin (%)	64.0	58.0	43.0	32.0	29.0	19.0	17.0	17.0	17.0	30.0	47.0	57.0	35.8
Rain (mm)	65.5	56.4	59.3	49.8	39.4	2.3	0.7	1.6	0.3	24.8	37.3	50.8	388.2

Station No.: 15 **Station Type:** Sinoptice **Longitude:** 48° 17' E
Station Name: Ardabil **Latitude:** 37° 32' N **Altitude:** 1372 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.0	4.5	9.4	15.7	20.6	23.8	25.9	25.8	23.3	17.6	11.6	6.2	15.6
T min (C)	-6.5	-6.1	-1.5	3.5	7.4	9.9	12.0	12.3	9.4	5.3	0.4	-3.2	3.6
T ave (C)	-1.8	-0.8	3.9	9.6	14.0	16.8	19.0	19.0	16.3	11.5	6.0	1.5	9.6
T rng (C)	9.5	10.6	10.9	12.2	13.2	13.9	13.9	13.5	13.9	12.3	11.2	9.4	12.0
RHmax (%)	73.0	73.0	78.0	75.0	77.0	77.0	76.0	78.0	80.0	82.0	82.0	78.0	77.4
RHmin (%)	67.0	66.0	64.0	49.0	62.0	61.0	60.0	60.0	61.0	64.0	68.0	67.0	62.4
Rain (mm)	32.0	24.8	43.8	58.0	56.5	26.9	6.1	3.7	13.7	48.4	35.1	36.7	385.7

Station No.: 16 **Station Type:** Climatological **Longitude:** 52° 24' E
Station Name: Ardestan **Latitude:** 33° 22' N **Altitude:** 1381 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.1	12.1	18.8	25.2	31.4	37.3	39.2	37.4	33.0	25.5	17.7	11.9	25.0
T min (C)	-2.7	-1.9	2.7	8.5	12.9	17.9	19.8	17.9	13.7	9.6	3.4	-1.5	8.4
T ave (C)	3.7	5.1	10.8	16.9	22.1	27.6	29.5	27.7	23.4	17.5	10.6	5.2	16.7
T rng (C)	12.8	14.0	16.1	16.7	18.5	19.4	19.4	19.5	19.3	15.9	14.3	13.4	16.6
RHmax (%)	74.0	73.0	61.0	52.0	50.0	46.0	42.0	47.0	45.0	48.0	61.0	67.0	55.5
RHmin (%)	50.0	46.0	38.0	33.0	30.0	33.0	30.0	33.0	29.0	33.0	43.0	52.0	37.5
Rain (mm)	21.2	18.4	15.6	17.3	9.7	1.6	0.0	0.3	0.0	10.1	13.3	13.4	120.9

Station No.: 17 **Station Type:** Climatological **Longitude:** 51° 59' E
Station Name: Ardakan **Latitude:** 30° 16' N **Altitude:** 2200 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.1	7.9	13.1	17.1	24.1	28.5	30.8	29.4	26.4	21.2	14.3	8.0	19.1
T min (C)	-3.6	-4.9	1.5	5.2	9.0	12.2	15.0	14.7	12.2	7.6	3.1	-2.6	5.8
T ave (C)	2.3	1.5	7.3	11.1	16.5	20.4	22.9	22.0	19.3	14.4	8.7	2.7	12.4
T rng (C)	11.7	12.8	11.6	11.9	15.1	16.3	15.8	14.7	14.2	13.6	11.2	10.6	13.3
RHmax (%)	70.0	76.0	77.0	73.0	65.0	57.0	51.0	56.0	59.0	59.0	72.0	75.0	65.8
RHmin (%)	57.0	67.0	57.0	57.0	48.0	48.0	44.0	49.0	47.0	48.0	57.0	60.0	53.3
Rain (mm)	112.3	92.8	100.4	55.5	16.0	0.0	1.3	6.6	0.2	8.2	64.2	120.7	578.2

Station No.: 18 **Station Type:** Sinoptice **Longitude:** 45° 05' E
Station Name: Urmieh **Latitude:** 37° 32' N **Altitude:** 1312 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.8	4.5	10.3	17.0	21.5	26.9	31.1	30.8	27.2	19.5	12.1	4.8	17.4
T min (C)	-6.0	-5.5	-0.7	4.9	8.7	12.1	16.2	15.7	11.3	6.0	0.8	-3.8	5.0
T ave (C)	-1.6	-0.5	4.8	10.9	15.1	19.5	23.7	23.3	19.3	12.8	6.5	0.5	11.2
T rng (C)	8.8	10.0	11.0	12.1	12.8	14.8	14.9	15.1	15.9	13.5	11.3	8.6	12.4
RHmax (%)	84.0	83.0	79.0	78.0	78.0	69.0	62.0	64.0	66.0	75.0	85.0	83.0	75.5
RHmin (%)	68.0	62.0	53.0	48.0	45.0	38.0	34.0	35.0	35.0	44.0	57.0	65.0	48.7
Rain (mm)	32.2	32.6	46 6	58.7	61.3	15.6	2.3	2.1	3.8	29.1	44.2	35.1	363.6

Station No.:	19			Station Type:		Climatological		Longitude:			47° 54' E	
Station Name:	Ostoor			Latitude:		37° 30' N		Altitude:			1200 m	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.8	5.1	13.2	22.2	24.8	32.0	34.4	35.0	31.7	24.1	14.9	7.4	20.7
T min (C)	-5.6	-4.8	1.8	7.3	11.6	15.7	18.9	19.7	14.8	8.9	2.3	-2.0	7.4
T ave (C)	-0.9	0.1	7.5	14.8	18.2	23.9	26.7	27.4	23.3	16.5	8.6	2.7	14.1
T rng (C)	9.4	9.9	11.4	14.9	13.2	16.3	15.5	15.3	16.9	15.2	12.6	9.4	13.3
RHmax (%)	85.0	85.0	84.0	78.0	75.0	61.0	53.0	51.0	58.0	69.0	82.0	85.0	72.2
RHmin (%)	75.0	73.0	59.0	44.0	43.0	32.0	32.0	29.0	29.0	41.0	56.0	67.0	48.3
Rain (mm)	24.5	24 6	53.9	61.6	58.6	10.6	3.7	2.0	3.6	26.8	32.1	34.9	336.9

Station No.:	20			Station Type:		Climatological		Longitude:			60° 01' E	
Station Name:	Asadabad-Birjand			Latitude:		32° 55' N		Altitude:			1500 m	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.2	11.1	17.3	24.1	28.6	32.9	33.2	31.4	28.8	24.4	17.5	12.3	22.6
T min (C)	-4.0	-2.5	2.3	7.4	11.2	15.5	17.4	15.4	9.8	5.1	0.3	-2.9	6.2
T ave (C)	2.6	4.3	9.8	15.8	19.9	24.1	25.3	23.4	19.3	14.8	8.9	4.7	14.4
T rng (C)	13.2	13.6	15.0	16.7	17.4	17.7	15.8	16.0	19.0	19.3	17.2	15.2	16.3
RHmax (%)	78.0	79.0	70.0	49.0	41.0	31.0	30.0	34.0	39.0	53.0	71.0	83.0	54.8
RHmin (%)	62.0	60.0	44.0	32.0	24.0	19.0	18.0	22.0	21.0	24.0	37.0	49.0	34.3
Rain (mm)	33.5	30.3	34.9	21.6	8.5	0.0	0.0	0.0	0.0	3.4	9.9	14.2	156.3

Station No.:	21			Station Type:		Climatological		Longitude:			46° 13' E	
Station Name:	Oskoo			Latitude:		37° 55' N		Altitude:			1500 m	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.1	5.8	10.9	17.0	22.0	27.8	32.6	32.5	28.8	19.8	11.9	5.6	18.1
T min (C)	-7.5	-5.3	-1.2	3.8	6.8	10.8	15.1	14.7	9.6	3.9	-1.0	-4.7	3.8
T ave (C)	-2.2	0.3	4.8	10.4	14.4	19.3	23.8	23.6	19.2	11.8	5.4	0.5	10.9
T rng (C)	10.6	11.1	12.1	13.2	15.2	17.0	17.5	17.8	19.2	15.9	12.9	10.3	14.4
RHmax (%)	86.0	88.0	85.0	79.0	82.0	75.0	61.0	61.0	68.0	82.0	87.0	88.0	78.5
RHmin (%)	81.0	78.0	66.0	52.0	48.0	40.0	36.0	35.0	36.0	48.0	60.0	75.0	54.6
Rain (mm)	22.3	19.4	37.8	58.1	63.2	11.3	4.6	0.6	4.7	32.2	26.8	18.4	399.4

Station No.:	22			Station Type:		Sinoptice		Longitude:			51° 40' E	
Station Name:	Isfahan			Latitude:		32° 37' N		Altitude:			1590 m	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.0	11.6	16.8	22.1	27.5	33.7	36.2	34.9	30.9	24.2	16.5	10.9	22.9
T min (C)	-2.2	-0.4	4.2	9.4	13.8	18.9	21.2	19.4	14.6	9.3	3.2	-0.7	9.2
T ave (C)	3.4	5.6	10.5	15.8	20.6	26.3	28.7	27.2	22.8	16.8	9.9	5.1	16.0
T rng (C)	11.2	12.0	12.6	12.7	13.7	14.8	15.0	15.5	16.3	14.9	13.3	11.6	13.6
RHmax (%)	74.0	69.0	60.0	54.0	46.0	33.0	31.0	32.0	37.0	52.0	67.0	73.0	52.3
RHmin (%)	49.0	40.0	30.0	27.0	23.0	16.0	16.0	15.0	17.0	25.0	35.0	44.0	28.1
Rain (mm)	22.2	16.3	17.0	19.4	12.7	0.9	0.1	0.2	0.0	7.2	12.2	22.5	130.7

Station No.:	23			Station Type:		Climatological		Longitude:			53° 15' E	
Station Name:	Afrachal			Latitude:		36° 14' N		Altitude:			23 m	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	13.5	13.0	17.7	23.3	27.2	30.1	31.8	32.1	29.3	25.0	19.7	16.3	23.2
T min (C)	1.7	1.2	3.8	7.3	9.3	11.9	13.8	13.5	11.0	8.7	5.7	3.8	7.6
T ave (C)	7.6	7.1	10.8	15.3	18.3	21.0	22.8	22.8	20.1	16.9	12.7	10.0	15.4
T rng (C)	11.8	11.8	13.9	16.0	17.9	18.2	18.0	18.6	18.3	16.3	14.0	12.5	15.6
RHmax(%)	77.0	79.0	78.0	76.0	75.0	77.0	78.0	78.0	78.0	80.0	78.0	78.0	77.7
RHmin (%)	72.0	72.0	72.0	71.0	70.0	71.0	72.0	68.0	69.0	71.0	69.0	71.0	70.7
Rain (mm)	105.1	136.9	150.1	99.5	72.3	64.7	44.4	50.6	91.6	105.5	95.5	118.2	1134.4

Station No.:	24			Station Type:		Climatological		Longitude:			51° 21' E	
Station Name:	Emam-Ghais			Latitude:		31° 44' N		Altitude: 2400 m				
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.3	5.7	10.7	16.4	22.5	28.9	32.0	31.5	27.8	21.3	13.3	7.3	18.4
T min (C)	-10.	-8.1	-2.3	2.6	6.6	9.7	13.0	12.0	6.7	2.0	-2.5	-6.5	1.9
T ave (C)	-3.3	-1.2	4.2	9.5	14.6	19.3	22.5	21.8	17.3	11.6	5.4	0.4	10.2
T rng (C)	13.3	13.8	13.0	13.8	15.9	19.2	19.0	19.5	21.1	19.3	15.8	13.8	16.5
RHmax (%)	73.0	74.0	74.0	67.0	61.0	51.0	52.0	52.0	55.0	64.0	69.0	72.0	63.7
RHmin (%)	61.0	64.0	51.0	41.0	32.0	24.0	24.0	23.0	23.0	28.0	41.0	54.0	38.8
Rain (mm)	113.1	99.8	118.0	98.4	37.2	2.8	3.7	1.0	0.0	27.0	75.4	105.	681.4

Station No.:	25	Station Type:	Climatological	Longitude:	51° 28' E
Station Name:	Aminabad	Latitude:	35° 35 N	Altitude:	1000 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.4	10.2	16.2	23.6	28.4	34.7	38.1	36.4	32.7	25.3	17.5	10.4	23.4
T min (C)	-2.1	-0.6	3.8	9.3	12.8	16.4	20.7	18.0	14.3	9.3	3.9	-0.2	8.8
T ave (C)	2.7	4.8	10.0	16.5	20.6	25.5	29.4	27.2	23.5	17.3	10.7	5.1	16.1
T rng (C)	9.5	10.8	12.4	14.3	15.6	18.3	17.4	18.4	18.4	16.0	13.6	10.6	14.6
RHmax (%)	82.0	80.0	72.0	62.0	65.0	57.0	50.0	55.0	57.0	67.0	72.0	84.0	66.9
RHmin (%)	59.0	53.0	46.0	37.0	35.0	24.0	23.0	27.0	26.0	35.0	43.0	54.0	38.5
Rain (mm)	40 0	36.5	34 3	35.8	36.6	7.3	1.8	3.0	0.3	21.7	17.8	27.3	262.4

Station No.:	26	Station Type:	Climatological	Longitude:	53° 40' E
Station Name:	Anarak	Latitude:	33° 20' N	Altitude:	1416 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.0	11.1	17.0	23.2	28.5	34.5	36.8	34.9	32.1	25.1	18.0	12.1	23.6
T min (C)	0.5	1.2	6.7	11.7	17.0	23.0	25.5	23.7	20.8	14.3	7.8	2.8	12.9
T ave (C)	5.3	6.2	11.9	17.5	22.8	28.8	31.1	19.3	26.4	19.7	12.9	7.5	18.3
T rng (C)	9.5	9.9	10.3	11.5	11.5	11.5	11.3	11.2	11.3	10.8	10.2	9.3	10.7
RHmax (%)	63.0	65.0	53.0	49.0	40.0	30.0	28.0	28.0	29.0	39.0	49.0	60.0	44.4
RHmin (%)	48.0	42.0	34.0	31.0	28.0	23.0	21.0	20.0	21.0	29.0	33.0	41.0	30.9
Rain (mm)	18.9	14.6	13.0	20.1	11.5	0.5	0.0	0.0	0.0	6.2	8.3	12.0	105.1

Station No.:	27	Station Type:	Climatological	Longitude:	48° 21' E
Station Name:	Andimeshk	Latitude:	32° 27' N	Altitude:	85 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	15.7	18.0	23.8	29.3	37.3	43.6	45.8	44.6	41.7	34.9	26.4	19.2	31.7
T min (C)	6.0	6.6	10.3	14.6	21.0	25.0	26.3	25.5	22.7	17.4	12.1	7.9	16.3
T ave (C)	10.9	12.3	17.0	22.0	29.1	34.3	36.0	35.0	32.2	26.2	19.3	13.6	24.0
T rng (C)	9.7	11.4	13.5	14.7	16.3	18.6	19.5	19.1	19.0	17.5	14.3	11.3	15.4
RHmax (%)	80.0	78.0	75.0	65.0	47.0	37.0	36.0	36.0	33.0	43.0	64.0	80.0	56.2
RHmin (%)	60.0	52.0	47.0	39.0	27.0	26.0	20.0	21.0	18.0	24.0	38.0	56.0	35.7
Rain (mm)	84.4	52.5	54.3	45.8	8.8	0.0	0.0	0.0	0.0	5.0	38.8	59.2	348.8

Station No.:	28	Station Type:	Climatological	Longitude:	47° 03' E
Station Name:	Ahar	Latitude:	38° 29' N	Altitude:	1157 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.2	5.8	11.1	17.0	21.3	26.2	29.3	28.9	26.2	20.5	13.6	7.9	17.7
T min (C)	-6.6	-6.2	-1.2	2.8	6.7	9.8	12.0	11.8	8.7	4.6	-0.2	-4.3	3.2
T ave (C)	-0.7	-0.2	5.0	9.9	14.0	18.0	20.6	20.4	17.5	12.6	6.7	1.8	10.5
T rng (C)	11.8	12.0	12.3	14.2	14.6	16.4	17.3	17.1	17.5	15.9	13.8	12.2	14.6
RHmax (%)	76.0	73.0	79.0	77.0	78.0	75.0	71.0	71.0	73.0	78.0	77.0	80.0	75.7
RHmin (%)	70.0	69.0	64.0	58.0	56.0	50.0	45.0	44.0	46.0	53.0	58.0	67.0	56.7
Rain (mm)	26.3	22.8	39.1	49.3	57.6	39.2	2.7	2.3	13.7	38.5	30.6	21.3	343.4

Station No.:	29	Station Type:	Sinoptice	Longitude:	48° 40' E
Station Name:	Ahwaz	Latitude:	31° 20' N	Altitude:	22 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.5	19.7	25.5	31.9	38.9	44.1	45.8	45.0	42.5	35.4	26.3	19.2	32.7
T min (C)	6.6	7.8	11.6	16.4	21.9	24.5	26.5	25.8	22.5	17.3	12.0	7.6	16.7
T ave (C)	12.1	13.8	18.5	24.1	30.4	34.3	36.2	35.4	32.5	26.4	19.1	13.4	24.7
T rng (C)	10.9	11.9	13.9	15.5	17.0	19.6	19.3	19.2	20.0	18.1	14.3	11.6	15.9
RHmax (%)	88.0	84.0	74.0	64.0	51.0	42.0	44.0	48.0	51.0	59.0	72.0	85.0	63.5
RHmin (%)	64.0	57.0	41.0	32.0	22.0	15.0	17.0	20.0	20.0	29.0	43.0	62.0	35.2
Rain (mm)	63.1	39.2	21.1	12.9	8.2	1.1	0.0	0.0	0.0	11.5	37.5	56.3	250.9

Station No.:	30	Station Type:	Climatological	Longitude:	48° 53' E
Station Name:	Ahwaz (Mollasani)	Latitude:	31° 36' N	Altitude:	50 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.3	19.2	24.4	31.0	37.3	42.2	43.9	43.3	41.0	34.5	26.1	19.6	31.6
T min (C)	6.4	6.7	9.6	14.5	19.1	21.1	23.5	23.4	19.4	15.6	9.7	6.8	14.7
T ave (C)	11.8	13.0	17.0	22.8	28.2	31.7	33.7	33.3	30.2	25.0	17.9	13.2	23.2
T rng (C)	10.9	12.5	14.8	16.5	18.2	21.1	20.4	19.9	21.6	18.9	16.4	12.8	17.0
RHmax (%)	91.0	90.0	83.0	77.0	72.0	68.0	68.0	71.0	71.0	73.0	80.0	89.0	77.8
RHmin (%)	62.0	61.0	54.0	46.0	37.0	32.0	36.0	39.0	33.0	41.0	48.0	61.0	45.8
Rain (mm)	71.7	45.2	27.5	20.4	5.2	0.1	0.0	0.0	0.0	3.6	40.9	59.0	273.8

Station No.: 31 **Station Type:** Sinoptice **Longitude:** 60° 42' E
Station Name: Iranshahr **Latitude:** 27° 12' N **Altitude:** 566 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	21.4	23.4	28.9	34.8	40.7	44.7	44.8	43.8	40.2	35.8	29.2	24.0	34.3
T min (C)	7.3	9.4	13.7	18.5	24.0	28.1	29.5	27.7	23.2	18.6	11.8	8.0	18.3
T ave (C)	14.4	16.4	21.3	26.6	32.3	36.4	37.2	35.8	31.7	27.2	20.5	16.0	26.3
T rng (C)	14.1	14.0	15.2	16.3	16.7	16.6	15.3	16.1	17.0	17.2	17.4	16.0	16.0
RHmax (%)	66.0	67.0	56.0	48.0	36.0	31.0	38.0	39.0	36.0	39.0	50.0	57.0	46.9
RHmin (%)	38.0	37.0	29.0	24.0	17.0	15.0	19.0	18.0	18.0	22.0	27.0	32.0	24.7
Rain (mm)	28.0	28 0	27.2	6.9	3.2	1.3	12.2	2.4	0.0	1.3	2.5	7.4	120.4

Station No.: 32 **Station Type:** Climatological **Longitude:** 46° 26' E
Station Name: Ilam **Latitude:** 33° 38' N **Altitude:** 1319 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.2	10.7	15.4	19.8	26.3	32.8	35.7	35.1	32.0	24.8	17.1	12.0	22.7
T min (C)	0.1	0.4	3.5	7.7	12.6	16.7	19.5	19.3	15.8	10.8	5.3	1.4	9.4
T ave (C)	5.2	5.5	9.4	13.8	19.5	24.8	27.6	27.2	23.9	17.8	11.2	6.7	16.0
T rng (C)	10.1	10.3	11.9	12.1	13.7	16.1	16.2	15.8	16.2	14.0	11.8	10.6	13.2
RHmax (%)	74.0	74.0	66.0	57.0	54.0	43.0	40.0	40.0	42.0	53.0	62.0	70.0	56.3
RHmin (%)	56.0	55.0	45.0	44.0	34.0	25.0	22.0	24.0	24.0	31.0	43.0	52.0	37.9
Rain (mm)	118.4	118.6	111.6	83.1	37.9	0.9	0.9	0.0	0.1	31.2	84.4	87.1	674.2

Station No.: 33 **Station Type:** Climatological **Longitude:** 52° 04' E
Station Name: Evanekey **Latitude:** 35° 21' N **Altitude:** 1400 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	13.4	16.0	19.8	23.9	28.7	35.8	38.3	37.5	33.3	25.9	20.0	14.5	25.6
T min (C)	-0.8	2.4	5.6	9.3	13.9	18.4	22.5	21.8	17.5	12.3	7.0	0.5	10.9
T ave (C)	6.3	9.2	12.7	16.6	21.3	27.1	30.4	29.6	25.4	19.1	13.5	7.5	18.2
T rng (C)	14.2	13.6	14.2	14.6	14.8	17.4	15.8	15.7	15.8	13.6	13.0	14.0	14.7
RHmax (%)	65.0	66.0	60.0	65.0	61.0	68.0	75.0	77.0	75.0	71.0	66.0	64.0	67.8
RHmin (%)	59.0	59.0	54.0	56.0	52.0	57.0	71.0	71.0	71.0	60.0	63.0	58.0	60.9
Rain (mm)	28.2	16.9	20.3	21.8	19.9	7.7	0.0	4.2	0.0	6.6	13.3	18.8	157.7

Station No.: 34 **Station Type:** Climatological **Longitude:** 52° 41' E
Station Name: Babol **Latitude:** 36° 33' N **Altitude:** 2 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	13.1	11.5	15.4	20.6	25.6	29.6	30.5	30.8	27.6	22.5	20.3	15.6	21.9
T min (C)	0.8	2.0	5.1	7.8	12.3	17.1	18.9	19.5	15.6	8.8	6.8	3.2	9.8
T ave (C)	7.0	6.8	10.3	14.2	19.0	23.4	24.7	25.1	21.6	15.6	13.5	9.4	15.9
T rng (C)	12.3	9.5	10.3	12.8	13.3	12.5	11.6	11.3	12.0	13.7	13.5	12.4	12.1
RHmax (%)	87.0	88.0	89.0	85.0	83.0	83.0	84.0	87.0	86.0	86.0	84.0	89.0	85.9
RHmin (%)	71.0	73.0	73.0	69.0	65.0	64.0	66.0	67.0	71.0	71.0	70.	73.0	69.4
Rain (mm)	64.7	63.4	58.0	37.5	16.3	15.1	12.8	36.6	49.7	84.2	79.9	76.5	594.7

Station No.: 35 **Station Type:** Sinoptice **Longitude:** 52° 39' E
Station Name: Babolsar **Latitude:** 36° 43' N **Altitude:** - 21 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.0	11.1	13.4	18.3	23.1	27.3	30.2	30.0	27.8	22.9	18.2	14.4	20.7
T min (C)	3.6	4.0	6.7	11.0	15.8	19.7	22.0	21.9	19.5	14.3	9.2	5.8	12.8
T ave (C)	7.8	7.6	10.0	14.6	19.5	23.5	26.1	26.0	23.6	18.6	13.7	10.1	16.8
T rng (C)	8.4	7.1	6.7	7.3	7.3	7.6	8.2	8.1	8.3	8.6	9.0	8.6	7.9
RHmax (%)	93.0	92.0	93.0	93.0	91.0	89.0	89.0	92.0	93.0	94.0	95.0	94.0	92.3
RHmin (%)	72.0	74.0	75.0	72.0	69.0	65.0	64.0	67.0	68.0	69.0	71.0	73.0	69.9
Rain (mm)	95.3	80.5	66.2	35.3	25.9	20.3	19.6	48.5	90.2	169.7	143.9	123.3	918.7

Station No.: 36 **Station Type:** Sinoptice **Longitude:** 47° 07' E
Station Name: Kermanshah **Latitude:** 34° 19' N **Altitude:** 1322 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.6	8.5	14.2	19.6	25.2	32.8	37.2	36.8	32.2	24.6	16.4	9.5	22.0
T min (C)	-3.4	-3.0	1.5	4.7	8.4	11.3	15.7	15.1	10.8	6.3	1.3	-1.2	5.6
T ave (C)	1.6	2.8	7.8	12.1	16.8	22.0	26.5	26.0	21.5	15.5	8.8	4.2	13.8
T rng (C)	10.0	11.5	12.7	14.9	16.8	21.5	21.5	21.7	21.4	18.3	15.1	10.7	16.3
RHmax (%)	84.0	73.0	80.0	78.0	74.0	49.0	38.0	38.0	42.0	62.0	77.0	83.0	64.8
RHmin (%)	68.0	63.0	48.0	42.0	36.0	18.0	16.0	16.0	17.0	31.0	44.0	61.0	38.3
Rain (mm)	68.8	69.4	90.9	79.9	39.6	0.6	0.0	0.5	1.1	34.2	55.2	70.6	510.8

Station No.: 37 **Station Type:** Climatological **Longitude:** 45° 14' E
Station Name: Barandoozchai **Latitude:** 37° 23' N **Altitude:** 1300 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.0	5.0	10.1	16.7	21.6	26.7	30.6	30.7	27.1	19.6	12.2	6.6	17.5
T min (C)	-7.8	-6.2	-1.8	4.3	8.2	11.4	14.0	13.2	9.1	4.8	-1.3	-4.7	3.6
T ave (C)	-2.4	-0.6	4.2	10.5	14.9	19.0	22.3	22.0	18.1	12.2	5.4	1.0	10.5
T rng (C)	10.8	11.2	11.9	12.4	13.4	15.3	16.6	17.5	18.0	14.8	13.5	11.3	13.9
RHmax (%)	77.0	77.0	80.0	81.0	81.0	78.0	79.0	81.0	81.0	83.0	82.0	78.0	79.8
RHmin (%)	72.0	73.0	69.0	70.0	69.0	63.0	61.0	60.0	62.0	69.0	72.0	74.0	67.8
Rain (mm)	27.7	28.2	48.0	57.5	51.6	11.6	0.4	1.7	6.0	28.7	23.1	32.2	316.7

Station No.: 38 **Station Type:** Climatological **Longitude:** 58° 42' E
Station Name: Bar-Nishaboor **Latitude:** 36° 29' N **Altitude:** 1520 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	4.4	5.9	11.8	18.9	24.7	30.1	32.4	30.8	27.5	20.9	13.5	7.6	19.0
T min (C)	-6.1	-4.9	0.6	6.1	9.7	14.6	17.3	16.1	11.5	6.6	0.7	-2.9	5.8
T ave (C)	-0.8	0.5	6.2	12.5	17.2	22.4	24.9	23.5	19.5	13.8	7.1	2.3	12.4
T rng (C)	10.5	10.8	11.2	12.8	15.0	15.5	15.1	14.7	16.0	14.3	12.8	10.5	13.3
RHmax (%)	83.0	83.0	74.0	66.0	56.0	44.0	40.0	41.0	46.0	57.0	72.0	79.0	61.8
RHmin (%)	69.0	71.0	55.0	44.0	32.0	26.0	23.0	24.0	26.0	36.0	47.0	60.0	42.8
Rain (mm)	53.8	59.3	70.1	56.2	32.0	7.0	0.7	0.1	2.5	19.9	26.2	41.4	369.2

Station No.: 39 **Station Type:** Climatological **Longitude:** 49° 53' E
Station Name: Bagh-Malak **Latitude:** 31° 31' N **Altitude:** 900 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	16.5	17.8	21.4	26.0	32.9	3905	41.5	39.9	36.1	31.5	22.6	18.0	28.6
T min (C)	4.7	5.5	8.0	11.8	14.4	17.7	20.7	19.4	16.5	12.2	9.9	6.0	12.2
T ave (C)	10.6	11.6	14.7	18.9	23.7	28.6	31.1	29.7	26.3	21.9	16.3	12.0	20.4
T rng (C)	11.8	12.3	13.4	14.2	18.5	21.8	20.8	20.5	19.6	19.3	12.7	12.0	16.4
RHmax (%)	69.0	72.0	63.0	61.0	58.0	53.0	53.0	50.0	60.0	60.0	65.0	71.0	61.3
RHmin (%)	57.0	64.0	56.0	52.0	43.0	35.0	34.0	32.0	36.0	41.0	52.0	61.0	46.9
Rain (mm)	148.1	58.4	65.2	76.6	8.7	0.0	0.0	0.3	0.0	7.8	36.5	83.7	485.3

Station No.: 40 **Station Type:** Climatological **Longitude:** 56° 38' E
Station Name: Baft **Latitude:** 29° 15' N **Altitude:** 2250 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.6	11.3	15.2	20.7	26.4	31.6	32.4	31.3	28.6	23.9	17.9	12.5	21.8
T min (C)	-3.9	-1.8	1.8	6.9	11.7	16.1	17.5	16.5	13.1	7.8	0.8	-2.0	7.0
T ave (C)	2.9	4.8	8.5	13.8	19.0	23.9	25.0	23.9	20.9	15.9	9.3	5.3	14.4
T rng (C)	13.5	13.1	13.4	13.8	14.7	15.5	14.9	14.8	15.5	16.1	17.1	14.5	14.7
RHmax (%)	73.0	71.0	62.0	54.0	42.0	37.0	41.0	43.0	45.0	51.0	54.0	65.0	53.2
RHmin (%)	44.0	44.0	35.0	31.0	26.0	24.0	29.0	30.0	31.0	32.0	32.0	38.0	33.0
Rain (mm)	51.6	44.0	50.5	23.6	6.6	0.6	4.2	1.7	0.0	0.0	7.8	2.3	192.9

Station No.: 41 **Station Type:** Climatological **Longitude:** 58° 11' E
Station Name: Bejestan **Latitude:** 34° 31' N **Altitude:** 1370 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.0	11.4	17.0	23.7	29.1	34.3	35.6	33.5	29.6	24.9	17.9	12.5	23.3
T min (C)	-2.4	-0.5	3.6	8.5	11.9	16.0	17.3	15.2	12.0	8.7	3.6	-0.6	7.8
T ave (C)	3.8	5.4	10.3	16.1	20.5	25.1	26.4	24.4	20.8	16.8	10.8	5.9	15.5
T rng (C)	12.4	11.9	13.4	15.2	17.2	18.3	18.3	18.3	17.6	16.2	14.3	13.1	15.5
RHmax (%)	65.0	67.0	61.0	56.0	47.0	40.0	38.0	37.0	41.0	50.0	57.0	62.0	51.8
RHmin (%)	53.0	55.0	50.0	45.0	37.0	30.0	31.0	29.0	31.0	38.0	42.0	50.0	40.9
Rain (mm)	33.5	35.7	27.8	31.2	11.5	0.0	0.3	0.0	0.0	3.6	8.2	25.9	177.7

Station No.: 42 **Station Type:** Sinoptice **Longitude:** 57° 20' E
Station Name: Bojnourd **Latitude:** 37° 28' N **Altitude:** 1074 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.8	7.3	13.1	19.6	24.5	29.6	32.3	32.2	28.5	21.1	14.2	9.1	19.8
T min (C)	-5.5	-4.0	0.7	5.7	9.8	13.1	15.8	13.8	10.0	5.0	-0.3	-2.8	5.1
T ave (C)	0.2	1.7	6.9	12.6	17.1	21.4	24.0	23.0	19.3	13.1	6.9	3.2	12.4
T rng (C)	11.3	11.3	12.4	13.9	14.7	16.5	16.5	18.4	18.5	16.1	14.5	11.9	14.7
RHmax (%)	81.0	83.0	82.0	79.0	78.0	66.0	64.0	61.0	68.0	79.0	83.0	80.0	75.3
RHmin (%)	61.0	60.0	52.0	46.0	43.0	34.0	33.0	29.0	30.0	42.0	43.0	55.0	44.0
Rain (mm)	25.1	33.9	34.1	48.7	40.9	8.0	8.4	2.1	6.9	16.3	22.1	19.9	266.4

Station No.: 43 **Station Type:** Climatological **Longitude:** 46° 50' E
Station Name: Bostanabad **Latitude:** 37° 50' N **Altitude:** 1720 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	1.2	2.0	6.9	14.0	20.3	26.3	30.5	31.0	26.0	20.4	12.2	5.5	16.4
Tmin(C)	-13.0	-10.7	-4.3	0.8	4.6	7.9	9.8	10.3	6.3	1.3	-2.7	-10.2	0.0
T ave (C)	-6.0	-4.3	1.3	7.4	12.4	17.1	20.1	20.6	16.1	10.8	4.8	-2.3	8.2
T rng (C)	14.4	12.7	11.2	13.2	15.7	18.4	20.7	20.7	19.7	19.1	14.9	15.7	16.4
RHmax (%)	78.0	76.0	81.0	78.0	76.0	75.0	72.0	75.0	81.0	84.0	84.0	80.0	78.3
RHmin (%)	75.0	72.0	60.0	57.0	45.0	41.0	40.0	43.0	40.0	55.0	60.0	71.0	54.9
Rain (mm)	14.7	17.0	26.4	35.0	47.0	15.6	10.6	8.7	19.5	29.3	20.4	20.7	265.8

Station No.: 44 **Station Type:** Sinoptice **Longitude:** 58° 24' E
Station Name: Bam **Latitude:** 29° 09' N **Altitude:** 1055 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.0	19.0	24.5	30.1	34.9	32.9	39.5	37.9	35.1	30.9	23.6	19.1	29.2
T min (C)	4.7	6.6	11.9	16.7	21.4	25.8	26.7	24.9	21.2	17.0	10.2	6.2	16.1
T ave (C)	10.9	12.8	18.2	23.4	28.2	32.5	33.1	31.4	28.1	24.0	16.9	12.6	22.7
T rng (C)	12.3	12.4	12.6	13.4	13.5	13.4	12.8	13.0	13.9	13.9	13.4	12.9	13.1
RHmax (%)	58.0	58.0	50.0	43.0	36.0	27.0	27.0	27.0	28.0	36.0	46.0	52.0	40.7
RHmin (%)	37.0	34.0	29.0	25.0	22.0	17.0	17.0	18.0	19.0	22.0	29.0	34.0	25.3
Rain (mm)	10.1	10.9	11.3	12.3	5.9	0.1	0.1	1.9	0.4	1.0	1.5	3.5	59.0

Station No.: 45 **Station Type:** Climatological **Longitude:** 60° 27' E
Station Name: Bampoor **Latitude:** 27° 12' N **Altitude:** 360 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	20.7	23.0	28.8	33.6	40.6	44.4	44.8	43.7	40.4	35.8	29.0	23.2	34.0
T min (C)	3.8	6.6	10.6	14.8	20.2	23.8	25.1	23.1	18.5	13.6	7.2	4.5	14.3
T ave (C)	12.3	14.8	19.7	24.2	30.4	34.1	35.0	33.4	29.5	24.7	18.1	13.9	24.2
T rng (C)	16.9	16.4	18.2	18.8	20.4	20.6	19.7	20.6	21.9	22.2	21.8	18.7	19.7
RHmax (%)	71.0	74.0	68.0	56.0	43.0	43.0	46.0	50.0	41.0	46.0	54.0	70.0	55.2
RHmin (%)	42.0	40.0	35.0	32.0	26.0	22.0	27.0	26.0	21.0	23.0	28.0	35.0	29.8
Rain (mm)	29.7	17.2	19.1	6.8	2.3	0.1	9.0	5.2	0.0	0.0	2.9	5.3	97.6

Station No.: 46 **Station Type:** Sinoptice **Longitude:** 49° 28' E
Station Name: Bandar-Anzali **Latitude:** 37° 28' N **Altitude:** -15 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.9	8.7	11.4	16.6	22.1	26.9	30.1	29.5	26.1	20.8	16.5	13.1	19.3
T min (C)	4.2	3.7	6.1	10.9	15.7	19.3	22.0	21.6	19.1	14.9	10.3	6.7	12.9
T ave (C)	7.0	6.2	8.8	13.8	18.9	23.1	26.0	25.5	22.6	17.8	13.4	9.9	16.1
T rng (C)	5.7	5.0	5.3	5.7	6.4	7.6	8.1	7.9	7.0	5.9	6.2	6.4	6.4
RHmax(%)	87.0	90.0	91.0	90.0	91.0	88.0	85.0	87.0	92.0	93.0	92.0	89.0	89.6
RHmin (%)	79.0	81.0	81.0	77.0	73.0	66.0	62.0	67.0	74.0	79.0	80.0	78.0	74.8
Rain (mm)	209.4	148.7	117.7	52.7	55.0	46.8	32.8	89.7	204.3	386.3	319.8	211.5	1874.7

Station No.: 47 **Station Type:** Climatological **Longitude:** 51° 56' E
Station Name: Banda-Dayyer **Latitude:** 27° 50' N **Altitude:** 12 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	22.4	22.8	26.7	31.8	38.4	40.7	40.1	39.1	37.8	35.6	30.4	25.2	32.6
T min (C)	9.9	9.9	13.6	16.9	21.9	24.4	24.2	24.7	21.1	19.0	13.9	10.8	17.5
T ave (C)	16.1	16.3	20.2	24.3	30.2	32.5	32.2	31.9	29.5	27.3	22.1	18.0	25.1
T rng (C)	12.5	12.9	13.1	14.9	16.5	16.3	15.9	14.4	16.7	16.6	16.5	14.4	15.1
RHmax (%)	71.0	70.0	66.0	63.0	57.0	60.0	63.0	69.0	66.0	68.0	62.0	66.0	65.1
RHmin (%)	54.0	53.0	51.0	54.0	48.0	54.0	58.0	61.0	58.0	54.0	46.0	52.0	53.6
Rain (mm)	60.0	43.7	19.5	10.2	0.1	0.0	0.0	0.0	0.0	3.7	28.5	60.5	226.2

Station No.: 48 **Station Type:** Sinoptice **Longitude:** 56° 22' E
Station Name: Bandar-Abbas **Latitude:** 27° 13' N **Altitude:** 10 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	23.9	24.4	27.7	32.0	36.5	38.5	38.3	38.0	37.1	35.0	30.7	25.9	32.3
T min (C)	12.3	13.6	17.3	20.9	24.5	27.8	30.1	29.9	27.3	23.8	17.7	13.4	21.6
T ave (C)	18.1	19.0	22.5	26.5	30.5	33.2	34.2	34.0	32.2	29.4	24.2	19.6	26.9
T rng (C)	11.6	10.8	10.4	11.1	12.0	10.7	8.2	8.1	9.8	11.2	13.0	12.5	10.8
RHmax (%)	81.0	86.0	85.0	82.0	78.0	80.0	81.0	82.0	81.0	84.0	74.0	79.0	81.1
RHmin (%)	51.0	55.0	56.0	53.0	51.0	55.0	58.0	59.0	54.0	52.0	44.0	48.0	53.0
Rain (mm)	39.7	48.8	48.1	11.2	7.4	0.0	0.8	2.5	1.4	2.5	2.7	20.5	185.6

Station No.: 49 **Station Type:** Sinoptice **Longitude:** 54° 50' E
Station Name: Bandar-Lengeh **Latitude:** 26° 35' N **Altitude:** 13 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	22.6	23.3	26.3	31.1	35.4	37.0	37.3	37.3	35.9	33.4	28.8	24.7	31.1
T min (C)	12.6	13.6	16.5	20.3	24.4	27.1	29.5	29.8	27.2	23.1	17.9	14.4	21.4
T ave (C)	17.6	18.5	21.4	25.7	29.9	32.0	33.4	33.5	31.6	28.3	23.3	19.5	26.2
T rng (C)	10.0	9.7	9.8	10.8	11.0	9.9	7.8	7.5	8.7	10.3	10.9	10.3	9.7
RHmax (%)	76.0	77.0	77.0	75.0	75.0	79.0	81.0	80.0	78.0	76.0	68.0	73.0	76.3
RHmin (%)	56.0	60.0	59.0	56.0	57.0	62.0	62.0	61.0	60.0	57.0	50.0	54.0	57.8
Rain (mm)	47.5	37.4	30.9	11.7	0.1	0.0	14.2	6.8	0.0	0.5	3.3	25.7	178.1

Station No.: 50 **Station Type:** Climatological **Longitude:** 49° 12' E
Station Name: Bandar-Mahshahr **Latitude:** 30° 30' N **Altitude:** 3 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	18.1	18.9	24.9	29.7	38.0	42.6	43.1	42.7	40.1	34.2	26.4	19.5	31.5
T min (C)	8.3	8.9	12.9	18.1	22.9	25.2	26.8	26.7	24.0	19.7	13.9	9.0	18.0
T ave (C)	13.2	13.9	18.9	23.9	30.5	33.9	34.9	34.7	32.0	27.0	20.1	14.3	24.8
T rng (C)	9.8	10.0	12.0	11.6	15.1	17.4	16.3	16.0	16.1	14.5	12.5	10.5	13.5
RHmax (%)	83.0	81.0	75.0	73.0	58.0	49.0	52.0	56.0	56.0	63.0	73.0	83.0	66.8
RHmin (%)	67.0	60.0	48.0	43.0	31.0	22.0	27.0	30.0	32.0	37.0	50.0	67.0	42.8
Rain (mm)	37.7	28.1	19.1	9.4	3.3	0.0	0.0	0.2	0.0	0.7	19.4	53.4	171.3

Station No.: 51 **Station Type:** Climatological **Longitude:** 48° 30' E
Station Name: Bonesydan **Latitude:** 32° 11' N **Altitude:** 5 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.2	18.9	24.0	29.6	38.3	43.9	45.6	44.9	41.7	34.6	26.3	18.7	32.0
T min (C)	5.0	5.7	9.1	13.4	19.0	21.6	24.5	24.1	20.4	15.7	10.7	6.3	14.6
T ave (C)	11.1	12.3	16.5	21.5	28.6	32.8	35.0	34.5	31.0	25.1	18.5	12.5	23.3
T rng (C)	12.2	13.2	14.9	16.2	19.3	22.3	21.1	20.8	21.3	18.9	15.6	12.4	17.4
RHmax (%)	91.0	91.0	84.0	77.0	52.0	39.0	41.0	43.0	45.0	57.0	79.0	8.6	59.0
RHmin (%)	64.0	58.0	48.0	37.0	19.0	14.0	15.0	18.0	18.0	28.0	44.0	62.0	35.4
Rain (mm)	87.7	43.7	44.6	38.2	10.6	0.0	0.0	0.0	2.7	7.3	62.2	113.6	410.6

Station No.: 52 **Station Type:** Climatological **Longitude:** 52° 26' E
Station Name: Bonkooh **Latitude:** 35° 18' N **Altitude:** 1006 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.3	11.7	17.8	24.3	29.1	34.3	35.6	34.8	31.5	24.7	17.5	11.4	23.5
T min (C)	-1.2	0.3	5.1	10.2	13.6	17.4	19.5	18.1	14.1	9.8	4.2	0.0	9.3
T ave (C)	4.1	6.0	11.4	17.3	21.4	25.8	27.5	26.5	22.8	17.3	10.9	5.7	16.4
T rng (C)	10.5	11.4	12.7	14.1	15.5	16.9	16.1	16.7	17.4	14.9	13.3	11.4	14.2
RHmax (%)	77.0	70.0	60.0	57.0	57.0	57.0	56.0	60.0	60.0	61.0	67.0	72.0	62.8
RHmin (%)	59.0	49.0	41.0	37.0	33.0	31.0	32.0	32.0	33.0	41.0	44.0	54.0	40.5
Rain (mm)	23.2	22.1	20.1	15.0	11.4	4.8	1.8	1.3	2.1	9.9	12.7	17.0	141.4

Station No.: 53 **Station Type:** Sinoptice **Longitude:** 50° 50' E
Station Name: Boshehr **Latitude:** 28° 59' N **Altitude:** 19 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	18.5	19.7	23.9	28.6	33.6	35.2	36.6	36.5	35.9	32.2	26.2	20.8	29.0
T min (C)	10.3	11.0	14.4	18.6	23.2	26.2	28.1	27.7	24.5	20.7	15.6	11.8	19.3
T ave (C)	14.4	15.4	19.1	23.6	28.4	30.7	32.3	32.1	30.2	26.5	20.9	16.3	24.2
T rng (C)	8.2	8.7	9.5	10.0	10.4	9.0	8.5	8.8	11.4	11.5	10.6	9.0	9.6
RHmax (%)	85.0	84.0	78.0	72.0	68.0	68.0	73.0	73.0	79.0	78.0	80.0	83.0	76.8
RHmin (%)	64.0	60.0	53.0	49.0	48.0	50.0	51.0	50.0	51.0	51.0	52.0	60.0	53.3
Rain (mm)	83.6	38.6	22.7	6.7	1.2	0.0	0.0	0.0	0.0	12.3	30.7	61.7	257.5

Station No.: 54 **Station Type:** Climatological **Longitude:** 50° 04' E
Station Name: Boein-Zahra **Latitude:** 35° 46' N **Altitude:** 1282 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.5	7.3	14.8	20.8	26.1	31.6	34.9	34.6	30.7	22.6	14.9	8.6	21.1
T min (C)	-5.2	-3.5	3.6	6.6	10.8	14.2	17.1	16.5	12.6	7.5	2.3	2.4	7.1
T ave (C)	0.7	1.9	9.2	13.7	18.5	22.9	26.0	25.5	21.7	15.1	8.6	5.5	14.1
T rng (C)	11.7	10.8	11.2	14.2	15.3	17.4	17.8	18.1	18.1	15.1	12.6	6.2	14.0
RHmax (%)	76.0	77.0	77.0	68.0	65.0	55.0	55.0	59.0	55.0	63.0	75.0	78.0	66.9
RHmin (%)	66.0	65.0	50.0	41.0	33.0	29.0	29.0	29.0	30.0	41.0	51.0	59.0	43.6
Rain (mm)	23.3	22.2	29.1	28.9	25.1	8.5	2.5	0.5	0.4	21.1	21.6	20.0	203.2

Station No.: 55 **Station Type:** Climatological **Longitude:** 55° 02' E
Station Name: Bayazeh-Biaabanak **Latitude:** 33° 20' N **Altitude:** 1450 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.9	11.8	14.8	23.0	29.3	36.0	37.4	35.2	32.1	27.8	16.6	12.7	24.0
T min (C)	1.8	2.7	5.4	11.4	15.8	19.1	20.2	19.8	17.9	14.2	5.8	3.0	11.4
T ave (C)	6.3	7.3	10.1	17.2	22.5	27.5	28.8	27.5	25.0	21.0	11.2	7.8	17.7
T rng (C)	9.1	9.1	9.4	11.6	13.5	16.9	17.2	15.4	14.2	13.6	10.8	9.7	12.5
RHmax (%)	52.0	54.0	50.0	42.0	40.0	28.0	25.0	26.0	29.0	39.0	49.0	51.0	40.4
RHmin (%)	51.0	47.0	45.0	40.0	33.0	23.0	22.0	23.0	26.0	34.0	44.0	48.0	36.3
Rain (mm)	19.7	21.3	22.3	15.6	7.0	0.1	0.0	0.0	0.0	2.9	8.0	25.6	122.5

Station No.: 56 **Station Type:** Climatological **Longitude:** 50° 23' E
Station Name: Bibalan **Latitude:** 37° 02' N **Altitude:** -10 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.5	11.2	15.2	19.5	24.4	27.5	29.8	29.7	27.4	22.1	17.8	15.4	21.0
T min (C)	0.9	1.1	3.2	7.0	12.1	14.4	16.5	16.2	13.6	8.8	4.7	2.8	8.4
T ave (C)	6.2	6.2	9.2	13.3	18.3	21.0	23.1	23.0	20.5	15.5	11.3	9.1	14.7
T rng (C)	10.6	10.1	12.0	12.5	12.3	13.1	13.3	13.5	13.8	13.3	13.1	12.6	12.5
RHmax(%)	84.0	87.0	85.0	84.0	85.0	85.0	84.0	85.0	87.0	85.0	84.0	82.0	84.8
RHmin (%)	77.0	78.0	78.0	74.0	77.0	78.0	77.0	79.0	81.0	80.0	79.0	76.0	77.8
Rain (mm)	107.7	107.7	132.6	87.2	78.3	72.5	51.6	85.0	197.9	261.4	146.3	114.7	1442.9

Station No.: 57 **Station Type:** Sinoptice **Longitude:** 59° 12' E
Station Name: Birjand **Latitude:** 32° 52' N **Altitude:** 1456 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.3	12.9	18.8	25.0	30.3	35.2	35.6	34.2	31.5	27.0	19.6	13.8	24.6
T min (C)	-1.8	0.0	4.5	9.7	13.9	17.9	19.4	16.9	12.0	8.1	2.1	-0.7	8.5
T ave (C)	4.8	6.4	11.6	17.4	22.1	26.5	27.5	25.5	21.8	17.5	10.9	6.6	16.6
T rng (C)	13.1	12.9	14.3	15.3	16.4	17.3	16.2	17.3	19.5	18.9	17.5	14.5	16.1
RHmax (%)	72.0	72.0	62.0	52.0	39.0	28.0	27.0	29.0	30.0	39.0	57.0	68.0	47.9
RHmin (%)	43.0	42.0	31.0	26.0	18.0	14.0	15.0	14.0	14.0	19.0	27.0	37.0	25.0
Rain (mm)	32.0	32.0	31.2	34.2	7.0	0.3	0.0	0.1	0.0	4.3	9.1	18.4	168.6

Station No.: 58 **Station Type:** Climatological **Longitude:** 47° 37' E
Station Name: Bijar **Latitude:** 35° 52' N **Altitude:** 1940 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	0.4	0.5	6.7	13.3	18.2	26.3	32.2	32.1	25.5	17.7	9.7	2.7	15.4
T min (C)	-12.2	-13.2	-6.5	0.2	5.2	9.2	12.4	12.6	7.9	2.6	-4.9	-9.0	0.4
T ave (C)	-5.9	-6.3	0.0	6.8	11.7	17.8	22.3	22.3	16.7	10.2	2.4	-3.2	7.9
T rng (C)	12.6	13.7	13.2	13.1	13.0	17.1	19.8	19.5	17.6	15.1	14.6	11.7	15.1
RHmax (%)	73.0	77.0	85.0	84.0	70.0	58.0	52.0	53.0	54.0	62.0	70.0	72.0	67.5
RHmin (%)	78.0	82.0	80.0	68.0	48.0	31.0	23.0	21.0	29.0	39.0	58.0	76.0	52.8
Rain (mm)	72.1	65.2	62.3	89.1	74.0	8.4	0.0	2.5	1.4	25.5	36.6	58.0	495.1

Station No.: 59 **Station Type:** Climatological **Longitude:** 47° 54' E
Station Name: Parsabad-Moghan **Latitude:** 39° 39' N **Altitude:** 59 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.9	8.6	13.5	20.3	26.5	30.9	34.7	33.9	29.8	20.7	15.5	10.4	21.0
T min (C)	-0.8	-0.8	3.1	7.4	11.7	15.3	19.2	18.9	16.2	10.3	5.9	1.4	9.0
T ave (C)	3.0	3.9	8.3	13.8	19.1	23.1	27.0	26.4	23.0	15.5	10.7	5.9	15.0
T rng (C)	7.7	9.4	10.4	12.9	14.8	15.6	15.5	15.0	13.6	10.4	9.6	9.0	12.0
RHmax (%)	82.0	84.0	83.0	81.0	78.0	75.0	70.0	73.0	75.0	78.0	82.0	81.0	78.5
RHmin (%)	79.0	75.0	71.0	66.0	62.0	60.0	51.0	55.0	58.0	68.0	73.0	73.0	65.9
Rain (mm)	31.3	27.0	28.3	32.8	34.1	29.7	4.1	5.9	13.4	39.6	28.3	25.6	300.1

Station No.: 60 **Station Type:** Climatological **Longitude:** 50° 54' E
Station Name: Pole-Zamankhan **Latitude:** 32° 29' N **Altitude:** 1860 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.4	15.1	18.2	20.9	25.6	32.5	35.7	34.6	31.0	26.2	20.7	16.7	24.1
T min (C)	-4.3	-4.0	-0.7	3.6	6.8	9.7	12.1	11.6	8.1	5.6	0.8	-4.0	3.8
T ave (C)	4.0	5.6	8.8	12.3	16.2	21.1	23.9	23.1	19.5	15.9	10.8	6.4	14.0
T rng (C)	16.7	19.1	18.9	17.3	18.8	22.8	23.6	23.0	22.9	20.6	19.9	20.7	20.4
RHmax (%)	77.0	75.0	75.0	71.0	62.0	45.0	39.0	40.0	48.0	58.0	71.0	75.0	61.3
RHmin (%)	48.0	48.0	40.0	34.0	26.0	23.0	25.0	25.0	25.0	29.0	33.0	44.0	33.3
Rain (mm)	48.0	56.9	54.4	51.2	25.2	1.0	1.6	0.5	0.0	16.1	33.1	49.0	337.0

Station No.: 61 **Station Type:** Climatological **Longitude:** 51° 14' E
Station Name: Pole-Kaleh **Latitude:** 32° 23' N **Altitude:** 1800 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.4	12.8	16.2	20.1	25.4	31.1	33.1	31.7	29.2	25.9	18.2	12.3	22.2
T min (C)	-5.3	-3.9	0.5	3.6	7.4	10.7	13.6	11.6	7.8	4.6	-0.1	-3.9	3.9
T ave (C)	2.5	4.4	8.4	11.9	16.4	20.9	23.3	21.7	18.5	15.3	9.1	4.2	13.0
T rng (C)	15.7	16.7	15.7	16.5	18.0	20.4	19.5	20.1	21.4	21.3	18.3	16.2	18.3
RHmax (%)	76.0	74.0	68.0	64.0	61.0	54.0	54.0	59.0	58.0	61.0	69.0	79.0	64.8
RHmin (%)	52.0	45.0	45.0	43.0	40.0	34.0	37.0	43.0	40.0	36.0	41.0	36.0	41.0
Rain (mm)	28.3	39.9	28.4	31.9	8.9	0.0	0.3	0.0	0.0	5.4	17.4	21.2	181.7

Station No.: 62 **Station Type:** Climatological **Longitude:** 49° 05' E
Station Name: Pilimbera **Latitude:** 37° 35' N **Altitude:** 6 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.0	10.6	12.6	17.9	23.1	27.5	30.8	29.3	26.4	20.8	16.2	13.4	19.9
T min (C)	3.0	3.3	5.5	9.1	13.6	17.2	19.7	19.4	17.2	12.8	8.7	5.9	11.3
T ave (C)	6.5	7.0	9.1	13.4	18.4	22.4	25.3	24.3	21.8	16.8	12.5	9.6	15.6
T rng (C)	7.0	7.3	7.1	8.5	9.5	10.3	11.1	9.9	9.2	8.0	7.5	7.5	8.6
RHmax(%)	91.0	91.0	93.0	93.0	92.0	91.0	88.0	91.0	93.0	94.0	91.0	94.0	91.8
RHmin(%)	81.0	81.0	77.0	79.0	74.0	70.0	65.0	70.0	75.0	77.0	79.0	79.0	75.6
Rain(mm)	216.4	112.5	150.9	121.1	140.5	125.7	62.5	179.3	217.8	351.9	251.1	185.5	2115.2

Station No.: 63 **Station Type:** Climatological **Longitude:** 47° 58' E
Station Name: Tazehkand **Latitude:** 37° 04' N **Altitude:** 63 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.7	4.0	12.5	18.4	24.2	30.9	34.4	34.2	29.7	21.4	12.4	6.2	19.3
T min (C)	-7.6	-6.1	1.0	5.7	9.0	12.5	15.1	15.0	10.9	6.2	0.4	-4.3	4.8
T ave (C)	-1.9	-1.0	6.8	12.0	16.6	21.7	24.8	24.6	20.3	13.8	6.4	0.9	12.1
T rng (C)	11.3	10.1	11.5	12.7	15.2	18.4	19.3	19.2	18.8	15.2	12.0	10.5	14.5
RHmax (%)	81.0	80.0	83.0	81.0	80.0	73.0	73.0	73.0	75.0	80.0	85.0	87.0	79.3
RHmin (%)	70.0	74.0	70.0	69.0	69.0	63.0	64.0	62.0	62.0	62.0	76.0	80.0	68.4
Rain (mm)	33.3	29.7	48.0	65.6	61.2	8.0	0.5	2.7	5.9	41.6	42.1	27.8	366.4

Station No.: 64 **Station Type:** Climatological **Longitude:** 55° 33' E
Station Name: Tashkouiyeh (Kallegah) **Latitude:** 28° 04' N **Altitude:** 750 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	20.1	22.0	26.8	32.7	39.3	43.8	44.6	43.6	40.4	35.3	27.4	22.3	33.2
T min (C)	4.9	7.0	10.9	15.7	20.9	24.9	27.3	26.6	21.7	16.3	9.6	5.9	16.0
T ave (C)	12.5	14.5	18.8	24.2	30.1	34.3	35.9	35.1	31.1	25.8	18.5	14.1	24.6
T rng (C)	15.2	15.0	15.9	17.0	18.4	18.9	17.3	17.0	18.7	19.0	17.8	16.4	17.2
RHmax (%)	78.0	78.0	67.0	57.0	47.0	41.0	49.0	52.0	51.0	51.0	62.0	72.0	58.8
RHmin (%)	51.0	47.0	39.0	30.0	24.0	19.0	23.0	25.0	23.0	29.0	35.0	45.0	32.5
Rain (mm)	34.8	55.0	35.6	17.6	3.6	0.5	9.1	4.2	0.1	0.8	4.0	14.5	179.8

Station No.: 65 **Station Type:** Climatological **Longitude:** 49° 42' E
Station Name: Takestan **Latitude:** 36° 04' N **Altitude:** 1361 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.5	8.1	13.7	19.9	25.4	30.6	33.1	33.5	29.9	21.8	14.1	8.1	20.4
T min (C)	-4.2	-2.9	1.5	5.9	10.0	13.8	16.4	15.9	11.9	6.6	1.4	-2.9	6.1
T ave (C)	1.2	2.6	7.6	12.9	17.7	22.2	24.8	24.9	20.9	14.2	7.8	2.6	13.3
T rng (C)	10.7	11.0	12.2	14.0	15.4	16.8	16.7	17.6	18.0	15.2	12.7	11.0	14.3
RHmax (%)	79.0	81.0	69.0	66.0	65.0	52.0	49.0	52.0	52.0	66.0	71.0	81.0	65.3
RHmin (%)	62.0	57.0	45.0	37.0	35.0	27.0	27.0	27.0	27.0	39.0	51.0	56.0	40.8
Rain (mm)	21.9	19.5	35.7	43.4	45.0	6.6	3.3	0.7	1.2	26.1	22.9	28.4	255.3

Station No.: 66 **Station Type:** Sinoptice **Longitude:** 46° 17' E
Station Name: Tabriz **Latitude:** 38° 05' N **Altitude:** 1361 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.0	4.3	10.2	16.8	22.0	28.1	32.6	32.4	28.2	19.9	11.7	4.9	17.8
T min (C)	-5.2	-3.2	0.5	5.8	10.5	14.8	19.2	19.1	14.4	7.9	1.6	-1.7	7.0
T ave (C)	-1.6	0.6	5.3	11.3	16.3	21.5	25.9	25.8	21.3	13.9	6.7	1.6	12.4
T rng (C)	7.2	7.5	9.7	11.0	11.5	13.3	13.4	13.3	13.8	12.0	10.1	6.6	10.8
RHmax (%)	77.0	78.0	75.0	71.0	68.0	55.0	45.0	46.0	51.0	66.0	77.0	79.0	65.7
RHmin (%)	62.0	59.0	51.0	44.0	40.0	29.0	24.0	25.0	25.0	39.0	51.0	61.0	42.5
Rain (mm)	24.6	23.6	48.3	56.1	52.9	24.3	1.8	3.5	9.9	29.3	28.3	27.6	330.2

Station No.: 67 **Station Type:** Climatological **Longitude:** 51° 27' E
Station Name: Tajrish (Dezashib) **Latitude:** 35° 48' N **Altitude:** 67 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.1	8.3	13.6	19.3	25.1	32.1	34.6	33.9	29.9	22.2	14.5	8.0	20.6
T min (C)	-2.6	-1.5	3.1	8.0	12.5	17.6	21.2	20.2	16.4	10.3	4.2	-0.5	9.1
T ave (C)	1.8	3.4	8.4	13.6	18.8	24.8	27.9	27.1	23.1	16.3	9.4	3.8	14.9
T rng (C)	8.7	9.8	10.5	11.3	12.6	14.5	13.4	13.7	13.5	11.9	10.3	8.5	11.6
RHmax (%)	81.0	80.0	75.0	72.0	74.0	64.0	66.0	64.0	57.0	70.0	79.0	81.0	71.9
RHmin (%)	73.0	67.0	57.0	54.0	53.0	42.0	51.0	48.0	42.0	52.0	60.0	67.0	55.5
Rain (mm)	57.9	47.6	57.0	52.2	46.4	6.0	6.6	3.9	1.3	28.8	39.9	59.0	406.6

Station No.: 68 **Station Type:** Sinoptice **Longitude:** 59° 13' E
Station Name: Torbat-Heydarieh **Latitude:** 35° 16' N **Altitude:** 1333 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.0	8.7	15.0	22.0	27.8	33.0	34.3	33.2	30.3	24.0	16.4	10.2	21.8
T min (C)	-4.5	-2.7	2.2	8.1	12.3	16.6	18.9	16.4	11.5	6.7	1.0	-1.7	7.1
T ave (C)	1.3	3.0	8.6	15.1	20.0	24.8	26.6	24.8	20.9	15.4	8.7	4.3	14.4
T rng (C)	11.5	11.4	12.8	13.9	15.5	16.4	15.4	16.8	18.8	17.3	15.4	11.9	14.8
RHmax (%)	82.0	83.0	79.0	72.0	57.0	44.0	40.0	41.0	47.0	62.0	74.0	81.0	63.5
RHmin (%)	61.0	59.0	48.0	38.0	28.0	22.0	20.0	20.0	21.0	30.0	41.0	54.0	36.8
Rain (mm)	59.0	57.1	47.3	39.9	17.7	3.4	0.4	0.0	0.1	6.9	18.1	45.4	295.3

Station No.: 69 **Station Type:** Climatological **Longitude:** 50° 02' E
Station Name: Tafresh **Latitude:** 34° 41' N **Altitude:** 1878 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.5	6.6	11.7	17.2	22.9	29.3	33.0	32.2	28.1	20.7	12.8	7.4	18.9
T min (C)	-4.9	-4.5	0.4	4.6	9.1	13.7	18.0	17.2	12.6	6.6	1.2	-2.6	6.0
T ave (C)	0.3	1.0	6.0	10.9	16.0	21.5	25.5	24.7	20.4	13.7	7.0	2.4	12.4
T rng (C)	10.4	11.1	11.3	12.6	13.8	15.6	15.0	15.0	15.5	14.1	11.6	10.0	13.0
RHmax (%)	74.0	76.0	72.0	65.0	55.0	46.0	40.0	39.0	44.0	57.0	72.0	74.0	59.5
RHmin (%)	67.0	62.0	51.0	41.0	34.0	24.0	21.0	20.0	21.0	33.0	46.0	59.0	39.9
Rain (mm)	43.2	28.8	43.8	39.9	41.2	4.0	2.3	0.8	0.3	20.5	22.5	28.7	276.0

Station No.: 70 **Station Type:** Climatological **Longitude:** 48° 45' E
Station Name: Tange-Panj **Latitude:** 32° 56' N **Altitude:** 641 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	13.5	15.9	21.6	26.7	34.0	41.6	44.4	43.9	40.5	32.4	22.3	15.4	29.3
T min (C)	5.8	7.0	11.2	15.3	21.8	28.4	31.9	31.3	27.3	20.7	12.5	7.8	18.4
T ave (C)	9.6	11.4	16.4	21.0	27.9	35.0	38.2	37.6	33.9	26.6	17.4	11.6	23.9
T rng (C)	7.7	8.9	10.4	11.4	12.2	13.2	12.5	12.6	13.2	11.7	9.8	7.6	10.9
RHmax (%)	77.0	73.0	68.0	63.0	46.0	24.0	20.0	23.0	25.0	36.0	64.0	73.0	49.3
RHmin (%)	59.0	50.0	43.0	36.0	24.0	14.0	12.0	12.0	13.0	20.0	46.0	59.0	32.3
Rain(mm)	231.4	186.3	179.8	99.8	41.1	0.0	0.0	0.0	0.0	33.0	115.	190.8	1077.2

Station No.: 71 **Station Type:** Climatological **Longitude:** 51° 23' E
Station Name: Tehran (Park-Shahr) **Latitude:** 35° 41' N **Altitude:** 1210 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.3	11.0	16.0	22.6	27.0	33.3	36.0	34.6	31.6	25.3	17.4	10.3	22.8
T min (C)	-1.8	0.4	4.7	10.0	13.1	17.4	20.6	19.0	15.6	10.8	4.9	0.9	9.6
T ave (C)	3.3	5.7	10.4	16.3	20.0	25.3	28.3	26.8	23.6	18.0	11.1	5.6	16.2
T rng (C)	10.1	10.6	11.3	12.6	13.9	15.9	15.4	15.6	16.0	14.5	12.5	9.4	13.1
RHmax (%)	76.0	76.0	68.0	66.0	69.0	64.0	65.0	63.0	65.0	70.0	75.0	80.0	69.8
RHmin (%)	61.0	53.0	45.0	40.0	38.0	31.0	32.0	31.0	35.0	39.0	49.0	59.0	42.8
Rain (mm)	29.3	30.6	43.4	25.4	24.9	5.7	0.3	3.6	0.5	17.2	22.4	40.8	244.1

Station No.: 72 **Station Type:** Sinoptice **Longitude:** 51° 25' E
Station Name: Tehran (Doshan-Tappeh) **Latitude:** 35° 42' N **Altitude:** 1232 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.9	10.1	15.4	23.1	27.5	33.5	36.9	35.3	31.9	23.9	15.8	10.3	22.6
T min (C)	-0.1	1.0	5.7	12.2	16.6	21.9	25.4	23.7	20.1	13.1	6.1	2.2	12.3
T ave (C)	3.9	5.6	10.5	17.6	22.0	27.7	31.2	29.5	26.0	18.5	10.9	6.3	17.5
T rng (C)	8.0	9.1	9.7	10.9	10.9	11.6	11.5	11.6	11.8	10.8	9.7	8.1	10.3
RHmax (%)	75.0	71.0	62.0	51.0	48.0	38.0	34.0	35.0	33.0	50.0	59.0	70.0	52.2
RHmin (%)	57.0	52.0	42.0	33.0	30.0	25.0	25.0	25.0	26.0	36.0	42.0	53.0	37.2
Rain (mm)	47.4	43.0	43.2	26.5	23.1	5.2	1.5	1.7	0.0	23.2	27.7	41.0	283.5

Station No.: 67 **Station Type:** Climatological **Longitude:** 51° 27' E
Station Name: Tajrish (Dezashib) **Latitude:** 35° 48' N **Altitude:** 67 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.1	8.3	13.6	19.3	25.1	32.1	34.6	33.9	29.9	22.2	14.5	8.0	20.6
T min (C)	-2.6	-1.5	3.1	8.0	12.5	17.6	21.2	20.2	16.4	10.3	4.2	-0.5	9.1
T ave (C)	1.8	3.4	8.4	13.6	18.8	24.8	27.9	27.1	23.1	16.3	9.4	3.8	14.9
T rng (C)	8.7	9.8	10.5	11.3	12.6	14.5	13.4	13.7	13.5	11.9	10.3	8.5	11.6
RHmax (%)	81.0	80.0	75.0	72.0	74.0	64.0	66.0	64.0	57.0	70.0	79.0	81.0	71.9
RHmin (%)	73.0	67.0	57.0	54.0	53.0	42.0	51.0	48.0	42.0	52.0	60.0	67.0	55.5
Rain (mm)	57.9	47.6	57.0	52.2	46.4	6.0	6.6	3.9	1.3	28.8	39.9	59.0	406.6

Station No.: 68 **Station Type:** Sinoptice **Longitude:** 59° 13' E
Station Name: Torbat-Heydarieh **Latitude:** 35° 16' N **Altitude:** 1333 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.0	8.7	15.0	22.0	27.8	33.0	34.3	33.2	30.3	24.0	16.4	10.2	21.8
T min (C)	-4.5	-2.7	2.2	8.1	12.3	16.6	18.9	16.4	11.5	6.7	1.0	-1.7	7.1
T ave (C)	1.3	3.0	8.6	15.1	20.0	24.8	26.6	24.8	20.9	15.4	8.7	4.3	14.4
T rng (C)	11.5	11.4	12.8	13.9	15.5	16.4	15.4	16.8	18.8	17.3	15.4	11.9	14.8
RHmax (%)	82.0	83.0	79.0	72.0	57.0	44.0	40.0	41.0	47.0	62.0	74.0	81.0	63.5
RHmin (%)	61.0	59.0	48.0	38.0	28.0	22.0	20.0	20.0	21.0	30.0	41.0	54.0	36.8
Rain (mm)	59.0	57.1	47.3	39.9	17.7	3.4	0.4	0.0	0.1	6.9	18.1	45.4	295.3

Station No.: 69 **Station Type:** Climatological **Longitude:** 50° 02' E
Station Name: Tafresh **Latitude:** 34° 41' N **Altitude:** 1878 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.5	6.6	11.7	17.2	22.9	29.3	33.0	32.2	28.1	20.7	12.8	7.4	18.9
T min (C)	-4.9	-4.5	0.4	4.6	9.1	13.7	18.0	17.2	12.6	6.6	1.2	-2.6	6.0
T ave (C)	0.3	1.0	6.0	10.9	16.0	21.5	25.5	24.7	20.4	13.7	7.0	2.4	12.4
T rng (C)	10.4	11.1	11.3	12.6	13.8	15.6	15.0	15.0	15.5	14.1	11.6	10.0	13.0
RHmax (%)	74.0	76.0	72.0	65.0	55.0	46.0	40.0	39.0	44.0	57.0	72.0	74.0	59.5
RHmin (%)	67.0	62.0	51.0	41.0	34.0	24.0	21.0	20.0	21.0	33.0	46.0	59.0	39.9
Rain (mm)	43.2	28.8	43.8	39.9	41.2	4.0	2.3	0.8	0.3	20.5	22.5	28.7	276.0

Station No.: 70 **Station Type:** Climatological **Longitude:** 48° 45' E
Station Name: Tange-Panj **Latitude:** 32° 56' N **Altitude:** 641 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	13.5	15.9	21.6	26.7	34.0	41.6	44.4	43.9	40.5	32.4	22.3	15.4	29.3
T min (C)	5.8	7.0	11.2	15.3	21.8	28.4	31.9	31.3	27.3	20.7	12.5	7.8	18.4
T ave (C)	9.6	11.4	16.4	21.0	27.9	35.0	38.2	37.6	33.9	26.6	17.4	11.6	23.9
T rng (C)	7.7	8.9	10.4	11.4	12.2	13.2	12.5	12.6	13.2	11.7	9.8	7.6	10.9
RHmax (%)	77.0	73.0	68.0	63.0	46.0	24.0	20.0	23.0	25.0	36.0	64.0	73.0	49.3
RHmin (%)	59.0	50.0	43.0	36.0	24.0	14.0	12.0	12.0	13.0	20.0	46.0	59.0	32.3
Rain(mm)	231.4	186.3	179.8	99.8	41.1	0.0	0.0	0.0	0.0	33.0	115.	190.8	1077.2

Station No.: 71 **Station Type:** Climatological **Longitude:** 51° 23' E
Station Name: Tehran (Park-Shahr) **Latitude:** 35° 41' N **Altitude:** 1210 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.3	11.0	16.0	22.6	27.0	33.3	36.0	34.6	31.6	25.3	17.4	10.3	22.8
T min (C)	-1.8	0.4	4.7	10.0	13.1	17.4	20.6	19.0	15.6	10.8	4.9	0.9	9.6
T ave (C)	3.3	5.7	10.4	16.3	20.0	25.3	28.3	26.8	23.6	18.0	11.1	5.6	16.2
T rng (C)	10.1	10.6	11.3	12.6	13.9	15.9	15.4	15.6	16.0	14.5	12.5	9.4	13.1
RHmax (%)	76.0	76.0	68.0	66.0	69.0	64.0	65.0	63.0	65.0	70.0	75.0	80.0	69.8
RHmin (%)	61.0	53.0	45.0	40.0	38.0	31.0	32.0	31.0	35.0	39.0	49.0	59.0	42.8
Rain (mm)	29.3	30.6	43.4	25.4	24.9	5.7	0.3	3.6	0.5	17.2	22.4	40.8	244.1

Station No.: 72 **Station Type:** Sinoptice **Longitude:** 51° 25' E
Station Name: Tehran (Doshan-Tappeh) **Latitude:** 35° 42' N **Altitude:** 1232 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.9	10.1	15.4	23.1	27.5	33.5	36.9	35.3	31.9	23.9	15.8	10.3	22.6
T min (C)	-0.1	1.0	5.7	12.2	16.6	21.9	25.4	23.7	20.1	13.1	6.1	2.2	12.3
T ave (C)	3.9	5.6	10.5	17.6	22.0	27.7	31.2	29.5	26.0	18.5	10.9	6.3	17.5
T rng (C)	8.0	9.1	9.7	10.9	10.9	11.6	11.5	11.6	11.8	10.8	9.7	8.1	10.3
RHmax (%)	75.0	71.0	62.0	51.0	48.0	38.0	34.0	35.0	33.0	50.0	59.0	70.0	52.2
RHmin (%)	57.0	52.0	42.0	33.0	30.0	25.0	25.0	25.0	26.0	36.0	42.0	53.0	37.2
Rain (mm)	47.4	43.0	43.2	26.5	23.1	5.2	1.5	1.7	0.0	23.2	27.7	41.0	283.5

Station No.: 73 **Station Type:** Climatological **Longitude:** 51° 25' E
Station Name: Tehran (Saadabad) **Latitude:** 35° 50' N **Altitude:** 1700 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.6	7.1	12.0	16.2	21.4	28.6	31.9	31.0	27.3	19.2	14.2	8.4	18.6
T min (C)	-3.9	-2.6	1.8	6.2	11.5	15.4	19.7	18.7	14.7	8.2	3.4	-1.6	7.6
T ave (C)	0.8	2.3	6.9	11.2	16.5	22.0	25.8	24.9	21.0	13.7	8.8	3.4	13.1
T rng (C)	9.5	9.7	10.2	10.0	9.9	13.2	12.2	12.3	12.6	11.0	10.8	10.0	10.9
RHmax (%)	77.0	75.0	68.0	60.0	58.0	48.0	48.0	44.0	46.0	59.0	67.0	73.0	60.3
RHmin (%)	67.0	65.0	52.0	46.0	36.0	25.0	26.0	25.0	28.0	40.0	43.0	57.0	42.5
Rain (mm)	59.8	46.6	48.7	50.3	32.8	5.4	4.8	2.0	1.7	24.9	34.0	50.9	361.9

Station No.: 74 **Station Type:** Sinoptice **Longitude:** 51° 19' E
Station Name: Tehran (Mehrabad) **Latitude:** 35° 41' N **Altitude:** 1191 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.5	9.7	15.4	22.3	27.7	33.7	36.8	35.4	31.5	24.0	16.0	10.0	22.5
T min (C)	-0.9	0.3	5.1	11.2	15.7	20.2	23.8	22.9	19.1	12.8	6.0	1.2	11.4
T ave (C)	3.3	5.0	10.3	16.8	21.7	27.0	30.3	29.2	25.3	18.4	11.0	5.6	17.0
T rng (C)	8.4	9.4	10.3	11.1	12.0	13.5	13.0	12.5	12.4	11.2	10.0	8.8	11.0
RHmax (%)	74.0	70.0	60.0	49.0	45.0	34.0	31.0	30.0	31.0	47.0	59.0	71.0	50.1
RHmin (%)	55.0	48.0	38.0	28.0	25.0	18.0	18.0	18.0	19.0	28.0	38.0	50.0	31.9
Rain (mm)	40.3	31.5	44.2	25.3	18.4	4.4	1.0	1.3	0.5	17.1	24.0	36.3	244.3

Station No.: 75 **Station Type:** Climatological **Longitude:** 51° 31' E
Station Name: Teahran (Narmak) **Latitude:** 34° 45' N **Altitude:** 1290 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.2	9.3	13.9	20.2	25.5	31.5	34.1	33.0	29.8	23.5	14.9	9.7	21.2
T min (C)	0.2	-1.2	3.3	9.0	14.4	19.1	21.5	20.2	16.7	11.1	4.3	0.5	9.9
T ave (C)	4.7	4.1	8.6	14.6	20.0	25.3	27.8	26.6	23.3	17.3	9.6	5.1	15.6
T rng (C)	9.0	10.5	10.6	11.2	11.1	12.4	12.6	12.8	13.1	12.4	10.6	9.2	11.3
RHmax (%)	77.0	80.0	64.0	55.0	49.0	40.0	40.0	41.0	44.0	51.0	62.0	76.0	56.6
RHmin (%)	51.0	55.0	43.0	34.0	40.0	23.0	22.0	23.0	25.0	33.0	44.0	54.0	37.3
Rain (mm)	37.3	40.7	71.8	37.8	30.8	6.7	11.4	1.9	0.3	11.4	32.1	56.9	339.1

Station No.: 76 **Station Type:** Climatological **Longitude:** 51° 25' E
Station Name: Teahran (Namayeshgah) **Latitude:** 35° 47' N **Altitude:** 1541 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.2	7.6	12.6	18.8	23.9	30.1	33.3	32.1	28.7	22.1	13.9	8.0	19.7
T min (C)	-2.8	-1.4	2.1	7.7	12.4	17.5	21.0	19.9	16.3	10.3	3.9	-0.4	8.9
T ave (C)	1.2	3.1	7.4	13.3	18.1	23.8	27.1	26.0	22.5	16.2	8.9	3.8	14.3
T rng (C)	8.0	9.0	10.5	11.1	11.5	12.6	12.3	12.2	12.4	11.8	10.0	8.4	10.8
RHmax (%)	74.0	71.0	65.0	56.0	51.0	43.0	39.0	41.0	41.0	52.0	66.0	73.0	56.0
RHmin (%)	65.0	59.0	47.0	37.0	36.0	27.0	24.0	26.0	26.0	35.0	48.0	61.0	40.9
Rain (mm)	61.0	47.1	74.0	41.9	39.1	4.9	4.6	2.1	2.1	20.1	33.2	62.7	392.8

Station No.: 77 **Station Type:** Sinoptice **Longitude:** 57° 46' E
Station Name: Jask **Latitude:** 25° 38' N **Altitude:** 4 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	23.4	23.6	26.5	30.1	33.7	35.2	34.5	33.7	33.2	32.1	28.7	25.6	30.0
T min (C)	15.5	16.3	19.3	22.8	26.0	28.7	29.5	29.0	27.1	24.0	20.3	17.7	23.0
T ave (C)	19.5	20.0	22.9	26.5	29.9	32.0	32.0	31.4	30.2	28.0	24.5	21.7	26.5
T rng (C)	7.9	7.3	7.2	7.3	7.7	6.5	5.0	4.7	6.1	8.1	8.4	7.9	7.0
RHmax (%)	67.0	67.0	70.0	68.0	68.0	73.0	78.0	79.0	75.0	72.0	65.0	66.0	70.7
RHmin (%)	53.0	54.0	57.0	56.0	56.0	63.0	67.0	68.0	64.0	60.0	54.0	53.0	58.8
Rain (mm)	59.0	45.2	23.2	16.0	0.0	0.0	4.4	0.4	0.0	12.2	9.2	7.5	177.1

Station No.: 78 **Station Type:** Climatological **Longitude:** 50° 16' E
Station Name: Jazireh-Khark **Latitude:** 29° 16' N **Altitude:** 3 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	18.5	19.3	23.2	28.0	34.7	37.5	38.3	37.9	36.5	32.5	26.3	21.8	29.5
T min (C)	12.6	12.3	15.2	18.6	23.4	26.8	28.4	28.8	26.6	23.2	18.7	14.7	20.8
T ave (C)	15.6	15.8	19.2	23.3	29.0	32.2	33.3	33.3	31.5	27.9	22.5	18.3	25.2
T rng (C)	5.9	7.0	8.0	9.4	11.3	10.7	9.9	9.1	9.9	9.3	7.6	7.1	8.8
RHmax (%)	76.0	78.0	76.0	77.0	70.0	65.0	69.0	73.0	79.0	76.0	71.0	72.0	73.5
RHmin (%)	66.0	63.0	59.0	54.0	44.0	40.0	46.0	50.0	53.0	53.0	55.0	63.0	53.8
Rain (mm)	70.5	32.3	19.2	9.8	1.7	0 0	0.0	0.0	0.0	14.9	53.1	62.5	264.0

Station No.:	79	Station Type:	Climatological	Longitude:	56° 15' E
Station Name:	Jazireh-Gheshm	Latitude:	26° 57' N	Altitude:	31 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	22.6	23.1	26.8	31.3	35.0	37.9	38.6	37.8	36.4	34.4	29.0	24.8	31.5
T min (C)	15.6	15.3	18.4	21.1	24.1	27.0	29.2	29.6	28.5	25.4	21.0	17.4	22.7
T ave (C)	19.1	19.2	22.6	26.2	29.5	32.5	33.9	33.7	32.5	29.9	25.0	21.1	27.1
T rng (C)	7.0	7.8	8.4	10.2	10.9	10.9	9.4	8.2	7.9	9.0	8.0	7.4	8.8
RHmax (%)	69.0	73.0	75.0	77.0	78.0	80.0	80.0	79.0	77.0	78.0	69.0	68.0	75.3
RHmin (%)	53.0	57.0	57.0	53.0	49.0	52.0	55.0	59.0	56.0	55.0	51.0	52.0	54.1
Rain (mm)	35.5	50.8	35.4	4.3	0.7	0.0	0.2	2.7	0.0	0.3	9.8	13.6	153.3

Station No.:	80	Station Type:	Climatological	Longitude:	45° 38' E
Station Name:	Jolfa	Latitude:	38° 56' N	Altitude:	704 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.6	8.9	15.1	21.7	27.1	31.9	35.6	35.3	31.5	22.9	14.8	9.7	21.8
T min (C)	-2.8	-1.4	2.6	8.7	13.8	18.4	22.0	21.7	16.2	9.2	2.5	-0.1	9.2
T ave (C)	1.9	3.7	8.9	15.2	20.5	25.1	28.8	28.5	23.9	16.0	8.6	4.8	15.5
T rng (C)	9.4	10.3	12.5	13.0	13.3	13.5	13.6	13.6	15.3	13.7	12.3	9.8	12.5
RHmax (%)	84.0	83.0	78.0	75.0	73.0	63.0	54.0	56.0	70.0	81.0	85.0	85.0	73.9
RHmin (%)	70.0	64.0	48.0	45.0	42.0	35.0	31.0	31.0	35.0	51.0	57.0	63.0	47.7
Rain (mm)	18.1	15.7	24.7	38.5	40.2	22.4	4.9	4.4	7.5	24.6	18.3	16.6	235.9

Station No.:	81	Station Type:	Climatological	Longitude:	57° 46' E
Station Name:	Jiroft	Latitude:	28° 37' N	Altitude:	668 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	19.5	21.6	26.6	31.9	38.0	42.3	43.4	42.0	38.6	34.2	25.8	21.0	32.1
T min (C)	5.6	7.3	12.0	16.8	19.5	21.5	21.9	20.8	17.3	14.0	8.8	5.9	14.3
T ave (C)	12.6	14.5	19.3	24.3	28.8	31.9	32.7	31.4	27.9	24.1	17.3	13.4	23.2
T rng (C)	13.9	14.3	14.6	15.1	18.5	20.8	21.5	21.2	21.3	20.2	17.0	15.1	17.8
RHmax (%)	72.0	77.0	71.0	66.0	49.0	49.0	53.0	55.0	55.0	52.0	58.0	64.0	60.1
RHmin (%)	55.0	58.0	55.0	48.0	33.0	31.0	31.0	36.0	34.0	34.0	38.0	44.0	41.4
Rain (mm)	53.1	53.4	53.3	18.3	1.7	0.1	2.2	0.1	0.0	5.5	4.7	18.0	192.4

Station No.:	82	Station Type:	Sinoptice	Longitude:	60° 22' E
Station Name:	Chahbahar	Latitude:	25° 26' N	Altitude:	10 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	24.6	25.2	28.5	31.7	34.6	35.7	34.1	33.4	33.2	32.8	29.9	26.7	30.9
T min (C)	15.3	16.0	19.1	22.0	24.9	27.5	27.9	27.1	25.1	22.6	18.4	15.9	21.8
T ave (C)	20.0	20.6	23.8	26.9	29.8	31.6	31.0	30.3	29.2	27.7	24.1	21.3	26.3
T rng (C)	9.3	9.2	9.4	9.7	9.7	8.2	6.2	6.3	8.1	10.2	11.5	10.8	9.1
RHmax (%)	70.0	71.0	77.0	77.0	80.0	83.0	82.0	83.0	80.0	83.0	75.0	72.0	77.8
RHmin (%)	50.0	53.0	54.0	54.0	58.0	62.0	66.0	66.0	59.0	57.0	49.0	48.0	56.3
Rain (mm)	45.0	41.0	18.8	7.1	0.0	0.9	7.5	2.5	2.4	0.0	5.3	7.5	138.0

Station No.:	83	Station Type:	Climatological	Longitude:	55° 28' E
Station Name:	Choghart	Latitude:	31° 40' N	Altitude:	1340 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	14.1	15.5	21.3	27.5	33.2	38.8	40.3	38.7	35.5	29.2	21.9	16.4	27.7
T min (C)	2.1	3.7	8.8	14.3	19.0	23.7	25.2	22.9	18.6	13.8	7.6	3.4	13.6
T ave (C)	8.1	9.6	15.0	20.9	26.1	31.3	32.8	30.8	27.0	21.5	14.8	9.9	20.6
T rng (C)	12.0	11.8	12.5	13.2	14.2	15.1	15.1	15.8	16.9	15.4	14.3	13.0	14.1
RHmax (%)	67.0	66.0	57.0	49.0	39.0	29.0	27.0	27.0	30.0	41.0	52.0	63.0	45.6
RHmin (%)	46.0	42.0	36.0	31.0	26.0	21.0	21.0	21.0	23.0	30.0	37.0	42.0	31.3
Rain (mm)	11.2	11.9	7.8	10.7	5.2	0.0	0.3	0.0	0.0	1.7	2.4	5.6	56.8

Station No.:	84	Station Type:	Climatological	Longitude:	59° 07' E
Station Name:	Chenaran	Latitude:	36° 38' N	Altitude:	1350 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.0	7.2	13.4	20.1	25.2	29.7	32.7	31.5	27.5	21.0	14.0	9.3	19.8
T min (C)	-5.2	-3.4	1.1	6.7	10.8	14.0	16.2	14.1	9.6	5.1	0.6	-2.2	5.6
T ave (C)	0.4	1.9	7.3	13.4	18.0	21.9	24.5	22.8	18.5	13.1	7.3	3.6	12.7
T rng (C)	11.2	10.6	12.3	13.4	14.4	15.7	16.5	17.4	17.9	15.9	13.4	11.5	14.2
RHmax (%)	85.0	87.0	80.0	76.0	68.0	60.0	56.0	59.0	61.0	74.0	83.0	86.0	72.9
RHmin (%)	61.0	57.0	52.0	49.0	43.0	37.0	35.0	34.0	37.0	45.0	50.0	56.0	46.3
Rain (mm)	40.7	37.7	51.6	41.8	38.4	5.7	2.9	0.1	4.0	16.7	25.6	25.4	290.6

Station No.: 85 **Station Type:** Climatological **Longitude:** 55° 55' E
Station Name: Hajiabad (Bandar-Abbas) **Latitude:** 28° 19' N **Altitude:** 900 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.5	19.5	25.1	30.1	37.3	42.1	42.6	41.7	38.5	33.0	26.2	20.2	31.2
T min (C)	5.8	6.5	10.9	15.2	20.9	24.7	27.6	26.6	22.2	16.7	10.6	6.3	16.2
T ave (C)	11.6	13.0	18.0	22.6	29.1	33.4	35.1	34.2	30.4	24.9	18.4	13.3	23.7
T rng (C)	11.7	13.0	14.2	14.9	16.4	17.4	15.0	15.1	16.3	16.3	15.6	13.9	15.0
RHmax (%)	65.0	66.0	57.0	49.0	31.0	29.0	43.0	30.0	31.0	35.0	42.0	60.0	44.8
RHmin (%)	41.0	40.0	31.0	27.0	17.0	16.0	24.0	17.0	22.0	23.0	29.0	35.0	26.8
Rain (mm)	74.2	60.5	43.6	39.8	3.7	3.5	11.4	7.5	4.7	1.8	2.0	22.9	275.6

Station No.: 86 **Station Type:** Climatological **Longitude:** 54° 02' E
Station Name: Hojatabad-Pishkooh **Latitude:** 31° 42' N **Altitude:** 1500 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.3	9.0	12.3	18.5	24.1	30.3	31.8	30.6	27.0	21.0	12.7	9.0	19.5
T min (C)	-3.4	-0.9	2.0	5.8	10.6	15.5	17.2	15.7	11.4	6.7	1.1	-1.7	6.7
T ave (C)	2.0	4.1	7.2	12.1	17.4	22.9	24.5	23.1	19.2	13.9	6.9	3.7	13.1
T rng (C)	10.7	9.9	10.3	12.7	13.5	14.8	14.6	14.9	15.6	14.3	11.6	10.7	12.8
RHmax (%)	74.0	72.0	66.0	57.0	41.0	35.0	33.0	34.0	40.0	49.0	69.0	75.0	53.8
RHmin (%)	56.0	49.0	39.0	31.0	25.0	19.0	19.0	18.0	21.0	28.0	40.0	51.0	33.0
Rain (mm)	30.0	25.5	30.5	27.1	10.4	0.4	3.2	0.0	0.0	6.2	11.8	29.1	174.2

Station No.: 87 **Station Type:** Climatological **Longitude:** 48° 26' E
Station Name: Hamidiyeh **Latitude:** 31° 29' N **Altitude:** 53 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	18.4	20.7	25.4	32.3	38.9	43.4	45.1	44.6	42.3	35.4	27.7	20.5	32.9
T min (C)	6.8	7.9	11.2	15.4	19.7	21.6	23.4	23.3	20.1	15.8	11.2	7.3	15.3
T ave (C)	12.6	14.3	18.3	23.8	29.3	32.5	34.3	33.9	31.2	25.6	19.5	13.9	24.1
T rng (C)	11.6	12.8	14.2	16.9	19.2	21.8	21.7	21.3	22.2	19.6	16.5	13.2	17.6
RHmax (%)	83.0	82.0	77.0	70.0	59.0	56.0	59.0	59.0	65.0	68.0	75.0	80.0	69.4
RHmin (%)	62.0	55.0	45.0	38.0	35.0	30.0	32.0	31.0	37.0	41.0	48.0	60.0	42.8
Rain (mm)	60.7	41.7	31.5	16.3	12.3	2.4	0.0	0.2	0.0	7.2	19.5	54.5	246.3

Station No.: 88 **Station Type:** Climatological **Longitude:** 51° 44' E
Station Name: Hanna **Latitude:** 31° 13' N **Altitude:** 2350 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.4	8.4	12.1	17.2	22.2	27.7	31.1	29.8	25.2	20.1	14.1	10.0	18.7
T min (C)	-9.2	-6.4	-0.4	3.4	6.8	9.6	12.1	11.0	6.5	2.4	-1.3	-4.8	2.5
T ave (C)	-1.4	1.0	5.9	10.3	14.5	18.7	21.6	20.4	15.9	11.3	6.4	2.6	10.6
T rng (C)	15.6	14.8	12.5	13.8	15.4	18.1	19.0	18.8	18.7	17.7	15.4	14.8	16.2
RHmax (%)	79.0	80.0	76.0	68.0	61.0	48.0	46.0	46.0	55.0	66.0	77.0	78.0	65.0
RHmin (%)	65.0	63.0	49.0	36.0	32.0	25.0	25.0	23.0	26.0	34.0	43.0	55.0	39.7
Rain (mm)	77.1	52.2	49.5	45.0	15.5	0.6	4.5	1.4	0.0	13.5	35.2	68.7	363.2

Station No.: 89 **Station Type:** Climatological **Longitude:** 61° 14' E
Station Name: Khash **Latitude:** 28° 13' N **Altitude:** 1430 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	15.2	17.1	21.9	27.8	33.6	37.5	38.0	34.7	33.0	29.3	22.7	18.1	27.4
T min (C)	0.4	2.8	6.8	11.4	15.6	19.3	19.9	17.8	13.1	9.6	4.0	0.8	10.1
T ave (C)	7.8	9.9	14.4	19.6	24.6	28.4	29.0	26.3	23.0	19.5	13.4	9.4	18.8
T rng (C)	14.8	14.3	15.1	16.4	18.0	18.2	18.1	16.9	19.9	19.7	18.7	17.3	17.3
RHmax (%)	71.0	68.0	63.0	50.0	43.0	39.0	38.0	39.0	39.0	44.0	57.0	67.0	51.5
RHmin (%)	45.0	41.0	35.0	27.0	27.0	26.0	23.0	22.0	23.0	27.0	33.0	40.0	30.8
Rain (mm)	39.1	38.3	40.6	8.5	2.2	1.2	3.2	2.9	0.0	2.6	3.0	15.7	157.3

Station No.: 90 **Station Type:** Sinoptice **Longitude:** 48° 18' E
Station Name: Khorramabad **Latitude:** 33° 30' N **Altitude:** 1134 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.6	13.3	17.7	23.0	28.4	35.5	39.2	39.0	35.0	27.6	20.6	13.3	25.3
T min (C)	1.1	1.6	5.0	8.9	12.4	16.1	19.7	19.0	14.8	10.4	5.8	2.3	9.8
T ave (C)	6.4	7.5	11.4	15.9	20.4	25.8	29.5	29.0	24.9	19.0	13.2	7.8	17.6
T rng (C)	10.5	11.7	12.7	14.1	16.0	19.4	19.5	20.0	20.2	17.2	14.8	11.0	15.6
RHmax (%)	79.0	78.0	73.0	70.0	61.0	41.0	35.0	35.0	39.0	54.0	70.0	79.0	59.5
RHmin (%)	56.0	51.0	43.0	38.0	30.0	19.0	17.0	17.0	18.0	29.0	38.0	53.0	34.1
Rain (mm)	98.1	82.5	87.2	71.3	44.3	0.3	0.0	0.2	0.1	29.7	50.4	85.6	549.7

Station No.: 91 **Station Type:** Climatological **Longitude:** 50° 59' E
Station Name: Khorramabad (Tonekabon) **Latitude:** 36° 46' N **Altitude:** 50 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.4	10.6	13.2	18.0	23.1	26.5	29.6	29.5	26.2	21.7	17.9	14.1	20.1
T min (C)	3.0	3.0	6.1	9.8	14.3	17.5	20.4	20.5	17.9	13.6	9.1	5.6	11.7
T ave (C)	7.2	6.8	9.6	13.9	18.7	22.0	25.0	25.0	22.0	17.7	13.5	9.9	15.9
T rng (C)	8.4	7.6	7.1	8.2	8.8	9.0	9.2	9.0	8.3	8.1	8.8	8.5	8.4
RHmax (%)	89.0	91.0	92.0	91.0	90.0	87.0	86.0	88.0	89.0	91.0	91.0	89.0	89.5
RHmin (%)	74.0	76.0	80.0	77.0	72.0	71.0	68.0	70.0	75.0	76.0	75.0	75.0	74.1
Rain (mm)	92.4	89.9	96.2	61.6	51.6	56.6	35.1	69.7	147.8	257.7	152.7	116.8	1228.1

Station No.: 92 **Station Type:** Climatological **Longitude:** 48° 11' E
Station Name: Khorramshahr **Latitude:** 30° 25' N **Altitude:** 5 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	18.6	19.9	24.7	29.1	36.4	40.9	42.4	42.6	40.8	34.8	26.0	19.4	31.3
T min (C)	8.4	9.5	13.6	18.4	23.3	27.5	28.6	27.9	24.3	19.8	14.1	9.7	18.8
T ave (C)	13.5	14.7	19.2	23.8	29.9	34.2	35.5	35.3	32.5	27.3	20.0	14.5	25.0
T rng (C)	10.2	10.4	11.1	10.7	13.1	13.4	13.8	14.7	16.5	15.0	11.9	9.7	12.5
RHmax (%)	85.0	81.0	72.0	69.0	56.0	51.0	48.0	50.0	51.0	65.0	73.0	81.0	65.2
RHmin (%)	66.0	56.0	45.0	40.0	34.0	29.0	28.0	31.0	30.0	36.0	53.0	65.0	42.8
Rain (mm)	37.6	18.0	18.0	13.0	5.0	0.3	0.0	0.0	0.0	1.5	17.1	29.1	139.6

Station No.: 93 **Station Type:** Climatological **Longitude:** 50° 52' E
Station Name: Khoshkedaran Tonekabon **Latitude:** 36° 48' N **Altitude:** -2 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.1	9.5	11.4	15.6	22.0	26.5	28.8	29.2	27.0	22.1	17.5	13.7	19.4
T min (C)	0.8	1.6	4.4	8.3	12.6	16.9	18.6	19.3	16.6	12.5	6.8	3.4	10.2
T ave (C)	5.5	5.6	7.9	12.0	17.3	21.7	23.7	24.3	21.8	17.3	12.1	8.6	14.8
T rng (C)	9.3	7.9	7.0	7.3	9.4	9.6	10.2	9.9	10.4	9.6	10.7	10.3	9.3
RHmax(%)	92.0	93.0	93.0	93.0	90.0	91.0	92.0	92.0	94.0	94.0	95.0	94.0	92.8
RHmin (%)	87.0	88.0	87.0	86.0	85.0	84.0	85.0	85.0	83.0	88.0	88.0	86.0	86.0
Rain (mm)	121.4	108.7	103.3	74.0	57.9	49.5	51.1	63.0	169.7	206.4	150.8	131.4	1287.2

Station No.: 94 **Station Type:** Climatological **Longitude:** 53° 12' E
Station Name: Khafr **Latitude:** 28° 58' N **Altitude:** 1300 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	13.9	16.1	21.4	25.8	33.2	38.8	40.7	39.5	35.8	30.1	22.4	16.3	27.8
T min (C)	-0.4	1.1	4.4	8.4	13.9	17.2	19.3	18.2	13.9	9.3	4.3	-0.2	9.1
T ave (C)	6.8	8.6	12.9	17.1	23.5	28.0	30.0	28.9	24.8	19.7	13.4	8.0	18.5
T rng (C)	14.3	15.0	17.0	17.4	19.3	21.6	21.4	21.3	21.9	20.8	18.1	16.5	18.7
RHmax (%)	70.0	69.0	59.0	60.0	44.0	38.0	36.0	38.0	36.0	39.0	54.0	64.0	50.6
RHmin (%)	48.0	43.0	36.0	32.0	26.0	22.0	22.0	20.0	19.0	24.0	31.0	40.0	30.3
Rain (mm)	80.7	63.5	28.7	31.5	2.1	0.2	4.1	1.4	0.1	3.6	15.6	41.9	273.4

Station No.: 95 **Station Type:** Climatological **Longitude:** 50° 19' E
Station Name: Khonsar **Latitude:** 33° 14' N **Altitude:** 2300 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.1	4.8	10.5	16.7	21.7	28.2	31.5	30.8	26.4	19.2	11.9	7.6	17.9
T min (C)	-6.1	-5.6	0.2	5.0	9.6	13.8	17.1	15.3	11.3	6.7	1.7	-3.1	5.5
T ave (C)	-0.5	-0.4	5.3	10.9	15.7	21.0	24.3	23.0	18.9	13.0	6.8	2.3	11.7
T rng (C)	11.2	10.4	10.3	11.7	12.1	14.4	14.4	15.5	15.1	12.5	10.2	10.7	12.4
RHmax (%)	70.0	66.0	64.0	59.0	51.0	39.0	36.0	42.0	45.0	59.0	66.0	66.0	55.3
RHmin (%)	58.0	53.0	44.0	36.0	31.0	23.0	23.0	26.0	29.0	42.0	49.0	54.0	39.0
Rain (mm)	62.8	32.0	59.4	54.7	28.4	0.3	0.0	0.9	0.0	21.4	37.7	36.0	333.6

Station No.: 96 **Station Type:** Climatological **Longitude:** 55° 02' E
Station Name: Khoor-Biabanak **Latitude:** 33° 47' N **Altitude:** 850 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.9	14.7	20.1	27.9	33.3	38.8	40.1	38.6	35.2	28.5	19.9	13.8	27.0
T min (C)	-0.3	1.2	6.3	12.7	17.6	22.8	24.5	22.6	17.9	12.3	4.9	1.0	12.0
T ave (C)	6.3	7.9	13.2	20.3	25.5	30.8	32.3	30.6	26.5	20.4	12.4	7.4	19.5
T rng (C)	13.2	13.5	13.8	15.2	15.7	16.0	15.6	16.0	17.3	16.2	15.0	12.8	15.0
RHmax (%)	66.0	70.0	58.0	46.0	38.0	28.0	27.0	29.0	33.0	44.0	62.0	69.0	47.5
RHmin (%)	46.0	42.0	30.0	22.0	19.0	17.0	16.0	15.0	16.0	22.0	33.0	44.0	26.8
Rain (mm)	13.1	10.9	11.7	8.5	8.7	0.6	0.0	0.0	0.0	3.2	4.6	10.4	71.7

Station No.:	97	Station Type:	Sinoptice	Longitude:	44° 58' E
Station Name:	Khoy	Latitude:	38° 33' N	Altitude:	1357 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.6	4.7	11.7	18.4	22.7	28.2	32.9	32.6	28.6	20.0	12.1	5.3	18.3
T min (C)	-5.5	-4.8	0.5	5.9	9.6	12.6	16.3	15.3	10.8	6.0	1.0	-2.3	5.4
T ave (C)	-1.5	0.0	6.1	12.1	16.2	20.4	24.6	23.9	19.7	13.0	6.6	1.5	11.9
T rng (C)	8.1	9.5	11.2	12.5	13.1	15.6	16.6	17.3	17.8	14.0	11.1	7.6	12.9
RHmax (%)	83.0	84.0	80.0	80.0	84.0	78.0	75.0	79.0	81.0	86.0	87.0	85.0	81.8
RHmin (%)	67.0	64.0	52.0	46.0	47.0	38.0	33.0	34.0	34.0	47.0	59.0	66.0	48.9
Rain (mm)	25.0	21.4	32.2	45.9	81.1	30.6	12.0	4.4	12.6	24.6	35.7	21.2	346.7

Station No.:	98	Station Type:	Climatological	Longitude:	54° 32' E
Station Name:	Darab	Latitude:	28° 45' N	Altitude: 1150 m	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	16.8	18.6	22.3	28.3	35.6	40.9	41.9	40.9	38.1	32.7	24.3	18.8	29.9
T min (C)	2.5	4.2	7.6	11.3	16.6	21.1	24.4	23.7	19.1	13.5	8.0	4.5	13.0
T ave (C)	9.6	11.4	14.9	19.8	26.1	31.0	33.2	32.3	28.6	23.1	16.1	11.6	21.5
T rng (C)	14.3	14.4	14.7	17.0	19.0	19.8	17.5	17.2	19.0	19.2	16.3	14.3	16.9
RHmax (%)	69.0	71.0	66.0	57.0	46.0	35.0	36.0	40.0	45.0	55.0	59.0	66.0	53.8
RHmin (%)	48.0	45.0	43.0	31.0	20.0	15.0	17.0	18.0	18.0	24.0	32.0	43.0	29.5
Rain (mm)	79.2	42.3	54.6	22.6	3.0	0.0	4.7	3.3	0.2	1.2	9.9	40.9	261.9

Station No.:	99	Station Type:	Climatological	Longitude:	46° 10' E
Station Name:	Dashband-Bookan	Latitude:	36° 38' N	Altitude:	1336 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.6	6.2	11.3	18.0	23.4	30.9	35.5	35.7	31.2	23.7	15.9	8.3	20.3
T min (C)	-7.0	-4.4	-0.2	3.7	6.4	9.0	12.7	12.2	8.0	3.6	-0.8	-3.8	3.3
T ave (C)	-1.7	0.9	5.6	10.9	14.9	20.0	24.1	24.0	19.6	13.7	7.5	2.3	11.8
T rng (C)	10.6	10.6	11.5	14.3	17.0	21.9	22.8	23.5	23.2	20.1	16.7	12.1	17.0
RHmax (%)	69.0	70.0	77.0	78.0	77.0	74.0	70.0	70.0	72.0	73.0	71.0	73.0	72.8
RHmin (%)	74.0	72.0	67.0	61.0	56.0	42.0	35.0	32.0	34.0	44.0	59.0	70.0	53.8
Rain (mm)	37.5	37.3	73.4	72.9	62.2	17.9	0.3	1.5	0.7	15.2	44.4	51.2	414.5

Station No.:	100	Station Type:	Climatological	Longitude:	54° 22' E
Station Name:	Damghan	Latitude:	36° 13' N	Altitude:	1170 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.0	9.8	16.0	21.4	27.5	32.6	34.8	34.0	30.3	23.4	16.3	9.2	21.9
T min (C)	-3.8	-1.7	2.9	8.2	13.4	17.7	20.0	18.7	15.1	10.1	2.7	-1.4	8.5
T ave (C)	1.6	4.1	9.4	14.8	20.5	25.1	27.4	26.4	22.7	16.8	9.5	3.9	15.2
T rng (C)	10.8	11.5	13.1	13.2	14.1	14.9	14.8	15.3	15.2	13.3	13.6	10.6	13.4
RHmax (%)	74.0	75.0	65.0	56.0	46.0	41.0	40.0	42.0	44.0	56.0	70.0	74.0	56.9
RHmin (%)	65.0	55.0	43.0	35.0	35.0	36.0	36.0	37.0	35.0	36.0	45.0	61.0	43.3
Rain (mm)	12.9	16.2	22.7	20.9	23.9	5.0	1.7	1.4	2.1	5.7	11.4	17.7	141.6

Station No.:	101	Station Type:	Climatological	Longitude:	50° 29' E
Station Name:	Damaneh-Faridan	Latitude:	33° 01' N	Altitude:	2300 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.4	3.5	8.4	14.6	20.2	27.4	30.6	29.7	25.7	19.3	11.2	4.9	16.5
T min (C)	-9.7	-8.2	-2.2	3.1	6.6	10.8	14.0	13.1	7.5	2.6	-1.5	-5.4	2.6
T ave (C)	-3.6	-2.3	3.1	8.9	13.4	19.1	22.3	21.4	16.6	10.9	4.8	-0.3	9.5
T rng (C)	12.1	11.7	10.6	11.5	13.6	16.6	16.6	16.6	18.2	16.7	12.7	10.3	13.9
RHmax (%)	66.0	70.0	70.0	69.0	57.0	44.0	40.0	39.0	48.0	57.0	70.0	71.0	58.4
RHmin (%)	61.0	64.0	51.0	36.0	28.0	20.0	19.0	18.0	22.0	27.0	42.0	56.0	37.0
Rain (mm)	39.3	55.1	51.9	46.9	26.5	0.7	1.2	0.2	0.4	20.7	41.0	34.5	318.4

Station No.:	102	Station Type:	Climatological	Longitude:	49° 22' E
Station Name:	Darrehtakht	Latitude:	33° 22' N	Altitude:	2000 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.7	3.7	11.2	17.6	22.0	28.1	32.2	32.0	27.6	21.9	13.5	6.0	18.2
T min (C)	-7.9	-8.1	-0.5	4.1	7.3	8.2	11.5	10.7	6.4	2.9	-0.1	-5.3	2.4
T ave (C)	-2.6	-2.2	5.3	10.9	14.6	18.1	21.9	21.4	17.0	12.4	6.7	0.3	10.3
T rng (C)	10.6	11.8	11.7	13.5	14.7	19.9	20.7	21.3	21.2	19.0	13.6	11.3	15.8
RHmax (%)	85.0	85.0	82.0	73.0	68.0	61.0	58.0	56.0	58.0	69.0	82.0	85.0	71.8
RHmin (%)	71.0	72.0	49.0	41.0	39.0	28.0	24.0	22.0	22.0	30.0	45.0	64.0	42.3
Rain (mm)	127.7	102.1	139.0	99.6	67.7	0.0	1.0	0.9	2.6	57.4	79.6	204.4	882.0

Station No.: 103 **Station Type:** Climatological **Longitude:** 59° 06' E
Station Name: Darreh Gaz **Latitude:** 37° 26' N **Altitude:** 500 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.8	11.0	15.2	21.8	28.1	34.2	35.6	35.3	30.1	22.6	16.1	11.9	22.6
T min (C)	-3.0	-1.6	3.9	7.8	12.0	15.8	18.3	15.7	12.2	8.2	2.6	0.7	7.7
T ave (C)	3.4	4.7	9.6	14.8	20.0	25.0	26.9	25.5	21.1	15.4	9.4	6.3	15.2
T rng (C)	12.8	12.6	11.3	14.0	16.1	18.4	17.3	19.6	17.9	14.4	13.5	11.2	14.9
RHmax (%)	77.0	77.0	76.0	71.0	68.0	49.0	48.0	47.0	52.0	64.0	77.0	76.0	65.2
RHmin (%)	66.0	62.0	57.0	52.0	50.0	35.0	40.0	32.0	34.0	46.0	55.0	62.0	49.3
Rain (mm)	28.5	38.6	39.9	46.6	38.3	6.5	3.1	1.1	2.0	25.8	25.2	20.2	275.8

Station No.: 104 **Station Type:** Climatological **Longitude:** 49° 09' E
Station Name: Doroud **Latitude:** 33° 29' N **Altitude:** 1402 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.9	9.7	14.9	20.6	25.6	33.7	37.4	36.3	32.0	24.9	16.9	11.1	22.6
T min (C)	-3.5	-2.3	2.5	7.0	8.9	11.1	14.3	13.1	8.9	5.3	2.0	-1.5	5.5
T ave (C)	2.2	3.7	8.7	13.8	17.3	22.4	25.9	24.7	20.5	15.1	9.4	4.8	14.0
T rng (C)	11.4	12.0	12.4	13.6	16.7	22.6	23.1	23.2	23.1	19.6	14.9	12.6	17.1
RHmax (%)	83.0	83.0	71.0	59.0	59.0	47.0	41.0	45.0	46.0	58.0	72.0	80.0	62.0
RHmin (%)	60.0	57.0	42.0	32.0	30.0	21.0	15.0	13.0	17.0	23.0	38.0	47.0	32.9
Rain (mm)	117.7	71.5	107.2	78.3	45.4	0.6	0.0	0.0	0.0	32.5	65.8	164.	683.0

Station No.: 105 **Station Type:** Sinoptice **Longitude:** 48° 23' E
Station Name: Dezfoul **Latitude:** 32° 24' N **Altitude:** 143 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.4	19.0	23.9	30.0	37.1	42.9	45.4	44.3	41.5	34.5	25.6	19.1	31.7
T min (C)	5.8	6.8	10.2	15.1	20.9	24.0	26.3	25.4	21.7	16.4	10.8	7.3	15.9
T ave (C)	11.6	12.9	17.0	22.5	29.0	33.5	35.8	34.8	31.6	25.5	18.2	13.2	23.8
T rng (C)	11.6	12.2	13.7	14.9	16.2	18.9	19.1	18.9	19.8	18.1	14.8	11.8	15.8
RHmax (%)	89.0	88.0	80.0	70.0	51.0	35.0	35.0	36.0	39.0	55.0	76.0	88.0	61.8
RHmin (%)	58.0	52.0	42.0	34.0	22.0	14.0	15.0	18.0	17.0	25.0	40.0	57.0	32.8
Rain (mm)	101.4	66.6	54.3	35.2	9.4	0.0	0.0	0.0	0.0	7.1	45.1	85.2	404.3

Station No.: 106 **Station Type:** Climatological **Longitude:** 53° 10' E
Station Name: Dashte-Naz **Latitude:** 36° 41' N **Altitude:** 28 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	13.0	11.6	14.8	21.2	25.7	29.1	31.5	31.1	28.4	24.8	20.6	14.8	22.2
T min (C)	1.5	1.7	4.3	7.9	12.1	15.9	20.3	20.5	17.0	11.0	6.2	7.1	10.5
T ave (C)	7.3	6.7	9.6	14.6	18.9	22.5	25.9	25.8	22.7	17.9	13.4	10.9	16.3
T rng (C)	11.5	9.9	10.5	13.3	13.6	13.2	11.2	10.6	11.4	13.8	14.4	7.7	11.8
RHmax (%)	94.0	92.0	94.0	90.0	87.0	85.0	85.0	88.0	89.0	86.0	92.0	93.0	89.6
RHmin (%)	74.0	78.0	74.0	69.0	67.0	62.0	64.0	69.0	69.0	69.0	75.0	79.0	70.8
Rain (mm)	64.8	61.6	76.0	35.0	32.5	23.8	14.3	40.8	50.0	103.6	62.8	84.1	649.3

Station No.: 107 **Station Type:** Climatological **Longitude:** 50° 50' E
Station Name: Deh-Soomeeh **Latitude:** 35° 57' N **Altitude:** 1500 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.0	10.9	14.0	20.5	24.4	31.3	34.3	33.9	30.9	26.8	18.3	12.4	22.3
T min (C)	-6.9	-7.2	-1.3	4.2	6.7	9.3	11.1	10.1	8.4	5.6	0.7	-3.8	3.1
T ave (C)	1.5	1.8	6.3	12.4	15.5	20.3	22.7	22.0	19.6	16.2	9.5	4.3	12.7
T rng (C)	16.9	18.1	15.3	16.3	17.7	22.0	23.2	23.8	22.5	21.2	17.6	16.2	19.2
RHmax (%)	72.0	71.0	68.0	63.0	62.0	58.0	55.0	53.0	57.0	60.0	68.0	68.0	62.9
RHmin (%)	59.0	57.0	57.0	43.0	40.0	32.0	28.0	26.0	29.0	35.0	52.0	62.0	43.3
Rain (mm)	34.5	36.5	49.2	40.2	34.7	9.9	1.0	1.2	0.2	8.6	27.4	40.6	284.0

Station No.: 108 **Station Type:** Climatological **Longitude:** 57° 31' E
Station Name: Deyhook **Latitude:** 33° 17' N **Altitude:** 1600 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.7	12.3	18.5	25.1	30.4	35.8	37.2	35.5	32.0	26.8	18.7	13.6	24.7
T min (C)	-0.1	-0.6	4.8	9.8	13.8	17.7	19.6	17.5	13.9	9.9	4.9	1.8	9.4
T ave (C)	5.3	5.8	11.6	17.5	22.1	26.8	28.4	26.5	23.0	18.3	11.8	7.7	17.1
T rng (C)	10.8	12.9	13.7	15.3	16.6	18.1	17.6	18.0	18.1	16.9	13.8	11.8	15.3
RHmax (%)	73.0	71.0	52.0	49.0	40.0	35.0	36.0	36.0	37.0	46.0	59.0	69.0	50.3
RHmin (%)	57.0	49.0	36.0	27.0	23.0	22.0	23.0	24.0	24.0	29.0	36.0	49.0	33.3
Rain (mm)	24.4	7.7	24.8	12.2	3.4	0.0	0.0	0.0	0.2	1.1	3.3	5.6	82.7

Station No.:	109	Station Type:	Climatological	Longitude:	51° 18' E
Station Name:	Zob-Ahan-Isfahan	Latitude:	32° 24' N	Altitude:	1768 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.8	10.0	15.7	20.9	26.7	33.1	35.3	34.2	30.3	23.7	15.6	10.6	22.0
T min (C)	-3.9	-2.4	2.0	7.2	11.7	16.1	18.8	17.1	12.8	7.8	2.1	-1.5	7.3
T ave (C)	2.0	3.8	8.9	14.0	19.2	24.6	27.0	25.7	21.5	15.8	8.9	4.6	14.7
T rng (C)	11.7	12.4	13.7	13.7	15.0	17.0	16.5	17.1	17.5	15.9	13.5	12.1	14.7
RHmax (%)	76.0	73.0	65.0	59.0	48.0	33.0	28.0	28.0	35.0	49.0	68.0	71.0	52.8
RHmin (%)	49.0	44.0	33.0	31.0	24.0	17.0	16.0	15.0	16.0	25.0	34.0	44.0	29.0
Rain (mm)	24.8	22.6	27.0	23.1	12.5	0.4	2.0	0.2	0.0	9.3	15.0	24.9	161.8

Station No.:	110	Station Type:	Sinoptice	Longitude:	50° 40' E
Station Name:	Ramsar	Latitude:	36° 54' N	Altitude:	-20 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.0	9.9	11.7	16.7	21.4	25.6	28.7	28.6	25.9	21.2	17.2	13.8	19.3
T min (C)	3.4	3.3	5.8	9.8	14.5	18.2	20.9	21.0	19.0	14.5	9.3	5.7	12.1
T ave (C)	7.2	6.6	8.8	13.3	18.0	21.9	24.8	24.8	22.5	17.9	13.3	9.8	15.7
T rng (C)	7.6	6.6	5.9	6.9	6.9	7.4	7.8	7.6	6.9	6.7	7.9	8.1	7.2
RHmax (%)	90.0	91.0	93.0	92.0	90.0	86.0	85.0	88.0	91.0	93.0	93.0	91.0	90.3
RHmin (%)	68.0	76.0	80.0	77.0	76.0	72.0	68.0	70.0	74.0	76.0	75.0	73.0	73.8
Rain (mm)	91.4	90.0	96.6	48.2	51.1	56.2	29.2	63.4	142.8	292.2	164.7	117.	1242.8

Station No.:	111	Station Type:	Climatological	Longitude:	49° 36' E
Station Name:	Ramhormoz	Latitude:	31° 16' N	Altitude:	200 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.4	19.5	24.8	31.5	38.9	43.8	45.3	44.7	42.3	36.0	27.5	19.8	32.6
T min (C)	6.3	7.1	10.6	15.2	20.5	23.9	26.2	25.2	22.9	17.8	12.0	7.8	16.3
T ave (C)	11.9	13.3	17.7	23.4	29.7	33.8	35.8	35.0	32.6	26.9	19.8	13.8	24.5
T rng (C)	11.1	12.4	14.2	16.3	18.4	19.9	19.1	19.5	19.4	18.2	15.5	12.0	16.3
RHmax (%)	83.0	81.0	76.0	65.0	50.0	48.0	51.0	51.0	48.0	57.0	68.0	80.0	63.2
RHmin (%)	68.0	64.0	54.0	41.0	29.0	24.0	29.0	29.0	27.0	38.0	49.0	64.0	43.0
Rain (mm)	82.5	60.0	40.5	26.2	7.3	0.0	0.0	0.0	0.0	9.7	47.3	98.8	372.3

Station No.:	112	Station Type:	Sinoptice	Longitude:	49° 36' E
Station Name:	Rasht	Latitude:	37° 15' N	Altitude:	-7 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.2	10.0	13.0	19.1	23.8	28.0	30.6	30.2	27.1	21.6	17.2	13.9	20.5
T min (C)	2.0	1.9	4.6	9.0	13.6	17.0	19.4	19.1	16.8	12.5	7.5	3.9	10.6
T ave (C)	6.6	5.9	8.8	14.1	18.7	22.5	25.0	24.7	22.0	17.0	12.4	8.9	15.5
T rng (C)	9.2	8.1	8.4	10.1	10.2	11.0	11.2	11.1	10.3	9.1	9.7	10.0	9.9
RHmax(%)	92.0	95.0	95.0	93.0	93.0	92.0	91.0	94.0	95.0	96.0	95.0	94.0	93.8
RHmin (%)	78.0	81.0	76.0	69.0	66.0	62.0	60.0	64.0	70.0	77.0	77.0	78.0	71.5
Rain (mm)	151.	134.2	119.0	56.2	67.5	44.9	41.1	64.0	128.1	227.5	208.7	170.4	1412.6

Station No.:	113	Station Type:	Climatological	Longitude:	49° 24' E
Station Name:	Roud-Bar	Latitude:	36° 48' N	Altitude:	280 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.2	12.5	16.1	22.6	25.7	28.5	31.1	30.9	28.8	24.0	19.1	15.1	22.2
T min (C)	3.2	2.8	5.3	8.7	12.3	15.8	18.1	18.6	16.4	12.7	8.3	4.7	10.6
T ave (C)	7.7	7.7	10.7	15.6	19.0	22.1	24.6	24.8	22.6	18.4	13.7	9.9	16.4
T rng (C)	9.0	9.7	10.8	13.9	13.4	12.7	13.0	12.3	12.4	11.3	10.8	10.4	11.6
RHmax (%)	72.0	74.0	75.0	70.0	73.0	72.0	72.0	75.0	79.0	79.0	77.0	73.0	74.3
RHmin (%)	57.0	58.0	57.0	50.0	53.0	52.0	51.0	53.0	56.0	59.0	58.0	58.0	55.2
Rain (mm)	43.4	45.1	63.7	38.4	30.0	8.6	3.3	1.7	5.6	24.5	55.5	56.2	376.0

Station No.:	114	Station Type:	Sinoptice	Longitude:	61° 29' E
Station Name:	Zabol	Latitude:	31° 01' N	Altitude:	487 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	15.6	18.1	25.0	31.7	36.5	40.3	41.5	39.3	36.1	30.9	23.1	18.4	29.7
T min (C)	2.0	4.5	10.0	16.1	21.1	25.1	27.3	25.2	20.0	14.1	7.1	3.5	14.7
T ave (C)	8.8	11.3	17.5	23.9	28.8	32.7	34.4	32.3	28.0	22.5	15.1	10.9	22.2
T rng (C)	13.6	13.6	15.0	15.6	15.4	15.2	14.2	14.1	16.1	16.8	16.0	14.9	15.0
RHmax (%)	76.0	74.0	67.0	58.0	44.0	35.0	31.0	32.0	37.0	49.0	64.0	76.0	53.6
RHmin (%)	44.0	41.0	34.0	27.0	21.0	17.0	16.0	16.0	16.0	22.0	29.0	41.0	27.0
Rain (mm)	20.3	11.1	12.7	5.3	0.5	0.2	1.5	0.7	2.4	6.6	2.9	3.6	67.8

Station No.: 115 **Station Type:** Sinoptice **Longitude:** 60° 53' E
Station Name: Zahedan **Latitude:** 29° 28' N **Altitude:** 1370 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	14.3	16.1	22.1	27.6	32.4	36.2	36.8	35.4	31.7	27.8	21.0	16.8	26.5
T min (C)	-0.1	2.4	7.8	12.5	15.8	18.6	19.1	16.5	11.9	8.6	2.9	1.0	9.8
T ave (C)	7.1	9.3	15.0	20.0	24.1	27.4	28.0	26.0	21.8	18.2	11.9	8.9	18.1
T rng (C)	14.4	13.7	14.3	15.1	16.6	17.6	17.7	18.9	19.8	19.2	18.1	15.8	16.8
RHmax (%)	70.0	68.0	57.0	49.0	38.0	32.0	31.0	32.0	35.0	45.0	56.0	64.0	48.1
RHmin (%)	34.0	33.0	27.0	21.0	17.0	16.0	15.0	14.0	15.0	19.0	23.0	30.0	22.0
Rain (mm)	17.5	24.8	14.0	9.7	3.2	0.6	0.7	0.8	0.1	3.6	4.3	5.6	84.9

Station No.: 116 **Station Type:** Climatological **Longitude:** 52° 59' E
Station Name: Zardgol-Sorkhabad **Latitude:** 35° 55' N **Altitude:** 1500 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.3	10.1	13.7	18.7	21.7	25.4	28.6	28.1	26.4	21.9	19.6	12.2	19.7
T min (C)	-7.7	-6.0	-3.7	2.5	6.1	10.0	11.9	12.2	10.0	5.3	0.7	-3.8	3.1
T ave (C)	1.3	2.1	5.0	10.6	13.9	17.7	20.3	20.1	18.2	13.6	10.2	4.2	11.4
T rng (C)	18.0	16.1	17.4	16.2	15.6	15.4	16.7	15.9	16.4	16.6	18.9	16.0	16.6
RHmax (%)	55.0	52.0	56.0	67.0	69.0	70.0	74.0	76.0	75.0	71.0	62.0	54.0	65.1
RHmin (%)	54.0	58.0	55.0	61.0	62.0	62.0	65.0	65.0	64.0	63.0	60.0	55.0	60.3
Rain (mm)	70.7	52.6	45.4	45.4	55.7	22.3	12.7	11.7	15.1	36.4	38.3	58.0	464.3

Station No.: 117 **Station Type:** Sinoptice **Longitude:** 48° 29' E
Station Name: Zanjan **Latitude:** 36° 41' N **Altitude:** 1663 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.9	4.5	10.7	17.6	22.5	28.4	32.3	31.8	28.1	20.4	12.2	5.7	18.1
T min (C)	-6.9	-5.8	-0.5	4.4	8.0	11.3	15.0	14.4	10.3	6.0	0.8	-3.5	4.5
T ave (C)	-2.0	-0.7	5.1	11.0	15.3	19.9	23.6	23.1	19.2	13.2	6.5	1.1	11.3
T rng (C)	9.8	10.3	11.2	13.2	14.5	17.1	17.3	17.4	17.8	14.4	11.4	9.2	13.6
RHmax (%)	80.0	80.0	77.0	71.0	72.0	62.0	57.0	56.0	54.0	66.0	74.0	78.0	68.9
RHmin (%)	62.0	59.0	50.0	41.0	37.0	30.0	29.0	29.0	28.0	38.0	48.0	58.0	42.4
Rain (mm)	32.3	30.2	51.4	49.1	54.3	9.8	3.7	2.0	4.0	28.2	30.2	33.8	329.0

Station No.: 118 **Station Type:** Climatological **Longitude:** 50° 21' E
Station Name: Saveh **Latitude:** 35° 01' N **Altitude:** 1167 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.2	11.7	18.2	24.9	30.4	36.3	38.9	38.0	34.4	26.4	18.6	13.0	25.1
T min (C)	-0.8	0.2	5.5	10.6	15.7	20.5	23.3	22.3	18.0	11.6	5.9	1.4	11.2
T ave (C)	4.7	5.9	11.9	17.8	23.0	28.4	31.1	30.1	26.2	19.0	12.2	7.2	18.1
T rng (C)	11.0	11.5	12.7	14.3	14.7	15.8	15.6	15.7	16.4	14.8	12.7	11.6	13.9
RHmax (%)	65.0	68.0	66.0	55.0	49.0	40.0	39.0	40.0	45.0	55.0	63.0	67.0	54.3
RHmin (%)	60.0	60.0	55.0	45.0	39.0	32.0	33.0	33.0	32.0	40.0	53.0	59.0	45.1
Rain (mm)	39.7	33.1	33.0	23.2	16.2	1.2	0.6	0.6	0.3	8.3	20.1	29.5	205.8

Station No.: 119 **Station Type:** Sinoptice **Longitude:** 57° 40' E
Station Name: Sabzvar **Latitude:** 36° 13' N **Altitude:** 941 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.0	10.6	17.4	24.4	30.0	35.5	37.3	35.8	32.4	25.4	17.7	11.4	23.8
T min (C)	-2.3	-0.5	4.6	106	15.4	20.2	22.3	20.0	15.8	10.3	3.8	0.0	10.0
T ave (C)	2.8	5.1	11.0	17.5	22.7	17.9	29.8	27.9	24.1	17.9	10.8	5.7	16.9
T rng (C)	10.3	11.1	12.8	13.8	14.6	15.3	15.0	15.8	16.6	15.1	13.9	11.4	13.8
RHmax (%)	77.0	76.0	70.0	62.0	48.0	36.0	33.0	32.0	36.0	52.0	65.0	74.0	55.1
RHmin (%)	56.0	50.0	39.0	31.0	25.0	19.0	19.0	17.0	18.0	28.0	35.0	49.0	32.2
Rain (mm)	37.3	32.0	35.4	33.4	17.1	1.0	1.3	0.0	1.0	9.8	13.7	28.0	210.0

Station No.: 120 **Station Type:** Climatological **Longitude:** 48° 53' E
Station Name: Sepid-Dasht **Latitude:** 33° 13' N **Altitude:** 1100 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.3	11.3	17.6	22.5	28.9	36.6	41.1	39.3	35.5	24.2	19.3	12.4	25.0
T min (C)	1.7	2.7	6.3	10.4	14.3	18.8	21.7	22.5	18.6	13.4	7.7	3.7	11.8
T ave (C)	6.5	7.0	12.0	16.5	21.6	27.7	31.4	30.9	27.0	18.8	13.5	8.1	18.4
T rng (C)	9.6	8.6	11.3	12.1	14.6	17.8	19.4	16.8	16.9	10.8	11.6	8.7	13.2
RHmax (%)	79.0	80.0	72.0	67.0	60.0	49.0	42.0	41.0	44.0	53.0	65.0	76.0	60.7
RHmin (%)	65.0	63.0	50.0	47.0	40.0	27.0	27.0	25.0	26.0	35.0	50.0	62.0	43.1
Rain (mm)	112.1	76.1	109.7	81.5	30.4	0.3	0.0	0.0	0.0	43.0	82.4	185.4	720.9

Station No.: 121 **Station Type:** Climatological **Longitude:** 47° 34' E
Station Name: Sarab **Latitude:** 37° 59' N **Altitude:** 1650 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	0.9	3.5	8.4	13.1	20.3	24.8	28.0	28.3	24.5	17.4	10.0	4.8	15.3
T min (C)	-9.7	-7.9	-1.6	2.0	5.1	7.8	10.6	11.0	6.9	2.4	-3.0	-6.3	1.4
T ave (C)	-4.4	-2.2	3.4	7.6	12.7	16.3	19.3	19.6	15.7	9.9	3.5	-0.8	8.4
T rng (C)	10.6	11.4	10.0	11.1	15.2	17.0	17.4	17.3	17.6	15.0	13.0	11.1	13.9
RHmax (%)	78.0	79.0	81.0	78.0	73.0	70.0	64.0	64.0	67.0	78.0	81.0	81.0	74.5
RHmin (%)	77.0	72.0	64.0	58.0	45.0	41.0	38.0	37.0	36.0	49.0	62.0	73.0	54.3
Rain (mm)	13.1	17.2	29.5	44.9	55.7	19.1	2.1	1.2	9.1	30.9	20.4	23.0	266.2

Station No.: 122 **Station Type:** Climatological **Longitude:** 62° 21' E
Station Name: Saravan **Latitude:** 27° 21' N **Altitude:** 1100 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.2	20.6	25.7	31.0	38.5	41.7	42.8	41.8	38.7	31.9	26.3	20.8	31.4
T min (C)	3.3	5.7	9.9	13.0	18.9	22.5	25.7	24.5	20.6	15.6	9.8	3.7	14.4
T ave (C)	10.3	13.1	17.8	22.0	28.7	32.1	34.3	33.2	29.7	23.8	18.0	12.3	22.9
T rng (C)	13.9	14.9	15.8	18.0	19.6	19.2	17.1	17.3	18.1	16.3	16.5	17.1	17.0
RHmax (%)	71.0	74.0	65.0	65.0	55.0	51.0	51.0	54.0	49.0	54.0	50.0	63.0	58.5
RHmin (%)	51.0	55.0	47.0	48.0	46.0	41.0	40.0	39.0	41.0	39.0	39.0	39.0	43.8
Rain (mm)	28.4	24.6	10.5	7.5	1.7	1.0	8.0	4.8	0.0	0.0	2.6	6.2	95.3

Station No.: 123 **Station Type:** Climatological **Longitude:** 61° 10' E
Station Name: Sarakhs **Latitude:** 36° 32' N **Altitude:** 225 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.3	10.7	17.6	25.0	31.5	36.7	38.5	36.7	32.6	25.2	18.2	11.9	24.5
T min (C)	-3.2	-0.9	4.2	9.7	15.0	19.1	21.8	19.5	14.3	8.9	3.9	0.2	9.4
T ave (C)	3.1	4.9	10.9	17.4	23.3	27.9	30.1	28.1	23.4	17.0	11.1	6.0	16.9
T rng (C)	12.5	11.6	13.4	15.3	16.5	17.6	16.7	17.2	18.3	16.3	14.3	11.7	15.1
RHmax (%)	84.0	88.0	81.0	75.0	61.0	46.0	44.0	44.0	48.0	63.0	75.0	87.0	66.3
RHmin (%)	65.0	69.0	60.0	47.0	35.0	30.0	27.0	26.0	30.0	42.0	51.0	65.0	45.6
Rain (mm)	43.6	33.7	47.2	30.5	19.4	0.2	0.0	0.0	0.5	22.9	20.5	30.1	248.6

Station No.: 124 **Station Type:** Climatological **Longitude:** 53° 10' E
Station Name: Sarkat-Tajan **Latitude:** 36° 24' N **Altitude:** 300 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.4	11.3	13.8	20.3	23.6	27.4	29.7	29.0	27.0	22.4	19.5	14.3	20.9
T min (C)	2.4	1.9	4.6	8.9	12.1	15.0	18.1	17.4	14.9	10.3	7.1	3.9	9.7
T ave (C)	7.4	6.6	9.2	14.6	17.9	21.2	23.9	23.2	21.0	16.4	13.3	9.1	15.3
T rng (C)	10.0	9.4	9.2	11.4	11.5	12.4	11.6	11.6	12.1	12.1	12.4	10.4	11.2
RHmax(%)	76.0	76.0	77.0	76.0	77.0	79.0	81.0	81.0	81.0	78.0	77.0	75.0	77.8
RHmin (%)	72.0	74.0	74.0	71.0	70.0	69.0	72.0	74.0	73.0	75.0	72.0	73.0	72.4
Rain (mm)	106.1	147.8	200.7	111.2	109.7	66.7	76.4	105.0	133.7	147.5	119.2	129.	1453.

Station No.: 125 **Station Type:** Sinoptice **Longitude:** 46° 16' E
Station Name: Saghez **Latitude:** 36° 15' N **Altitude:** 1494 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.3	5.7	11.0	17.6	23.3	30.5	34.3	34.1	29.7	22.0	12.7	5.2	19.0
T min (C)	-7.4	-5.8	-0.6	4.5	7.8	10.7	14.0	14.0	9.1	4.9	-0.2	-4.4	3.9
T ave (C)	-2.6	0.0	5.2	11.1	15.5	20.6	24.1	24.0	19.4	13.4	6.3	0.4	11.5
T rng (C)	9.7	11.5	11.6	13.1	15.5	19.8	20.3	20.1	20.6	17.1	12.9	9.6	15.2
RHmax (%)	80.0	80.0	79.0	79.0	76.0	66.0	54.0	51.0	53.0	68.0	79.0	79.0	70.3
RHmin (%)	63.0	60.0	53.0	45.0	41.0	30.0	27.0	24.0	25.0	38.0	50.0	61.0	43.1
Rain (mm)	74.4	60.9	81.5	87.0	71.0	7.9	1.3	1.8	0.8	36.2	52.0	68.6	543.4

Station No.: 126 **Station Type:** Sinoptice **Longitude:** 52° 23' E
Station Name: Semnan **Latitude:** 35° 33' N **Altitude:** 1138 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.2	11.6	17.6	24.5	29.6	35.3	38.1	37.0	33.2	25.6	17.7	11.5	24.2
T min (C)	-0.8	0.5	5.3	11.4	16.3	21.5	24.3	22.7	18.8	12.9	5.7	1.0	11.6
T ave (C)	4.2	6.1	11.5	18.0	23.0	28.4	31.2	29.9	26.0	19.3	11.7	6.3	17.9
T rng (C)	10.0	11.1	12.3	13.1	13.3	13.8	13.8	14.3	14.4	12.7	12.0	10.5	12.6
RHmax (%)	74.0	71.0	62.0	52.0	49.0	39.0	37.0	39.0	39.0	53.0	61.0	73.0	54.1
RHmin (%)	55.0	48.0	40.0	32.0	29.0	23.0	23.0	24.0	25.0	34.0	41.0	50.0	35.3
Rain (mm)	24.1	20.8	21.6	13.7	16.5	3.6	1.2	1.2	1.7	9.5	10.5	18.7	143.1

Station No.: 127 **Station Type:** Climatological **Longitude:** 48° 34' E
Station Name: Sangtarash **Latitude:** 33° 14' N **Altitude:** 1584 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.6	8.2	13.1	18.3	24.2	33.0	37.3	36.0	32.8	26.0	16.4	9.8	21.9
T min (C)	-0.2	-0.3	3.5	7.5	12.6	18.7	22.5	22.2	18.5	14.4	7.5	1.4	10.7
T ave (C)	3.7	3.9	8.3	12.9	18.4	25.9	29.9	29.1	25.6	20.2	11.9	5.6	16.3
T rng (C)	7.8	8.5	9.6	10.8	11.6	14.3	14.8	13.8	14.3	11.6	8.9	8.4	11.2
RHmax (%)	72.0	73.0	68.0	60.0	52.0	36.0	33.0	34.0	37.0	44.0	60.0	72.0	53.4
RHmin (%)	64.0	58.0	49.0	39.0	34.0	20.0	18.0	19.0	22.0	31.0	47.0	55.0	38.0
Rain (mm)	128.6	145.3	123.4	88.6	36.1	0.0	0.5	0.0	0.0	22.0	98.6	166.0	809.1

Station No.: 128 **Station Type:** Climatological **Longitude:** 58° 45' E
Station Name: Sangsoorakh **Latitude:** 37° 38' N **Altitude:** 1100 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.8	6.5	11.9	18.2	23.6	29.4	32.3	31.2	27.0	19.3	13.3	9.9	19.1
T min (C)	-3.1	-2.5	2.0	7.5	11.8	16.3	18.4	16.8	12.7	6.8	2.3	-0.2	7.4
T ave (C)	1.9	2.0	6.9	12.9	17.7	22.8	25.3	24.0	19.9	13.0	7.8	4.8	13.3
T rng (C)	9.9	9.0	9.9	10.7	11.8	13.1	13.9	14.4	14.3	12.5	11.0	10.1	11.7
RHmax (%)	77.0	79.0	75.0	69.0	59.0	44.0	35.0	39.0	46.0	65.0	72.0	74.0	61.2
RHmin (%)	60.0	64.0	59.0	49.0	43.0	30.0	22.0	22.0	28.0	43.0	50.0	56.0	43.8
Rain (mm)	23.9	32.3	56.8	60.4	50.9	12.8	4.3	0.8	6.0	18.1	24.6	39.9	330.8

Station No.: 129 **Station Type:** Sinoptice **Longitude:** 47° 00' E
Station Name: Sanandaj **Latitude:** 35° 14' N **Altitude:** 1373 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.8	6.9	13.2	19.5	24.4	32.0	36.8	35.7	31.7	23.9	15.5	8.5	21.2
T min (C)	-4.7	-4.6	0.3	4.7	8.1	12.1	16.7	16.5	10.5	5.8	1.0	-2.6	5.3
T ave (C)	0.6	1.2	6.8	12.1	16.3	22.0	26.8	26.1	21.1	14.9	8.3	3.0	13.2
T rng (C)	10.5	11.5	12.9	14.8	16.3	19.9	20.1	19.2	21.2	18.1	14.5	11.1	15.8
RHmax (%)	84.0	82.0	79.0	77.0	73.0	54.0	43.0	42.0	49.0	66.0	78.0	81.0	67.3
RHmin (%)	64.0	61.0	49.0	40.0	34.0	20.0	16.0	17.0	18.0	31.0	47.0	58.0	37.9
Rain (mm)	78.5	72.4	97.2	73.6	53.6	2.5	0.8	1.2	0.7	33.3	59.4	66.1	539.3

Station No.: 130 **Station Type:** Climatological **Longitude:** 48° 14' E
Station Name: Soobashi **Latitude:** 35° 10' N **Altitude:** 2039 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	-0.6	0.7	5.7	12.4	18.2	24.9	30.5	29.2	23.6	16.5	8.1	1.9	14.3
T min (C)	-14.0	-12.0	-5.3	0.2	4.3	8.0	13.0	11.8	6.5	1.7	-3.2	-9.3	0.1
T ave (C)	-7.3	-5.7	0.2	6.3	11.3	16.5	21.8	20.5	15.1	9.1	2.5	-3.7	7.2
T rng (C)	13.4	12.7	11.0	12.2	13.9	16.9	17.5	17.4	17.1	14.8	11.3	11.2	14.1
RHmax (%)	68.0	65.0	69.0	59.0	56.0	46.0	43.0	39.0	40.0	53.0	66.0	65.0	55.8
RHmin (%)	67.0	68.0	62.0	48.0	42.0	29.0	29.0	29.0	27.0	38.0	55.0	64.0	46.5
Rain (mm)	41.9	95.9	41.6	49.4	51.8	0.8	3.0	6.7	6.2	46.6	47.8	82.4	474.1

Station No.: 131 **Station Type:** Sinoptice **Longitude:** 55° 02' E
Station Name: Shahroud **Latitude:** 36° 25' N **Altitude:** 1345 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.1	8.1	14.5	21.4	26.1	30.9	33.2	32.5	29.6	22.5	14.9	8.4	20.7
T min (C)	-3.7	-2.3	2.2	7.4	11.8	16.2	19.2	17.7	13.1	7.3	1.4	-1.5	7.4
T ave (C)	1.2	2.9	8.4	14.4	19.0	23.5	26.2	25.1	21.4	14.9	8.1	3.4	14.0
T rng (C)	9.8	10.4	12.3	13.9	14.3	14.7	14.0	14.8	16.5	15.2	13.5	9.9	13.3
RHmax (%)	80.0	77.0	70.0	65.0	62.0	54.0	51.0	52.0	57.0	71.0	75.0	80.0	66.2
RHmin (%)	56.0	51.0	42.0	37.0	36.0	31.0	29.0	28.0	29.0	36.0	42.0	52.0	39.1
Rain (mm)	20.7	25.6	25.4	28.3	25.9	5.0	1.4	1.4	1.7	8.9	13.8	20.7	178.8

Station No.: 132 **Station Type:** Climatological **Longitude:** 51° 06' E
Station Name: Shabankareh **Latitude:** 29° 20' N **Altitude:** 120 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	20.0	21.8	27.3	32.9	39.8	43.3	44.1	43.3	41.7	36.7	28.7	22.3	33.5
T min (C)	7.3	8.2	11.4	15.2	19.4	21.8	24.3	24.0	21.0	17.0	12.0	8.6	15.9
T ave (C)	13.6	15.0	19.3	24.1	29.6	32.5	34.2	33.7	31.4	26.9	20.4	15.4	24.7
T rng (C)	12.7	13.6	15.9	17.7	20.4	21.5	19.8	19.3	20.7	19.7	16.7	13.7	17.6
RHmax (%)	88.0	88.0	81.0	73.0	64.0	59.0	70.0	72.0	74.0	73.0	79.0	85.0	75.5
RHmin (%)	58.0	54.0	43.0	34.0	27.0	24.0	26.0	27.0	26.0	30.0	40.0	53.0	36.8
Rain (mm)	77.8	43.9	23.8	11.8	1.9	0.0	0.0	0.3	0.0	9.5	27.2	60.8	257.0

Station No.: 133 **Station Type:** Climatological **Longitude:** 49° 44' E
Station Name: Shamsabad-Arak **Latitude:** 33° 49' N **Altitude:** 2400 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.8	4.7	9.6	15.2	20.7	26.5	31.7	30.6	26.5	19.6	12.3	6.6	17.3
T min (C)	-8.2	-7.7	-2.5	2.5	6.8	9.9	14.3	13.8	7.8	3.5	-0.4	-4.6	2.9
T ave (C)	-2.2	-1.5	3.6	8.9	13.8	18.2	23.0	22.2	17.1	11.6	6.0	1.0	10.1
T rng (C)	12.0	12.4	12.1	12.7	13.9	16.6	17.4	16.8	18.7	16.1	12.7	11.2	14.4
RHmax (%)	55.0	58.0	62.0	60.0	55.0	48.0	44.0	44.0	47.0	53.0	62.0	57.0	53.8
RHmin (%)	57.0	55.0	53.0	43.0	38.0	34.0	31.0	31.0	31.0	36.0	46.0	53.0	42.3
Rain (mm)	53.9	35.5	58.1	72.3	46.0	1.4	0.2	1.1	0.0	28.1	33.3	46.9	376.8

Station No.: 134 **Station Type:** Climatological **Longitude:** 48° 21' E
Station Name: Shamoun **Latitude:** 32° 23' N **Altitude:** 60 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.4	19.2	24.1	29.6	37.5	43.3	45.2	44.5	41.5	34.6	26.6	19.4	31.9
T min (C)	4.9	5.4	9.1	12.7	18.4	21.2	23.9	23.2	19.8	15.3	10.9	6.4	14.3
T ave (C)	11.2	12.3	16.6	21.1	28.0	32.3	34.5	33.8	30.6	24.9	18.8	12.9	23.1
T rng (C)	12.6	13.8	15.0	16.9	19.1	22.1	21.3	21.3	21.7	19.3	15.7	13.0	17.6
RHmax (%)	91.0	91.0	85.0	82.0	60.0	43.0	45.0	52.0	53.0	64.0	80.0	89.0	69.6
RHmin (%)	65.0	58.0	49.0	43.0	26.0	16.0	19.0	21.0	21.0	28.0	45.0	61.0	37.7
Rain (mm)	82.3	43.5	44.6	34.1	8.9	0.0	0.0	0.0	0.0	6.4	38.8	63.6	322.2

Station No.: 135 **Station Type:** Climatological **Longitude:** 48° 15' E
Station Name: Shoush **Latitude:** 32° 12' N **Altitude:** 180 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	16.9	18.9	23.6	29.3	37.5	43.9	45.5	44.8	41.6	34.4	25.9	18.8	31.8
T min (C)	4.8	5.3	9.0	13.6	19.0	22.7	24.5	23.9	20.9	15.9	10.9	6.3	14.7
T ave (C)	10.9	12.1	16.3	21.5	28.3	33.3	35.0	34.3	31.3	25.2	18.4	12.5	23.2
T rng (C)	12.1	13.6	14.6	15.7	18.5	21.2	21.0	20.9	20.7	18.5	15.0	12.5	17.0
RHmax (%)	87.0	88.0	83.0	78.0	55.0	38.0	41.0	46.0	44.0	59.0	77.0	87.0	65.3
RHmin (%)	63.0	56.0	49.0	41.0	25.0	17.0	17.0	19.0	21.0	30.0	43.0	60.0	36.8
Rain (mm)	71.3	37.6	48.1	35.5	9.5	0.0	0.0	0.0	0.0	11.9	41.5	59.2	314.6

Station No.: 136 **Station Type:** Climatological **Longitude:** 48° 50' E
Station Name: Shoshtar **Latitude:** 32° 03' N **Altitude:** 150 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	18.0	19.6	25.0	31.5	38.1	44.3	46.2	45.3	42.7	35.8	26.5	19.4	32.7
T min (C)	7.3	8.3	11.3	16.4	22.2	26.1	27.3	26.1	23.5	18.9	12.8	7.8	17.3
T ave (C)	12.6	14.0	18.1	24.0	30.1	35.2	36.8	35.7	33.1	27.3	19.6	13.6	25.0
T rng (C)	10.7	11.3	13.7	15.1	15.9	18.2	18.9	19.2	19.2	16.9	13.7	11.6	15.4
RHmax (%)	83.0	81.0	67.0	55.0	42.0	32.0	33.0	35.0	37.0	47.0	66.0	82.0	55.0
RHmin (%)	66.0	58.0	45.0	35.0	23.0	17.0	17.0	20.0	21.0	29.0	46.0	64.0	36.0
Rain (mm)	75.5	57.0	40.3	30.1	8.6	0.2	0.0	0.2	0.0	13.6	37.6	106.1	369.6

Station No.: 137 **Station Type:** Sinoptice **Longitude:** 50° 51' E
Station Name: Shahre-Kord **Latitude:** 32° 19' N **Altitude:** 2066 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.0	7.2	12.9	18.6	24.8	32.0	35.0	34.3	30.4	23.4	15.2	8.8	20.6
T min (C)	-7.1	-5.2	-0.2	4.4	7.9	11.0	14.4	13.3	8.3	4.1	0.0	-3.7	3.9
T ave (C)	-1.0	1.0	6.3	11.5	16.4	21.5	24.7	23.8	19.4	13.8	7.6	2.6	12.3
T rng (C)	12.1	12.4	13.1	14.2	16.9	21.5	20.6	21.0	22.1	19.3	15.2	12.5	16.7
RHmax (%)	76.0	74.0	69.0	66.0	63.0	50.0	42.0	41.0	45.0	59.0	70.0	74.0	60.8
RHmin (%)	52.0	46.0	39.0	35.0	31.0	26.0	25.0	25.0	26.0	33.0	38.0	46.0	35.2
Rain (mm)	61.1	53.2	50.1	50.3	14.4	0.5	0.8	0.3	0.0	12.0	40.1	54.0	336.8

Station No.: 138 **Station Type:** Sinoptice **Longitude:** 52° 35' E
Station Name: Shiraz **Latitude:** 29° 32' N **Altitude:** 1491 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.3	14.3	18.6	23.7	30.3	35.9	37.6	37.0	33.4	27.7	20.3	14.6	25.5
T min (C)	-0.2	1.2	4.4	8.2	12.8	16.7	20.1	18.6	13.5	8.6	3.5	0.4	9.0
T ave (C)	6.1	7.8	11.5	16.0	21.5	26.3	28.8	27.8	23.5	18.2	11.9	7.5	17.2
T rng (C)	12.5	13.1	14.2	15.5	17.5	19.2	17.5	18.4	19.9	19.1	16.8	14.2	16.5
RHmax (%)	81.0	78.0	71.0	67.0	48.0	33.0	34.0	36.0	40.0	54.0	69.0	80.0	57.6
RHmin (%)	46.0	42.0	36.0	30.0	19.0	12.0	13.0	13.0	12.0	18.0	29.0	43.0	26.1
Rain (mm)	82.3	55.5	55.0	30.4	7.5	0.4	0.7	0.1	0 0	8.8	24.9	56.6	322.2

Station No.:	139	Station Type:	Climatological	Longitude:	52° 54' E
Station Name:	Shirgah	Latitude:	36° 17' N	Altitude:	223 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.9	10.6	14.5	19.2	24.4	28.0	30.3	30.0	27.2	23.0	18.6	15.3	21.2
T min (C)	0.3	0.5	2.6	6.5	9.4	12.6	14.1	14.3	12.7	8.7	5.1	2.2	7.4
T ave (C)	6.6	5.6	8.6	12.9	16.9	20.3	22.2	22.1	20.0	15.9	11.9	8.8	14.3
T rng (C)	12.6	10.1	11.9	12.7	15.0	15.4	16.2	15.7	14.5	14.3	13.5	13.1	13.8
RHmax (%)	86.0	88.0	88.0	86.0	87.0	88.0	89.0	90.0	90.0	89.0	88.0	87.0	88.0
RHmin (%)	72.0	77.0	77.0	77.0	76.0	74.0	75.0	75.0	76.0	77.0	72.0	77.0	75.4
Rain (mm)	72.9	105.8	95.2	55.5	57.8	57.2	58.2	75.6	106.2	136.0	119.4	92.3	1032.1

Station No.:	140	Station Type:	Climatological	Longitude:	48° 48' E
Station Name:	Shirvan-Broujerd	Latitude:	33° 46' N	Altitude:	1392 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	4.2	6.9	12.7	18.0	23.6	31.2	35.8	35.9	31.4	22.6	14.6	8.2	20.4
T min (C)	-3.8	-2.6	1.8	5.3	7.7	9.9	13.2	13.5	8.0	4.0	1.0	-1.2	4.7
T ave (C)	0.2	2.2	7.3	11.6	15.6	20.5	24.5	24.7	19.7	13.3	7.8	3.5	12.6
T rng (C)	8.0	9.5	10.9	12.7	15.9	21.3	22.6	22.4	23.4	18.6	13.6	9.4	15.7
RHmax (%)	78.0	80.0	82.0	79.0	77.0	67.0	60.0	56.0	59.0	70.0	76.0	78.0	71.8
RHmin (%)	70.0	67.0	64.0	55.0	47.0	36.0	31.0	27.0	27.0	41.0	55.0	64.0	48.7
Rain (mm)	105.0	85.5	73.2	54.9	31.3	2.3	1.1	0.0	0.0	55.2	47.87	86.5	542.8

Station No.:	141	Station Type:	Sinoptice	Longitude:	56° 54' E
Station Name:	Tabas	Latitude:	33° 36' N	Altitude:	690 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	14.0	17.0	23.7	28.8	35.1	40.7	42.2	40.5	37.1	30.8	22.6	16.0	29.0
T min (C)	0.2	2.3	8.9	12.9	18.4	22.9	25.0	22.5	17.7	12.3	5.7	1.6	12.5
T ave (C)	7.1	9.6	16.3	20.8	26.8	31.8	33.6	31.5	27.4	21.5	14.1	8.8	20.8
T rng (C)	13.8	14.7	14.8	15.9	16.7	17.8	17.2	18.0	19.4	18.5	16.9	14.4	16.5
RHmax (%)	81.0	76.0	62.0	61.0	52.0	41.0	39.0	39.0	41.0	45.0	68.0	77.0	57.6
RHmin (%)	47.0	40.0	29.0	27.0	22.0	15.0	16.0	15.0	16.0	23.0	31.0	41.0	26.8
Rain (mm)	18.2	12.7	10.5	17.4	4.0	0.0	0.0	0.0	0.0	2.9	6.5	13.2	85.4

Station No.:	142	Station Type:	Climatological	Longitude:	59° 33' E
Station Name:	Torogh-kertian	Latitude:	36° 10' N	Altitude:	1300 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.0	7.1	12.8	19.1	24.3	29.4	31.6	30.8	26.7	20.4	14.1	9.1	19.4
T min (C)	-3.6	-3.2	1.6	7.0	11.7	16.1	18.1	17.1	12.6	6.8	2.5	-1.2	7.1
T ave (C)	1.7	1.9	7.2	13.1	18.0	22.8	24.9	24.0	19.7	13.6	8.3	4.0	13.2
T rng (C)	10.6	10.3	11.2	12.1	12.6	13.3	13.5	13.7	14.1	13.6	11.6	10.3	12.2
RHmax (%)	79.0	73.0	70.0	70.0	59.0	43.0	37.0	37.0	43.0	60.0	67.0	71.0	59.1
RHmin (%)	60.0	64.0	51.0	43.0	35.0	24.0	23.0	23.0	22.0	36.0	45.0	54.0	40.0
Rain (mm)	34.7	29.9	59.8	32.4	39.2	2.1	1.8	0.0	2.9	16.5	29.5	27.7	276.5

Station No.:	143	Station Type:	Climatological	Longitude:	50° 38' E
Station Name:	Abbassabad-Ghom	Latitude:	34° 04' N	Altitude:	1445 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.6	9.5	14.8	19.5	25.9	33.4	36.9	35.6	29.5	21.1	13.2	9.5	21.3
T min (C)	-2.5	-0.2	3.3	7.0	11.2	15.0	18.3	17.0	12.2	6.8	1.7	-0.9	7.4
T ave (C)	2.0	4.7	9.1	13.3	18.5	24.2	27.6	26.3	20.9	14.0	7.4	4.3	14.3
T rng (C)	9.1	9.7	11.5	12.5	14.7	18.4	18.6	18.6	17.3	14.3	11.5	10.4	13.9
RHmax (%)	75.0	77.0	72.0	64.0	58.0	50.0	47.0	50.0	59.0	66.0	73.0	75.0	63.8
RHmin (%)	56.0	57.0	49.0	48.0	47.0	39.0	37.0	37.0	41.0	47.0	51.0	60.0	47.4
Rain (mm)	20.1	14.9	9.9	11.1	15.2	1.8	0.3	0.0	0.0	6.4	11.2	20.5	111.4

Station No.:	144	Station Type:	Climatological	Longitude:	51° 03' E
Station Name:	Adl	Latitude:	32° 04' N	Altitude:	2280 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	4.6	7.2	12.2	18.1	23.0	29.3	32.8	31.7	28.0	21.3	13.2	8.5	19.2
T min (C)	-7.9	-5.9	-2.0	3.0	4.9	7.1	10.7	9.6	4.4	1.5	-1.6	-4.3	1.6
T ave (C)	-1.7	0.6	5.1	10.6	13.9	18.2	21.8	20.7	16.2	11.4	5.8	2.1	10.4
T rng (C)	12.5	13.1	14.2	15.1	18.1	22.2	22.1	22.1	23.6	19.8	14.8	12.8	17.5
RHmax (%)	82.0	80.0	79.0	74.0	70.0	64.0	60.0	63.0	69.0	71.0	75.0	81.0	72.3
RHmin (%)	63.0	57.0	47.0	40.0	32.0	22.0	22.0	22.0	22.0	32.0	43.0	55.0	38.1
Rain (mm)	93.7	66.0	79.0	53.4	27.1	2.1	3.5	0.3	0.0	18.0	53.0	72.8	460.5

Station No.: 145 **Station Type:** Climatological **Longitude:** 58° 09' E
Station Name: Ferdous **Latitude:** 34° 01' N **Altitude:** 1290 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.8	11.9	16.8	23.2	29.1	34.1	37.2	35.4	31.4	24.2	15.4	11.8	23.4
T min (C)	-2.2	-0.2	3.7	8.5	13.6	17.3	19.9	16.9	11.9	7.0	1.0	-0.6	8.1
T ave (C)	3.8	5.8	10.3	15.9	21.4	25.7	28.5	26.2	21.6	15.6	8.2	5.6	15.7
T rng (C)	12.0	12.1	13.1	14.7	15.5	16.8	17.3	18.5	19.5	17.2	14.4	12.4	15.3
RHmax (%)	77.0	75.0	69.0	63.0	48.0	39.0	36.0	37.0	40.0	50.0	63.0	73.0	55.8
RHmin (%)	56.0	49.0	42.0	34.0	27.0	23.0	19.0	20.0	21.0	28.0	39.0	54.0	34.3
Rain (mm)	23.5	29.6	26.4	19.0	7.6	0.6	0.1	0.0	0.0	2.1	7.2	24.1	140.2

Station No.: 146 **Station Type:** Sinoptice **Longitude:** 53° 41' E
Station Name: Fasa **Latitude:** 28° 58' N **Altitude:** 1383 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	14.3	16.2	20.8	26.5	32.9	38.1	39.4	38.3	35.0	29.7	22.2	16.5	27.5
T min (C)	1.7	3.0	6.8	11.2	16.9	20.7	22.7	21.5	17.5	12.5	6.6	2.9	12.0
T ave (C)	8.0	9.6	13.8	18.9	24.9	29.4	31.1	29.9	26.3	21.1	14.4	9.7	19.7
T rng (C)	12.6	13.2	14.0	15.3	16.0	17.4	16.7	16.8	17.5	17.2	15.6	13.6	15.5
RHmax (%)	77.0	76.0	70.0	59.0	41.0	30.0	33.0	34.0	32.0	40.0	56.0	71.0	51.6
RHmin (%)	47.0	43.0	37.0	28.0	19.0	15.0	17.0	19.0	17.0	21.0	31.0	43.0	28.1
Rain (mm)	81.1	61.9	52.1	17.4	2.3	0.1	2.1	0.1	0.0	1.4	17.6	49.4	285.5

Station No.: 147 **Station Type:** Climatological **Longitude:** 49° 19' E
Station Name: Fooman **Latitude:** 37° 12' N **Altitude:** -10 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.4	10.2	12.3	17.5	22.6	28.6	30.3	29.9	27.0	23.1	18.4	13.8	20.3
T min (C)	3.5	3.5	5.9	9.4	13.0	16.6	18.8	18.9	16.7	14.0	11.0	6.5	11.5
T ave (C)	6.9	6.8	9.1	13.4	17.8	22.6	24.5	24.4	21.9	18.5	14.7	10.1	15.9
T rng (C)	6.9	6.7	6.4	8.1	9.6	12.0	11.5	11.0	10.3	9.1	7.4	7.3	8.9
RHmax (%)	84.0	89.0	90.0	89.0	89.0	86.0	85.0	87.0	89.0	91.0	91.0	88.0	88.2
RHmin (%)	74.0	78.0	77.0	71.0	69.0	69.0	64.0	64.0	71.0	75.0	80.0	77.0	72.4
Rain (mm)	86.3	72.7	78.6	58.5	54.1	57.9	28.1	62.4	144.2	168.5	126.8	133.5	1071.6

Station No.: 148 **Station Type:** Climatological **Longitude:** 48° 13' E
Station Name: Firouzabad-Khalkhal **Latitude:** 37° 35' N **Altitude:** 1090 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	4.1	5.9	12.0	19.4	23.9	29.6	33.8	33.3	30.1	21.6	13.3	8.3	19.6
T min (C)	-11.4	-8.9	-3.7	2.5	7.0	10.7	15.0	14.8	9.6	3.2	-5.4	-8.4	2.1
T ave (C)	-3.6	-1.5	4.2	10.9	15.4	20.1	24.4	24.0	19.9	12.4	4.0	0.0	10.8
T rng (C)	15.5	14.8	15.7	16.9	16.9	18.9	18.8	18.5	20.5	18.4	18.7	16.7	17.5
RHmax (%)	49.0	60.0	66.0	77.0	81.0	74.0	66.0	66.0	69.0	71.0	62.0	56.0	66.4
RHmin (%)	60.0	63.0	54.0	46.0	46.0	34.0	32.0	31.0	30.0	44.0	54.0	57.0	45.9
Rain (mm)	32.9	42.9	53.6	57.8	59.3	15.8	0.0	1.3	3.7	40.0	37.8	33.5	378.6

Station No.: 149 **Station Type:** Climatological **Longitude:** 52° 53' E
Station Name: Ghaemshahr **Latitude:** 36° 29' N **Altitude:** 50 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.6	11.3	14.6	21.3	24.7	28.8	31.4	30.9	29.2	23.0	17.7	13.8	21.5
T min (C)	1.5	2.3	4.9	10.2	14.7	18.5	21.4	21.2	18.9	12.6	7.4	3.8	11.4
T ave (C)	6.6	6.8	9.8	15.8	19.7	23.6	26.4	26.0	24.0	17.8	12.6	8.8	16.5
T rng (C)	10.1	9.0	9.7	11.1	10.0	10.3	10.0	9.7	10.3	10.4	10.3	10.0	10.1
RHmax (%)	90.0	91.0	89.0	87.0	87.0	85.0	85.0	87.0	90.0	91.0	90.0	90.0	88.5
RHmin (%)	67.0	69.0	71.0	63.0	65.0	63.0	61.0	64.0	65.0	66.0	65.0	67.0	65.5
Rain (mm)	83.3	86.6	63.4	37.4	45.2	33.1	24.0	34.7	58.2	75.2	74.2	71.3	686.6

Station No.: 150 **Station Type:** Climatological **Longitude:** 59° 12' E
Station Name: Ghaen **Latitude:** 33° 44' N **Altitude:** 1471 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.7	8.8	14.2	19.1	25.4	31.6	33.4	31.3	25.9	19.8	17.4	10.6	20.4
T min (C)	-4.7	-1.9	2.9	6.0	11.3	14.0	14.8	13.9	9.3	5.8	1.0	-2.2	5.9
T ave (C)	1.5	3.5	8.6	12.6	18.4	22.8	24.1	22.6	17.6	12.8	9.2	4.2	13.1
T rng (C)	12.4	10.7	11.3	13.1	14.1	17.6	18.6	17.4	16.6	14.0	16.4	12.8	14.6
RHmax (%)	74.0	72.0	72.0	67.0	65.0	62.0	55.0	59.0	49.0	63.0	64.0	70.0	64.3
RHmin (%)	56.0	61.0	53.0	48.0	53.0	52.0	50.0	55.0	48.0	44.0	43.0	51.0	51.2
Rain (mm)	30.0	38.0	27.3	40.0	5.5	0.0	0.1	0.0	0.0	3.0	15.7	22.9	182.5

Station No.:	151	**Station Type:**	Climatological	**Longitude:**	52° 47' E
Station Name:	Ghoran-Talar	**Latitude:**	36° 29' N	**Altitude:**	90 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.6	11.1	14.1	19.4	24.5	27.6	29.5	29.2	27.0	23.1	18.1	13.0	20.6
T min (C)	0.7	0.9	4.1	8.3	12.7	16.1	18.1	18.8	16.2	12.3	7.4	3.4	9.9
T ave (C)	5.7	6.0	9.1	13.9	18.6	21.9	23.8	24.0	21.6	17.7	12.8	8.2	15.3
T rng (C)	9.9	10.2	10.0	11.1	11.8	11.5	11.4	10.4	10.8	10.8	10.7	9.6	10.7
RHmax (%)	88.0	87.0	88.0	88.0	88.0	89.0	88.0	90.0	89.0	90.0	89.0	91.0	88.8
RHmin (%)	80.0	78.0	77.0	78.0	80.0	79.0	79.0	81.0	80.0	83.0	81.0	83.0	79.9
Rain (mm)	70.8	76.9	89.4	63.6	45.1	56.1	54.1	87.2	91.0	97.3	85.6	71.1	888.2

Station No.:	152	**Station Type:**	Climatological	**Longitude:**	47° 42' E
Station Name:	Ghareh-Aghaj	**Latitude:**	39° 02' N	**Altitude:**	700 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.2	6.2	16.0	16.8	20.8	25.7	28.0	28.7	24.7	17.7	12.7	9.2	17.6
T min (C)	-4.5	-4.0	-0.4	4.9	8.5	12.1	15.0	14.7	11.4	6.3	1.6	-1.2	5.4
T ave (C)	0.3	1.1	7.8	10.8	14.6	18.9	21.5	21.7	18.0	12.0	7.2	4.0	11.5
T rng (C)	9.7	10.2	16.4	11.9	12.3	13.6	13.0	14.0	13.3	11.4	11.1	10.4	12.3
RHmax (%)	76.0	79.0	75.0	69.0	72.0	66.0	59.0	63.0	71.0	76.0	74.0	75.0	71.3
RHmin (%)	65.0	67.0	61.0	57.0	57.0	48.0	39.0	42.0	54.0	65.0	64.0	62.0	56.8
Rain (mm)	27.5	30.0	59.3	68.8	87.9	44.2	6.2	7.5	27.9	49.7	35.3	28.0	472.3

Station No.:	153	**Station Type:**	Sinoptice	**Longitude:**	50° 00' E
Station Name:	Ghazvin	**Latitude:**	36° 15' N	**Altitude:**	1377 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.5	7.5	13.7	20.6	25.6	31.9	35.6	34.7	31.0	23.0	14.8	8.2	21.1
T min (C)	-3.5	-2.8	1.8	6.7	10.6	14.3	17.4	16.6	12.7	7.8	2.5	-1.4	6.9
T ave (C)	1.5	2.3	7.8	13.6	18.1	23.1	26.5	25.7	21.9	15.4	8.6	3.4	14.0
T rng (C)	10.0	10.3	11.9	13.9	15.0	17.6	18.2	18.1	18.3	15.2	12.3	9.6	14.2
RHmax (%)	82.0	80.0	76.0	70.0	71.0	61.0	58.0	56.0	57.0	69.0	74.0	80.0	69.5
RHmin (%)	61.0	56.0	46.0	37.0	35.0	26.0	26.0	25.0	25.0	35.0	45.0	58.0	39.6
Rain (mm)	42.2	36.6	59.4	34.7	44.1	8.7	1.4	1.7	0.5	24.1	31.9	49.9	335.2

Station No.:	154	**Station Type:**	Climatological	**Longitude:**	45° 34' E
Station Name:	Ghasreshirin	**Latitude:**	34° 31' N	**Altitude:**	300 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	15.1	17.0	20.6	26.3	30.7	37.4	42.1	41.1	35.7	29.8	20.8	16.1	27.7
T min (C)	3.9	4.8	7.8	11.6	14.3	17.2	18.0	18.4	15.2	12.0	7.9	5.7	11.4
T ave (C)	9.5	10.9	14.2	19.0	22.5	27.3	30.0	29.8	25.5	20.9	14.3	10.9	19.6
T rng (C)	11.2	12.2	12.8	14.7	16.4	20.2	24.1	22.7	20.5	17.8	12.9	10.4	16.3
RHmax (%)	71.0	68.0	67.0	67.0	65.0	61.0	60.0	58.0	59.0	61.0	69.0	76.0	65.2
RHmin (%)	57.0	56.0	55.0	55.0	51.0	48.0	42.0	41.0	38.0	43.0	49.0	59.0	49.5
Rain (mm)	90.2	67.8	86.3	70.4	23.3	0.4	0.4	0.2	0.0	16.2	40.0	76.8	472.0

Station No.:	155	**Station Type:**	Climatological	**Longitude:**	45° 15' E
Station Name:	Ghotourchai	**Latitude:**	38° 51' N	**Altitude:**	950 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.9	6.1	13.9	21.1	25.7	30.8	35.3	35.3	31.0	22.0	13.6	7.0	20.5
T min (C)	-5.4	-4.5	1.2	7.2	11.8	15.9	19.9	19.1	14.1	7.5	1.5	-1.9	7.2
T ave (C)	-0.8	0.8	7.5	14.1	18.8	23.3	27.6	27.2	22.5	14.8	7.6	2.5	13.8
T rng (C)	9.3	10.6	12.7	13.9	13.9	14.9	15.4	16.2	16.9	14.5	12.1	8.9	13.3
RHmax (%)	84.0	83.0	79.0	78.0	77.0	68.0	61.0	61.0	71.0	79.0	83.0	87.0	75.9
RHmin (%)	73.0	69.0	52.0	46.0	46.0	39.0	34.0	36.0	40.0	52.0	63.0	69.0	51.6
Rain (mm)	14.5	13.0	29.1	43.1	57.2	28.2	10.4	1.5	8.6	25.8	24.6	14.0	270.0

Station No.:	156	**Station Type:**	Climatological	**Longitude:**	50° 53' E
Station Name:	Ghom	**Latitude:**	34° 38' N	**Altitude:**	928 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.6	11.3	17.8	25.0	31.5	37.5	40.3	38.4	34.4	26.3	18.8	12.2	25.3
T min (C)	-0.2	2.2	5.5	10.7	15.2	19.8	22.7	20.2	17.2	12.5	6.4	2.2	11.2
T ave (C)	4.7	6.8	11.6	17.9	23.4	28.6	31.5	29.3	25.8	19.4	12.6	7.2	18.2
T rng (C)	9.8	9.1	12.3	14.3	16.3	17.7	17.6	18.2	17.2	13.8	12.4	10.0	14.1
RHmax (%)	72.0	73.0	62.0	51.0	47.0	33.0	32.0	31.0	35.0	48.0	64.0	70.0	51.5
RHmin (%)	49.0	50.0	42.0	31.0	27.0	20.0	18.0	19.0	22.0	29.0	38.0	46.0	32.6
Rain (mm)	29.2	19.6	27.5	31.5	16.6	2.7	0.6	0.6	0.0	7.5	11.6	17.5	164.9

Station No.: 157 **Station Type:** Climatological **Longitude:** 51° 51' E
Station Name: Ghomsheh (Shahreza) **Latitude:** 32° 01' N **Altitude:** 1700 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.9	11.7	14.5	20.1	25.4	33.7	35.8	33.4	29.6	22.8	16.6	10.3	22.0
T min (C)	-3.4	-0.9	2.1	6.4	10.9	15.3	15.4	13.8	9.9	5.8	1.3	-1.8	6.2
T ave (C)	3.2	5.4	8.3	13.3	18.1	24.5	25.6	23.6	19.8	14.3	8.9	4.3	14.1
T rng (C)	13.3	12.6	12.4	13.7	14.5	18.4	20.4	19.6	19.7	17.0	15.3	12.1	15.8
RHmax (%)	80.0	75.0	73.0	64.0	48.0	39.0	33.0	37.0	40.0	56.0	67.0	74.0	57.2
RHmin (%)	51.0	47.0	40.0	34.0	28.0	26.0	26.0	25.0	26.0	32.0	36.0	50.0	35.1
Rain (mm)	17.3	22.1	21.4	18.5	10.2	1.3	0.1	0.0	0.0	6.4	14.3	20.0	131.6

Station No.: 158 **Station Type:** Climatological **Longitude:** 58° 30' E
Station Name: Ghouchan **Latitude:** 37° 06' N **Altitude:** 1282 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	4.3	6.6	11.6	18.1	22.8	29.2	31.5	30.1	27.4	20.2	13.1	8.8	18.6
T min (C)	-7.3	-4.4	0.0	4.9	8.8	12.6	14.8	13.2	10.0	5.2	-0.1	-2.7	4.6
T ave (C)	-1.5	1.1	5.8	11.5	15.8	20.9	23.1	21.6	18.7	12.7	6.5	3.1	11.6
T rng (C)	11.6	11.0	11.6	13.2	14.0	16.6	16.7	16.9	17.4	15.0	13.2	11.5	14.1
RHmax (%)	82.0	84.0	81.0	77.0	68.0	60.0	52.0	54.0	60.0	72.0	80.0	79.0	70.8
RHmin (%)	71.0	72.0	62.0	51.0	44.0	33.0	26.0	29.0	33.0	44.0	54.0	64.0	48.6
Rain (mm)	24.4	39.0	41.9	42.3	43.9	8.4	0.9	1.2	5.8	20.7	22.2	24.1	274.8

Station No.: 159 **Station Type:** Climatological **Longitude:** 51° 40' E
Station Name: Kazeroun **Latitude:** 29° 36' N **Altitude:** 766 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.0	17.7	22.7	27.9	35.1	40.5	42.7	42.0	39.2	33.5	24.5	20.3	30.3
T min (C)	3.9	4.1	7.9	11.6	17.2	21.0	23.6	23.1	19.1	14.1	8.7	5.2	13.3
T ave (C)	10.4	10.9	15.3	19.8	26.1	30.8	33.2	32.5	29.2	23.8	16.6	12.8	21.8
T rng (C)	13.1	13.6	14.8	16.3	17.9	19.5	19.1	18.9	20.1	19.4	15.8	15.1	17.0
RHmax (%)	82.0	81.0	76.0	72.0	58.0	52.0	52.0	56.0	58.0	65.0	74.0	77.0	66.9
RHmin (%)	62.0	60.0	50.0	44.0	35.0	36.0	35.0	37.0	37.0	41.0	46.0	57.0	45.0
Rain (mm)	145.2	79.6	66.6	33.9	9.5	0.0	0.3	0.1	0.8	18.1	58.0	96.1	508.2

Station No.: 160 **Station Type:** Sinoptice **Longitude:** 51° 27' E
Station Name: Kashan **Latitude:** 33° 59' N **Altitude:** 975 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.2	13.3	20.0	26.9	32.1	37.9	41.4	40.2	35.9	28.0	18.8	12.3	26.4
T min (C)	-0.3	1.1	6.6	12.7	17.5	22.2	25.1	23.2	18.5	13.0	6.2	1.7	12.3
T ave (C)	4.9	7.2	13.3	19.8	24.8	30.1	33.3	31.7	27.2	20.5	12.5	7.0	19.4
T rng (C)	10.5	12.2	13.4	14.2	14.6	15.7	16.3	17.0	17.4	15.0	12.6	10.6	14.1
RHmax (%)	79.0	77.0	66.0	59.0	54.0	42.0	37.0	38.0	41.0	54.0	70.0	77.0	57.8
RHmin (%)	54.0	49.0	39.0	32.0	30.0	23.0	21.0	22.0	22.0	31.0	43.0	52.0	34.8
Rain (mm)	30.0	24.0	23.3	14.8	14.0	1.7	0.2	0.6	0.0	4.7	15.7	19.0	148.0

Station No.: 161 **Station Type:** Climatological **Longitude:** 58° 28' E
Station Name: Kashmar **Latitude:** 35° 12' N **Altitude:** 1060 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.0	9.9	17.1	23.9	30.7	36.6	37.6	36.5	31.7	24.3	15.8	10.0	23.5
T min (C)	-0.5	1.7	6.3	10.7	15.5	21.0	21.9	20.5	15.3	11.3	5.3	1.0	10.8
T ave (C)	3.8	5.8	11.7	17.3	23.1	28.8	29.8	28.5	23.5	17.8	10.6	5.5	17.2
T rng (C)	8.5	8.2	10.8	13.2	15.2	15.6	15.7	16.0	16.4	13.0	10.5	9.0	12.7
RHmax (%)	69.0	62.0	55.0	51.0	40.0	31.0	34.0	33.0	37.0	47.0	56.0	65.0	48.3
RHmin (%)	58.0	54.0	40.0	30.0	30.0	19.0	20.0	21.0	24.0	31.0	42.0	56.0	35.4
Rain (mm)	36.6	24.7	35.2	41.2	13.1	3.1	0.1	0.0	0.3	5.8	13.0	34.1	207.2

Station No.: 162 **Station Type:** Sinoptice **Longitude:** 56° 58' E
Station Name: Kerman **Latitude:** 30° 15' N **Altitude:** 1749 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.6	13.6	18.1	24.6	29.7	34.9	35.3	33.8	30.2	25.8	18.5	14.6	24.2
T min (C)	-3.2	-1.1	3.6	8.0	12.1	16.2	17.0	14.2	9.1	5.3	-0.7	-3.0	6.5
T ave (C)	4.2	6.3	10.9	16.3	20.9	25.6	26.1	24.0	19.7	15.5	8.9	5.8	15.3
T rng (C)	14.8	14.7	14.5	16.6	17.6	18.7	18.3	19.6	21.1	20.5	19.2	17.6	17.8
RHmax (%)	71.0	68.0	65.0	52.0	40.0	29.0	28.0	34.0	33.0	44.0	57.0	62.0	48.6
RHmin (%)	41.0	36.0	30.0	21.0	16.0	12.0	12.0	16.0	13.0	18.0	24.0	32.0	22.6
Rain (mm)	34.8	23.5	37.7	14.4	6.2	0.2	1.1	1.1	0.5	1.1	10.4	12.7	143.7

Station No.: 163 **Station Type:** Climatological **Longitude:** 46° 15' E
Station Name: karand **Latitude:** 34° 17' N **Altitude:** 1500 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.7	8.2	12.5	15.8	23.6	30.1	34.3	35.0	31.0	25.3	15.5	10.3	20.9
T min (C)	-1.1	-0.5	2.3	5.3	10.6	14.6	19.5	21.4	17.3	11.4	5.1	0.5	8.9
T ave (C)	3.8	3.8	7.4	10.6	17.1	22.4	26.9	28.2	24.1	18.3	10.3	5.4	14.9
T rng (C)	9.8	8.7	10.2	10.5	13.0	15.5	14.8	13.6	13.7	13.9	10.4	9.8	12.0
RHmax (%)	58.0	88.0	82.0	72.0	53.0	38.0	27.0	21.0	26.0	40.0	67.0	85.0	57.0
RHmin (%)	70.0	74.0	60.0	57.0	33.0	17.0	14.0	14.0	15.0	22.0	44.0	66.0	40.5
Rain (mm)	127.6	82.9	76.6	84.2	22.6	0.0	0.0	0.0	0.0	21.1	40.6	58.6	514.2

Station No.: 164 **Station Type:** Climatological **Longitude:** 52° 22' E
Station Name: Karesang **Latitude:** 36° 19' N **Altitude:** 500 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.1	10.5	12.9	19.2	23.5	26.1	26.7	27.7	23.8	21.8	18.0	14.9	19.8
T min (C)	2.1	1.4	4.5	7.4	13.4	16.3	18.3	18.6	15.4	10.8	6.4	4.3	9.9
T ave (C)	7.1	5.9	8.7	13.3	18.5	21.2	22.5	23.2	19.6	16.3	12.2	9.6	14.8
T rng (C)	10.0	9.1	8.4	11.8	10.1	9.8	8.4	9.1	8.4	11.0	11.6	10.6	9.9
RHmax (%)	75.0	76.0	73.0	70.0	71.0	71.0	80.0	78.0	80.0	80.0	75.0	76.0	75.4
RHmin (%)	66.0	64.0	68.0	69.0	70.0	74.0	78.0	78.0	80.0	74.0	69.0	69.0	71.6
Rain (mm)	55.8	61.8	90.8	47.8	55.5	59.1	57.3	54.5	91.8	140.4	75.8	58.3	848.9

Station No.: 165 **Station Type:** Climatological **Longitude:** 60° 50' E
Station Name: Kashafroud **Latitude:** 35° 59' N **Altitude:** 580 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.1	9.5	15.0	23.3	29.4	34.7	36.9	34.9	31.3	24.8	15.8	11.3	22.9
T min (C)	-1.4	0.7	4.7	9.8	13.7	17.8	20.7	18.8	14.1	9.5	3.3	0.9	9.4
T ave (C)	3.4	5.1	9.9	16.5	21.5	26.3	28.8	26.9	22.7	17.1	9.6	6.1	16.1
T rng (C)	9.5	8.8	10.3	13.5	15.7	16.9	16.2	16.1	17.2	15.3	12.5	10.4	13.5
RHmax (%)	70.0	70.0	69.0	64.0	53.0	42.0	39.0	33.0	37.0	56.0	73.0	76.0	56.8
RHmin (%)	58.0	60.0	53.0	44.0	32.0	28.0	26.0	24.0	24.0	33.0	47.0	52.0	40.1
Rain (mm)	29.9	48.1	64.0	55.9	20.2	0.0	0.0	0.0	2.0	13.7	22.1	31.3	287.2

Station No.: 166 **Station Type:** Climatological **Longitude:** 48° 26' E
Station Name: Koutiyan-Safiabad **Latitude:** 32° 16' N **Altitude:** 52 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	16.2	18.1	23.1	28.8	36.8	42.5	44.5	43.7	40.7	34.0	25.1	18.4	31.0
T min (C)	4.7	5.4	9.2	13.0	18.3	21.0	23.3	22.7	19.3	14.9	10.4	6.2	14.0
T ave (C)	10.5	11.8	16.1	20.9	27.5	31.8	33.9	33.2	30.0	24.5	17.8	12.3	22.5
T rng (C)	11.5	12.7	13.9	15.8	18.5	21.5	21.2	21.0	21.4	19.1	14.7	12.2	17.0
RHmax (%)	88.0	87.0	83.0	78.0	58.0	46.0	47.0	53.0	56.0	63.0	81.0	87.0	68.9
RHmin (%)	63.0	57.0	51.0	41.0	24.0	17.0	19.0	22.0	22.0	31.0	45.0	61.0	37.8
Rain (mm)	62.0	44.8	46.5	31.5	11.0	0.0	0.0	0.0	0.0	8.8	52.2	57.3	314.1

Station No.: 167 **Station Type:** Climatological **Longitude:** 48° 48' E
Station Name: Gotvand **Latitude:** 32° 14' N **Altitude:** 150 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	18.9	20.5	25.6	31.7	40.4	46.0	48.1	46.9	44.1	37.7	27.8	21.2	34.1
T min (C)	6.6	7.6	10.7	14.7	19.3	22.0	24.1	23.1	19.8	16.5	11.5	7.6	15.3
T ave (C)	12.8	14.1	18.1	23.2	29.9	34.0	36.1	35.0	31.9	27.1	19.6	14.4	24.7
T rng (C)	12.3	12.9	14.9	17.0	21.1	24.0	24.0	23.8	24.3	21.1	16.3	13.6	18.8
RHmax (%)	74.0	73.0	69.0	60.0	52.0	49.0	48.0	47.0	55.0	57.0	68.0	72.0	60.3
RHmin (%)	65.0	61.0	54.0	44.0	36.0	28.0	27.0	23.0	26.0	33.0	46.0	56.0	41.6
Rain (mm)	67.8	42.9	40.7	25.0	8.3	0.0	0.0	0.0	0.0	3.4	37.0	78.1	303.2

Station No.: 168 **Station Type:** Climatological **Longitude:** 50° 50' E
Station Name: Gachsaran **Latitude:** 30° 20' N **Altitude:** 709 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	15.9	17.1	22.0	27.1	35.0	40.1	42.1	41.4	38.7	32.3	24.0	17.8	29.5
T min (C)	3.9	4.2	7.1	10.8	16.7	20.2	23.9	22.8	18.7	13.8	8.7	5.2	13.0
T ave (C)	9.9	10.6	14.6	19.0	25.9	30.1	33.0	32.1	28.7	23.0	16.4	11.5	21.2
T rng (C)	12.0	12.9	14.9	16.3	18.3	19.9	18.2	18.6	20.0	18.5	15.3	12.6	16.5
RHmax (%)	87.0	87.0	76.0	73.0	44.0	27.0	30.0	32.0	36.0	44.0	67.0	84.0	57.3
RHmin (%)	53.0	49.0	38.0	31.0	16.0	8.0	11.0	11.0	11.0	16.0	33.0	48.0	27.1
Rain (mm)	114.7	66.8	58.1	37.8	4.5	0.0	0.2	0.8	0.0	14.3	42.8	102.0	442.0

Station No.: 169 **Station Type:** Sinoptice **Longitude:** 54° 28' E
Station Name: Gorgan **Latitude:** 36° 49' N **Altitude:** 155 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.3	11.7	15.3	21.5	26.3	30.3	32.6	32.4	30.0	24.2	19.0	14.6	22.5
T min (C)	3.5	3.6	6.5	11.4	16.1	19.9	22.9	22.9	20.0	14.3	9.4	6.1	13.1
T ave (C)	7.9	7.6	10.9	16.5	21.2	25.1	27.8	27.7	25.0	19.3	14.2	10.4	17.8
T rng (C)	8.8	8.1	8.8	10.1	10.2	10.4	9.7	9.5	10.0	9.9	9.6	8.5	9.5
RHmax (%)	74.0	77.0	79.0	77.0	76.0	74.0	72.0	74.0	75.0	78.0	76.0	75.0	75.6
RHmin (%)	60.0	63.0	63.0	59.0	53.0	49.0	50.0	53.0	52.0	55.0	57.0	60.0	56.2
Rain (mm)	60.3	68.1	81.8	48.7	52.3	39.1	20.3	28.3	40.2	83.7	67.6	67.2	657.6

Station No.: 170 **Station Type:** Climatological **Longitude:** 49° 58' E
Station Name: Garakan-Ashtiyan **Latitude:** 34° 33' N **Altitude:** 1791 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.8	4.7	9.4	15.9	21.0	28.8	31.6	30.6	28.2	21.5	14.3	6.7	18.0
T min (C)	-5.3	-4.2	0.9	6.0	10.8	15.3	18.0	17.8	14.1	8.9	3.3	-2.9	6.9
T ave (C)	-0.8	0.3	5.1	10.9	15.9	22.0	24.8	24.2	21.2	15.2	8.8	1.9	12.5
T rng (C)	9.1	8.9	8.5	9.9	10.2	13.5	13.6	12.8	14.1	12.6	11.0	9.6	11.2
RHmax (%)	75.0	75.0	71.0	63.0	53.0	49.0	42.0	40.0	40.0	50.0	65.0	68.0	57.6
RHmin (%)	67.0	67.0	63.0	48.0	41.0	34.0	30.0	26.0	25.0	34.0	47.0	60.0	45.2
Rain (mm)	37.4	25.3	34.9	45.1	42.6	5.9	0.2	1.7	1.9	21.6	37.7	22.5	276.8

Station No.: 171 **Station Type:** Climatological **Longitude:** 52° 20' E
Station Name: Garmsar **Latitude:** 35° 15' N **Altitude:** 856 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	10.4	12.0	18.5	25.6	31.4	36.4	39.0	37.6	33.6	26.4	18.7	12.2	25.2
T min (C)	-3.2	-2.0	3.5	8.6	14.1	18.3	21.0	19.6	13.7	8.9	2.2	-2.8	8.5
T ave (C)	3.6	5.0	11.0	17.1	22.8	27.4	30.0	28.6	23.6	17.6	10.5	4.7	16.8
T rng (C)	13.6	14.0	15.0	17.0	17.3	18.1	18.0	18.0	19.9	17.5	16.5	15.0	16.7
RHmax (%)	71.0	69.0	65.0	59.0	55.0	53.0	49.0	50.0	51.0	59.0	63.0	72.0	59.7
RHmin (%)	56.0	48.0	45.0	37.0	36.0	35.0	33.0	29.0	31.0	38.0	46.0	54.0	40.7
Rain (mm)	20.1	17.4	19.5	9.6	7.2	5.6	0.2	0.0	0.8	8.8	11.4	8.1	108.7

Station No.: 172 **Station Type:** Climatological **Longitude:** 59° 11' E
Station Name: Golmakan **Latitude:** 36° 28' N **Altitude:** 1300 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	4.2	5.6	12.9	19.2	22.9	28.1	30.4	29.5	25.5	19.3	13.5	7.6	18.2
T min (C)	-4.8	-4.3	1.5	7.3	10.8	14.2	16.7	15.2	10.4	6.6	2.2	-1.6	6.2
T ave (C)	-0.3	0.6	7.2	13.3	16.9	21.1	23.5	22.4	18.0	12.9	7.8	3.0	12.2
T rng (C)	9.0	9.9	11.4	11.9	12.1	13.9	13.7	14.3	15.1	12.7	11.3	9.2	12.0
RHmax (%)	76.0	78.0	76.0	65.0	65.0	57.0	52.0	48.0	53.0	65.0	66.0	75.0	64.7
RHmin (%)	66.0	66.0	52.0	43.0	41.0	34.0	31.0	27.0	28.0	45.0	45.0	61.0	44.9
Rain (mm)	25.4	27.3	36.7	35.8	31.3	6.4	2.6	1.1	4.8	15.3	23.8	19.9	230.4

Station No.: 173 **Station Type:** Climatological **Longitude:** 58° 42' E
Station Name: Gonabad **Latitude:** 34° 21' N **Altitude:** 1150 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.8	12.8	19.2	24.6	31.6	36.7	37.3	36.1	32.4	27.2	20.0	14.1	25.2
T min (C)	-3.6	-2.1	3.5	7.9	12.9	15.9	16.6	15.8	11.7	8.1	3.1	-2.0	7.3
T ave (C)	3.1	5.4	11.4	16.3	22.3	26.3	27.0	25.9	22.1	17.7	11.6	6.1	16.2
T rng (C)	13.4	14.9	15.7	16.7	18.7	20.8	20.7	20.3	20.7	19.1	16.9	16.1	17.8
RHmax (%)	81.0	78.0	73.0	65.0	57.0	48.0	45.0	45.0	48.0	55.0	67.0	75.0	61.4
RHmin (%)	69.0	65.0	55.0	44.0	34.0	30.0	31.0	29.0	29.0	35.0	46.0	58.0	43.8
Rain (mm)	27.0	34.5	21.7	30.6	6.6	0.0	0.5	0.0	0.0	2.8	11.5	17.3	152.5

Station No.: 174 **Station Type:** Climatological **Longitude:** 55° 10' E
Station Name: Gonabad-Ghabous **Latitude:** 37° 15' N **Altitude:** 174 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	14.0	13.3	16.8	22.0	27.5	32.9	35.5	34.7	31.9	26.7	20.7	15.8	24.3
T min (C)	1.9	1.7	4.8	8.8	13.3	18.4	21.4	21.3	18.6	12.7	7.1	3.8	11.2
T ave (C)	7.9	7.5	10.8	15.4	20.4	25.7	28.5	28.0	25.3	19.7	13.9	9.8	17.7
T rng (C)	12.1	11.6	12.0	13.2	14.2	14.5	14.1	13.4	13.3	14.0	13.6	12.0	13.2
RHmax (%)	82.0	83.0	84.0	84.0	80.0	77.0	75.0	81.0	79.0	81.0	84.0	84.0	81.2
RHmin (%)	59.0	61.0	58.0	56.0	54.0	50.0	49.0	53.0	53.0	53.0	53.0	57.0	54.7
Rain (mm)	43.8	66.6	67.8	72.1	47.5	24.7	11.7	20.6	20.2	35.7	59.1	51.3	521.1

Station No.: 175 **Station Type:** Climatological **Longitude:** 56° 13' E
Station Name: Gorgin-Khobr **Latitude:** 28° 50' N **Altitude:** 1825 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	14.9	15.0	18.2	23.8	30.5	35.3	35.9	35.2	32.9	28.3	22.7	16.8	25.8
T min (C)	-0.8	1.6	4.3	6.9	10.6	14.7	16.6	16.2	13.1	8.4	3.9	1.2	8.1
T ave (C)	7.0	8.3	11.3	15.3	20.5	25.0	26.3	25.7	23.0	18.3	13.3	9.0	16.9
T rng (C)	15.7	13.4	13.9	16.9	19.9	20.6	19.3	19.0	19.8	19.9	18.8	15.6	17.7
RHmax (%)	73.0	74.0	69.0	65.0	56.0	52.0	54.0	59.0	57.0	61.0	63.0	69.0	62.7
RHmin (%)	46.0	48.0	48.0	39.0	29.0	28.0	32.0	30.0	32.0	36.0	35.0	41.0	37.0
Rain (mm)	61.1	75.1	75.5	29.1	8.1	4.8	24.8	9.7	6.0	5.2	15.0	31.5	345.9

Station No.: 176 **Station Type:** Climatological **Longitude:** 48° 14' E
Station Name: Gousheh-Nahavand **Latitude:** 34° 17' N **Altitude:** 1520 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.1	7.0	13.2	19.2	25.0	30.5	36.6	36.4	31.1	23.3	15.3	9.5	21.1
T min (C)	-4.4	-3.6	0.4	4.7	8.0	10.1	14.9	14.1	9.2	5.5	1.1	-2.3	4.8
T ave (C)	0.8	1.7	6.8	12.0	16.5	20.3	25.8	25.3	20.1	14.4	8.2	3.6	13.0
T rng (C)	10.5	10.6	12.8	14.5	17.0	20.4	21.7	22.3	21.9	17.8	14.2	11.8	16.3
RHmax (%)	85.0	88.0	80.0	73.0	70.0	59.0	52.0	49.0	57.0	69.0	85.0	86.0	71.1
RHmin (%)	67.0	66.0	50.0	41.0	39.0	26.0	24.0	23.0	22.0	35.0	48.0	61.0	41.8
Rain (mm)	56.5	48.5	62.3	53.9	35.8	0.0	0.3	0.6	0.1	31.2	36.3	42.5	368.0

Station No.: 177 **Station Type:** Climatological **Longitude:** 52° 05' E
Station Name: Lar-Polour **Latitude:** 35° 50' N **Altitude:** 2400 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	-0.9	0.5	5.2	11.9	17.1	22.8	26.2	26.0	22.8	16.1	8.8	1.3	13.2
T min (C)	-12.2	-11.2	-5.2	1.2	5.0	8.0	11.0	10.2	6.4	2.3	-2.9	-8.0	0.4
T ave (C)	-6.5	-5.3	0.0	6.5	11.1	15.4	18.6	18.1	14.6	9.2	3.0	-3.3	6.8
T rng (C)	11.3	11.7	10.4	10.7	12.1	14.8	15.2	15.8	16.8	13.8	11.7	9.3	12.8
RHmax (%)	64.0	67.0	80.0	79.0	78.0	72.0	78.0	75.0	72.0	80.0	78.0	74.0	74.8
RHmin (%)	72.0	74.0	67.0	52.0	43.0	35.0	36.0	36.0	34.0	40.0	49.0	72.0	50.8
Rain (mm)	61.2	55.6	75.0	85.8	67.1	23.3	12.6	8.3	3.5	37.1	41.8	57.5	528.8

Station No.: 178 **Station Type:** Climatological **Longitude:** 54° 20' E
Station Name: Lar-Fars **Latitude:** 27° 41' N **Altitude:** 900 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.9	19.3	24.7	28.1	37.0	41.9	42.9	41.6	36.4	33.0	26.5	20.8	30.8
T min (C)	5.3	6.4	8.9	11.2	15.0	18.7	21.6	21.8	18.0	13.4	9.2	6.2	13.0
T ave (C)	11.6	12.8	16.8	19.6	26.0	30.3	32.3	31.7	27.2	23.2	17.9	13.5	21.9
T rng (C)	12.6	12.9	15.8	16.9	22.0	23.2	21.3	19.8	18.4	19.6	17.3	14.6	17.9
RHmax (%)	75.0	74.0	62.0	61.0	53.0	48.0	56.0	56.0	56.0	52.0	63.0	68.0	60.3
RHmin (%)	51.0	47.0	40.0	35.0	31.0	27.0	32.0	31.0	30.0	28.0	37.0	46.0	36.3
Rain (mm)	55.5	37.9	29.9	27.2	0.8	0.7	11.9	6.2	0.3	0.3	5.2	23.0	198.4

Station No.: 179 **Station Type:** Climatological **Longitude:** 50° 00' E
Station Name: Lahijan **Latitude:** 37° 11' N **Altitude:** -2 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	13.4	13.2	14.8	20.8	25.0	28.0	30.7	30.8	28.2	23.0	19.3	16.3	22.0
T min (C)	3.1	3.0	4.4	8.6	13.5	16.5	19.5	19.9	17.5	13.2	8.7	5.6	11.1
T ave (C)	8.3	8.1	9.6	14.7	19.3	22.3	25.1	25.3	22.9	18.1	14.0	10.9	16.5
T rng (C)	10.3	10.2	10.4	12.2	11.5	11.5	11.2	10.9	10.7	9.8	10.6	10.7	10.8
RHmax(%)	82.0	86.0	86.0	84.0	86.0	85.0	81.0	86.0	86.0	86.0	86.0	82.0	84.7
RHmin (%)	68.0	74.0	75.0	67.0	68.0	63.0	62.0	65.0	71.0	77.0	76.0	73.0	69.9
Rain(mm)	105.6	12.3.3	121.0	71.8	61.0	60.9	37.4	60.4	157.0	250.8	159.8	135.0	1344.0

Station No.: 180 **Station Type:** Climatological **Longitude:** 51° 41' E
Station Name: Latian **Latitude:** 35° 46' N **Altitude:** 1600 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.7	8.4	13.4	19.3	24.7	31.2	34.6	34.0	29.8	22.4	15.9	10.0	20.9
T min (C)	-3.0	-2.3	2.0	7.2	11.9	16.1	19.8	19.1	14.8	9.2	3.8	0.0	8.2
T ave (C)	1.8	3.0	7.7	13.3	18.3	23.7	27.2	26.5	22.3	15.8	9.8	5.0	14.5
T rng (C)	9.7	10.7	11.4	12.1	12.8	15.1	14.8	14.9	15.0	13.2	12.1	10.0	12.7
RHmax (%)	72.0	71.0	69.0	62.0	59.0	48.0	44.0	41.0	46.0	59.0	69.0	72.0	59.3
RHmin (%)	61.0	57.0	48.0	39.0	35.0	29.0	26.0	26.0	26.0	37.0	44.0	54.0	40.2
Rain (mm)	68.4	50.3	79.5	60.4	36.5	10.3	3.5	2.6	1.7	26.7	41.5	51.3	432.7

Station No.: 181 **Station Type:** Climatological **Longitude:** 50° 48' E
Station Name: Lordjan **Latitude:** 31° 31' N **Altitude:** 1700 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.1	10.6	15.3	20.6	27.3	33.7	36.0	35.3	30.8	24.5	17.4	12.2	22.7
T min (C)	-2.9	-2.0	2.1	5.6	8.7	12.8	16.1	15.0	10.7	5.5	1.8	-2.2	5.9
T ave (C)	3.1	4.3	8.7	13.0	18.0	23.3	26.0	25.1	20.8	15.0	9.6	5.0	14.3
T rng (C)	12.0	12.6	13.2	15.2	18.6	20.9	19.9	20.3	20.1	19.0	15.6	14.4	16.8
RHmax (%)	84.0	80.0	77.0	72.0	56.0	49.0	45.0	44.0	43.0	56.0	76.0	80.0	63.5
RHmin (%)	56.0	55.0	47.0	38.0	27.0	21.0	21.0	20.0	20.0	29.0	41.0	53.0	35.7
Rain (mm)	120.5	95.4	80.1	53.7	14.0	0.0	1.4	0.0	0.0	16.0	56.8	92.2	530.1

Station No.: 182 **Station Type:** Climatological **Longitude:** 46° 26' E
Station Name: Lighvan **Latitude:** 37° 50' N **Altitude:** 2100 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	-1.7	-1.8	3.8	9.8	15.6	20.4	24.6	25.0	21.3	14.2	7.5	1.5	11.7
T min (C)	-10.8	-11.4	-5.6	0.5	5.2	7.4	10.0	10.7	7.8	3.0	-2.2	-7.8	0.6
T ave (C)	-6.3	-6.6	-0.9	5.2	10.4	13.9	17.3	17.9	14.5	8.6	2.7	-3.2	6.1
T rng (C)	9.1	9.6	9.4	9.3	10.4	13.0	14.6	14.3	13.5	11.2	9.7	9.3	11.1
RHmax (%)	65.0	73.0	74.0	70.0	67.0	62.0	58.0	54.0	53.0	62.0	69.0	68.0	64.6
RHmin (%)	62.0	67.0	71.0	56.0	53.0	46.0	39.0	37.0	37.0	48.0	60.0	58.0	52.8
Rain (mm)	19.1	25.8	56.6	64.8	72.1	25.5	2.3	2.3	7.7	30.5	13.5	23.7	343.9

Station No.: 183 **Station Type:** Climatological **Longitude:** 44° 31' E
Station Name: Makoo **Latitude:** 39° 18' N **Altitude:** 1634 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.5	2.6	11.4	16.7	22.5	27.3	32.5	32.8	25.9	21.0	13.3	5.8	17.9
T min (C)	-10.0	-10.1	-0.5	5.1	7.9	11.2	14.9	15.1	10.6	7.6	1.2	-3.8	4.1
T ave (C)	-3.8	-3.8	5.4	10.9	15.2	19.3	23.7	24.0	18.3	14.3	7.3	1.0	11.0
T rng (C)	12.5	12.7	11.9	11.6	14.6	16.1	17.6	17.7	15.3	13.4	12.1	9.6	13.8
RHmax (%)	81.0	82.0	78.0	77.0	76.0	75.0	67.0	68.0	70.0	72.0	75.0	82.0	75.3
RHmin (%)	79.0	81.0	60.0	63.0	64.0	59.0	48.0	43.0	44.0	60.0	70.0	76.0	62.3
Rain (mm)	13.8	12.7	15.5	25.3	47.4	33.9	1.3	3.6	5.6	29.7	9.8	17.8	216.4

Station No.: 184 **Station Type:** Climatological **Longitude:** 46° 14' E
Station Name: maragheh **Latitude:** 37° 24' N **Altitude:** 1419 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	4.1	6.7	11.2	17.2	24.5	29.8	34.1	34.9	29.4	21.4	14.4	7.7	19.6
T min (C)	-6.5	-3.7	0.0	4.7	8.8	11.9	17.1	17.2	12.7	6.4	1.6	-2.6	5.6
T ave (C)	-1.2	1.5	5.6	11.0	16.6	20.8	25.6	26.1	21.0	13.9	8.0	2.5	12.6
T rng (C)	10.6	10.4	11.2	12.5	15.7	17.9	17.0	17.7	16.7	15.0	12.8	10.3	14.0
RHmax (%)	84.0	86.0	83.0	78.0	74.0	63.0	59.0	59.0	64.0	75.0	74.0	81.0	73.3
RHmin (%)	75.0	73.0	63.0	57.0	50.0	41.0	41.0	40.0	44.0	51.0	58.0	64.0	54.8
Rain (mm)	29.4	20.6	47.6	87.5	57.8	8.2	0.0	3.7	2.3	67.2	29.9	46.8	401.0

Station No.: 185 **Station Type:** Climatological **Longitude:** 45° 46' E
Station Name: Marand **Latitude:** 38° 46' N **Altitude:** 1305 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	1.5	3.7	10.3	16.8	22.0	27.8	32.9	32.4	28.2	19.2	10.2	5.0	17.5
T min (C)	-7.4	-5.6	-0.6	5.1	9.0	12.5	16.2	16.1	12.0	5.5	-0.1	-3.2	5.0
T ave (C)	-3.0	-0.9	4.8	10.9	15.5	20.1	24.6	24.3	20.1	12.4	5.0	0.9	11.2
T rng (C)	8.9	9.3	10.9	11.7	13.0	15.3	16.7	16.3	16.2	13.7	10.3	8.2	12.5
RHmax (%)	82.0	83.0	79.0	74.0	74.0	68.0	57.0	60.0	71.0	80.0	85.0	86.0	74.9
RHmin (%)	78.0	75.0	61.0	49.0	42.0	33.0	29.0	29.0	33.0	52.0	67.0	79.0	52.3
Rain (mm)	28.5	25.3	41.9	58.6	69.8	29.4	3.5	3.1	8.7	31.7	34.1	26.2	360.8

Station No.: 186 **Station Type:** Climatological **Longitude:** 52° 48' E
Station Name: Marvdasht **Latitude:** 29° 59' N **Altitude:** 1603 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.3	13.4	18.0	23.5	29.6	35.2	37.3	36.5	33.1	27.7	20.1	13.3	24.9
T min (C)	-0.7	0.3	3.5	7.5	12.1	15.6	18.5	17.7	13.2	8.8	2.5	-0.1	8.2
T ave (C)	5.3	6.8	10.8	15.5	20.9	25.4	27.9	27.1	23.1	18.3	11.3	6.6	16.6
T rng (C)	12.0	13.1	14.5	16.0	17.5	19.6	18.8	18.8	19.9	18.9	17.6	13.4	16.7
RHmax (%)	80.0	79.0	74.0	66.0	52.0	36.0	33.0	36.0	37.0	47.0	67.0	81.0	57.3
RHmin (%)	56.0	52.0	44.0	38.0	26.0	15.0	15.0	15.0	15.0	21.0	32.0	51.0	31.7
Rain (mm)	68.5	76.6	44.4	21.7	6.2	0.0	0.0	1.2	0.0	2.6	18.0	43.9	283.1

Station No.: 187 **Station Type:** Climatological **Longitude:** 49° 16' E
Station Name: Masjed-Soleiman **Latitude:** 31° 59' N **Altitude:** 362 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	16.8	18.0	23.7	29.0	36.8	42.5	44.5	43.6	40.7	33.7	25.3	18.3	31.1
T min (C)	6.9	7.9	12.0	16.3	22.7	26.8	29.8	28.9	25.3	20.1	13.1	8.3	18.2
T ave (C)	11.8	12.9	17.9	22.6	29.8	34.7	37.2	36.3	33.0	26.9	19.2	13.3	24.6
T rng (C)	9.9	10.1	11.7	12.7	14.1	15.7	14.7	14.7	15.4	13.6	12.2	10.0	12.9
RHmax (%)	79.0	77.0	61.0	53.0	34.0	21.0	22.0	23.0	24.0	35.0	59.0	76.0	47.0
RHmin (%)	59.0	53.0	38.0	32.0	17.0	9.0	12.0	11.0	11.0	21.0	36.0	59.0	29.8
Rain (mm)	90.2	60.9	55.1	38.8	13.0	0.0	0.0	0.0	0.1	9.2	59.7	93.5	420.5

Station No.: 188 **Station Type:** Sinoptice **Longitude:** 59° 38' E
Station Name: Mashhad **Latitude:** 36° 16' N **Altitude:** 985 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.7	7.9	14.3	21.2	26.6	32.0	34.2	32.7	29.0	22.0	15.1	9.7	21.0
T min (C)	-5.5	-3.4	2.3	8.0	11.4	14.9	16.8	14.3	10.0	5.5	0.7	-2.5	6.0
T ave (C)	0.6	2.3	8.3	14.6	19.0	23.5	25.5	23.5	19.5	13.8	7.9	3.6	13.5
T rng (C)	12.2	11.3	12.0	13.2	15.2	17.1	17.4	18.4	19.0	16.5	14.4	12.2	14.9
RHmax (%)	86.0	87.0	86.0	79.0	66.0	53.0	49.0	49.0	57.0	74.0	84.0	86.0	71.3
RHmin (%)	62.0	63.0	56.0	45.0	34.	24.0	21.0	20.0	24.0	39.0	48.0	59.0	41.3
Rain (mm)	38.1	32.7	53.1	40.5	24.7	3.3	1.2	0.2	2.1	17.1	21.3	28.5	262.8

Station No.: 189 **Station Type:** Climatological **Longitude:** 47° 31' E
Station Name: Moshiran **Latitude:** 38° 42' N **Altitude:** 653 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.3	9.2	14.0	20.5	24.0	28.5	32.0	30.9	27.0	20.8	16.0	10.8	20.2
T min (C)	-3.3	-2.0	1.7	6.1	10.1	12.6	14.7	13.8	11.5	7.3	3.2	0.0	6.3
T ave (C)	2.5	3.6	7.8	13.3	17.0	20.5	23.4	22.4	19.3	14.0	9.6	5.4	13.2
T rng (C)	11.6	11.2	12.3	14.4	13.9	15.9	17.3	17.1	15.5	13.5	12.8	10.8	13.9
RHmax (%)	79.0	82.0	81.0	82.0	84.0	78.0	69.0	72.0	80.0	85.0	83.0	82.0	79.8
RHmin (%)	69.0	71.0	66.0	61.0	63.0	60.0	54.0	58.0	63.0	69.0	69.0	72.0	64.6
Rain (mm)	13.6	11.9	18.5	31.7	39.9	26.9	2.4	1.5	13.4	30.3	21.4	15.2	226.7

Station No.: 190 **Station Type:** Climatological **Longitude:** 48° 49' E
Station Name: Malayer **Latitude:** 34° 17' N **Altitude:** 1740 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	6.9	7.4	13.1	19.9	25.1	31.8	35.5	35.0	30.5	24.2	15.0	8.8	21.1
T min (C)	-4.8	-3.9	2.1	6.5	10.2	13.5	16.9	16.3	12.5	8.7	3.0	-1.7	6.6
T ave (C)	1.0	1.8	7.6	13.2	17.6	22.6	26.2	25.6	21.5	16.5	9.0	3.6	13.9
T rng (C)	11.7	11.3	11.0	13.4	14.9	18.3	18.6	18.7	18.0	15.5	12.0	10.5	14.5
RHmax (%)	69.0	76.0	73.0	63.0	57.0	43.0	38.0	42.0	58.0	67.0	70.0	66.0	60.2
RHmin (%)	58.0	63.0	45.0	39.0	31.0	29.0	22.0	17.0	16.0	29.0	38.0	51.0	36.5
Rain (mm)	37.3	41.7	65.2	46.9	38.5	1.2	2.0	2.3	0.0	17.5	38.2	36.2	327.0

Station No.: 191 **Station Type:** Climatological **Longitude:** 49° 39' E
Station Name: Moochan **Latitude:** 33° 50' N **Altitude:** 1786 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.7	5.4	10.4	16.9	21.4	28.9	32.6	31.9	26.9	20.4	12.4	7.0	18.2
T min (C)	-6.9	-6.4	-0.9	2.5	5.9	8.3	11.1	10.3	6.4	2.8	-2.1	-5.6	2.1
T ave (C)	-1.6	-0.5	4.8	9.7	13.6	18.6	21.8	21.1	16.6	11.6	5.1	0.7	10.1
T rng (C)	10.6	11.8	11.3	14.4	15.5	20.6	21.5	21.6	20.5	17.6	14.5	12.6	16.0
RHmax (%)	78.0	70.0	72.0	66.0	61.0	55.0	52.0	49.0	51.0	61.0	70.0	70.0	62.9
RHmin (%)	74.0	68.0	57.0	47.0	41.0	30.0	25.0	26.0	24.0	33.0	51.0	66.0	45.2
Rain (mm)	78.8	53.2	91.7	63.6	37.0	2.3	0.9	1.4	0.0	17.6	57.4	54.1	458.0

Station No.: 192 **Station Type:** Climatological **Longitude:** 45° 55' E
Station Name: Mahabad **Latitude:** 36° 50' N **Altitude:** 1300 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.9	4.7	10.9	17.4	22.7	28.8	33.3	32.7	29.2	22.0	13.5	7.2	18.8
T min (C)	-6.4	-3.4	-0.4	4.1	7.3	10.0	13.5	13.1	9.8	5.8	0.6	-3.0	4.3
T ave (C)	-1.8	0.6	5.3	10.8	15.0	19.4	23.4	22.9	19.5	13.9	7.1	2.1	11.5
T rng (C)	9.3	8.1	11.3	13.3	15.4	18.8	19.8	19.6	19.4	16.2	12.9	10.2	14.5
RHmax (%)	76.0	76.0	77.0	73.0	70.0	63.0	57.0	61.0	59.0	69.0	76.0	78.0	69.6
RHmin (%)	73.0	71.0	64.0	55.0	50.0	42.0	38.0	39.0	39.0	47.0	60.0	68.0	53.8
Rain (mm)	59.0	41.5	65.5	72.6	50.0	13.1	0.5	0.2	0.3	29.6	38.1	46.6	417.0

Station No.: 193 **Station Type:** Climatological **Longitude:** 51° 31' E
Station Name: Mehrgerd **Latitude:** 31° 33' N **Altitude:** 2600 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	4.8	5.6	9.7	13.9	20.8	27.4	30.9	29.1	25.0	19.4	12.8	6.4	17.1
T min (C)	-8.1	-6.0	-0.7	1.6	5.5	8.2	11.3	10.1	6.2	2.9	-1.5	-4.7	2.1
T ave (C)	-1.7	-0.2	4.5	7.8	13.1	17.8	21.1	19.6	15.6	11.1	5.7	0.9	9.6
T rng (C)	12.9	11.6	10.4	12.3	15.3	19.2	19.6	19.0	18.8	16.5	14.3	11.1	15.1
RHmax (%)	77.0	78.0	75.0	68.0	60.0	55.0	48.0	47.0	46.0	54.0	67.0	77.0	62.7
RHmin (%)	65.0	64.0	57.0	46.0	37.0	24.0	20.0	18.0	18.0	27.0	42.0	59.0	39.8
Rain (mm)	76.5	55.9	52.5	67.9	14.5	3.3	1.1	0.0	0.0	15.5	37.4	68.7	393.3

Station No.: 194 **Station Type:** Climatological **Longitude:** 46° 06' E
Station Name: Miandouab **Latitude:** 36° 58' N **Altitude:** 1314 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	4.5	6.4	12.5	18.6	23.4	29.5	33.3	33.3	29.7	21.1	13.2	7.3	19.4
T min (C)	-5.1	-3.3	0.4	4.6	8.1	11.4	15.6	14.8	10.4	5.0	0.0	-3.0	4.9
T ave (C)	-0.3	1.6	6.4	11.6	15.8	20.5	24.5	24.0	20.0	13.1	6.6	2.2	12.2
T rng (C)	9.6	9.7	12.1	14.0	15.3	18.1	17.7	18.5	19.3	16.1	13.2	10.3	14.5
RHmax (%)	79.0	83.0	81.0	75.0	75.0	71.0	61.0	60.0	62.0	71.0	82.0	83.0	73.6
RHmin (%)	73.0	73.0	57.0	48.0	45.0	33.0	30.0	29.0	30.0	43.0	56.0	65.0	48.5
Rain (mm)	32.1	21.4	67.8	49.5	35.5	6.7	0.8	0.0	0.8	18.5	24.9	35.0	293.0

Station No.: 195 **Station Type:** Climatological **Longitude:** 47° 42' E
Station Name: Mianeh **Latitude:** 37° 20' N **Altitude:** 1094 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.8	6.2	12.7	18.5	24.1	30.6	34.1	33.9	30.1	22.6	13.7	6.4	19.7
T min (C)	-6.0	-4.9	0.6	6.0	10.9	14.3	17.7	16.8	13.4	8.0	2.1	-2.4	6.4
T ave (C)	-1.1	0.6	6.7	12.3	17.5	22.5	25.9	25.4	21.8	15.3	7.9	2.0	13.0
T rng (C)	9.8	11.1	12.1	12.5	13.2	16.3	16.4	17.1	16.7	14.6	11.6	8.8	13.4
RHmax (%)	82.0	80.0	80.0	74.0	72.0	64.0	60.0	58.0	61.0	72.0	78.0	84.0	72.1
RHmin (%)	78.0	75.0	62.0	55.0	57.0	48.0	47.0	43.0	46.0	55.0	64.0	77.0	58.9
Rain (mm)	28.2	21.9	30.9	56.2	51.0	15.3	2.8	1.2	4.0	20.3	23.4	31.3	286.5

Station No.: 196 **Station Type:** Climatological **Longitude:** 61° 27' E
Station Name: Mirjaveh **Latitude:** 29° 01' N **Altitude:** 900 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	17.0	19.7	26.1	31.0	35.7	40.6	41.4	38.4	36.9	32.6	26.7	20.8	30.6
T min (C)	1.0	4.5	8.8	13.5	18.1	23.3	24.6	23.7	18.6	13.6	8.4	3.4	13.5
T ave (C)	9.0	12.1	17.5	22.3	26.9	31.9	33.0	31.1	27.8	23.1	17.5	12.1	22.0
T rng (C)	16.0	15.2	17.3	17.5	17.6	17.3	16.8	14.7	18.3	19.0	18.3	17.4	17.1
RHmax (%)	62.0	64.0	49.0	42.0	29.0	23.0	20.0	21.0	24.0	31.0	40.0	56.0	38.4
RHmin (%)	34.0	35.0	25.0	20.0	16.0	14.0	13.0	14.0	15.0	17.0	22.0	25.0	20.8
Rain (mm)	14.1	9.1	4.1	3.1	1.8	0.5	0.0	0.3	0.0	0.0	1.0	2.1	36.1

Station No.: 197 **Station Type:** Climatological **Longitude:** 51° 10' E
Station Name: Meimeh **Latitude:** 33° 26' N **Altitude:** 1980 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.2	7.8	12.5	19.5	24.0	30.7	33.6	32.2	29.2	21.7	13.1	7.6	19.8
T min (C)	-7.7	-6.0	-1.2	4.3	8.1	13.3	14.8	13.2	9.4	3.8	-1.4	-5.2	3.8
T ave (C)	-1.3	0.9	5.7	11.9	16.0	22.0	24.2	22.7	19.3	12.8	5.9	1.2	11.8
T rng (C)	12.9	13.8	13.7	15.2	15.9	17.4	18.8	19.0	19.8	17.9	14.5	12.8	16.0
RHmax (%)	81.0	79.0	72.0	63.0	57.0	46.0	45.0	45.0	51.0	58.0	75.0	78.0	62.5
RHmin (%)	56.0	54.0	43.0	33.0	28.0	26.0	23.0	24.0	27.0	32.0	46.0	52.0	37.0
Rain (mm)	25.2	32.0	33.0	16.0	20.3	4.1	3.6	2.0	0.0	8.3	14.2	28.3	187.0

Station No.: 198 **Station Type:** Climatological **Longitude:** 57° 04' E
Station Name: Minab **Latitude:** 27° 09' N **Altitude:** 30 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	23.9	24.5	28.6	32.3	37.8	40.1	40.1	39.6	38.1	36.3	30.8	25.7	33.2
T min (C)	11.1	12.2	15.5	19.3	23.7	25.4	27.7	27.5	25.4	22.5	17.0	13.8	20.1
T ave (C)	17.5	18.4	22.0	25.8	30.8	32.8	33.9	33.5	31.8	29.4	23.9	19.8	26.6
T rng (C)	12.8	12.3	13.1	13.0	14.1	14.7	12.4	12.1	12.7	13.8	13.8	11.9	13.1
RHmax (%)	69.0	74.0	71.0	68.0	66.0	70.0	74.0	75.0	72.0	70.0	63.0	67.0	69.9
RHmin (%)	47.0	48.0	46.0	44.0	40.0	41.0	43.0	45.0	43.0	38.0	40.0	45.0	43.3
Rain (mm)	59.5	58.3	16.9	6.4	0.0	0.0	0.7	3.9	0.0	0.8	9.2	29.0	184.7

Station No.: 199 **Station Type:** Climatological **Longitude:** 53° 05' E
Station Name: Naein **Latitude:** 32° 52' N **Altitude:** 1600 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.3	11.4	17.3	23.7	28.9	35.2	36.6	35.7	31.9	24.8	16.1	10.9	23.5
T min (C)	-1.1	-0.6	4.3	10.0	13.6	18.6	20.9	19.8	14.3	8.7	3.1	-0.8	9.2
T ave (C)	4.1	5.4	10.8	16.9	21.3	26.9	28.8	27.8	23.1	16.8	9.6	5.0	16.4
T rng (C)	10.4	12.0	13.0	13.7	15.3	16.6	15.7	15.9	17.6	16.1	13.0	11.7	14.2
RHmax (%)	77.0	74.0	64.0	59.0	50.0	44.0	42.0	45.0	45.0	54.0	66.0	75.0	57.9
RHmin (%)	53.0	50.0	40.0	40.0	36.0	30.0	32.0	29.0	25.0	31.0	46.0	51.0	38.6
Rain (mm)	36.8	21.3	17.1	14.6	13.2	0.6	0.0	0.0	0.0	4.1	17.6	11.8	137.1

Station No.: 200 **Station Type:** Climatological **Longitude:** 51° 22' E
Station Name: Najafabad **Latitude:** 32° 38' N **Altitude:** 1350 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.5	10.9	15.8	21.3	27.2	33.0	35.7	33.9	29.5	23.3	16.0	10.7	22.1
T min (C)	-4.6	-2.6	1.7	6.7	11.7	16.3	19.1	17.4	11.8	7.2	1.4	-2.9	6.9
T ave (C)	2.0	4.1	8.8	14.0	19.5	24.6	27.4	25.7	20.6	15.3	8.7	3.9	14.5
T rng (C)	13.1	13.5	14.1	14.6	15.5	16.7	16.6	16.5	17.7	16.1	14.6	13.6	15.2
RHmax (%)	75.0	75.0	72.0	61.0	49.0	36.0	34.0	37.0	46.0	58.0	75.0	75.0	57.8
RHmin (%)	57.0	49.0	37.0	33.0	24.0	15.0	15.0	18.0	20.0	28.0	39.0	51.0	32.2
Rain (mm)	26.2	24.8	22.7	23.4	11.9	0.8	0.3	0.2	0.0	9.4	13.0	24.4	157.1

Station No.: 201 **Station Type:** Climatological **Longitude:** 51° 56' E
Station Name: Natanz **Latitude:** 33° 32' N **Altitude:** 1800 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	8.4	10.3	15.9	21.5	26.4	31.6	34.0	33.6	30.0	23.5	16.0	11.3	21.9
T min (C)	-3.8	-2.9	2.4	6.3	10.2	14.6	15.0	14.7	11.9	7.2	1.8	-1.3	6.3
T ave (C)	2.3	3.7	9.1	13.9	18.3	23.1	24.5	24.1	21.0	15.4	8.9	5.0	14.1
T rng (C)	12.2	13.2	13.5	15.2	16.2	17.0	19.0	18.9	18.1	16.3	14.2	12.6	15.5
RHmax (%)	74.0	73.0	63.0	57.0	54.0	44.0	43.0	45.0	51.0	61.0	68.0	68.0	58.4
RHmin (%)	57.0	51.0	43.0	35.0	30.0	25.0	23.0	26.0	28.0	36.0	43.0	53.0	37.5
Rain (mm)	24.4	18.9	22.0	18.4	13.3	2.1	0.1	0.0	0.0	10.4	11.5	12.9	134.0

Station No.: 202 **Station Type:** Climatological **Longitude:** 51° 32' E
Station Name: Noorabad-Mamasani **Latitude:** 30° 13' N **Altitude:** 900 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	14.5	16.3	20.7	26.3	33.6	39.8	42.2	41.0	37.7	31.5	22.9	16.8	28.6
T min (C)	3.8	4.9	8.4	12.1	17.0	21.4	24.7	23.9	19.8	14.7	9.7	5.4	13.8
T ave (C)	9.1	10.6	14.6	19.2	25.3	30.6	33.5	32.5	28.8	23.1	16.3	11.1	21.2
T rng (C)	10.7	11.4	12.3	14.2	16.6	18.4	17.5	17.1	17.9	16.8	13.2	11.4	14.8
RHmax (%)	82.0	82.0	76.0	69.0	49.0	36.0	35.0	38.0	42.0	50.0	68.0	80.0	58.9
RHmin (%)	63.0	58.0	53.0	44.0	28.0	18.0	17.0	18.0	19.0	26.0	42.0	58.0	37.0
Rain (mm)	149.0	94.5	86.4	51.8	15.0	0.0	1.0	2.9	0.0	21.6	56.7	136.1	615.0

Station No.: 203 **Station Type:** Climatological **Longitude:** 48° 32' E
Station Name: Nojian **Latitude:** 33° 15' N **Altitude:** 1984 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	3.4	4.3	8.3	14.1	18.7	27.1	31.2	30.3	26.6	19.3	11.3	5.6	16.7
T min (C)	-4.5	-4.1	-0.1	4.7	10.2	15.2	18.2	17.1	14.3	9.3	1.8	-2.9	6.6
T ave (C)	-0.5	0.1	4.1	9.4	14.5	21.1	24.7	23.7	20.5	14.3	6.6	1.3	11.6
T rng (C)	7.9	8.4	8.4	9.4	8.5	11.9	13.0	13.2	12.3	10.0	9.5	8.5	10.1
RHmax (%)	65.0	58.0	68.0	64.0	54.0	40.0	40.0	39.0	39.0	47.0	58.0	65.0	53.1
RHmin (%)	59.0	61.0	55.0	46.0	40.0	30.0	28.0	25.0	28.0	34.0	46.0	58.0	42.5
Rain (mm)	143.1	160.2	108.8	96.3	56.2	0.0	0.5	0.0	0.1	30.3	74.7	141.8	812.0

Station No.: 204 **Station Type:** Climatological **Longitude:** 51° 33' E
Station Name: Noushahr **Latitude:** 36° 39' N **Altitude:** -20 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.9	11.4	13.1	17.6	23.6	27.0	29.9	29.6	27.1	22.6	18.2	14.9	20.6
T min (C)	2.1	2.7	4.9	9.2	13.6	17.2	20.5	20.4	18.0	13.1	7.9	4.2	11.1
T ave (C)	7.0	7.0	9.0	13.4	18.6	22.1	25.2	25.0	22.5	17.9	13.1	9.5	15.9
T rng (C)	9.8	8.7	8.2	8.4	10.0	9.8	9.4	9.2	9.1	9.5	10.3	10.7	9.4
RHmax(%)	91.0	92.0	93.0	91.0	90.0	87.0	85.0	87.0	89.0	91.0	90.0	91.0	89.8
RHmin (%)	76.0	77.0	79.0	76.0	75.0	72.0	68.0	72.0	75.0	76.0	76.0	75.0	74.8
Rain (mm)	128.0	122.8	102.6	55.4	54.6	61.4	42.6	74.0	137.9	237.9	209.8	139.1	1366.1

Station No.:	205	Station Type:	Climatological	Longitude:	54° 19' E
Station Name:	Neyriz	Latitude:	29° 11' N	Altitude:	2100 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.9	15.5	20.1	24.3	30.8	35.5	36.7	35.5	32.4	26.8	19.5	15.3	25.4
T min (C)	-0.6	2.4	5.7	9.0	12.2	15.9	18.6	17.3	13.8	10.2	4.5	0.7	9.1
T ave (C)	6.1	8.9	12.9	16.6	21.5	25.7	27.7	26.4	23.1	18.5	12.0	8.0	17.3
T rng (C)	13.5	13.1	14.4	15.3	18.6	19.6	18.1	18.2	18.6	16.6	15.0	14.6	16.3
RHmax (%)	74.0	71.0	62.0	53.0	46.0	45.0	44.0	45.0	49.0	51.0	56.0	66.0	55.2
RHmin (%)	55.0	51.0	42.0	38.0	30.0	24.0	26.0	27.0	27.0	31.0	42.0	47.0	36.7
Rain (mm)	44.1	38.2	42.2	17.9	4.1	0.0	0.7	0.8	0.0	1.3	12.3	16.3	178.1

Station No.:	206	Station Type:	Climatological	Longitude:	58° 48' E
Station Name:	Neyshabour	Latitude:	36° 12' N	Altitude:	1350 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.2	12.6	16.8	23.4	28.9	33.9	34.3	33.3	30.5	22.1	16.0	11.2	22.5
T min (C)	-7.2	-0.5	3.2	7.4	11.4	15.2	16.6	15.1	10.7	5.2	0.0	-2.6	6.2
T ave (C)	0.2	6.1	10.0	15.4	20.1	24.6	25.5	24.2	20.6	13.6	8.0	4.3	14.4
T rng (C)	14.7	13.1	13.6	16.0	17.5	18.7	17.5	18.2	19.8	16.9	16.0	13.8	16.3
RHmax (%)	77.0	81.0	70.0	63.0	58.0	45.0	39.0	40.0	42.0	57.0	67.0	76.0	59.6
RHmin (%)	64.0	59.0	52.0	43.0	40.0	26.0	23.0	23.0	26.0	35.0	41.0	58.0	40.8
Rain (mm)	61.2	44.0	33.7	31.3	17.9	0.9	5.0	0.0	4.0	17.7	25.2	21.9	262.8

Station No.:	207	Station Type:	Climatological	Longitude:	51° 39' E
Station Name:	Varamin	Latitude:	35° 19' N	Altitude:	1000 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.9	10.9	17.2	24.5	29.7	35.2	38.4	36.7	33.1	26.2	17.5	11.3	24.0
T min (C)	-2.8	-1.3	3.5	9.3	13.5	17.2	20.2	18.4	14.0	9.1	3.1	-0.5	8.6
T ave (C)	2.6	4.8	10.4	16.9	21.6	26.2	29.3	27.5	14.0	17.7	10.3	5.4	16.3
T rng (C)	10.7	12.2	13.7	15.2	16.2	18.0	18.2	18.3	23.5	17.1	14.4	11.8	15.4
RHmax (%)	86.0	82.0	75.0	66.0	64.0	56.0	53.0	54.0	19.1	68.0	78.0	85.0	68.8
RHmin (%)	62.0	51.0	42.0	34.0	30.0	23.0	25.0	25.0	59.0	32.0	41.0	54.0	37.0
Rain (mm)	38.6	25.4	24.4	20.3	15.9	5.2	0.0	0.6	25.0	15.1	18.9	25.4	190.6

Station No.:	208	Station Type:	Climatological	Longitude:	52° 37' E
Station Name:	Varzaneh	Latitude:	32° 24' N	Altitude:	1450 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	9.7	12.5	17.9	23.0	28.5	35.2	38.1	35.9	32.2	25.8	17.8	11.4	24.0
T min (C)	-4.8	-3.2	1.6	6.6	10.9	16.1	20.0	17.7	11.9	5.3	0.0	-4.1	6.5
T ave (C)	2.4	4.7	9.8	14.8	19.7	25.7	29.0	26.8	22.0	15.5	8.9	3.6	15.3
T rng (C)	14.5	15.7	16.3	16.4	17.6	19.1	18.1	18.2	20.3	20.5	17.8	15.5	17.5
RHmax (%)	78.0	73.0	64.0	60.0	52.0	40.0	36.0	35.0	37.0	51.0	63.0	76.0	55.4
RHmin (%)	51.0	41.0	31.0	30.0	25.0	20.0	19.0	17.0	18.0	23.0	33.0	48.0	29.7
Rain (mm)	11.9	5.8	10.6	15.5	11.4	1.4	0.1	0.0	0.2	3.6	8.3	11.8	80.6

Station No.:	209	Station Type:	Climatological	Longitude:	49° 58' E
Station Name:	Valadabad	Latitude:	35° 56' N	Altitude:	1210 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	5.0	7.5	13.9	21.1	26.2	31.0	34.3	33.9	30.4	21.9	14.7	8.4	20.7
T min (C)	-6.9	-4.8	1.0	5.6	9.7	13.2	15.9	15.3	10.5	5.2	0.0	-4.1	5.0
T ave (C)	-1.0	1.3	7.4	13.4	18.0	22.1	25.1	24.6	20.5	13.5	7.3	2.1	12.9
T rng (C)	11.9	12.3	12.9	15.5	16.5	17.8	18.4	18.6	19.9	16.7	14.7	12.5	15.6
RHmax (%)	75.0	80.0	76.0	70.0	70.0	63.0	62.0	63.0	61.0	69.0	77.0	77.0	70.3
RHmin (%)	70.0	66.0	52.0	40.0	36.0	30.0	27.0	27.0	29.0	43.0	52.0	62.0	44.5
Rain (mm)	23.3	26.5	40.9	33.3	35.4	7.3	2.4	0.0	0.6	16.0	20.2	25.9	231.8

Station No.:	210	Station Type:	Climatological	Longitude:	48° 21' E
Station Name:	Haft-Tapeh	Latitude:	32° 05' N	Altitude:	80 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	16.9	18.8	24.3	30.4	37.8	43.7	45.5	44.3	41.1	33.9	25.3	18.6	31.7
T min (C)	5.9	6.8	10.5	15.1	20.6	23.5	24.9	23.6	20.4	16.4	11.1	7.2	15.5
T ave (C)	11.4	12.8	17.4	22.8	29.2	33.6	35.2	34.0	30.8	25.2	18.2	12.9	23.6
T rng (C)	11.0	12.0	13.8	15.3	17.2	20.2	20.6	20.7	20.7	17.5	14.2	11.4	16.2
RHmax (%)	91.0	90.0	81.0	69.0	55.0	44.0	48.0	54.0	56.0	64.0	80.0	89.0	68.4
RHmin (%)	66.0	61.0	46.0	37.0	27.0	21.0	21.0	25.0	27.0	36.0	49.0	64.0	40.0
Rain (mm)	79.1	47.1	32.7	23.3	8.8	0.0	0.0	0.2	0.0	6.1	34.5	59.2	291.0

Station No.: 211	**Station Type:** Sinoptice	**Longitude:** 48° 43' E	
Station Name: Hamedan-Nozheh	**Latitude:** 35° 12' N	**Altitude:** 1644 m	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.5	4.2	11.5	18.5	23.3	30.5	34.8	34.1	29.6	21.6	13.1	6.0	19.1
T min (C)	-9.7	-8.7	-2.3	2.7	6.5	9.8	13.8	12.7	8.0	2.6	-2.3	-6.2	2.2
T ave (C)	-3.6	-2.3	4.6	10.6	14.9	20.1	24.3	23.4	18.8	12.1	5.4	0.0	10.7
T rng (C)	12.2	12.9	13.8	15.8	16.8	20.7	21.0	21.4	21.6	19.0	15.4	12.2	16.9
RHmax (%)	85.0	83.0	80.0	74.0	75.0	56.0	45.0	45.0	49.0	67.0	73.0	83.0	67.9
RHmin (%)	70.0	64.0	51.0	38.0	34.0	21.0	19.0	18.0	20.0	33.0	47.0	62.0	39.8
Rain (mm)	42.9	40.5	53.8	51.7	48.6	3.9	0.8	1.8	0.3	24.0	28.7	40.6	337.6

Station No.: 212	**Station Type:** Climatological	**Longitude:** 51° 27' E	
Station Name: Hamgin	**Latitude:** 31° 55' N	**Altitude:** 2150 m	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	7.2	7..8	13.3	19.2	24.5	30.5	32.7	31.6	28.1	22.6	15.5	9.3	20.2
T min (C)	-7.0	-6.0	-0.9	3.2	7.0	9.9	11.6	10.7	7.2	3.9	-0.2	-4.3	2.9
T ave (C)	0.0	0.9	6.2	11.2	15.8	20.2	22.2	21.1	17.6	13.3	7.7	2.5	11.6
T rng (C)	14.2	13.8	14.2	16.0	17.5	20.6	21.1	20.9	20.9	18.7	15.7	13.6	17.3
RHmax (%)	72.0	69.0	72.0	64.0	59.0	50.0	45.0	45.0	53.0	62.0	68.0	69.0	60.7
RHmin (%)	58.0	58.0	44.0	35.0	31.0	28.0	24.0	26.0	27.0	33.0	43.0	50.0	38.1
Rain (mm)	54.6	55.0	70.5	30.8	20.6	0.7	4.7	1.3	0.1	15.4	28.3	40.8	322.8

Station No.: 213	**Station Type:** Climatological	**Longitude:** 52° 05' E	
Station Name: Hamand-Absard	**Latitude:** 35° 39' N	**Altitude:** 1800 m	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	2.9	3.2	8.4	15.7	20.3	27.4	31.0	29.9	25.9	18.3	10.5	5.1	16.6
T min (C)	-7.7	-7.9	-2.7	3.4	7.2	10.9	14.5	13.3	9.3	4.7	-1.1	-5.6	3.2
T ave (C)	-2.4	-2.3	2.8	9.6	13.8	19.1	22.8	21.6	17.6	11.5	4.7	-0.3	9.9
T rng (C)	10.6	11.1	11.1	12.3	13.1	16.5	16.5	16.6	16.6	13.6	11.6	10.7	13.4
RHmax (%)	79.0	81.0	73.0	64.0	56.0	46.0	40.0	42.0	44.0	59.0	72.0	77.0	61.1
RHmin (%)	72.0	73.0	57.0	41.0	33.0	24.0	21.0	20.0	22.0	31.0	45.0	65.0	42.0
Rain (mm)	37.1	38.8	60.8	53.4	35.4	12.6	3.9	2.4	2.1	30.2	31.3	35.9	343.9

Station No.: 214	**Station Type:** Climatological	**Longitude:** 55° 16' E	
Station Name: Hotan-Chat	**Latitude:** 37° 59' N	**Altitude:** 214 m	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	11.4	11.9	17.3	23.1	28.7	33.7	35.5	35.9	32.2	24.2	18.1	13.0	23.8
T min (C)	-0.6	-1.1	4.0	8.7	14.4	18.9	21.4	21.6	16.5	10.4	4.3	1.1	10.0
T ave (C)	5.4	5.4	10.6	15.9	21.5	26.3	28.5	28.8	24.4	17.3	11.2	7.1	16.9
T rng (C)	12.0	13.0	13.3	14.4	14.3	14.8	14.1	14.3	15.7	13.8	13.8	11.9	13.8
RHmax (%)	84.0	84.0	82.0	75.0	70.0	71.0	76.0	75.0	73.0	67.0	77.0	83.0	76.4
RHmin (%)	60.0	59.0	53.0	49.0	41.0	44.0	45.0	43.0	47.0	48.0	54.0	58.0	50.1
Rain (mm)	29.7	16.5	22.8	24.4	17.1	4.5	3.7	1.9	5.5	12.6	19.8	23.3	181.8

Station No.: 215	**Station Type:** Climatological	**Longitude:** 48° 04' E	
Station Name: Hoveyzeh	**Latitude:** 31° 26' N	**Altitude:** 32 m	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	16.4	19.5	24.7	30.1	36.0	42.3	44.0	43.3	41.4	34.7	25.9	19.2	31.5
T min (C)	5.6	7.1	11.5	15.1	20.2	23.0	24.8	23.5	20.5	15.9	10.7	7.8	15.5
T ave (C)	11.0	13.3	18.1	22.6	28.1	32.7	34.4	33.4	31.0	25.3	18.3	13.5	23.5
T rng (C)	10.8	12.4	13.2	15.0	15.8	19.3	19.2	19.8	20.9	18.8	15.2	11.4	16.0
RHmax (%)	86.0	84.0	77.0	72.0	62.0	56.0	53.0	57.0	58.0	66.0	77.0	86.0	69.5
RHmin (%)	68.0	58.0	50.0	41.0	34.0	25.0	26.0	25.0	25.0	33.0	44.0	64.0	41.1
Rain (mm)	47.4	22.2	25.9	20.5	6.6	0.0	0.0	0.0	0.0	4.1	13.1	50.6	190.4

Station No.: 216	**Station Type:** Sinoptice	**Longitude:** 54° 24' E	
Station Name: Yazd	**Latitude:** 31° 54' N	**Altitude:** 1230 m	

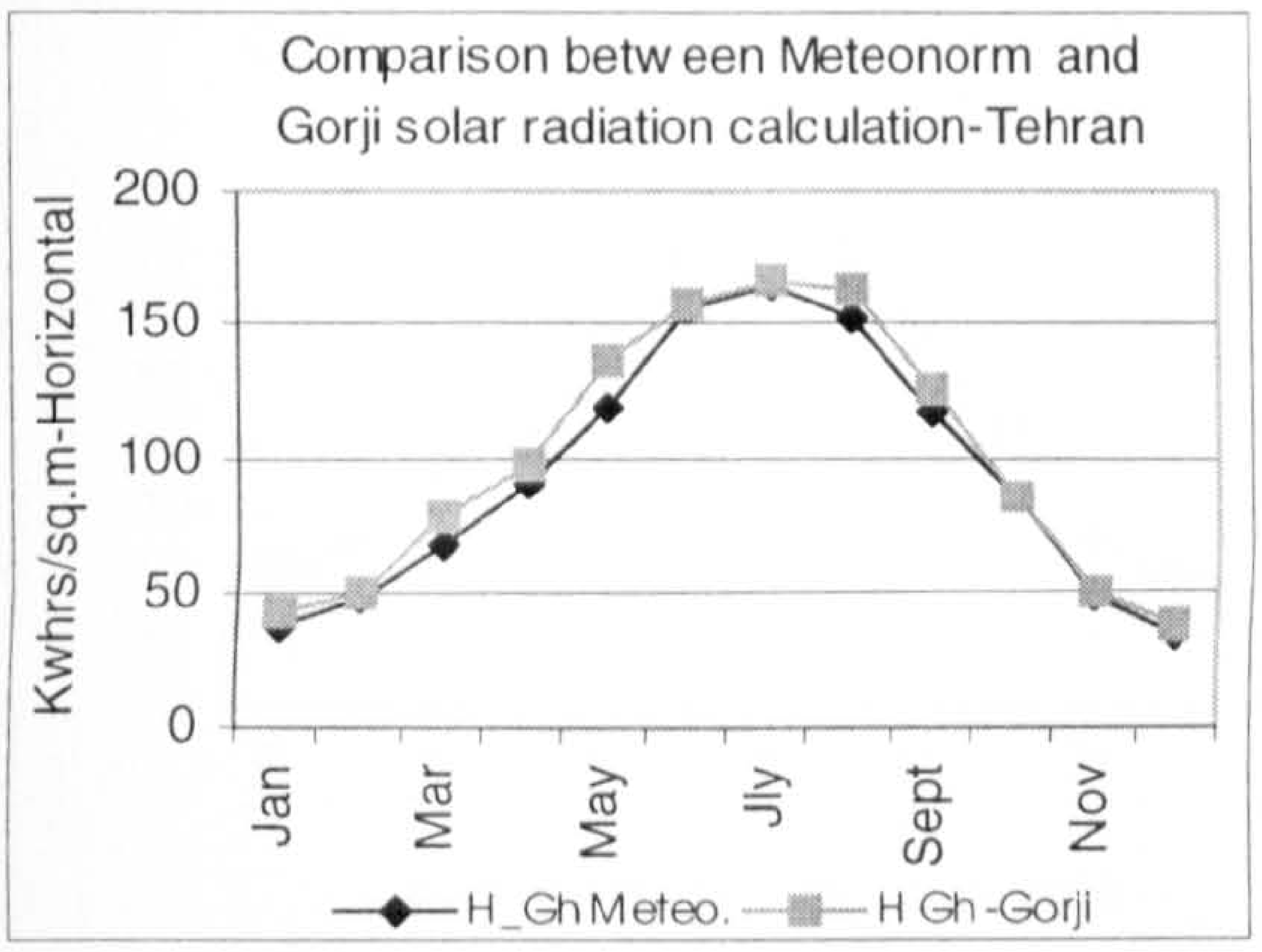
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
T max (C)	12.5	14.7	20.2	26.2	31.8	37.1	39.3	37.6	33.9	27.5	19.7	14.7	26.3
T min (C)	-0.9	1.3	6.3	12.1	17.0	21.9	23.4	21.0	16.3	11.2	4.0	0.3	11.2
T ave (C)	5.8	8.0	13.3	19.2	24.4	29.5	31.3	29.3	25.1	19.4	11.9	7.5	18.7
T rng (C)	13.4	13.4	13.9	14.1	14.8	15.2	15.9	16.6	17.6	16.3	15.7	14.4	15.1
RHmax (%)	70.0	66.0	54.0	47.0	36.0	24.0	22.0	22.0	25.0	38.0	54.0	65.0	43.6
RHmin (%)	41.0	36.0	26.0	23.0	18.0	13.0	12.0	13.0	14.0	21.0	27.0	35.0	23.3
Rain (mm)	11.0	12.7	12.7	13.2	5.0	0.0	0.0	0.0	0.0	2.3	3.9	10.2	71.0

Appendix B

Comparison Between the Spreadsheet Excel Program and Meteonorm Calculation of Solar Radiation

Table and Figures C.1: Comparison between Meteonorm and Gorji solar radiation calculation in horizontal surface-Tehran-Iran Units: Kwhrs/sq.m

Horizontal	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	38	43.09	41.8	34.2	13.39
Feb.	47	49.28	54.0	42.3	4.85
Mar.	67	77.19	83.9	60.3	15.21
Apr.	91	97.5	106.6	81.9	7.14
May	118	136.4	148.2	106.2	15.59
Jun.	156	156.9	172.5	140.4	0.58
Jly	165	165.85	182.4	148.5	0.52
Aug.	153	162.13	177.4	137.7	5.97
Sept.	117	126	137.7	105.3	7.69
Oct.	85	85.25	93.8	76.5	0.29
Nov.	48	49.5	54.3	43.2	3.13
Dec.	34	37.82	41.2	30.6	11.24



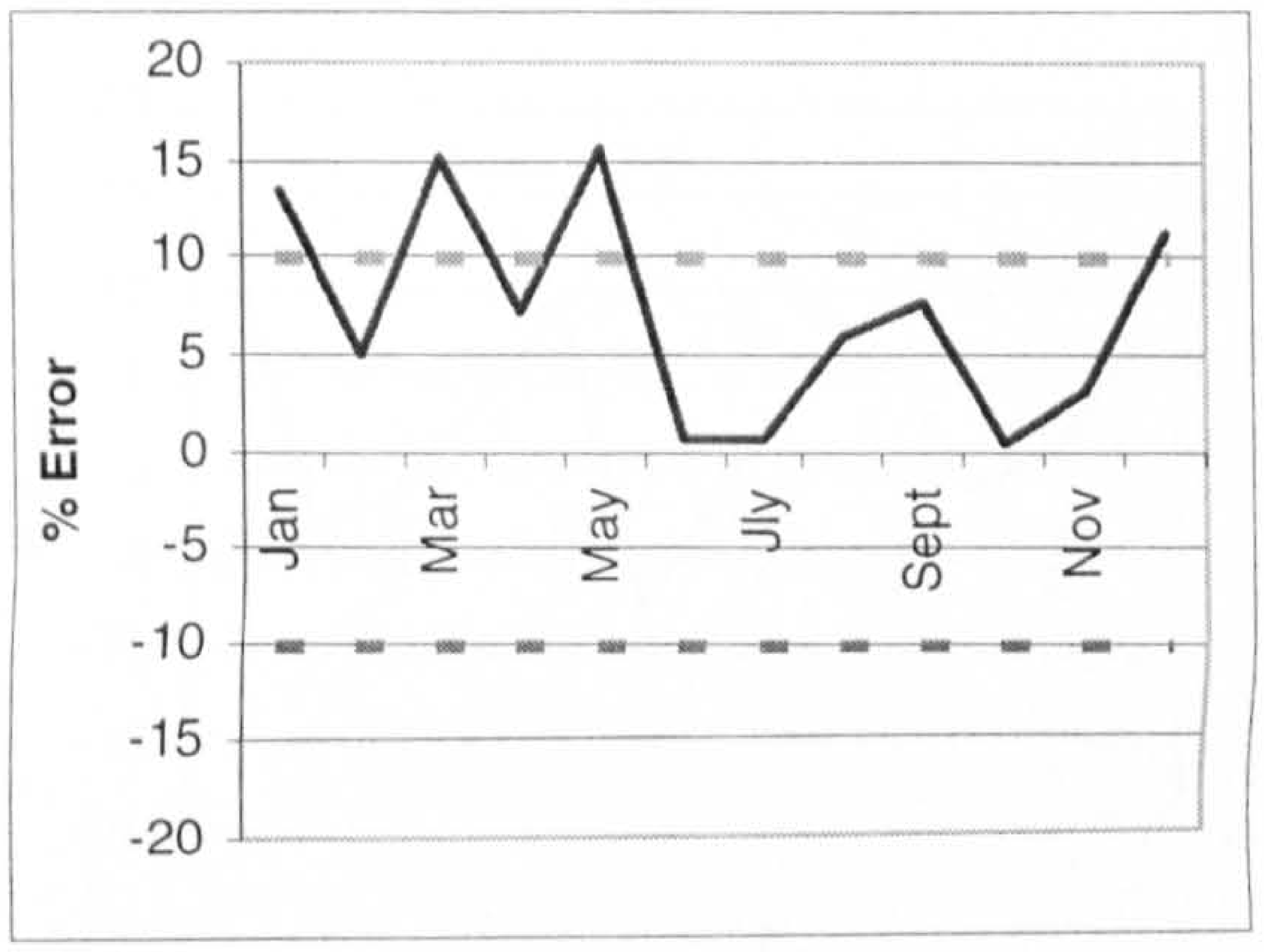
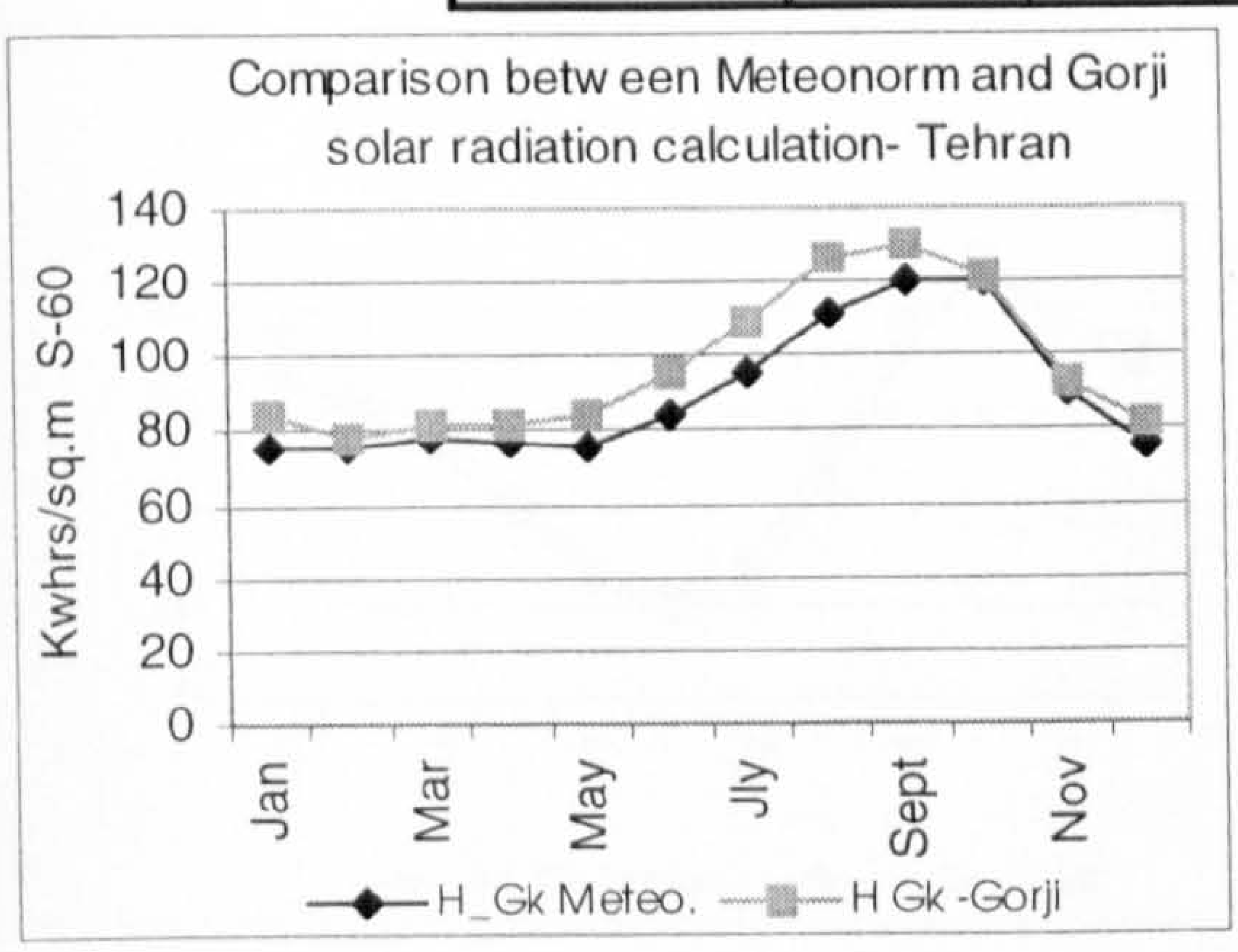


Table and Figures C.2: Comparison between Meteonorm and Gorji solar radiation calculation in south surface-Tehran-Iran Units: Kwhrs/sq.m

S -60 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	76	83.7	83.6	68.4	10.13
Feb.	75	78.12	85.6	67.5	4.16
Mar.	78	81.22	89.0	70.2	4.13
Apr.	77	81.6	89.3	69.3	5.97
May	75	84.01	91.5	67.5	12.01
Jun.	84	96	104.4	75.6	14.29
Jly	96	108.5	118.1	86.4	13.02
Aug.	112	125.86	137.1	100.8	12.38
Sept.	120	130.2	142.2	108	8.5
Oct.	120	121.52	133.5	108	1.27
Nov.	90	92.7	101.7	81	3
Dec.	76	82.15	89.8	68.4	8.09



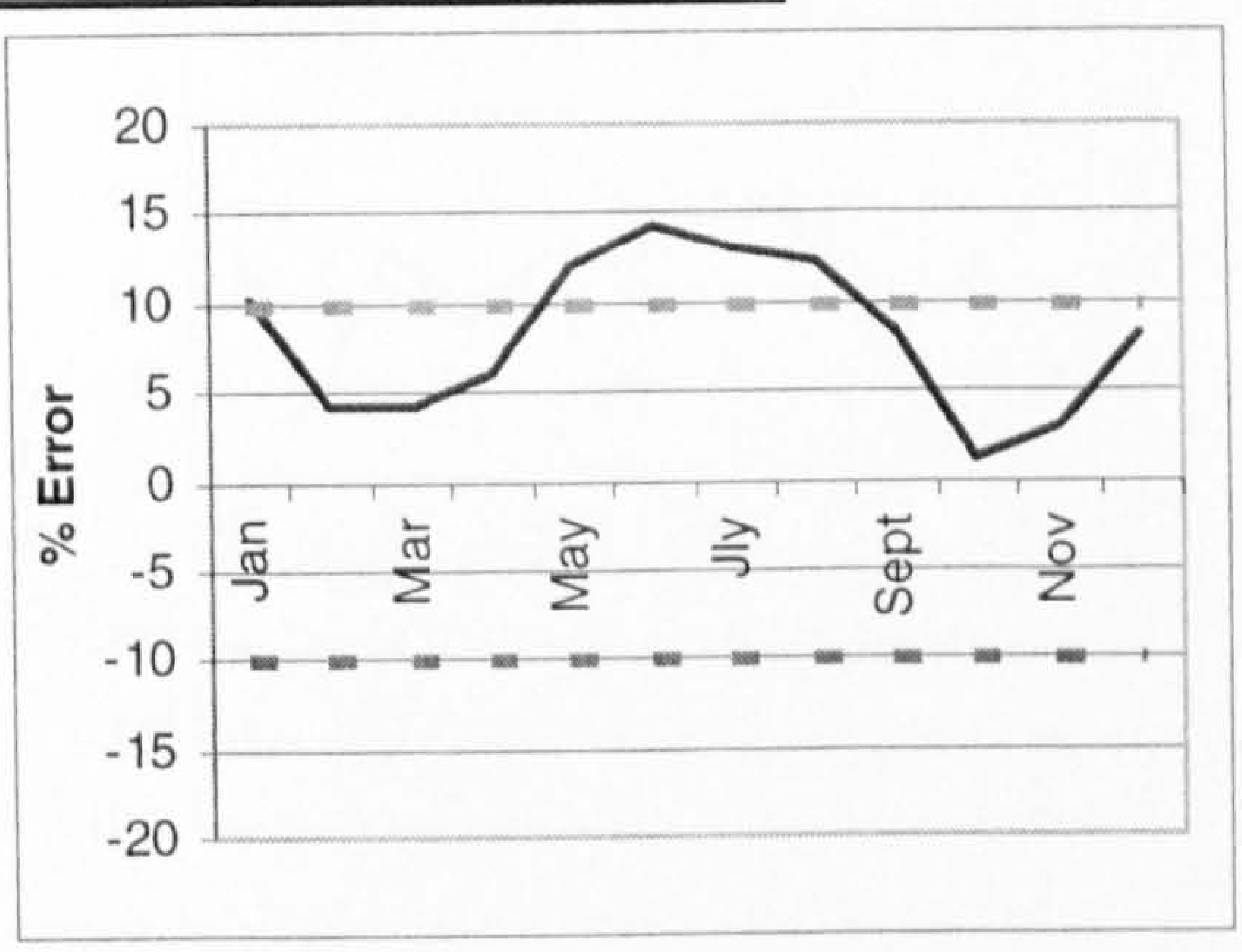
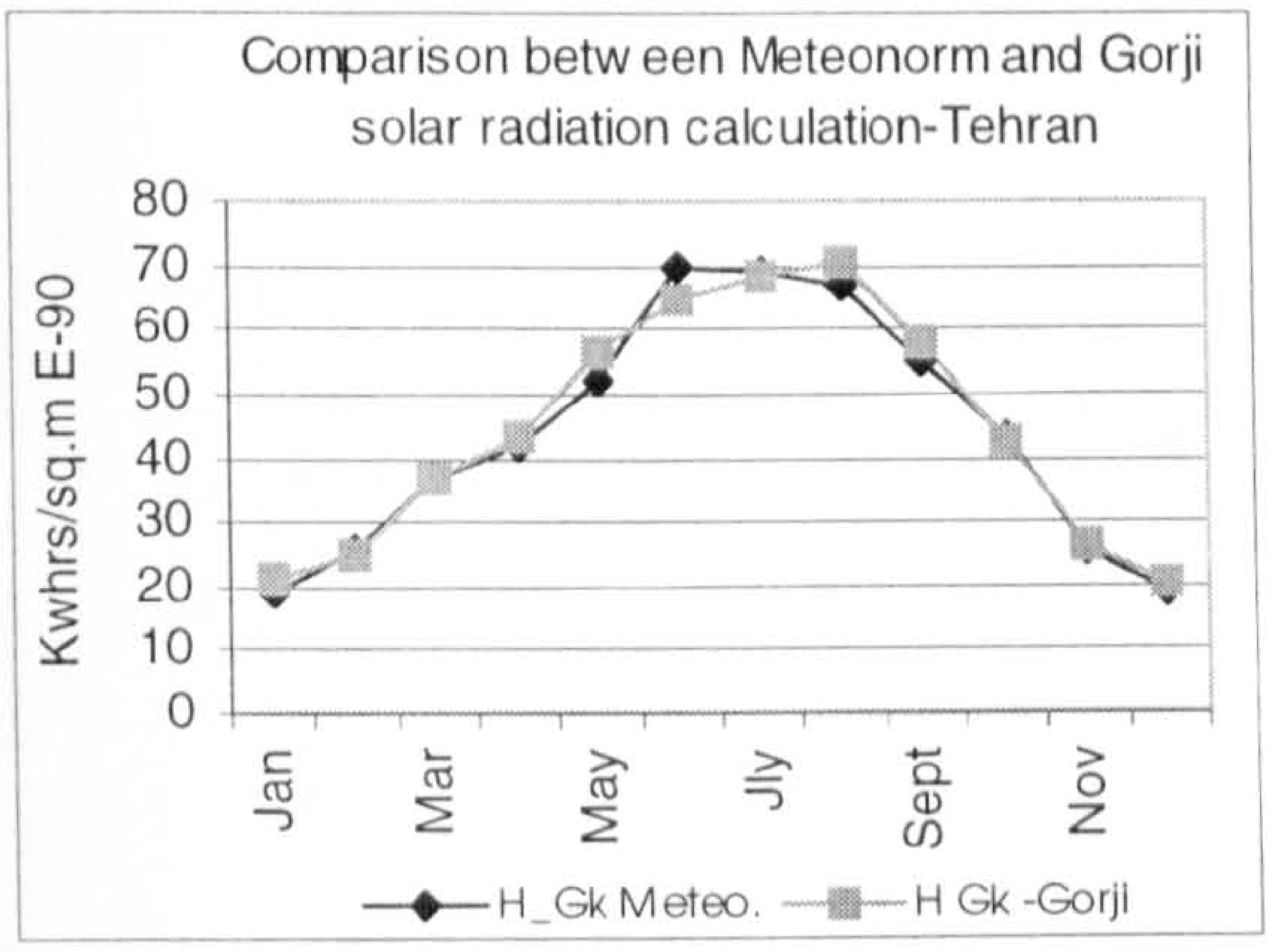


Table and Figures C.3: Comparison between Meteonorm and Gorji solar radiation calculation in east surface-Tehran-Iran Units: Kwhrs/sq.m

E -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	19	21.39	20.9	17.1	12.58
Feb.	26	25.2	27.8	23.4	-3.08
Mar.	37	36.58	40.3	33.3	-1.14
Apr.	42	43.5	47.7	37.8	3.57
May	52	56.73	61.9	46.8	9.1
Jun.	70	64.8	71.8	63	-7.43
Jly	69	68.51	75.4	62.1	-0.71
Aug.	67	70.37	77.1	60.3	5.03
Sept.	55	58.2	63.7	49.5	5.82
Oct.	43	42.47	46.8	38.7	-1.23
Nov.	26	26.4	29.0	23.4	1.54
Dec.	19	20.46	22.4	17.1	7.68



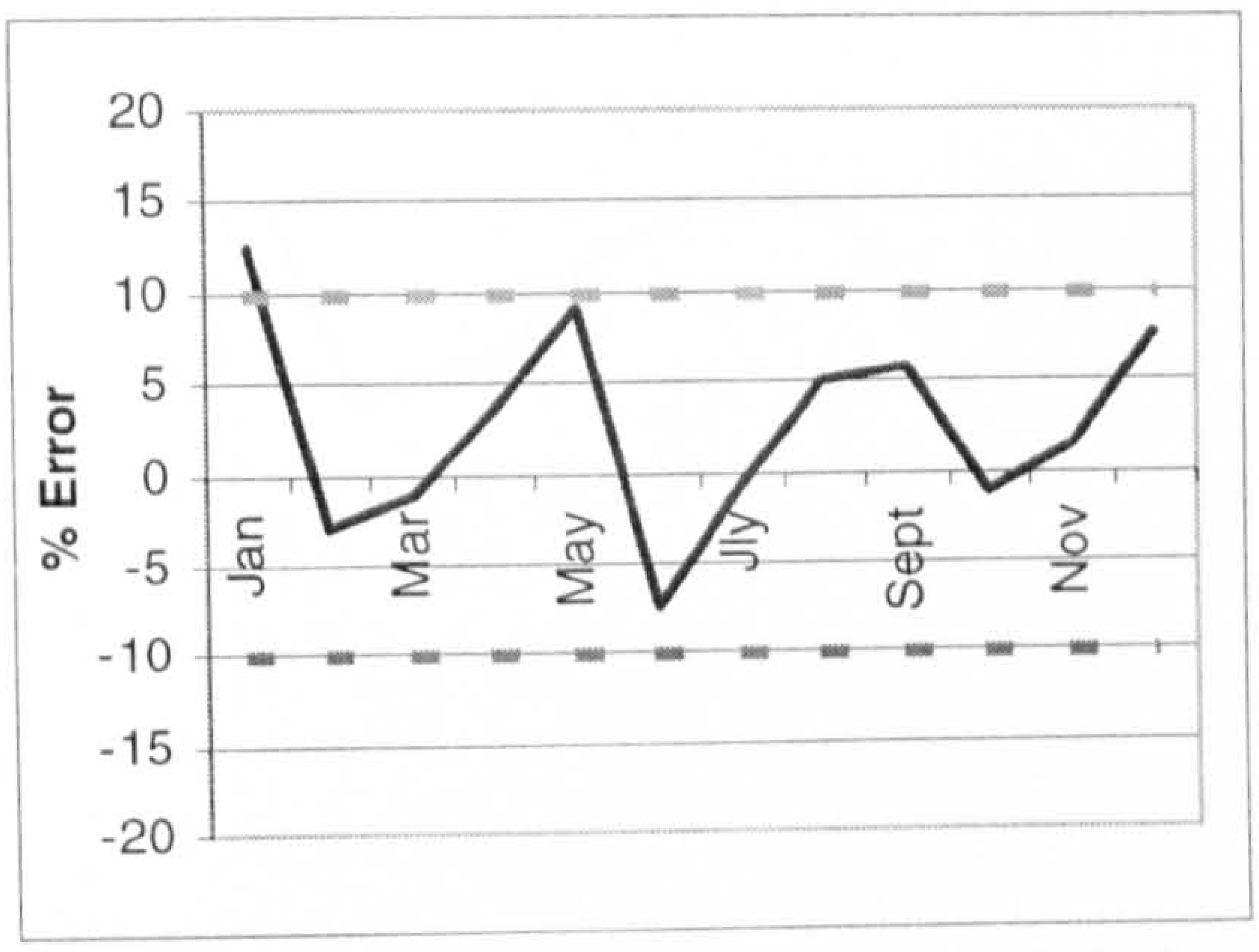
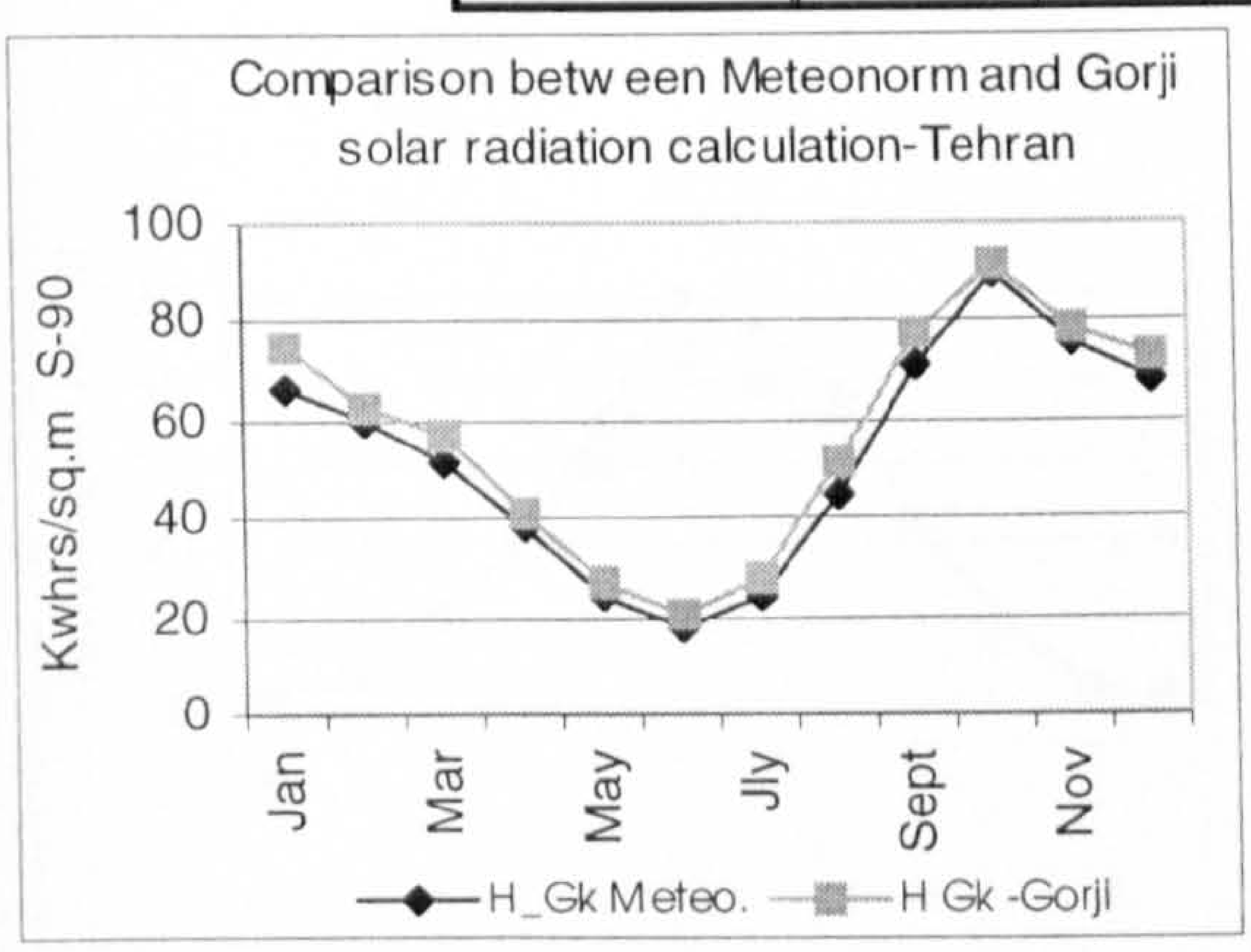


Table and Figures C.4: Comparison between Meteonorm and Gorji solar radiation calculation in south surface-Tehran-Iran Units: Kwhrs/sq.m

S -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	66	74.4	72.6	59.4	12.73
Feb.	60	62.44	68.4	54	4.07
Mar.	51	57.35	62.5	45.9	12.45
Apr.	38	41.1	44.9	34.2	8.16
May	24	26.97	29.4	21.6	12.38
Jun.	18	20.1	21.9	16.2	11.67
Jly	24	27.59	30.0	21.6	14.96
Aug.	45	51.77	56.3	40.5	15.04
Sept.	71	77.7	84.8	63.9	9.44
Oct.	90	91.14	100.1	81	1.27
Nov.	76	78.6	86.2	68.4	3.42
Dec.	68	73.16	80.0	61.2	7.59



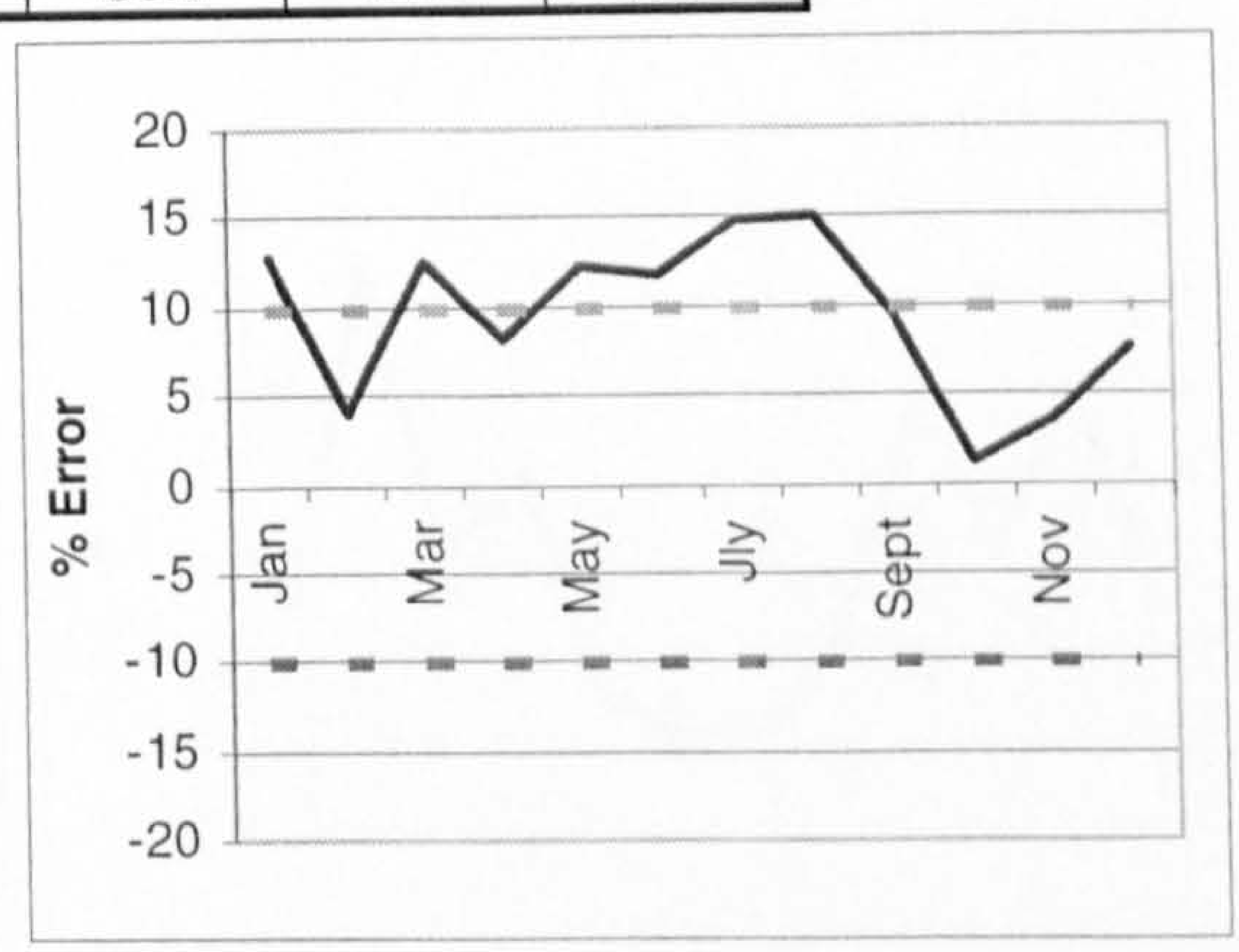
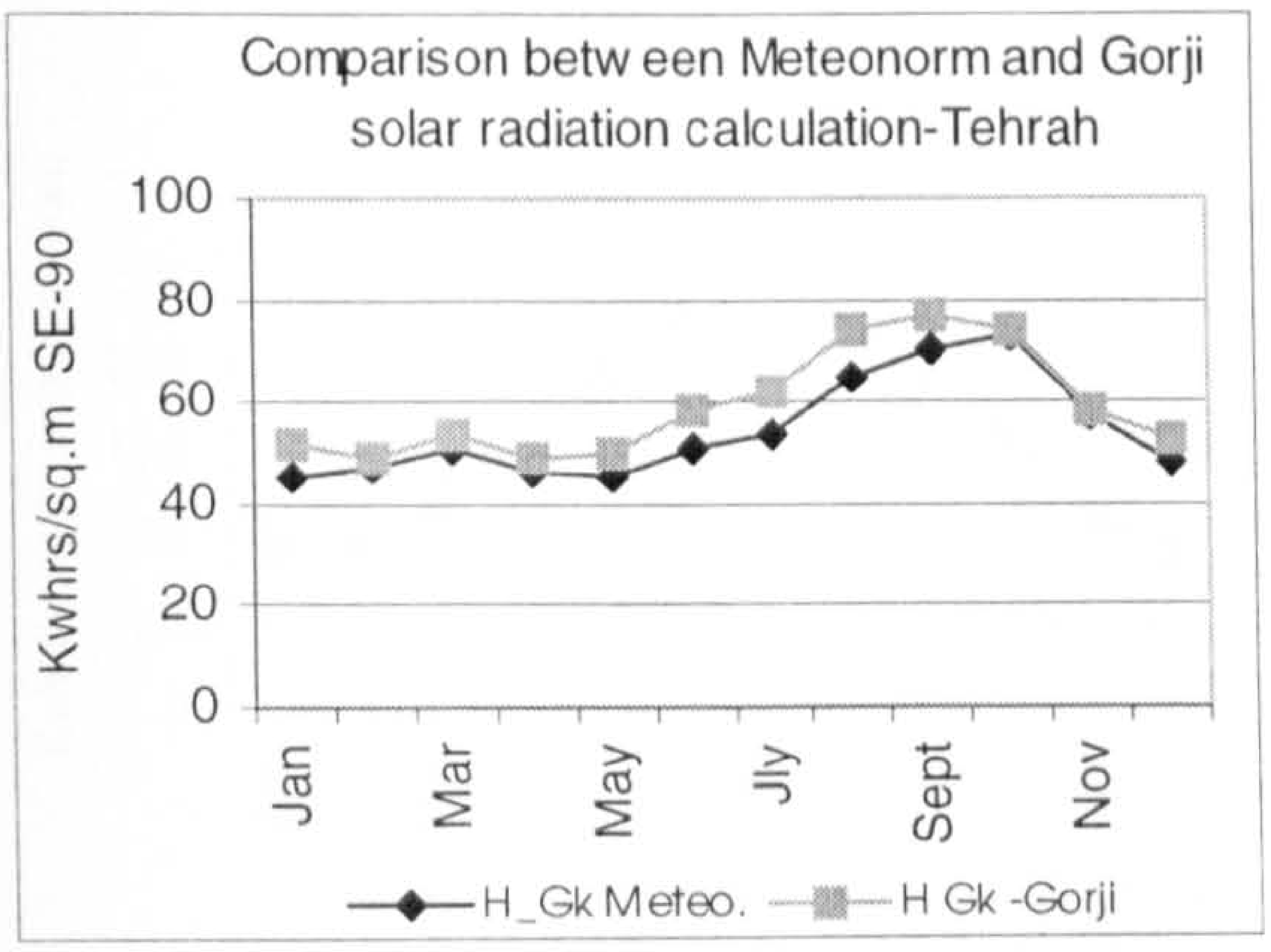


Table and Figures C.5: Comparison between Meteonorm and Gorji solar radiation calculation in south-east surface-Tehran-Iran Units: Kwhrs/sq.m

SE -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	45	51.46	49.5	40.5	14.36
Feb.	47	48.72	53.4	42.3	3.66
Mar.	51	53.63	58.7	45.9	5.16
Apr.	46	49.2	53.8	41.4	6.96
May	45	50.22	54.7	40.5	11.6
Jun.	51	57.9	63.0	45.9	13.53
Jly	54	61.69	67.1	48.6	14.24
Aug.	65	74.09	80.6	58.5	13.98
Sept.	70	76.8	83.8	63	9.71
Oct.	73	74.09	81.4	65.7	1.49
Nov.	57	58.5	64.2	51.3	2.63
Dec.	48	52.7	57.5	43.2	9.79



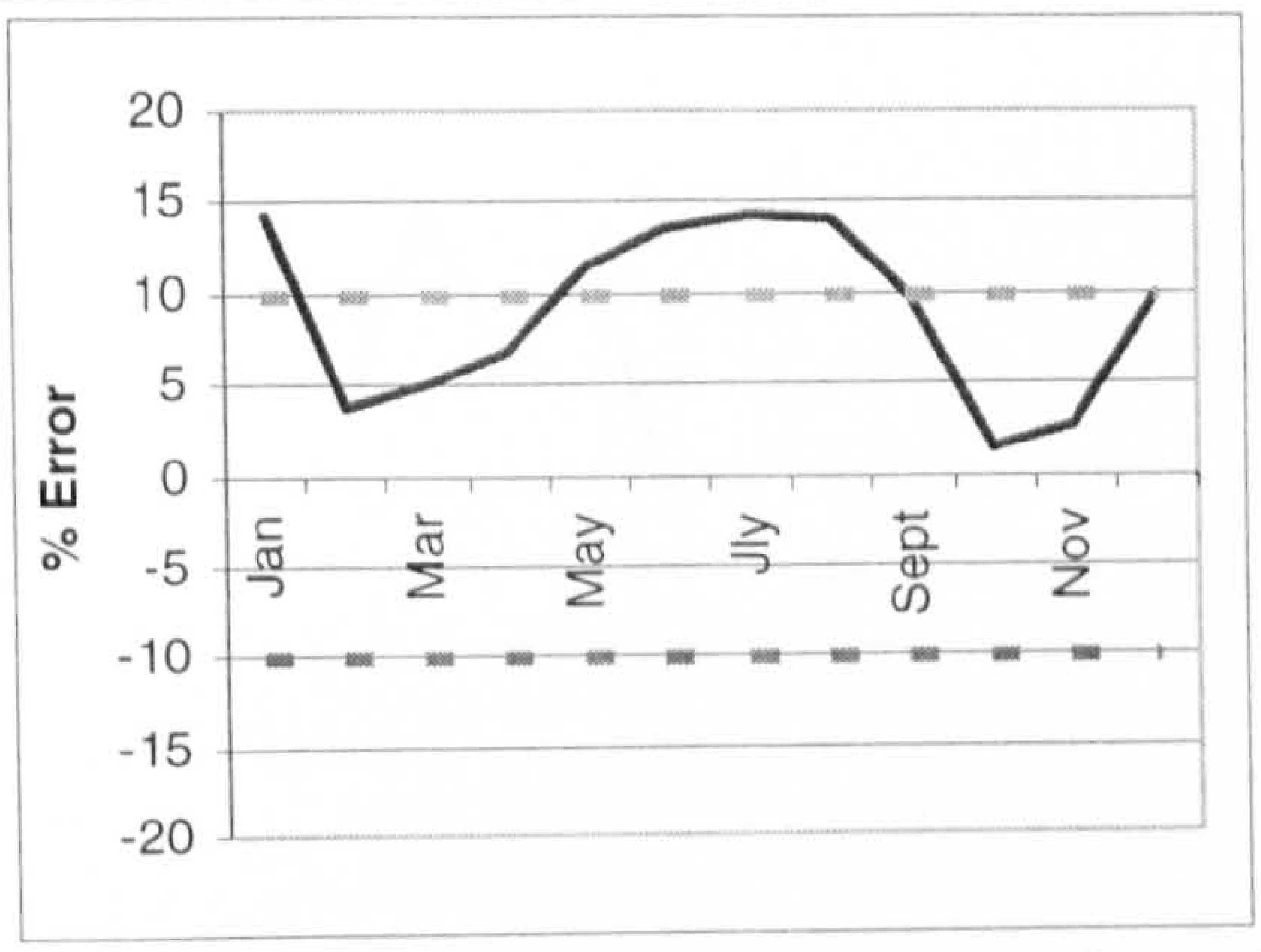
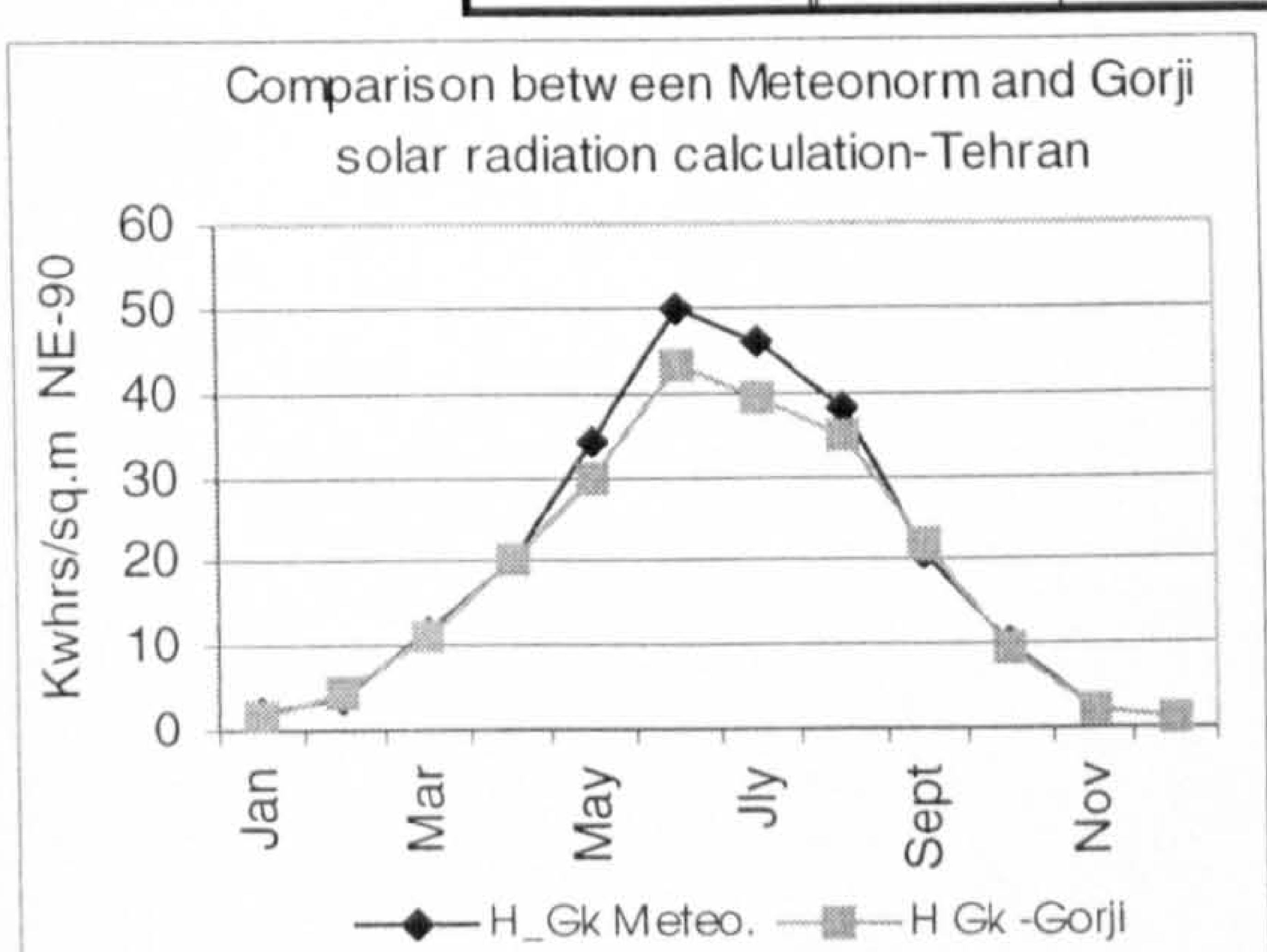


Table and Figures C.6: Comparison between Meteonorm and Gorji solar radiation calculation in north-east surface-Tehran-Iran Units: Kwhrs/sq.m

NE -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	2	1.86	2.2	1.8	-7
Feb.	4	4.48	4.9	3.6	12
Mar.	12	11.47	12.7	10.8	-4.42
Apr.	20	20.1	22.1	18	0.5
May	34	29.76	33.2	30.6	-12.47
Jun.	50	42.9	47.9	45	-14.2
Jly	46	39.37	44.0	41.4	-14.41
Aug.	38	34.72	38.5	34.2	-8.63
Sept.	21	21.9	24.0	18.9	4.29
Oct.	10	9.61	10.6	9	-3.9
Nov.	2	2.1	2.3	1.8	5
Dec.	1	0.93	1.0	0.9	-7



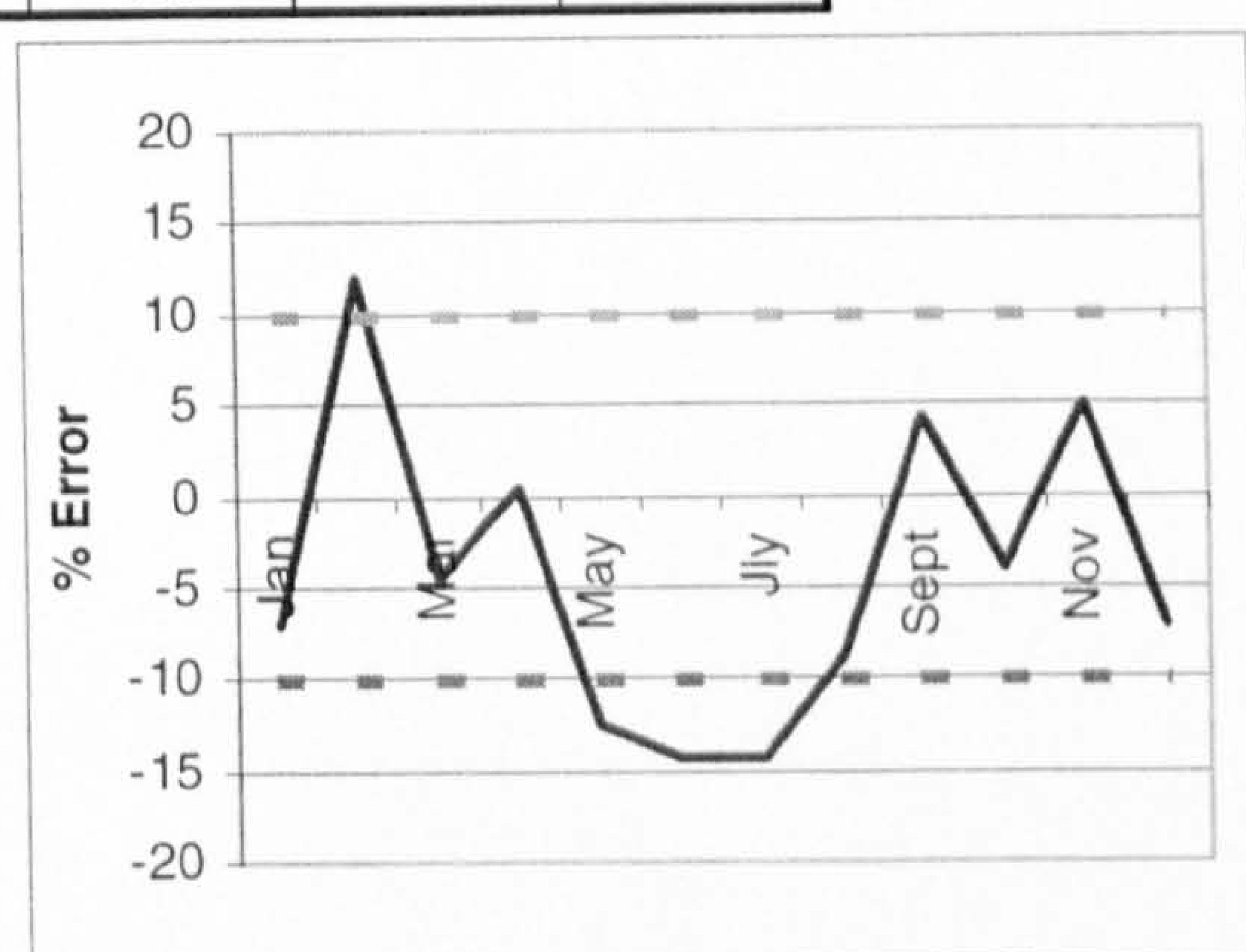
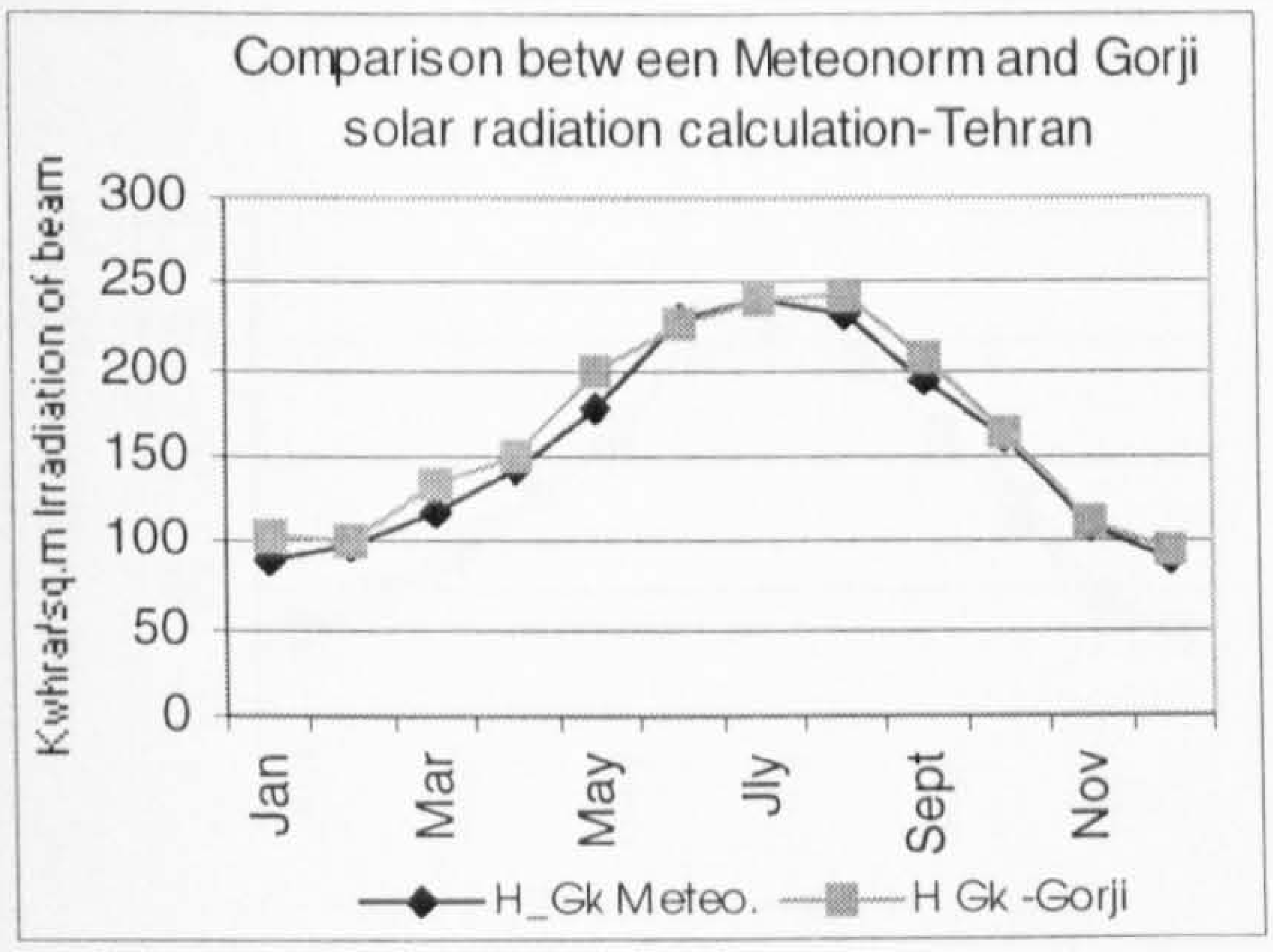


Table and Figures C.7: Comparison between Meteonorm and Gorji solar radiation calculation in irradiation of beam-Tehran-Iran Units: Kwhrs/sq.m

Irradiation of beam	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	91	103.23	100.1	81.9	13.44
Feb.	98	101.36	111.2	88.2	3.43
Mar.	116	132.99	144.6	104.4	14.65
Apr.	143	150.6	164.9	128.7	5.31
May	178	197.78	215.6	160.2	11.11
Jun.	229	226.2	249.1	206.1	-1.22
Jly	239	238.7	262.6	215.1	-0.13
Aug.	231	242.73	265.8	207.9	5.08
Sept.	194	206.4	225.8	174.6	6.39
Oct.	161	163.06	179.2	144.9	1.28
Nov.	109	113.1	124.0	98.1	3.76
Dec.	90	96.1	105.1	81	6.78



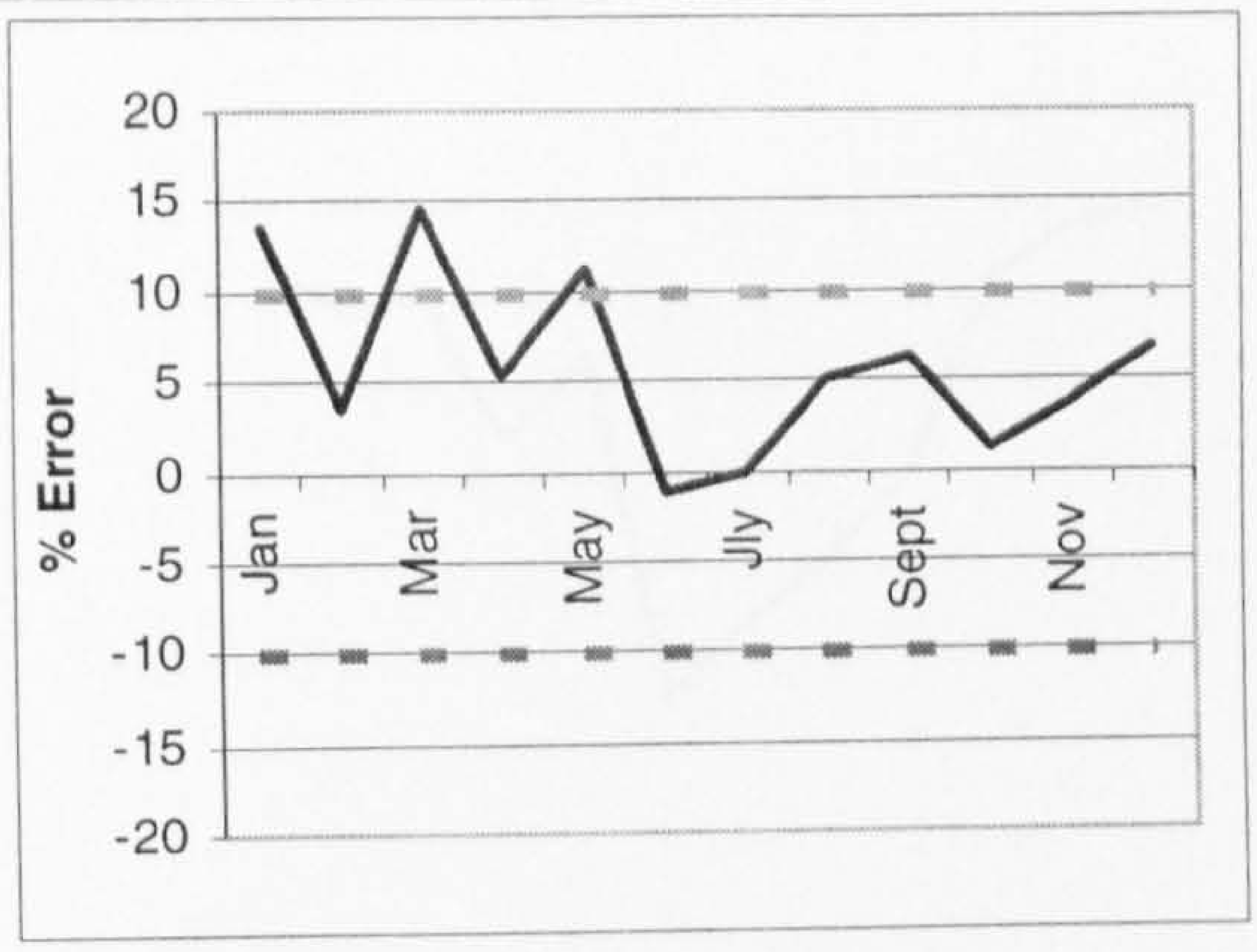
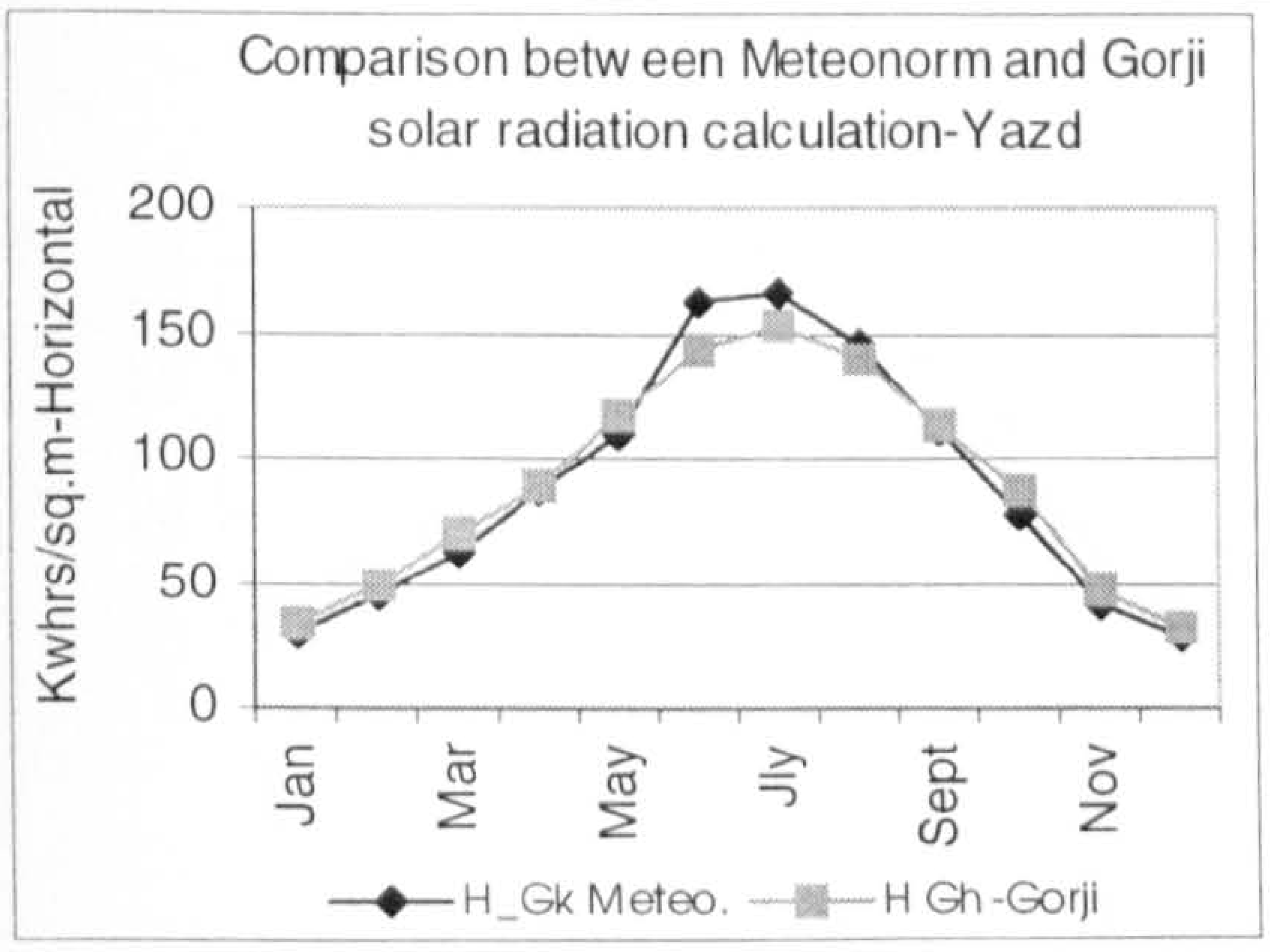


Table and Figures C.8: Comparison between Meteonorm and Gorji solar radiation calculation in horizontal surface-Yazd-Iran Units: Kwhrs/sq.m

Horizontal	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	31	34.72	34.1	27.9	12
Feb.	45	49.28	53.8	40.5	9.51
Mar.	63	69.44	75.7	56.7	10.22
Apr.	87	88.80	97.5	78.3	2.07
May	109	116.56	127.5	98.1	6.94
Jun.	163	143.10	159.4	146.7	-12.21
Jly	166	153.14	169.7	149.4	-7.75
Aug.	146	139.50	154.1	131.4	-4.45
Sept.	112	112.80	124.0	100.8	0.71
Oct.	78	86.80	94.6	70.2	11.28
Nov.	41	46.80	50.9	36.9	14.15
Dec.	28	32.24	35.0	25.2	15.14



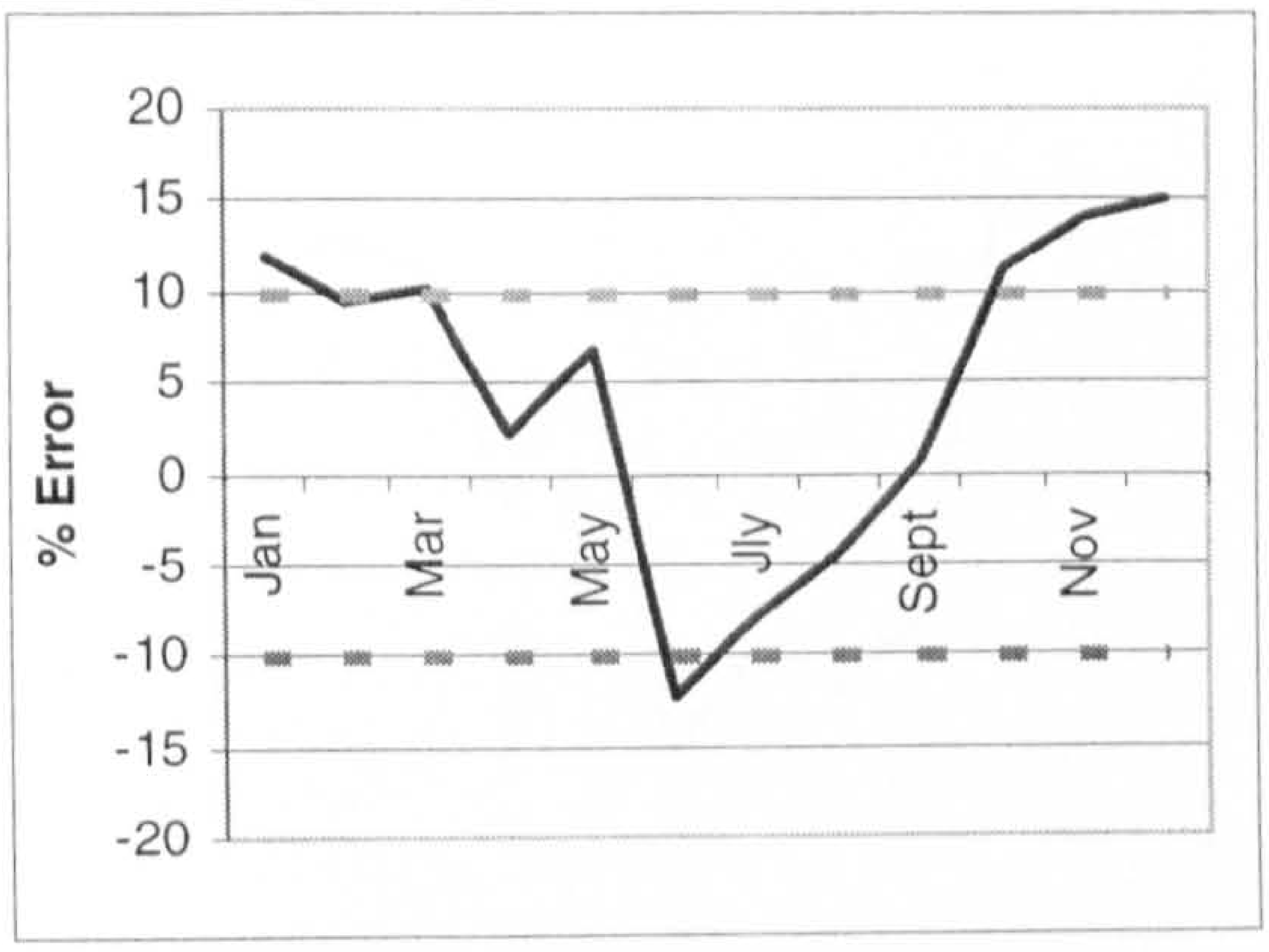
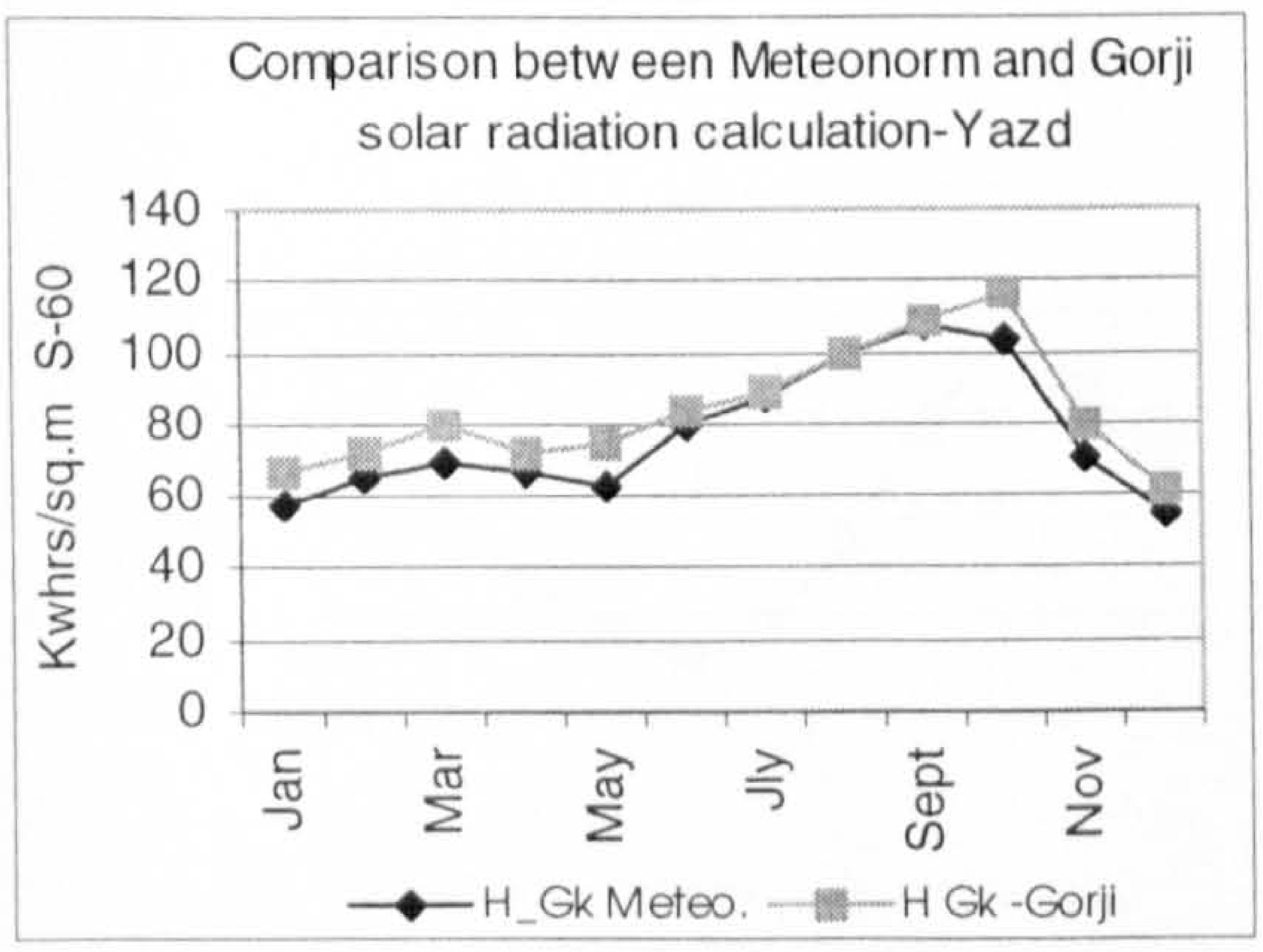


Table and Figures C.9: Comparison between Meteonorm and Gorji solar radiation calculation in south surface-Yazd-Iran Units: Kwhrs/sq.m

S -60 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	57	66.96	62.7	51.3	17.47
Feb.	66	71.68	78.3	59.4	8.61
Mar.	70	79.36	86.4	63	13.37
Apr.	67	72.00	78.7	60.3	7.46
May	63	74.40	80.7	56.7	18.1
Jun.	80	84.00	92.0	72	5
Jly	88	89.28	98.1	79.2	1.45
Aug.	100	99.20	109.2	90	-0.8
Sept.	107	108.00	118.7	96.3	0.93
Oct.	103	116.56	126.9	92.7	13.17
Nov.	71	79.20	86.3	63.9	11.55
Dec.	55	62.00	67.5	49.5	12.73



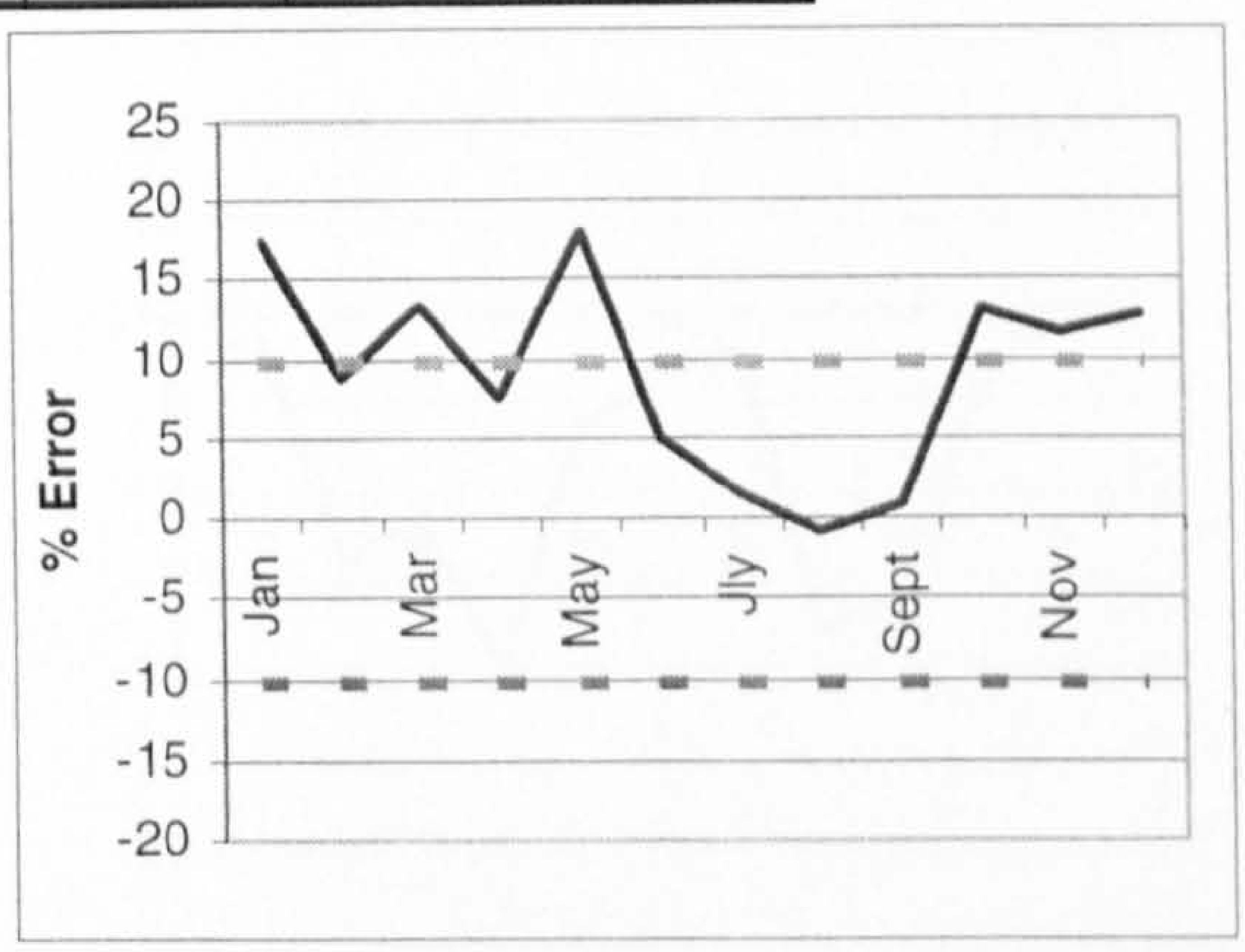
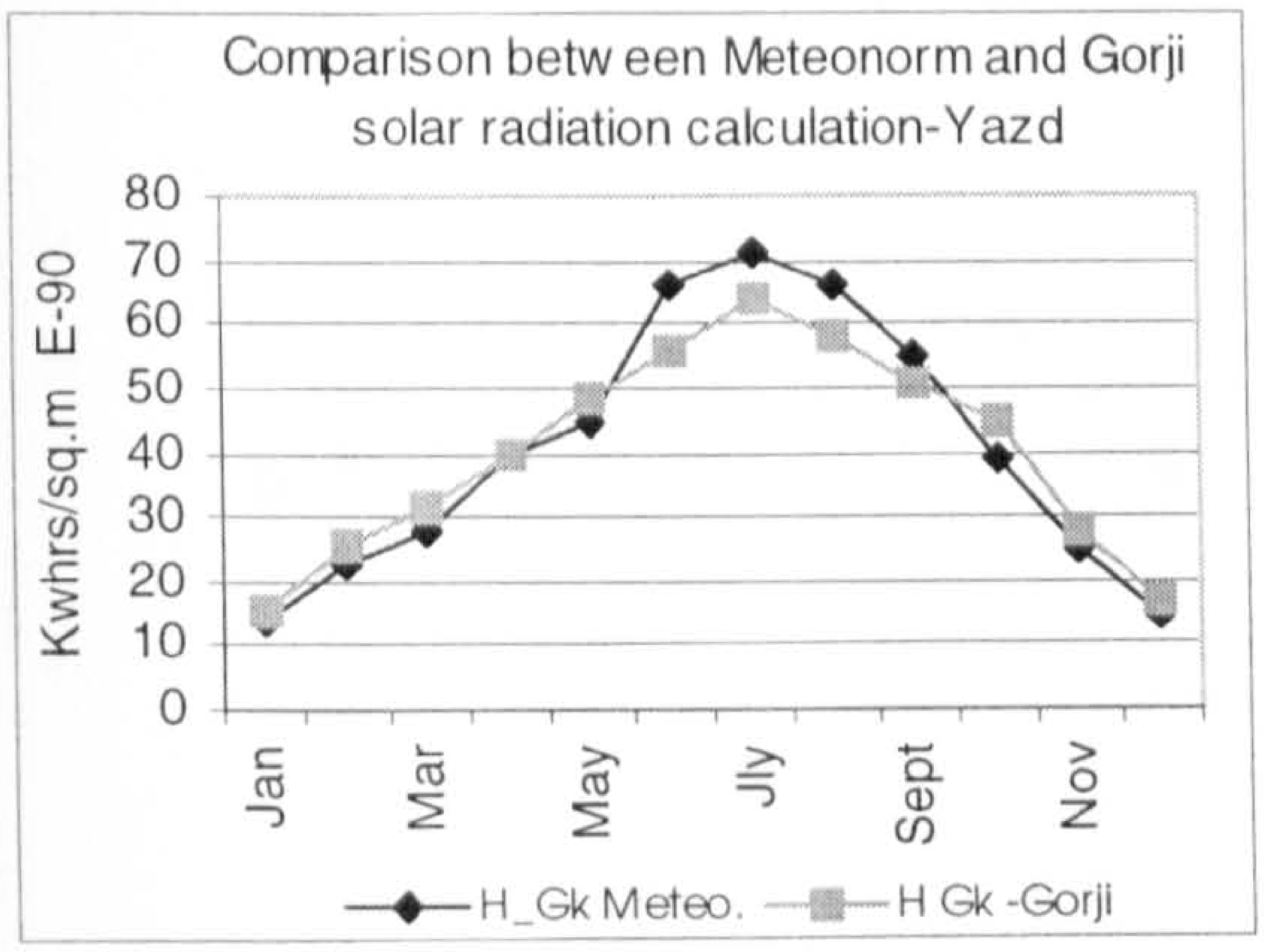


Table and Figures C.10: Comparison between Meteonorm and Gorji solar radiation calculation in east surface-Yazd-Iran Units: Kwhrs/sq.m

E -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	14	15.50	15.4	12.6	10.71
Feb.	23	26.04	28.3	20.7	13.22
Mar.	28	31.31	34.1	25.2	11.82
Apr.	40	39.42	43.4	36	-1.44
May	45	48.23	52.7	40.5	7.17
Jun.	66	56.10	62.7	59.4	-15
Jly	71	64.17	71.3	63.9	-9.62
Aug.	66	58.31	64.9	59.4	-11.65
Sept.	55	50.67	56.2	49.5	-7.88
Oct.	39	44.64	48.5	35.1	14.46
Nov.	25	28.20	30.7	22.5	12.8
Dec.	15	17.05	18.6	13.5	13.67



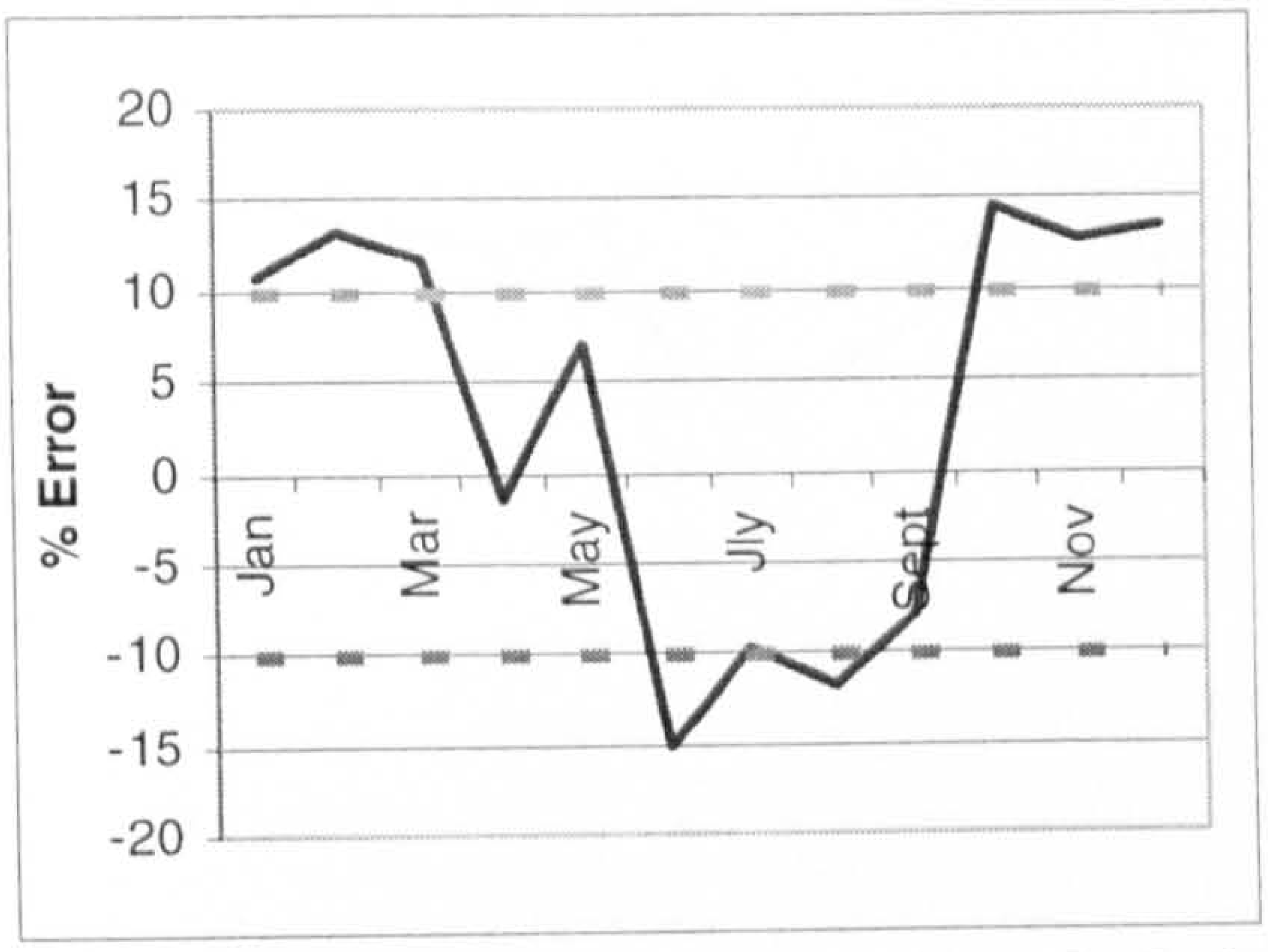
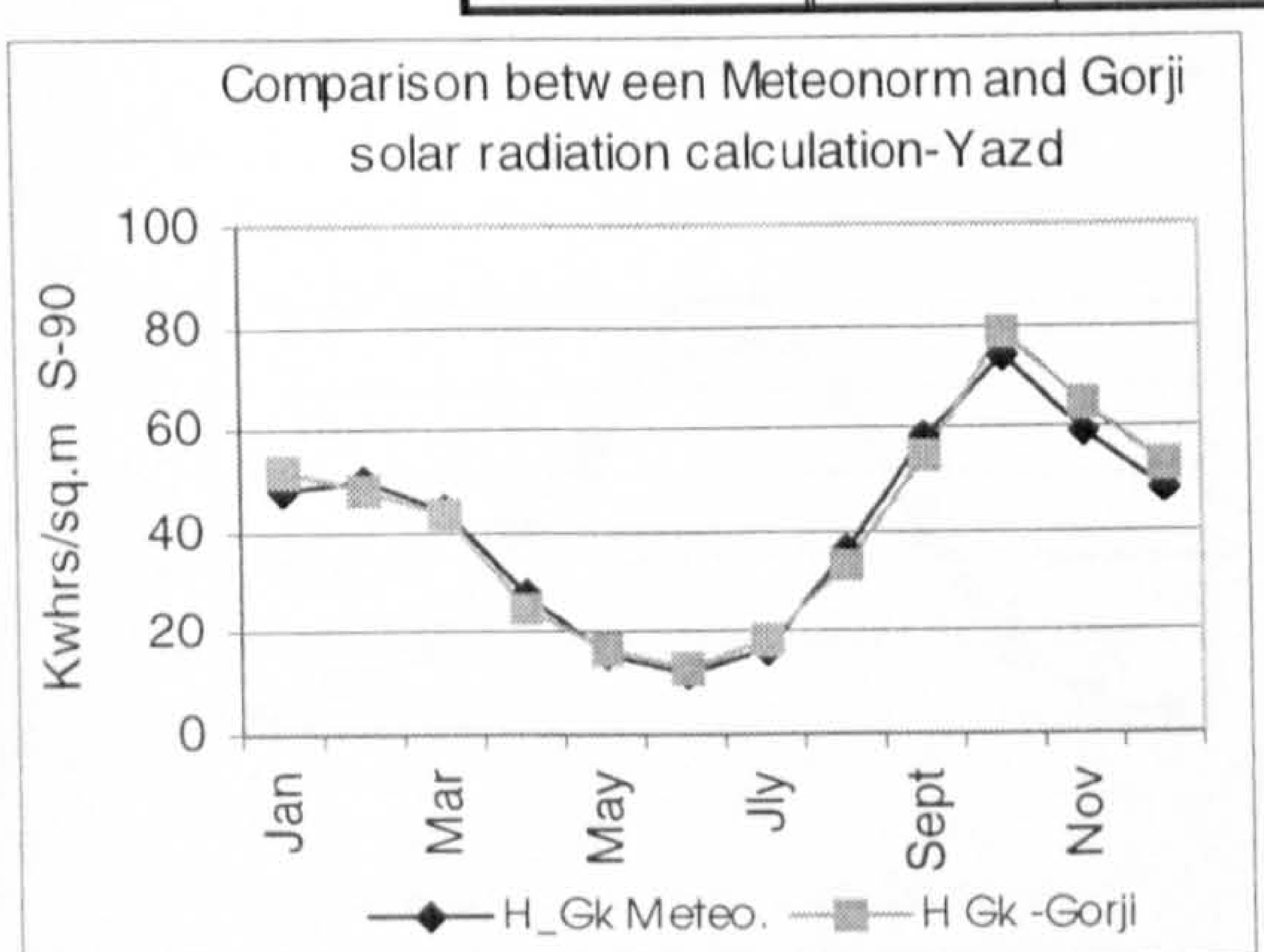


Table and Figures C.11: Comparison between Meteonorm and Gorji solar radiation calculation in south surface-Yazd-Iran Units: Kwhrs/sq.m

S -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	48	52.08	52.8	43.2	8.5
Feb.	50	48.16	53.2	45	-3.68
Mar.	44	43.40	47.8	39.6	-1.36
Apr.	28	25.20	28.0	25.2	-10
May	16	16.62	18.2	14.4	3.85
Jun.	12	12.72	13.9	10.8	6
Jly	17	18.35	20.1	15.3	7.95
Aug.	36	33.23	36.8	32.4	-7.69
Sept.	58	54.48	60.3	52.2	-6.07
Oct.	74	78.37	85.8	66.6	5.9
Nov.	59	64.80	70.7	53.1	9.83
Dec.	48	52.33	57.1	43.2	9.02



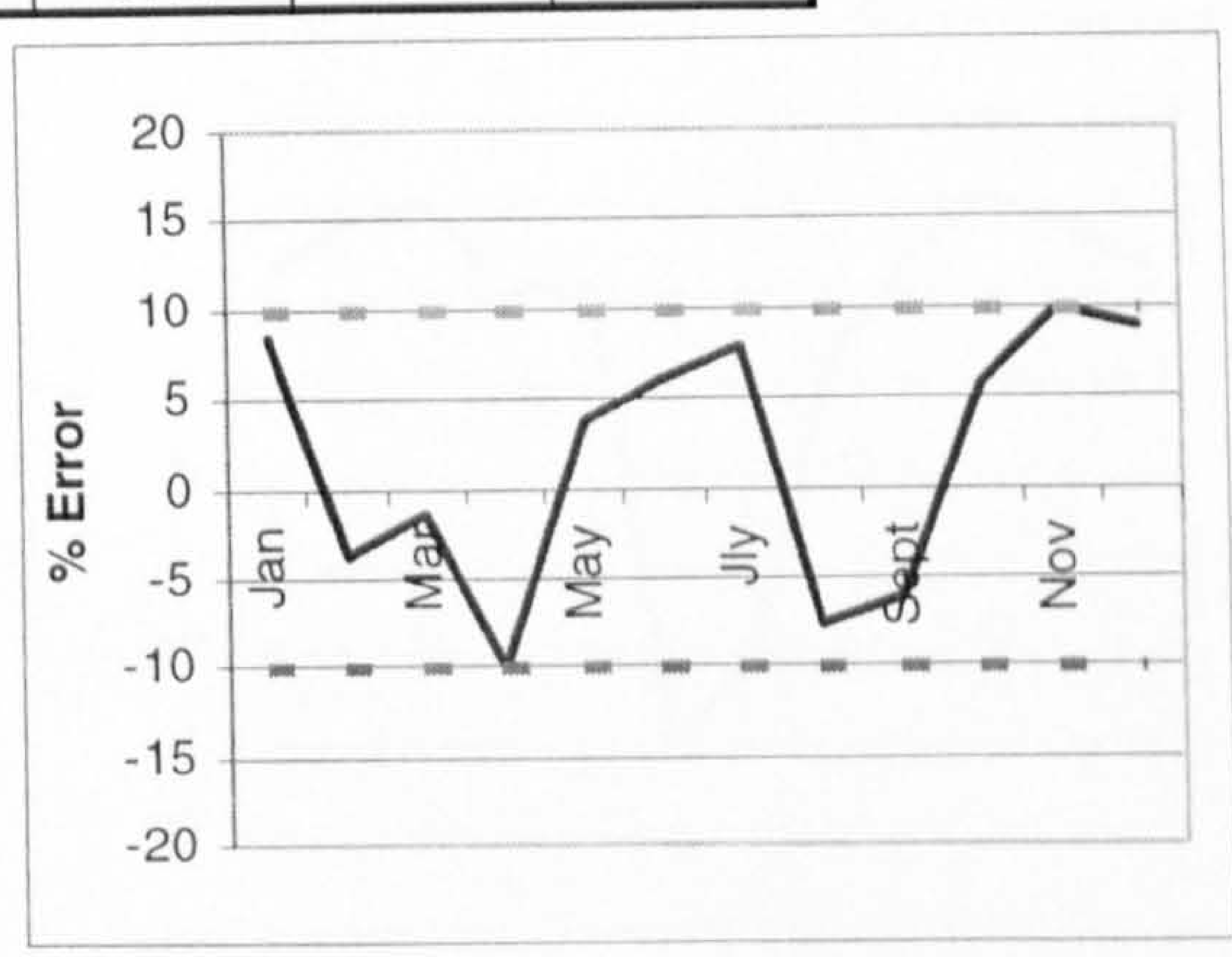
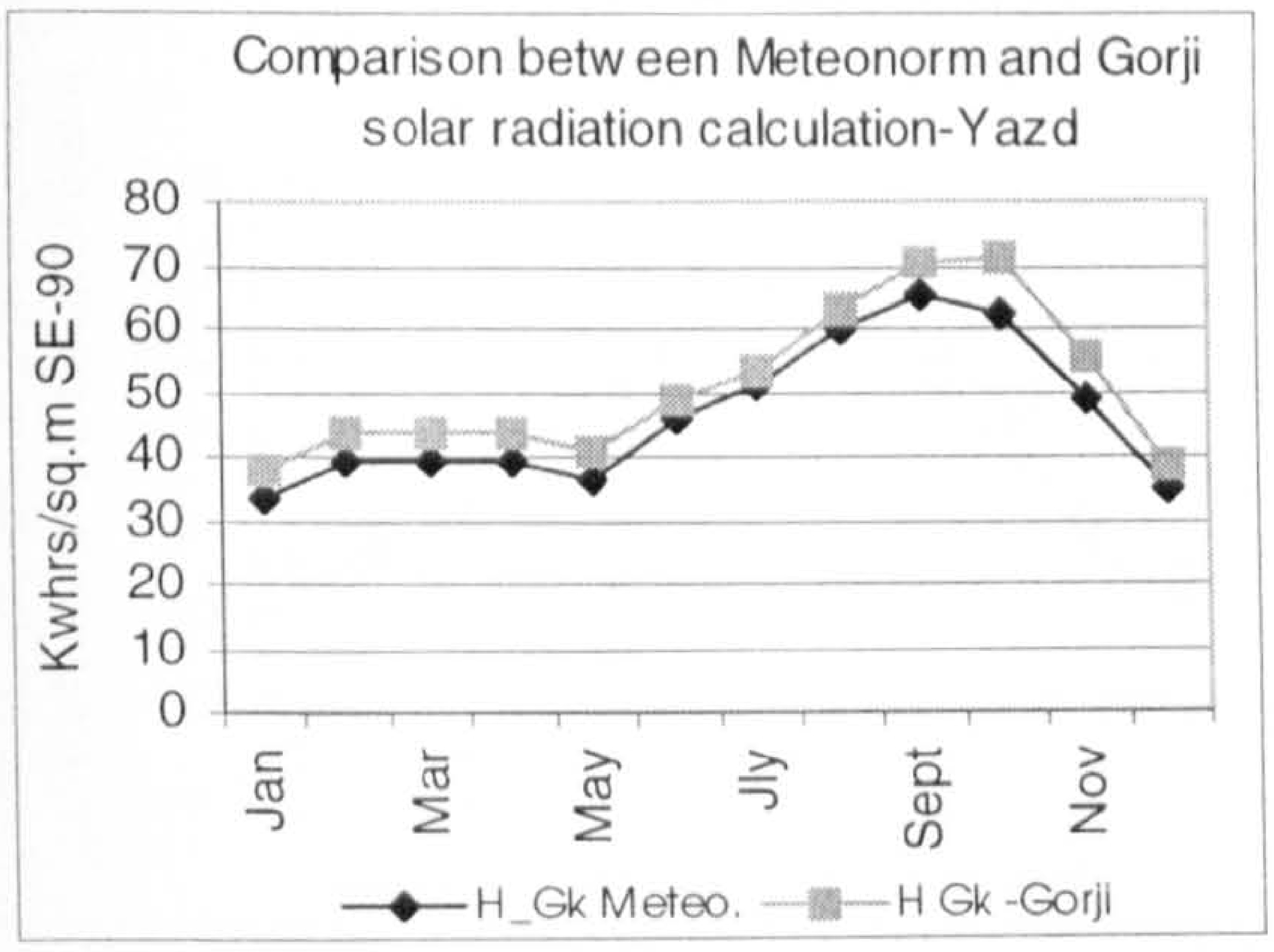


Table and Figures C.12: Comparison between Meteonorm and Gorji solar radiation calculation in south-east surface-Yazd-Iran Units: Kwhrs/sq.m

SE -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	33	37.82	36.3	29.7	14.61
Feb.	39	43.96	47.9	35.1	12.72
Mar.	39	44.02	47.9	35.1	12.87
Apr.	39	43.50	47.4	35.1	11.54
May	36	40.92	44.5	32.4	13.67
Jun.	46	48.60	53.2	41.4	5.65
Jly	51	53.32	58.4	45.9	4.55
Aug.	60	63.24	69.2	54	5.4
Sept.	65	70.20	76.7	58.5	8
Oct.	62	70.99	77.2	55.8	14.5
Nov.	49	55.80	60.7	44.1	13.88
Dec.	35	38.75	42.3	31.5	10.71



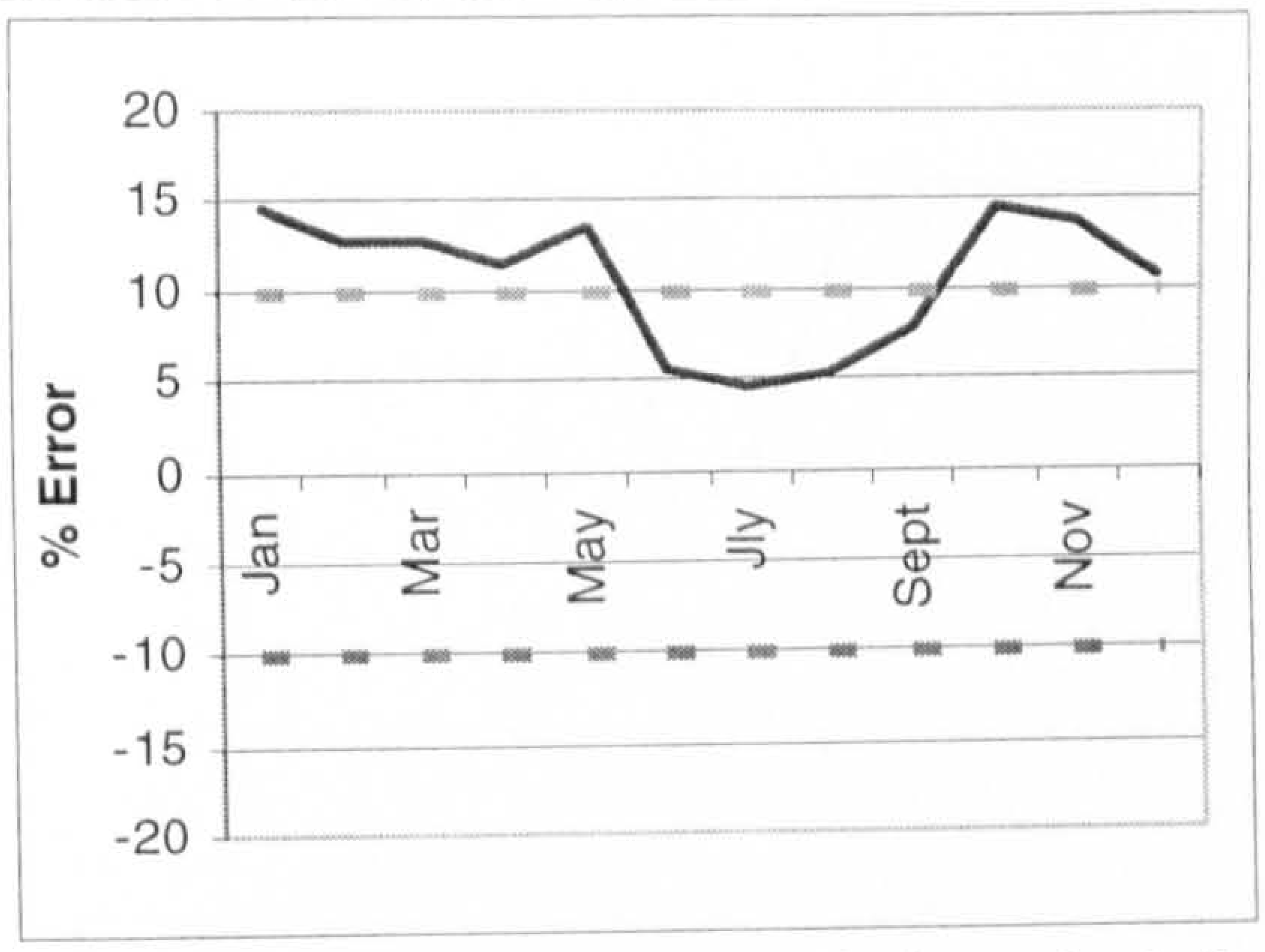
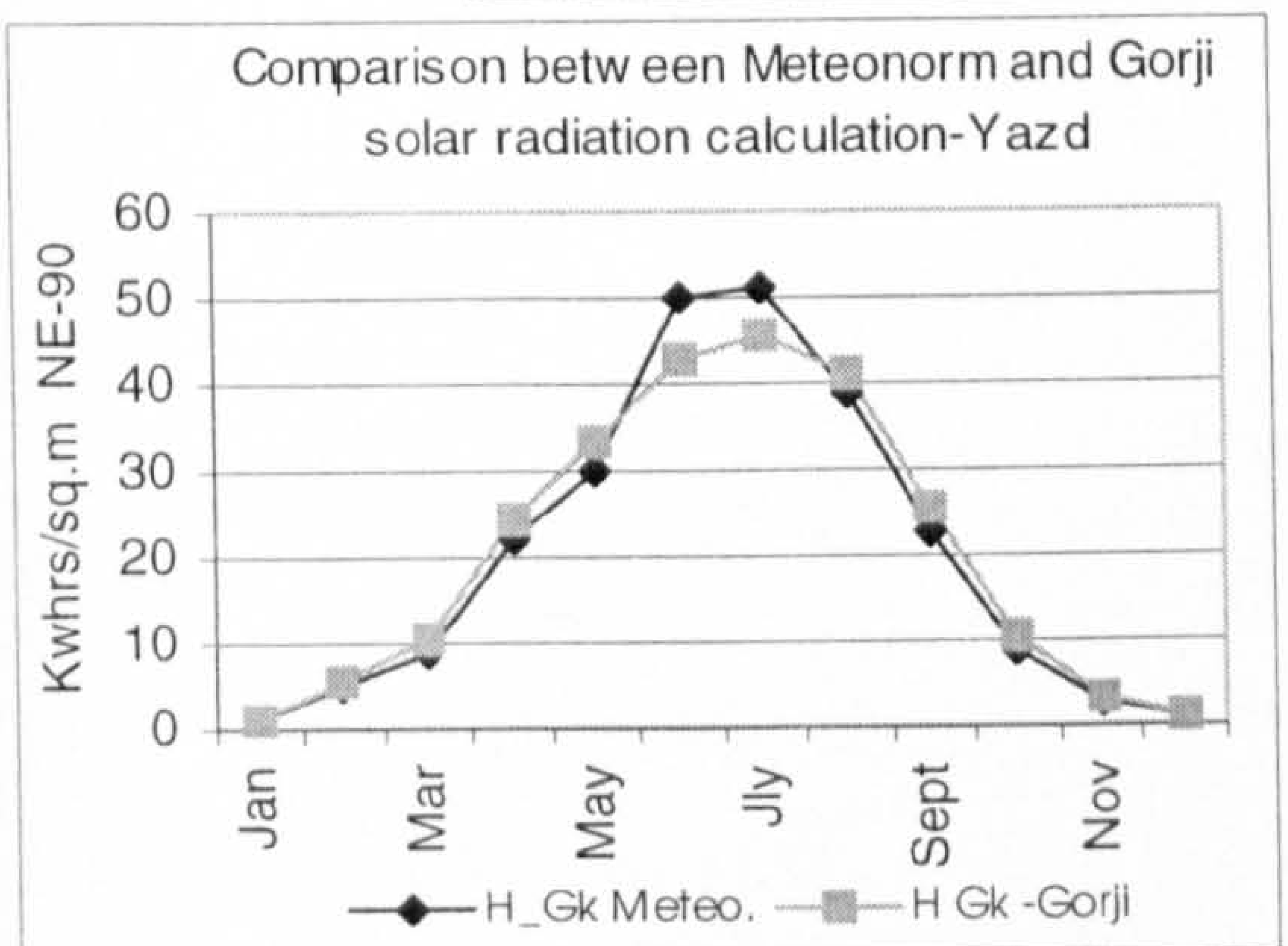


Table and Figures C.13: Comparison between Meteonorm and Gorji solar radiation calculation in north-east surface-Yazd-Iran Units: Kwhrs/sq.m

NE -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	1	1.12	1.1	0.9	11.6
Feb.	5	5.71	6.2	4.5	14.24
Mar.	9	10.39	11.3	8.1	15.39
Apr.	22	24.25	26.4	19.8	10.21
May	30	33.25	36.3	27	10.84
Jun.	50	42.77	47.8	45	-14.46
Jly	51	45.49	50.6	45.9	-10.81
Aug.	39	41.23	45.1	35.1	5.71
Sept.	23	25.68	28.0	20.7	11.66
Oct.	9	10.39	11.3	8.1	15.39
Nov.	3	3.42	3.7	2.7	14
Dec.	1	1.12	1.2	0.9	11.6



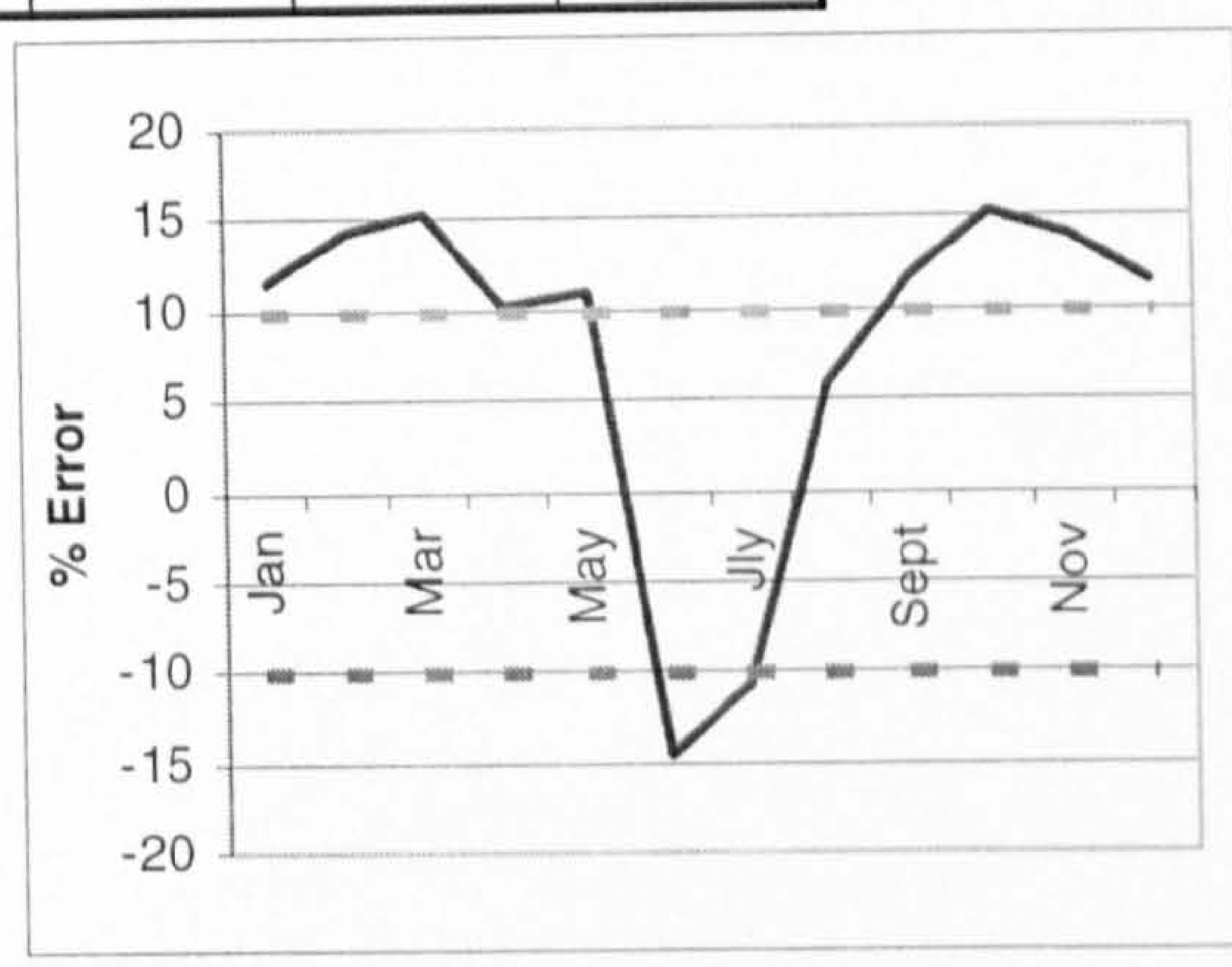
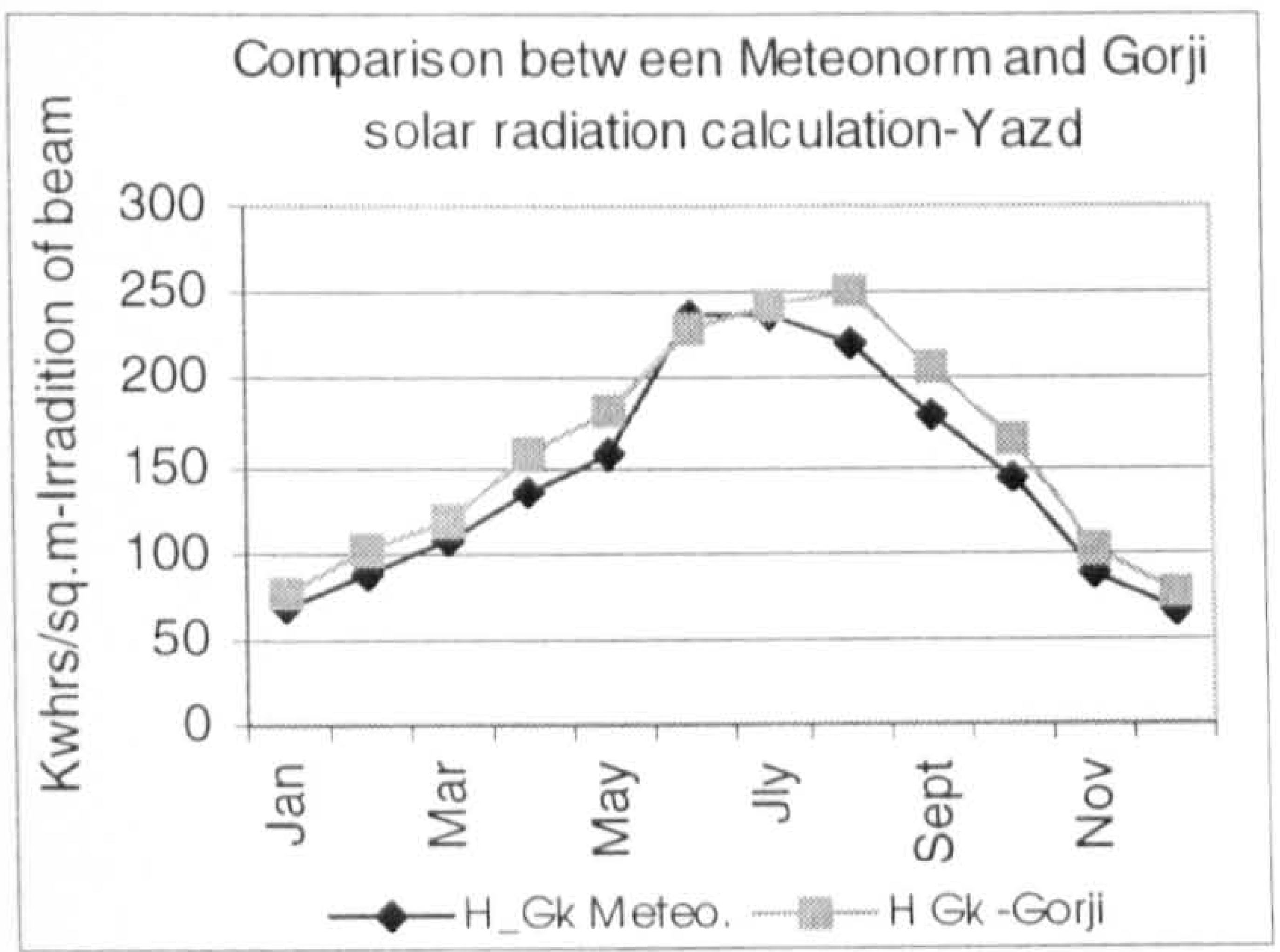


Table and Figures C.14: Comparison between Meteonorm and Gorji solar radiation calculation in irradiation of beam-Yazd-Iran Units: Kwhrs/sq.m

Irradiation of beam	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	69	77.50	75.9	62.1	12.32
Feb.	88	100.80	109.6	79.2	14.55
Mar.	106	118.73	129.3	95.4	12.01
Apr.	136	156.90	170.5	122.4	15.37
May	158	181.04	196.8	142.2	14.58
Jun.	236	227.58	251.2	212.4	-3.57
Jly	238	241.44	265.2	214.2	1.45
Aug.	221	251.64	273.7	198.9	13.86
Sept.	179	207.60	225.5	161.1	15.98
Oct.	143	164.92	179.2	128.7	15.33
Nov.	88	101.70	110.5	79.2	15.57
Dec.	67	75.99	82.7	60.3	13.41



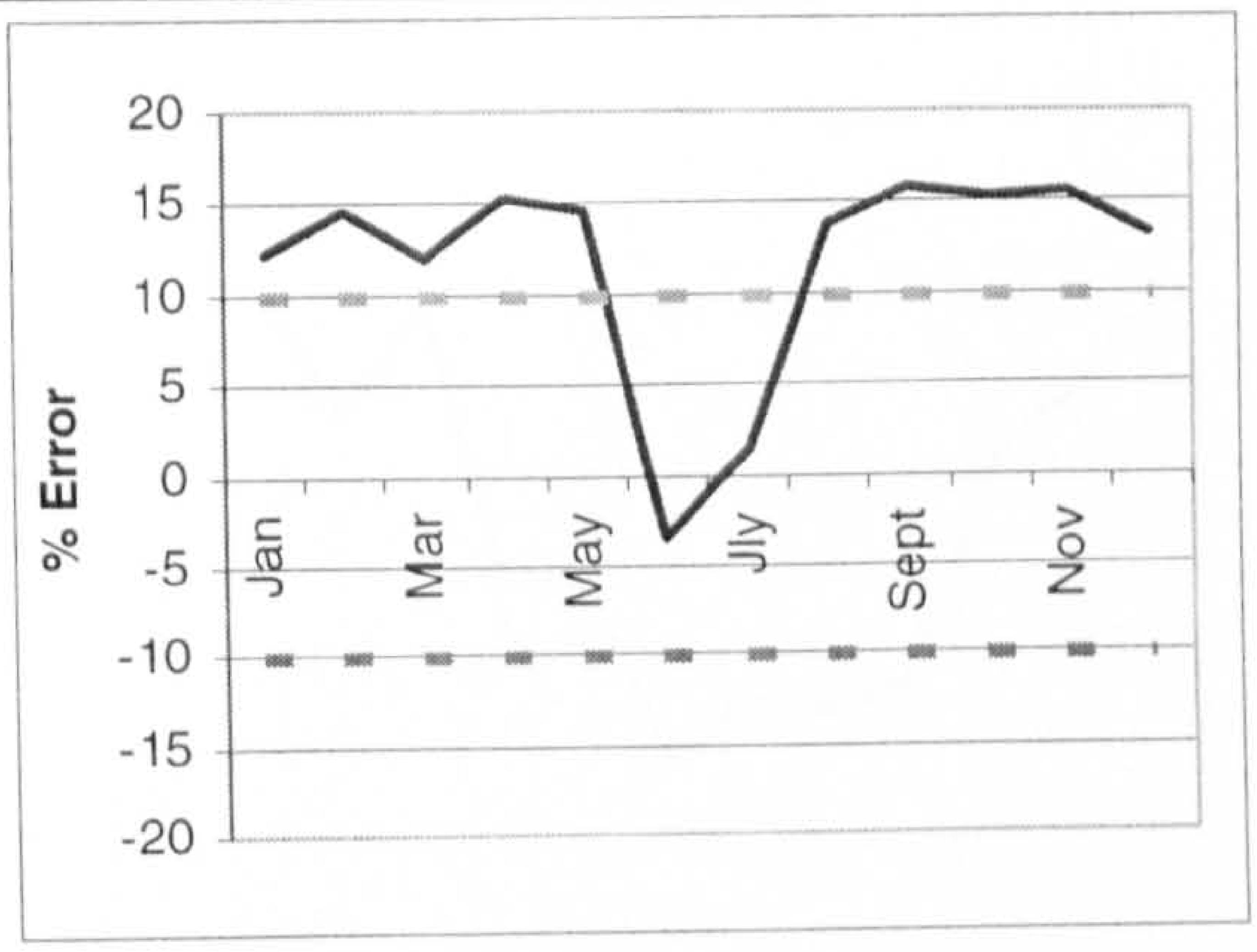
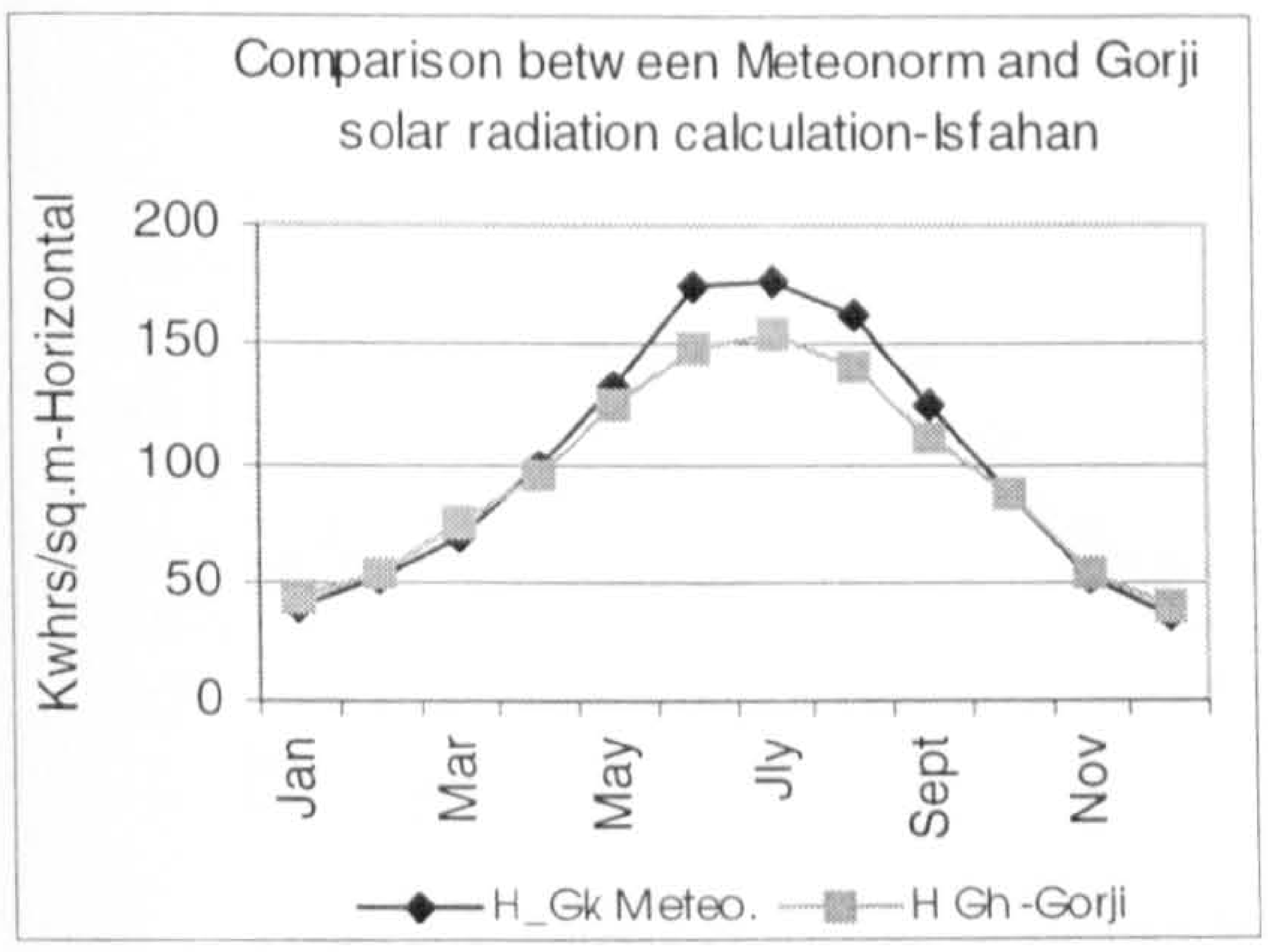


Table and Figures C.15: Comparison between Meteonorm and Gorji solar radiation calculation in horizontal surface-Isfahan-Iran Units: Kwhrs/sq.m

Horizontal	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	39	43.40	42.9	35.1	11.28
Feb.	52	53.76	59.0	46.8	3.38
Mar.	69	75.64	82.5	62.1	9.62
Apr.	100	94.56	104.6	90	-5.44
May	132	124.25	137.4	118.8	-5.87
Jun.	175	147.60	165.1	157.5	-15.66
Jly	176	154.38	172.0	158.4	-12.28
Aug.	162	141.05	157.3	145.8	-12.93
Sept.	124	110.64	123.0	111.6	-10.77
Oct.	87	88.04	96.7	78.3	1.2
Nov.	51	53.52	58.6	45.9	4.94
Dec.	36	39.68	43.3	32.4	10.22



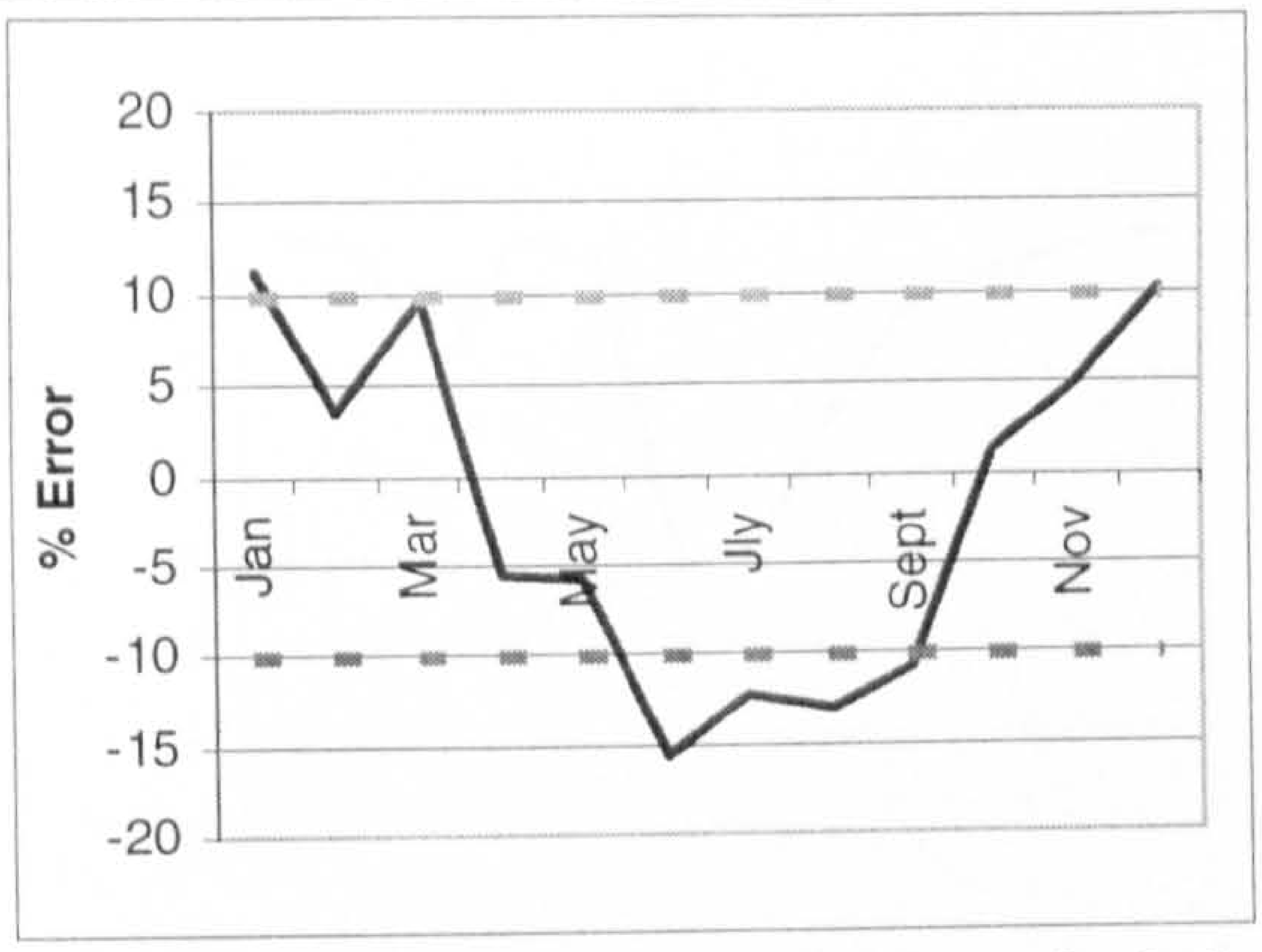
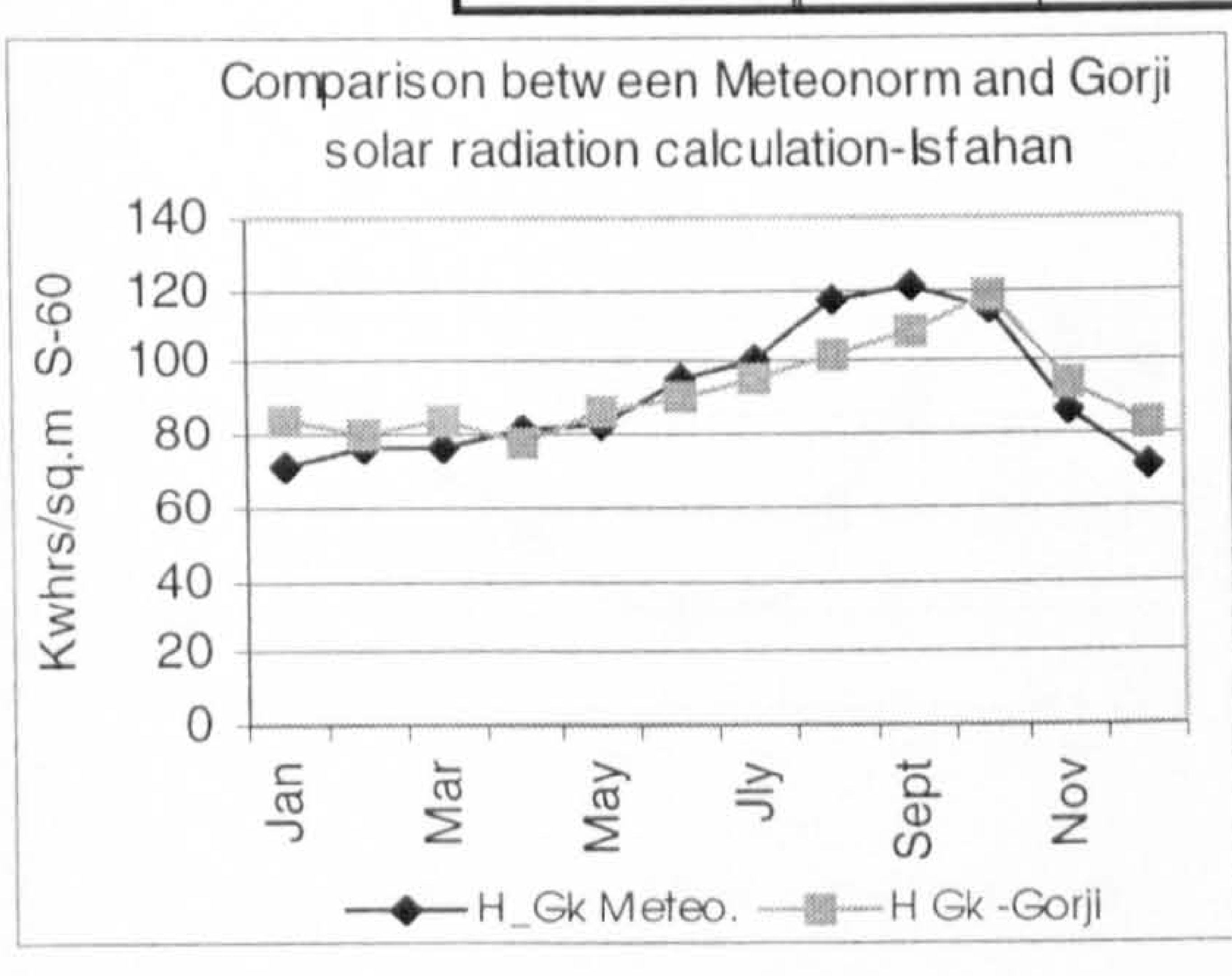


Table and Figures C.16: Comparison between Meteonorm and Gorji solar radiation calculation in south surface-Isfahan-Iran Units: Kwhrs/sq.m

S -60 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	71	84.32	78.1	63.9	18.76
Feb.	76	80.42	88.0	68.4	5.81
Mar.	77	84.32	92.0	69.3	9.51
Apr.	82	77.52	85.7	73.8	-5.46
May	83	86.06	94.4	74.7	3.68
Jun.	95	90.72	100.2	85.5	-4.51
Jly	101	94.98	105.1	90.9	-5.96
Aug.	117	101.93	113.6	105.3	-12.88
Sept.	121	108.00	120.1	108.9	-10.74
Oct.	115	117.80	129.3	103.5	2.43
Nov.	87	93.84	102.5	78.3	7.86
Dec.	71	82.58	89.7	63.9	16.32



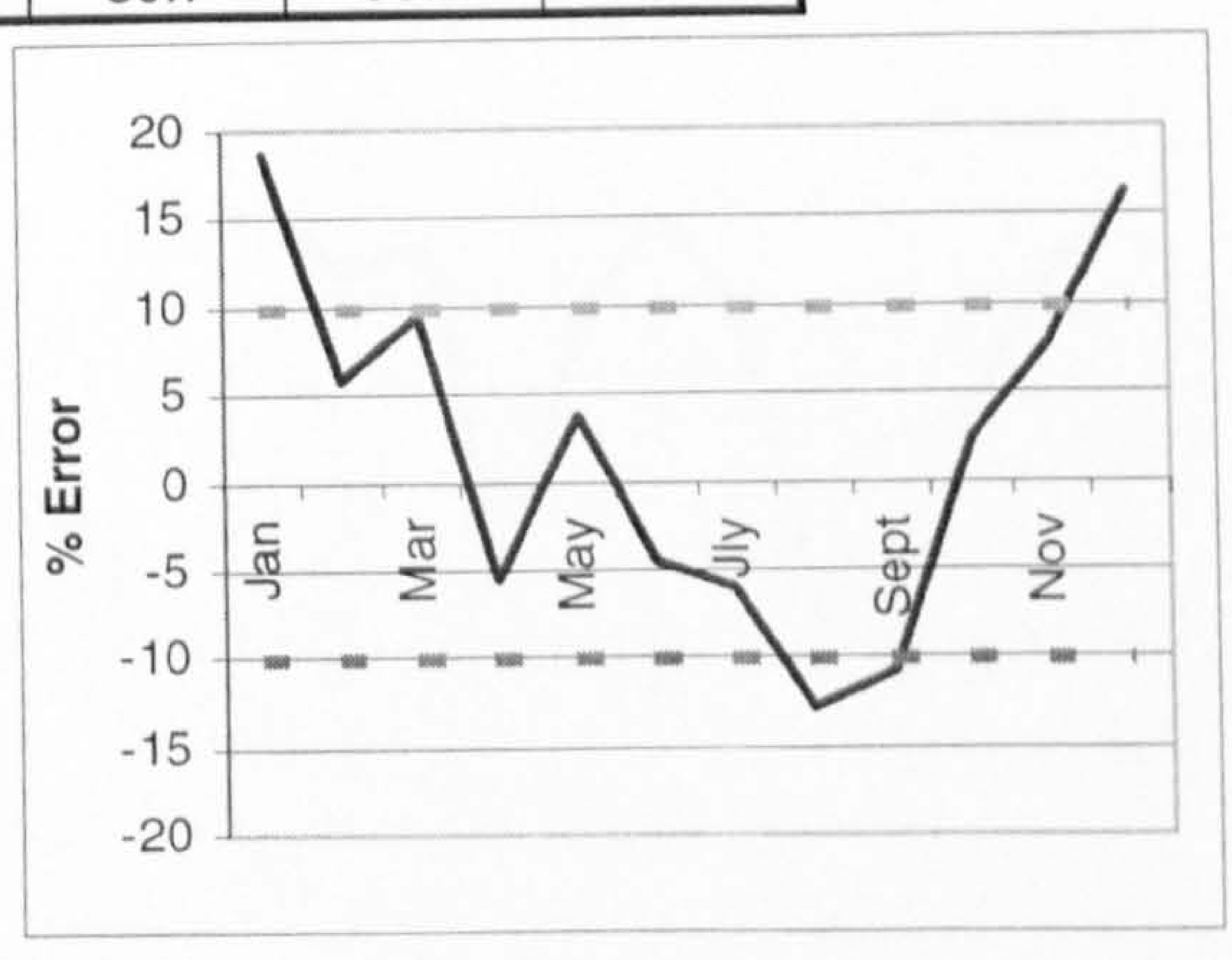
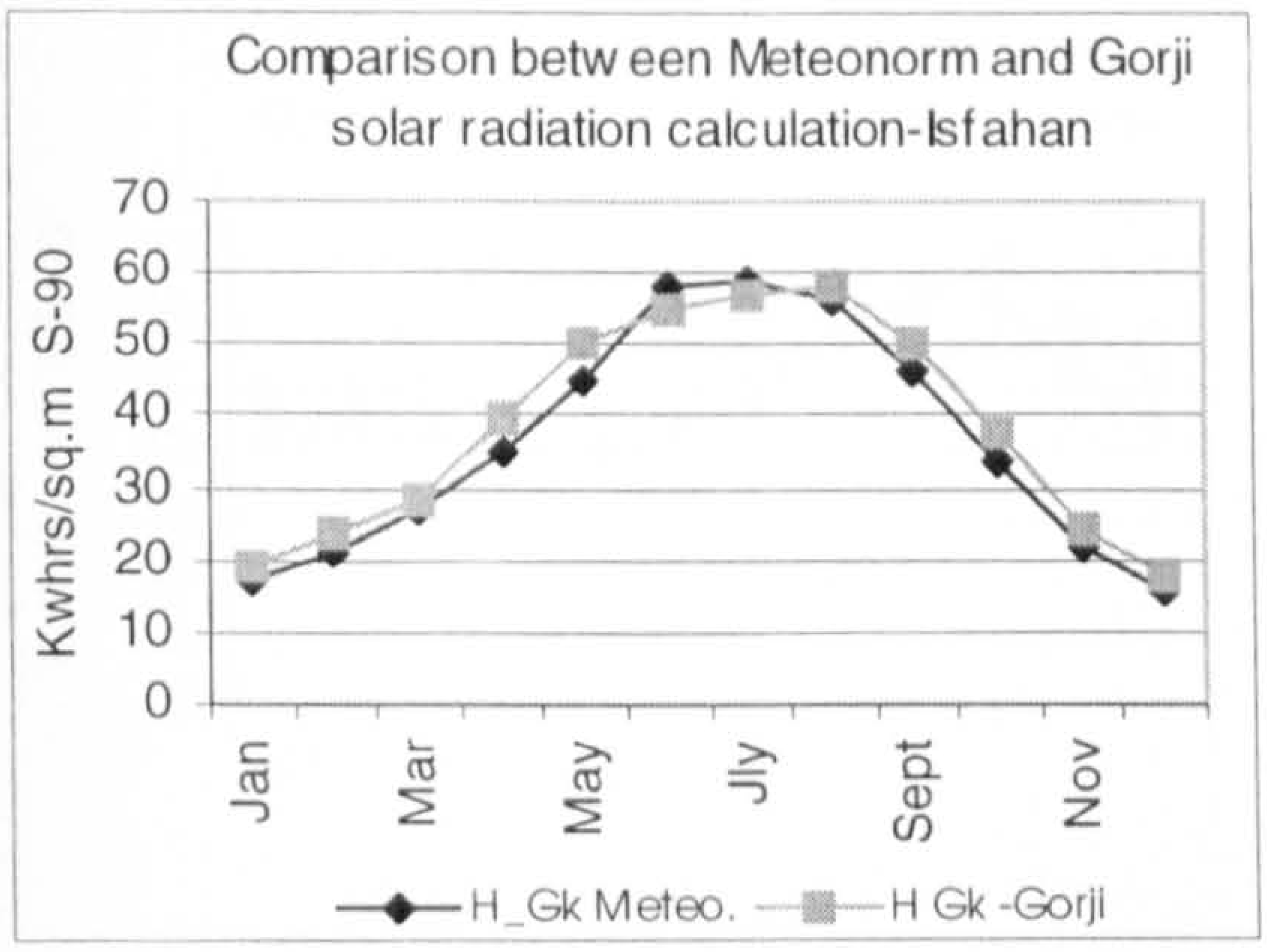


Table and Figures C.17: Comparison between Meteonorm and Gorji solar radiation calculation in east surface-Isfahan-Iran Units: Kwhrs/sq.m

E -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	17	19.22	18.7	15.3	13.06
Feb.	21	23.52	25.6	18.9	12
Mar.	27	28.52	31.2	24.3	5.63
Apr.	35	39.60	43.1	31.5	13.14
May	45	50.10	54.6	40.5	11.32
Jun.	58	54.72	60.5	52.2	-5.66
Jly	59	56.79	62.7	53.1	-3.74
Aug.	56	58.03	63.6	50.4	3.63
Sept.	46	50.40	55.0	41.4	9.57
Oct.	34	37.70	41.1	30.6	10.87
Nov.	22	24.72	26.9	19.8	12.36
Dec.	16	18.10	19.7	14.4	13.15



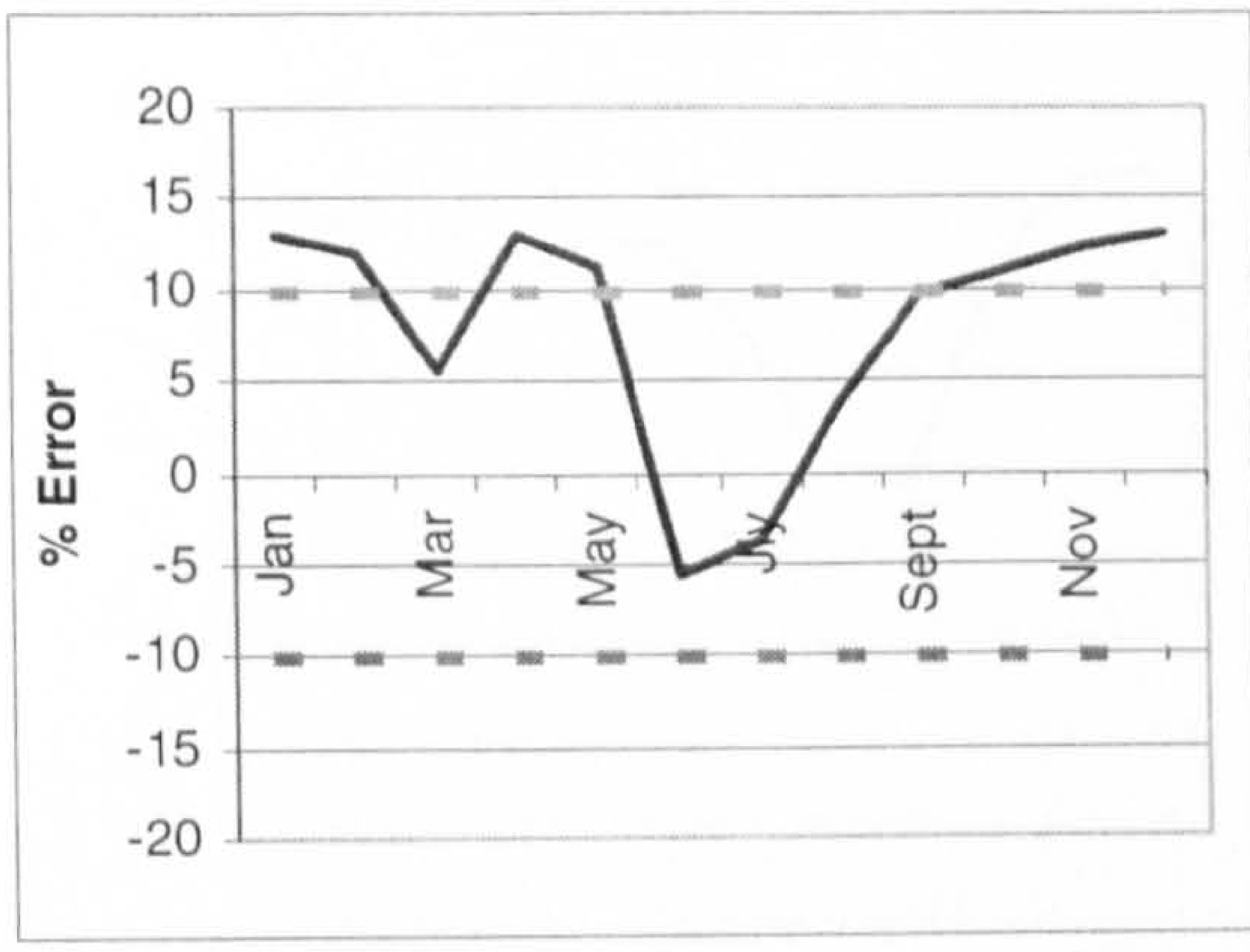
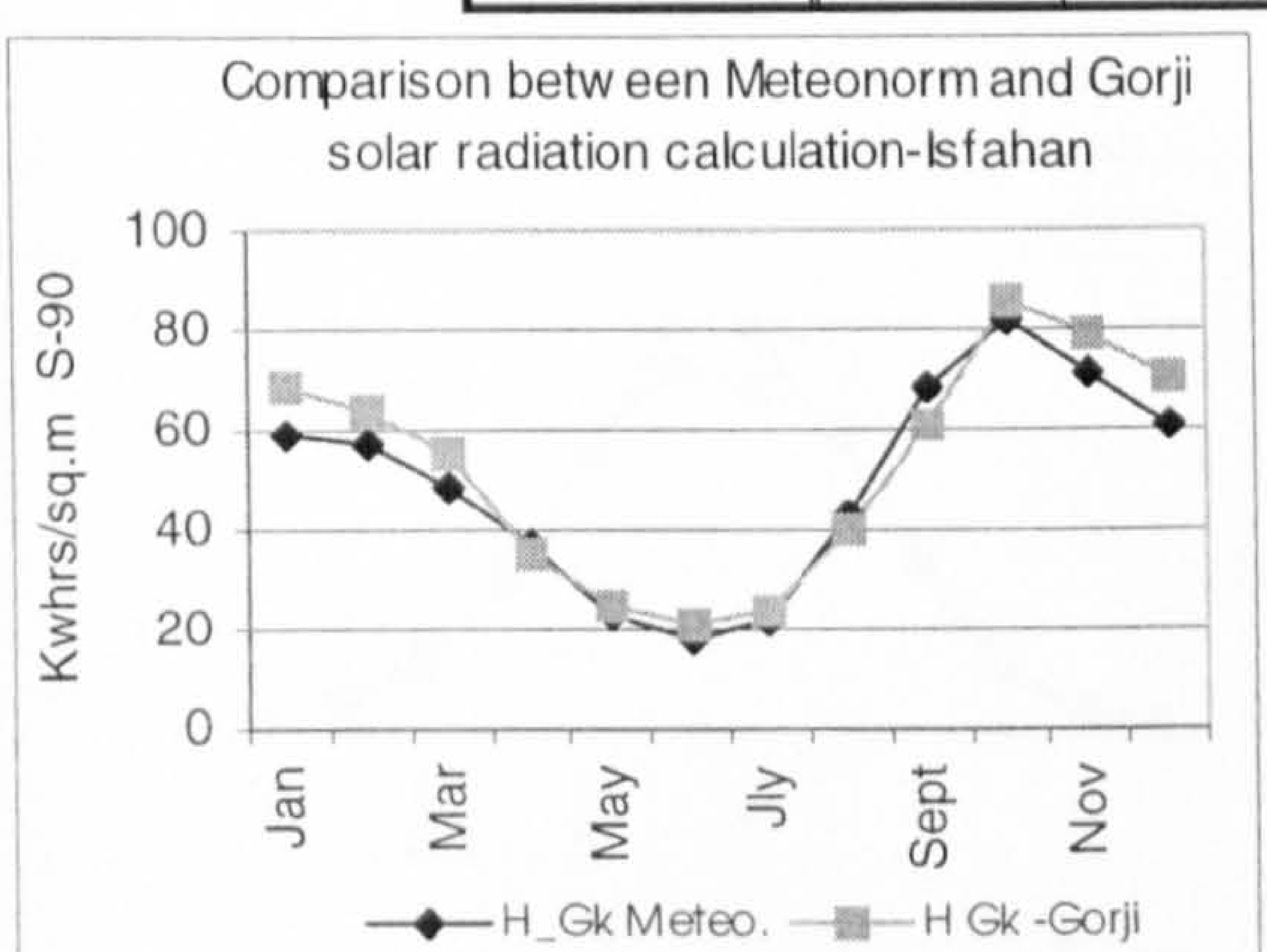


Table and Figures C.18: Comparison between Meteonorm and Gorji solar radiation calculation in south surface-Isfahan-Iran Units: Kwhrs/sq.m

S -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	59	68.20	64.9	53.1	15.59
Feb.	57	63.56	69.3	51.3	11.51
Mar.	49	55.49	60.4	44.1	13.24
Apr.	37	34.80	38.5	33.3	-5.95
May	23	25.05	27.3	20.7	8.9
Jun.	18	20.70	22.5	16.2	15
Jly	22	24.06	26.3	19.8	9.35
Aug.	43	39.68	44.0	38.7	-7.72
Sept.	69	60.72	67.6	62.1	-12
Oct.	82	85.31	93.5	73.8	4.04
Nov.	71	79.20	86.3	63.9	11.55
Dec.	61	70.37	76.5	54.9	15.36



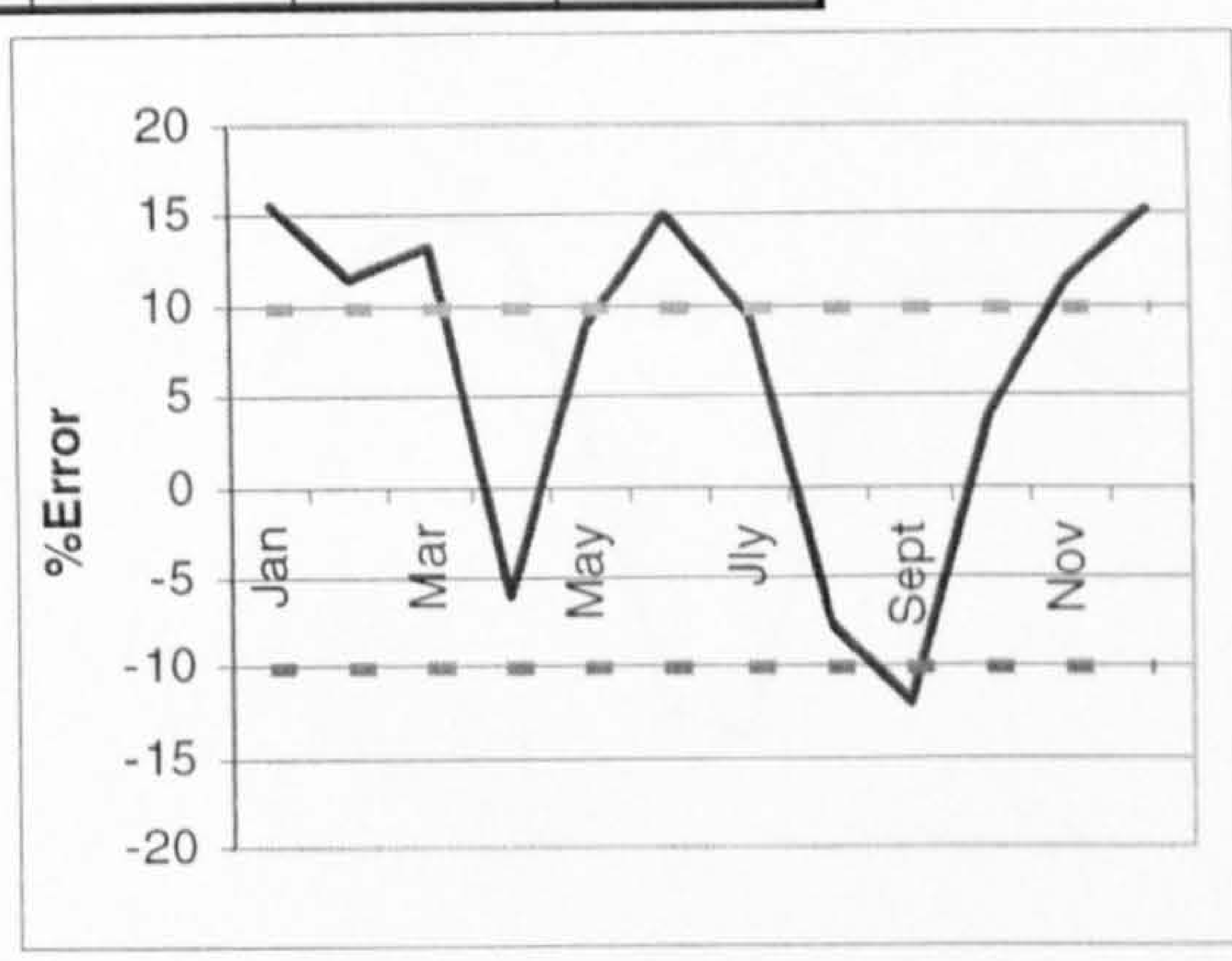
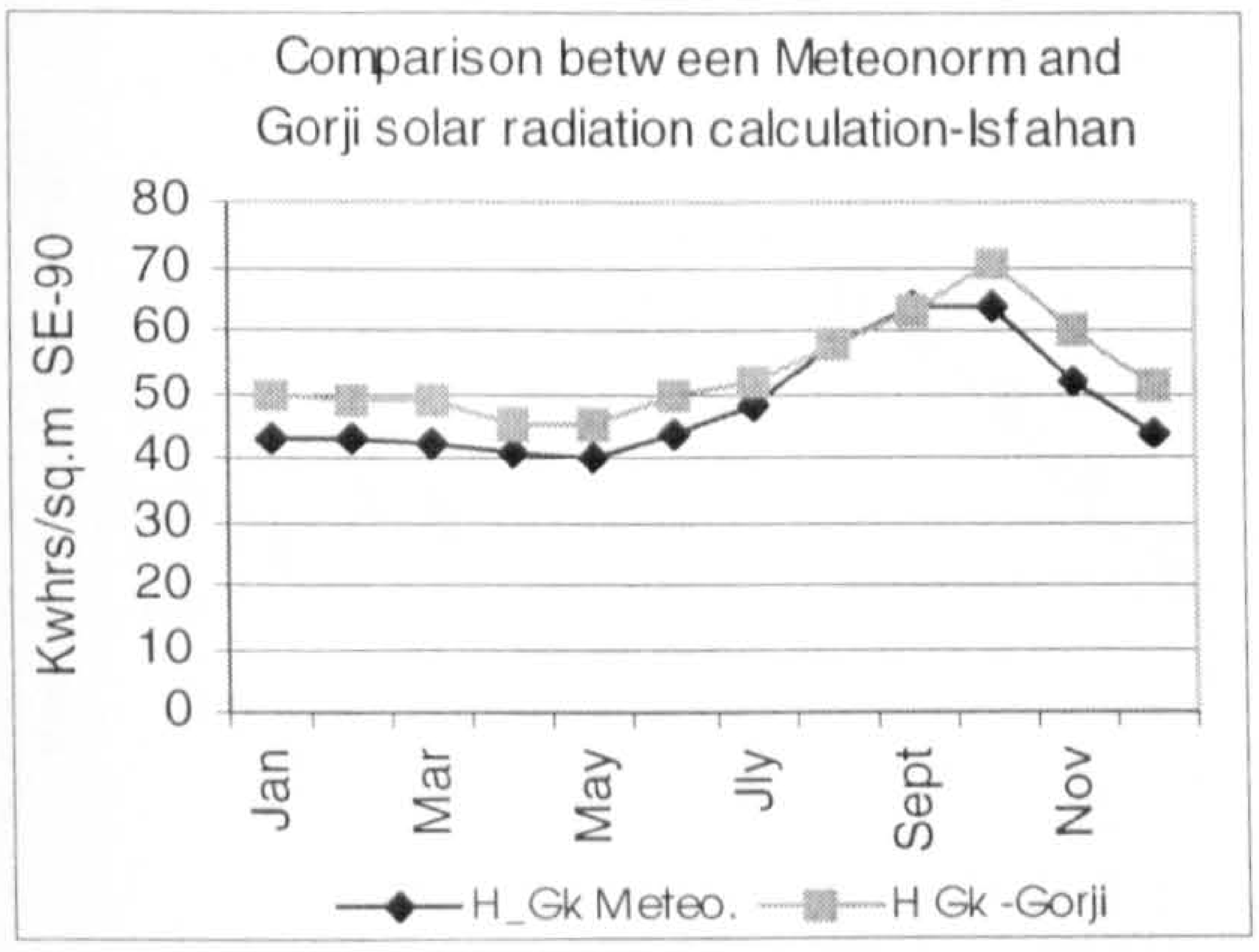


Table and Figures C.19: Comparison between Meteonorm and Gorji solar radiation calculation in south-east surface-Isfahan-Iran Units: Kwhrs/sq.m

SE -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	43	49.91	47.3	38.7	16.07
Feb.	43	48.72	53.0	38.7	13.3
Mar.	42	48.67	52.9	37.8	15.88
Apr.	41	44.88	49.0	36.9	9.46
May	40	44.89	48.9	36	12.22
Jun.	44	49.44	53.8	39.6	12.36
Jly	48	51.58	56.4	43.2	7.47
Aug.	58	58.03	63.8	52.2	0.06
Sept.	64	63.12	69.5	57.6	-1.37
Oct.	64	70.68	77.1	57.6	10.44
Nov.	52	60.00	65.2	46.8	15.38
Dec.	44	51.15	55.6	39.6	16.25



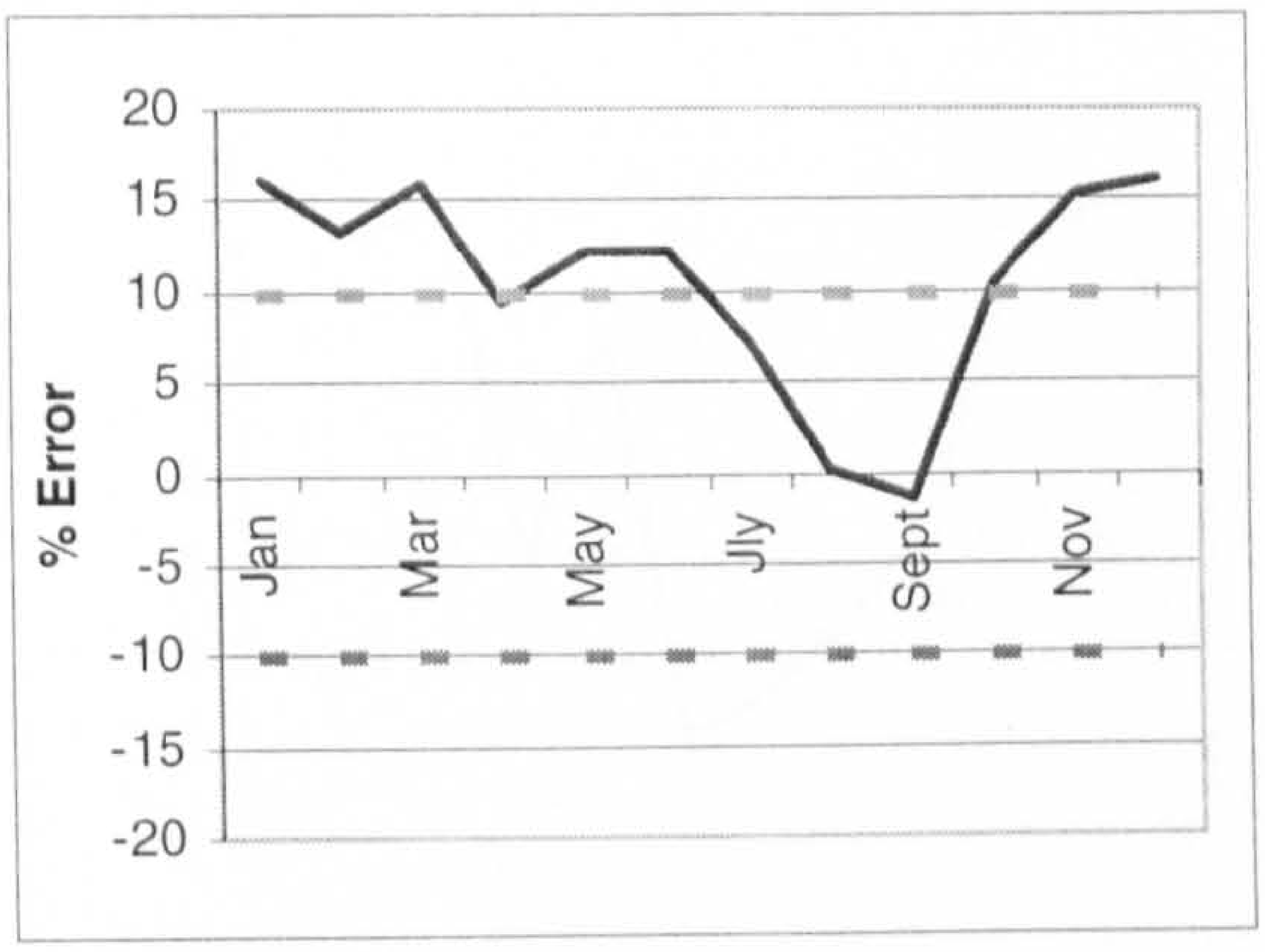
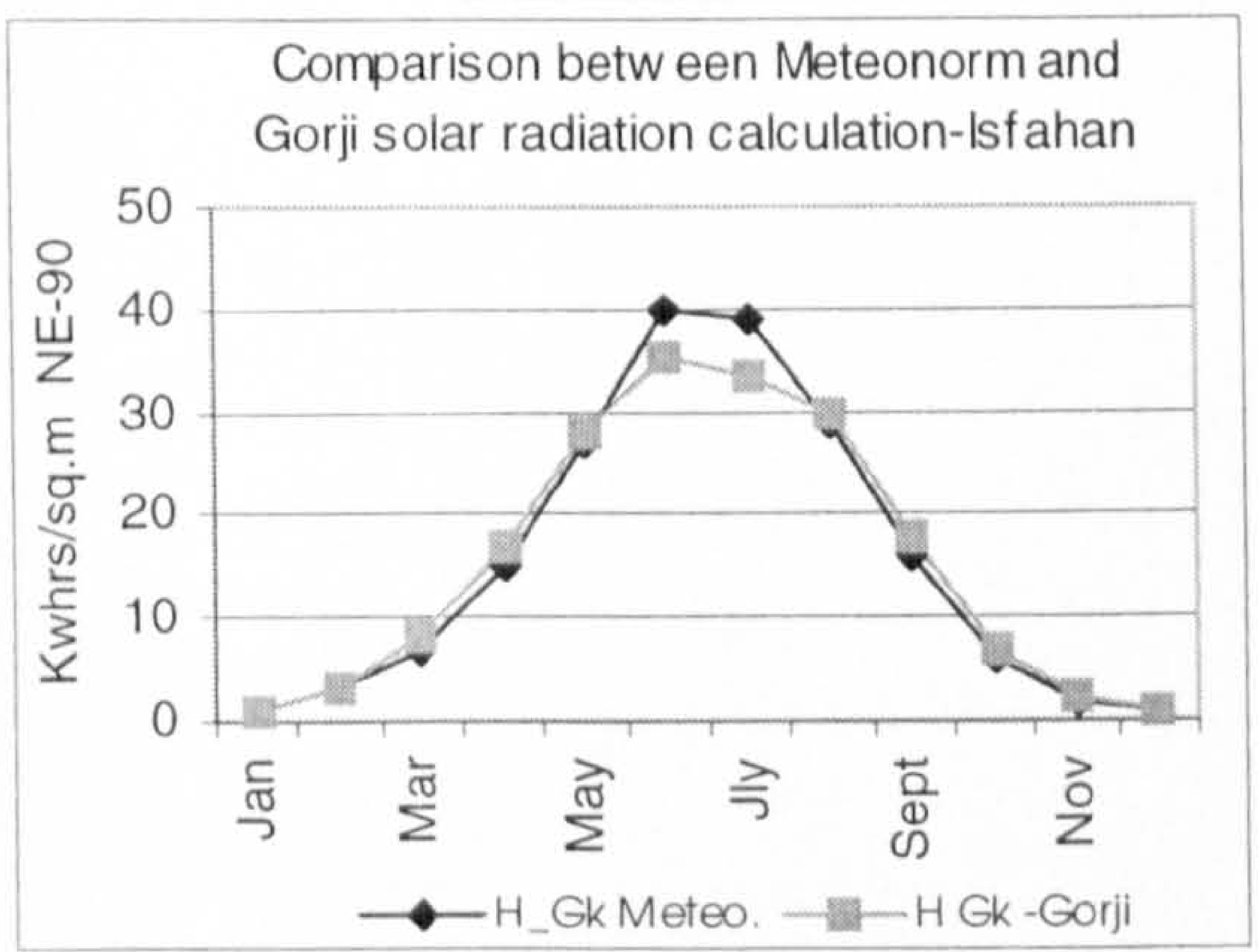


Table and Figures C.20: Comparison between Meteonorm and Gorji solar radiation calculation in north-east surface-Isfahan-Iran Units: Kwhrs/sq.m

NE -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	1	1.07	1.1	0.9	6.64
Feb.	3	3.36	3.7	2.7	12
Mar.	7	8.06	8.8	6.3	15.14
Apr.	15	17.10	18.6	13.5	14
May	27	27.78	30.5	24.3	2.87
Jun.	40	35.10	39.1	36	-12.25
Jly	39	33.48	37.4	35.1	-14.15
Aug.	29	29.76	32.7	26.1	2.62
Sept.	16	17.76	19.4	14.4	11
Oct.	6	6.70	7.3	5.4	11.6
Nov.	2	2.16	2.4	1.8	8
Dec.	1	1.04	1.1	0.9	4.16



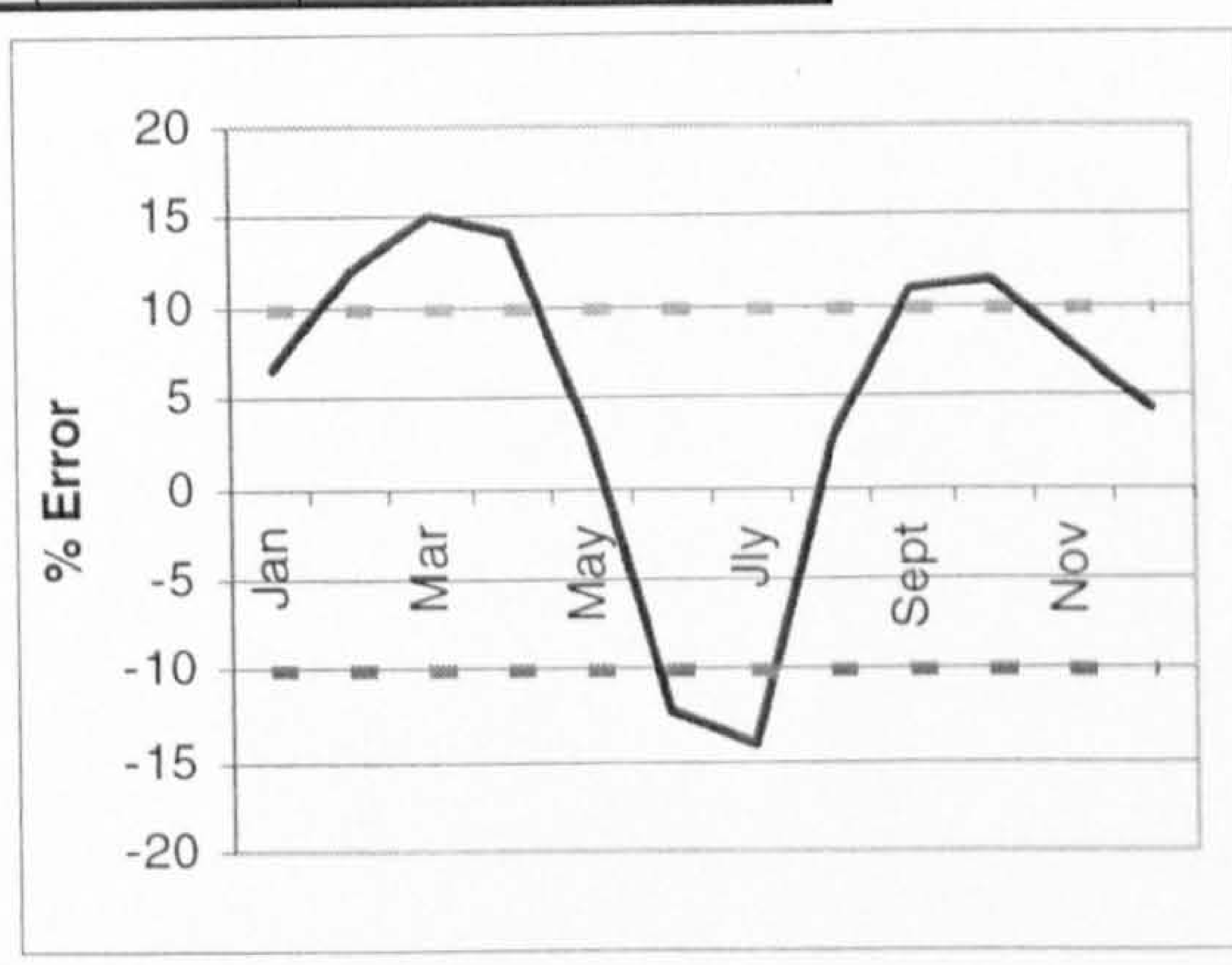
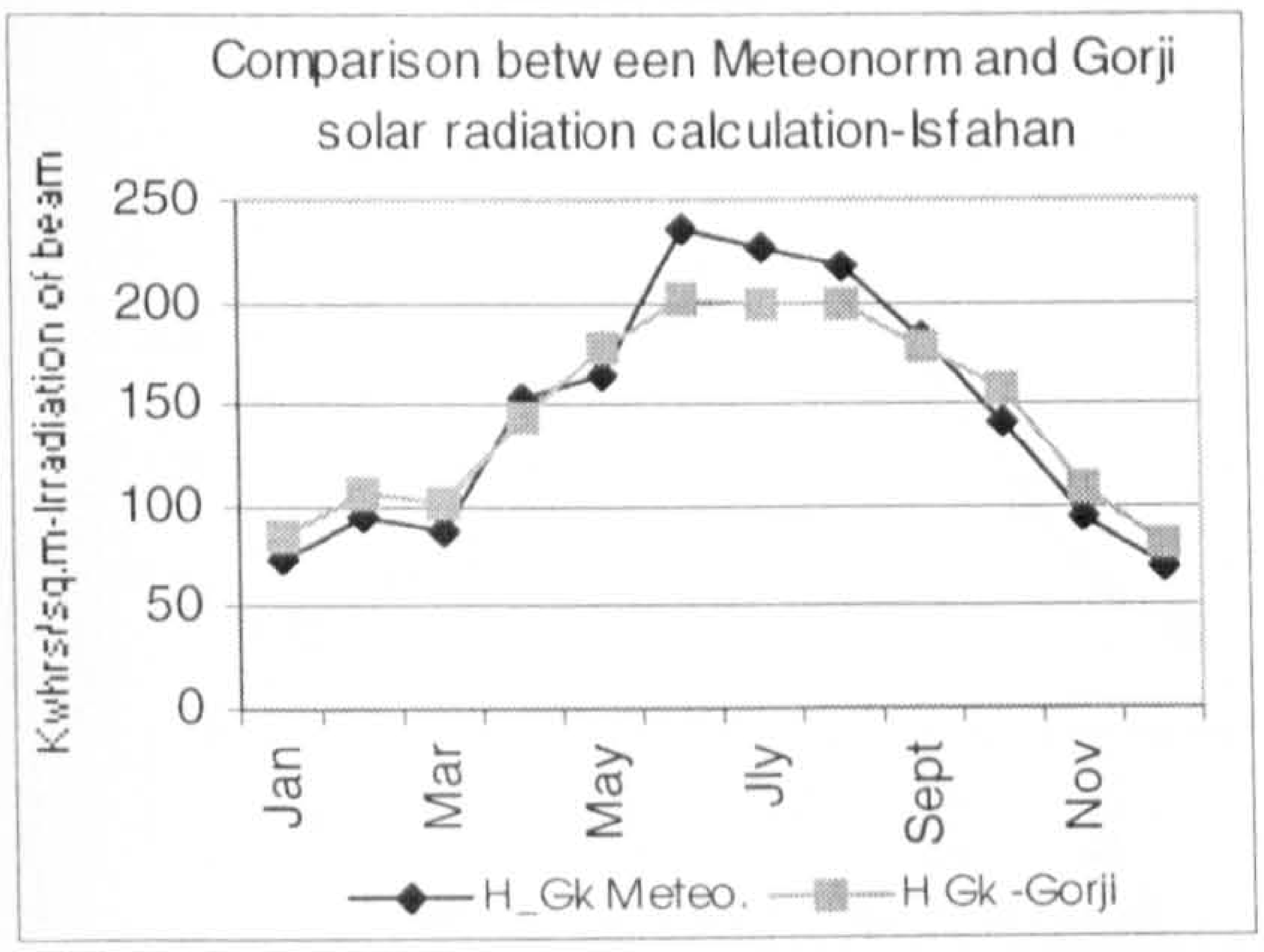


Table and Figures C.21: Comparison between Meteonorm and Gorji solar radiation calculation in irradiation of beam-Isfahan-Iran Units: Kwhrs/sq.m

Irradiation of beam	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	75	86.80	82.5	67.5	15.73
Feb.	94	106.18	115.6	84.6	12.95
Mar.	89	101.99	110.9	80.1	14.6
Apr.	152	144.24	159.4	136.8	-5.11
May	165	178.06	194.6	148.5	7.92
Jun.	237	202.50	226.2	213.3	-14.56
Jly	226	199.14	221.7	203.4	-11.88
Aug.	218	200.14	221.9	196.2	-8.19
Sept.	182	177.36	195.6	163.8	-2.55
Oct.	141	156.49	170.6	126.9	10.98
Nov.	95	108.90	118.4	85.5	14.63
Dec.	70	80.60	87.6	63	15.14



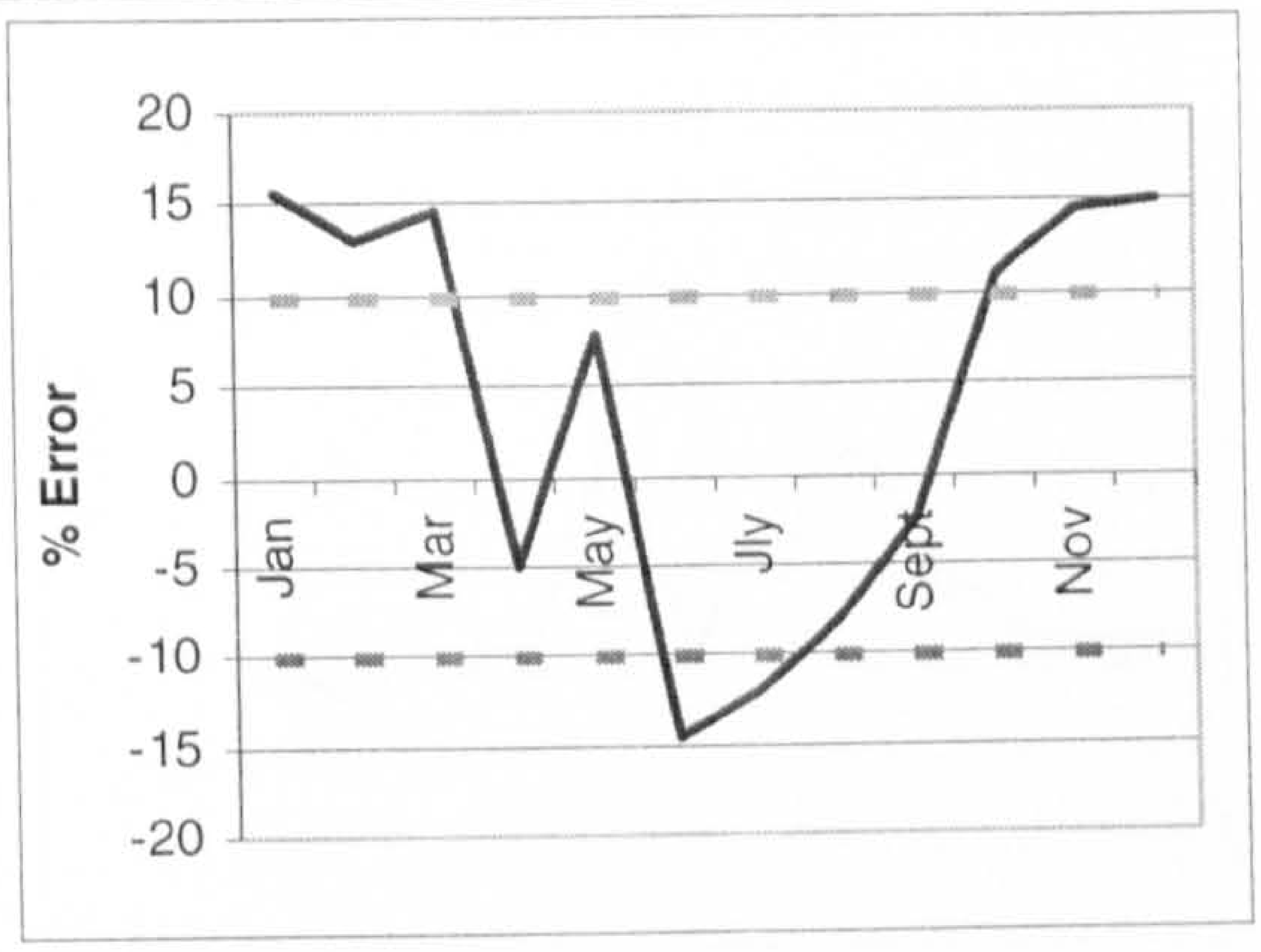
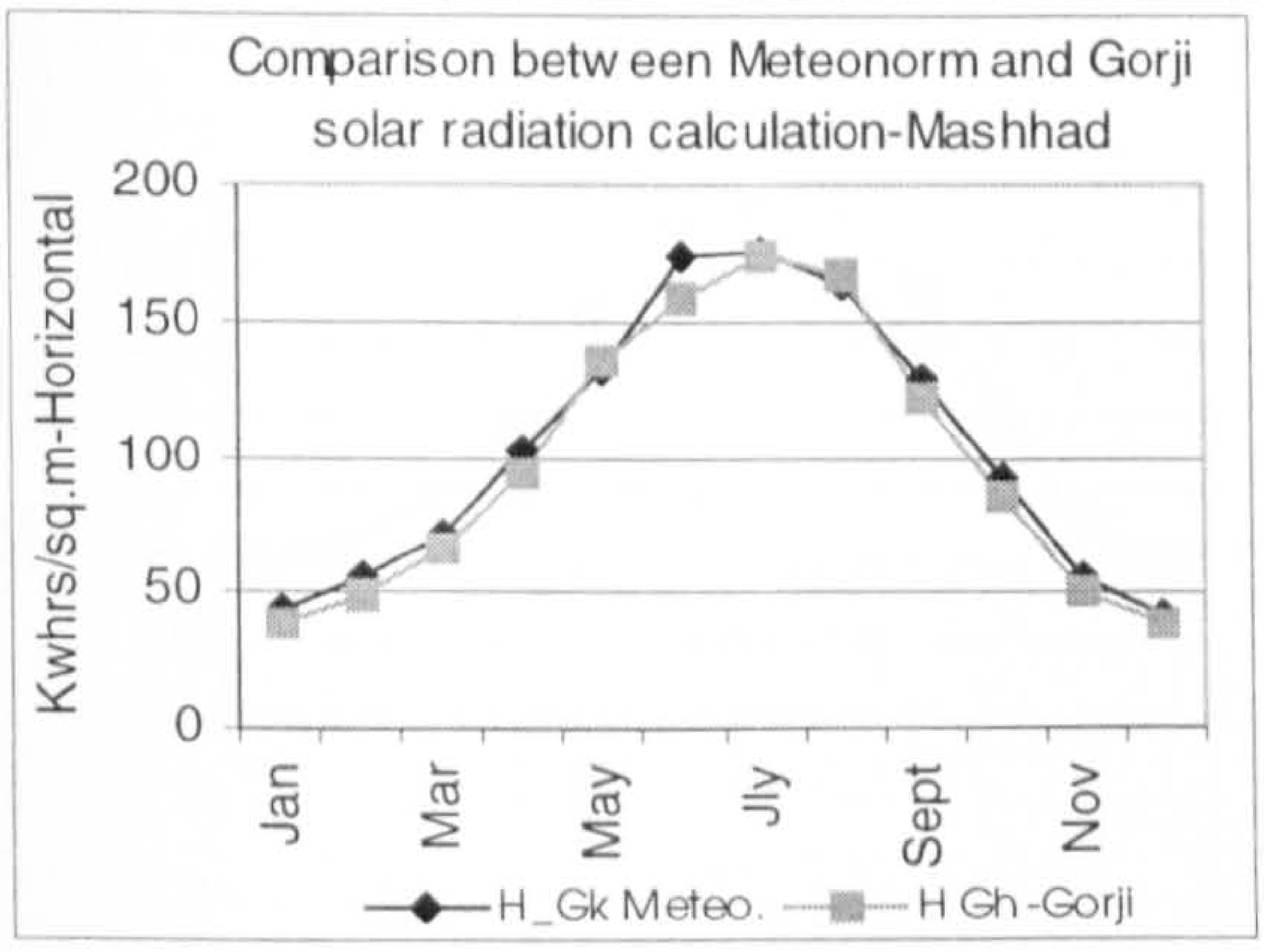


Table and Figures C.22: Comparison between Meteonorm and Gorji solar radiation calculation in horizontal surface-Mashhad-Iran Units: Kwhrs/sq.m

Horizontal	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	43	38.75	47.3	38.7	-9.88
Feb.	56	49.18	54.8	50.4	-12.17
Mar.	72	65.47	72.7	64.8	-9.07
Apr.	103	93.50	103.8	92.7	-9.22
May	132	135.43	148.6	118.8	2.6
Jun.	174	158.01	175.4	156.6	-9.19
Jly	175	173.26	190.8	157.5	-0.99
Aug.	164	167.72	184.1	147.6	2.27
Sept.	128	122.28	135.1	115.2	-4.47
Oct.	93	85.52	94.8	83.7	-8.04
Nov.	56	51.23	56.8	50.4	-8.52
Dec.	41	37.55	41.7	36.9	-8.4



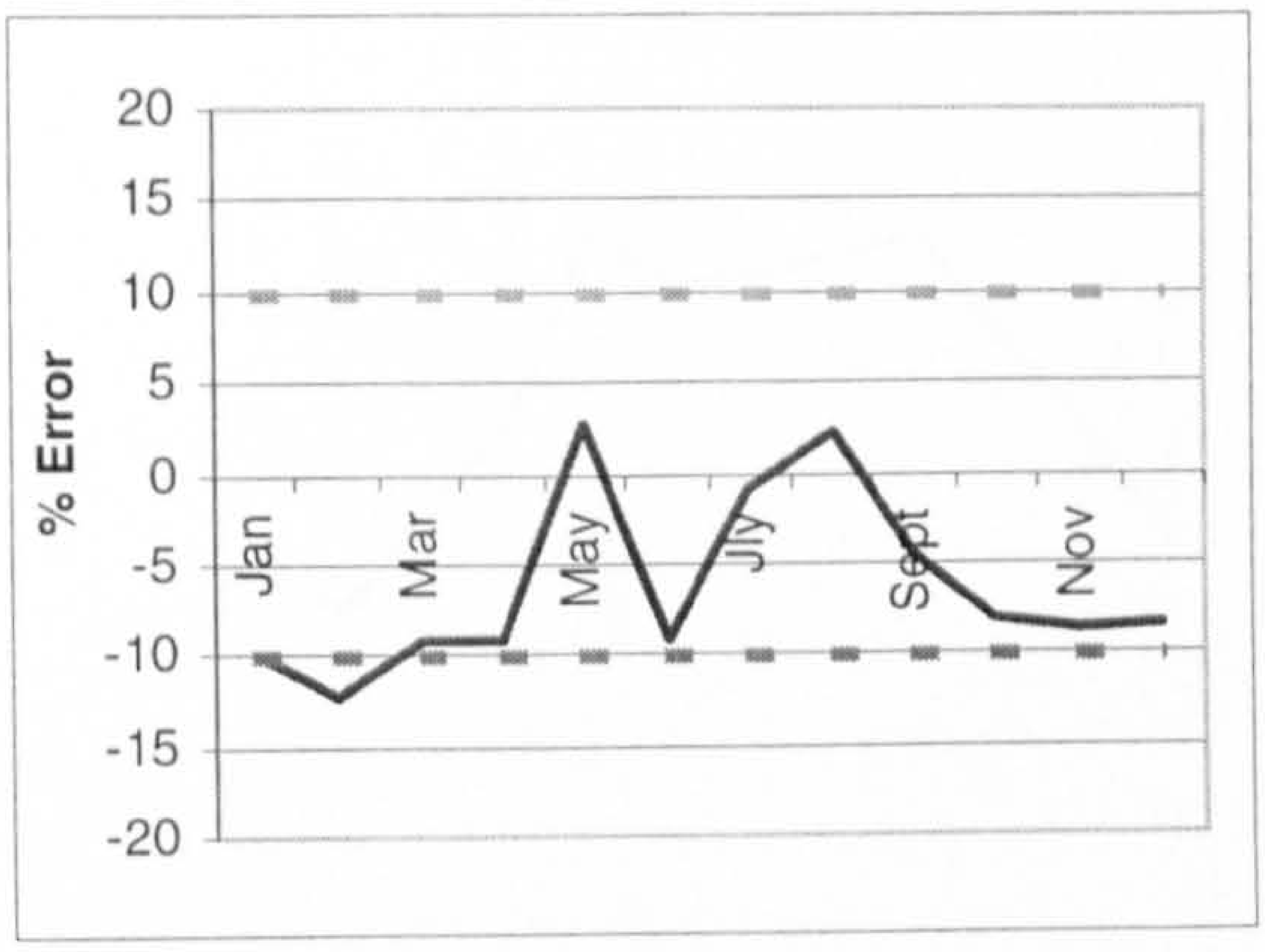
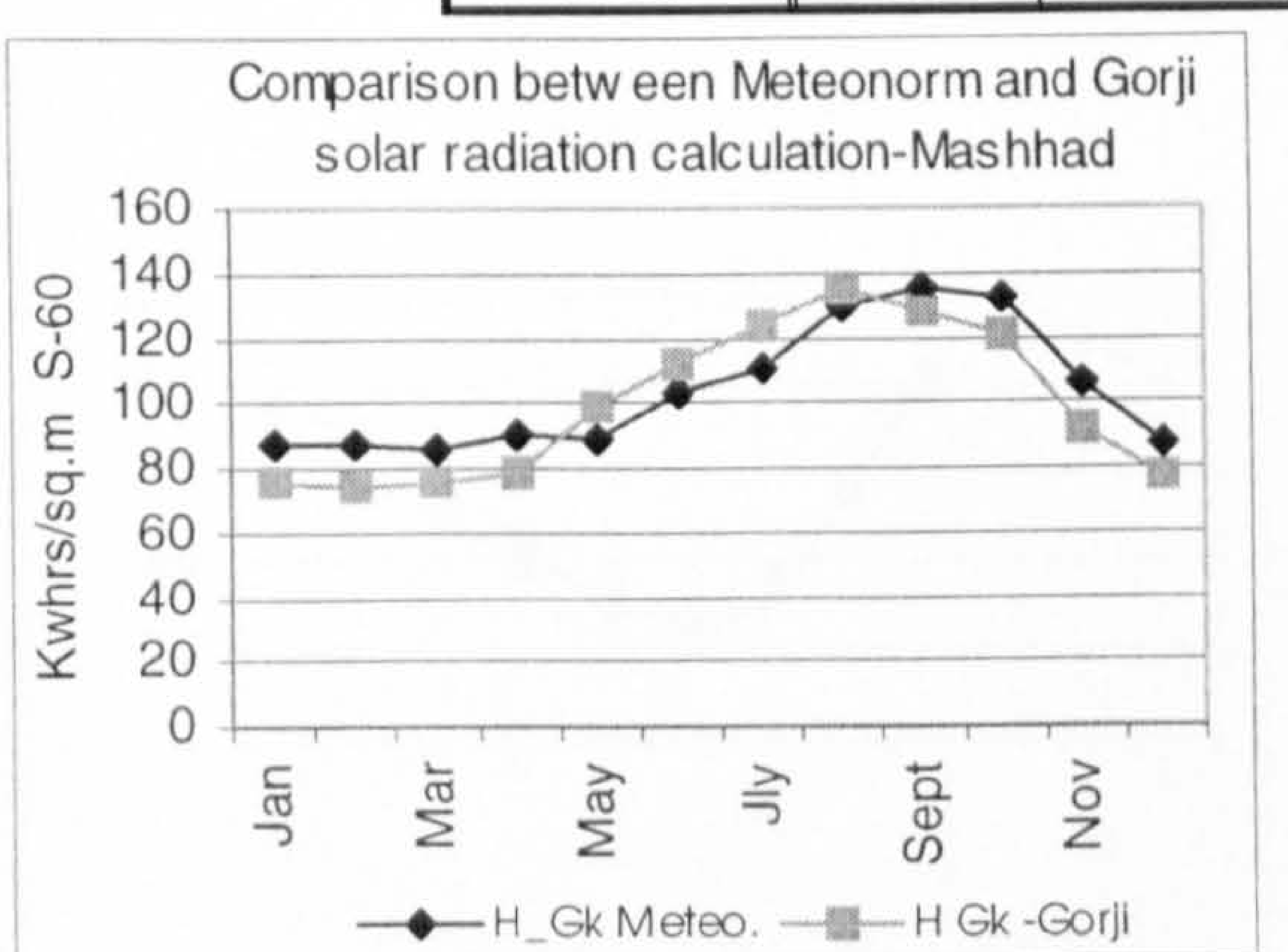


Table and Figures C.23: Comparison between Meteonorm and Gorji solar radiation calculation in south surface-Mashhad-Iran Units: Kwhrs/sq.m

S -60 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	87	76.19	95.7	78.3	-12.43
Feb.	88	74.76	83.6	79.2	-15.05
Mar.	86	75.33	83.9	77.4	-12.41
Apr.	90	78.60	87.6	81	-12.67
May	89	99.36	108.3	80.1	11.64
Jun.	103	111.87	122.2	92.7	8.61
Jly	110	123.93	134.9	99	12.67
Aug.	129	134.88	147.8	116.1	4.56
Sept.	136	127.92	141.5	122.4	-5.94
Oct.	133	120.54	133.8	119.7	-9.37
Nov.	106	91.87	102.5	95.4	-13.33
Dec.	88	77.71	86.5	79.2	-11.69



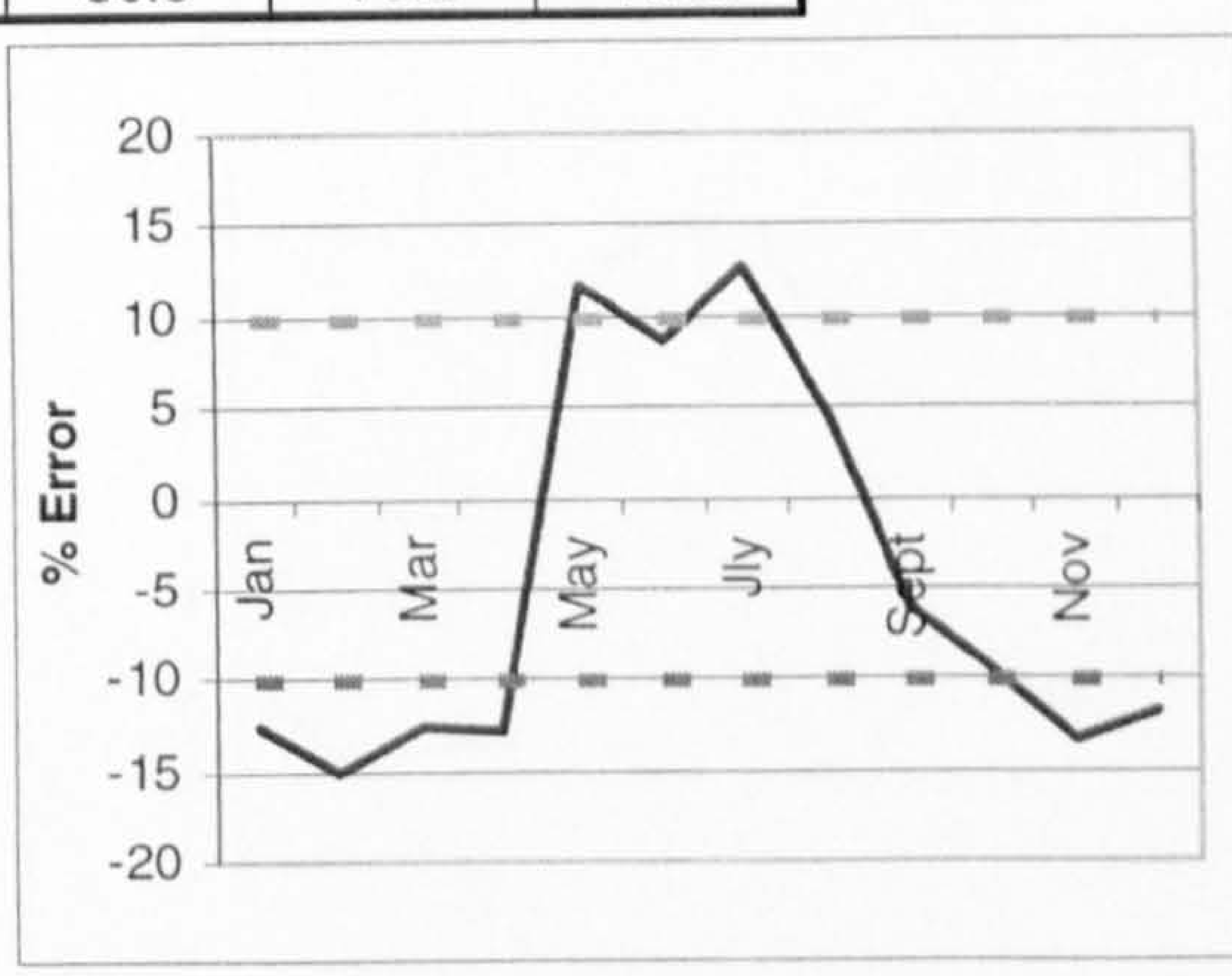
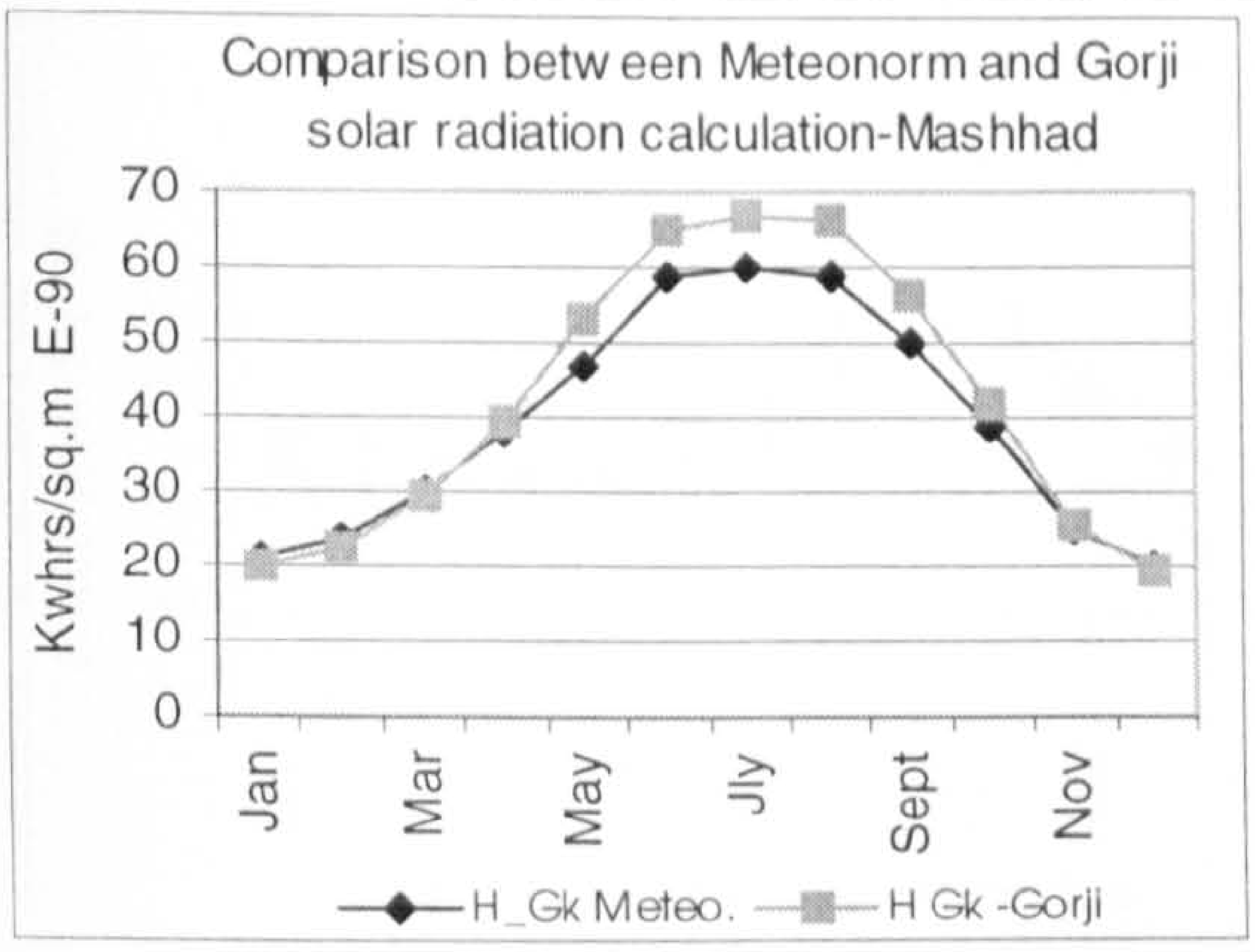


Table and Figures C.24: Comparison between Meteonorm and Gorji solar radiation calculation in east surface-Mashhad-Iran Units: Kwhrs/sq.m

E -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	21	19.90	23.1	18.9	-5.25
Feb.	24	22.23	24.6	21.6	-7.37
Mar.	30	29.44	32.4	27	-1.87
Apr.	38	39.08	42.9	34.2	2.85
May	47	53.32	58.0	42.3	13.45
Jun.	59	65.19	71.1	53.1	10.5
Jly	60	66.65	72.7	54	11.08
Aug.	59	66.03	71.9	53.1	11.92
Sept.	50	56.50	61.5	45	12.99
Oct.	39	41.87	45.8	35.1	7.35
Nov.	25	25.66	28.2	22.5	2.64
Dec.	20	19.24	21.2	18	-3.81



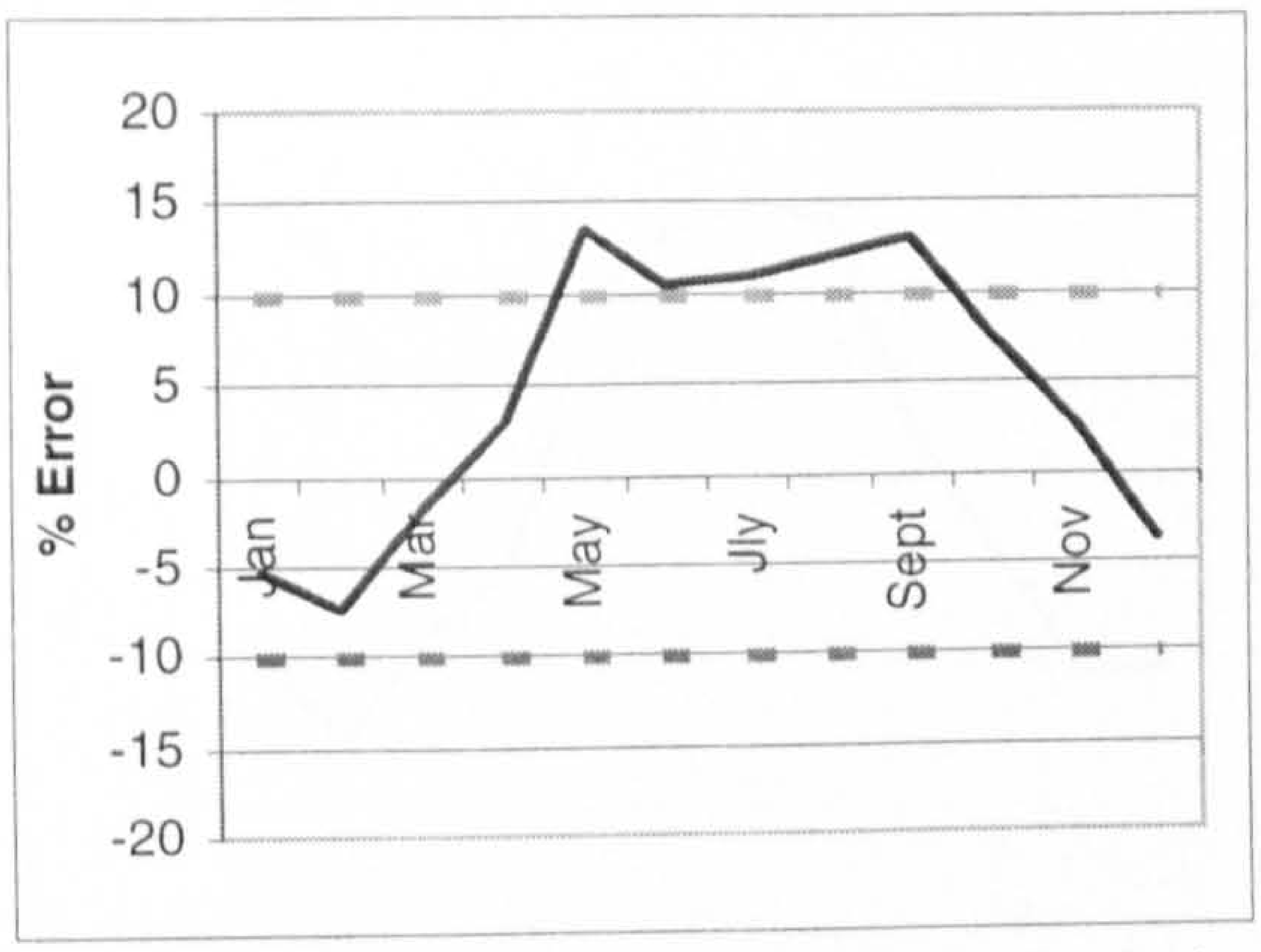
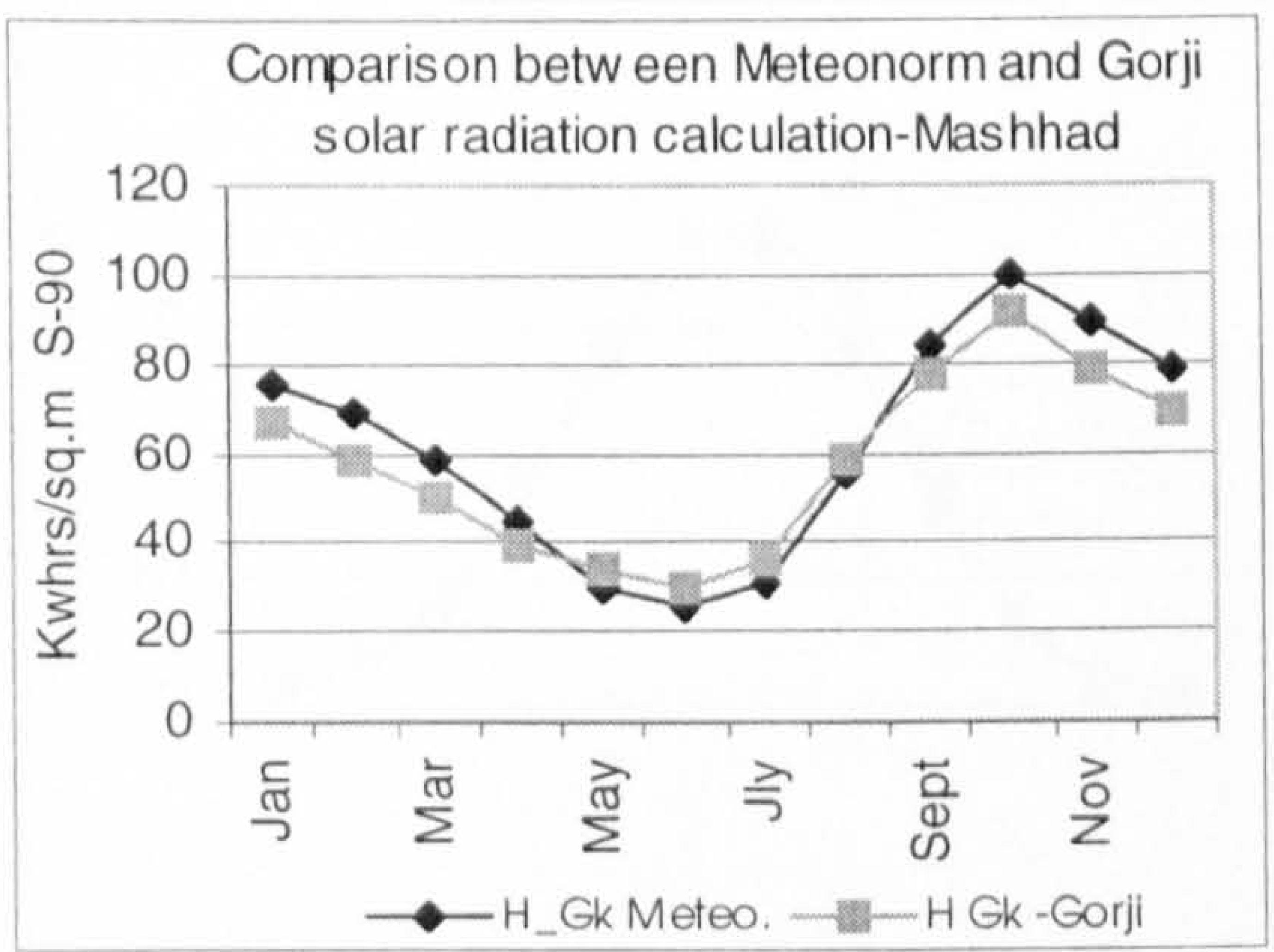


Table and Figures C.25: Comparison between Meteonorm and Gorji solar radiation calculation in south surface-Mashhad-Iran Units: Kwhrs/sq.m

S -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	75	66.52	82.5	67.5	-11.3
Feb.	69	58.52	65.4	62.1	-15.19
Mar.	58	50.22	56.0	52.2	-13.41
Apr.	45	39.00	43.5	40.5	-13.33
May	30	33.79	36.8	27	12.63
Jun.	26	30.00	32.6	23.4	15.38
Jly	31	35.65	38.8	27.9	15
Aug.	55	58.89	64.4	49.5	7.08
Sept.	84	77.09	85.5	75.6	-8.22
Oct.	100	90.87	100.9	90	-9.13
Nov.	89	78.23	87.1	80.1	-12.1
Dec.	79	69.48	77.4	71.1	-12.05



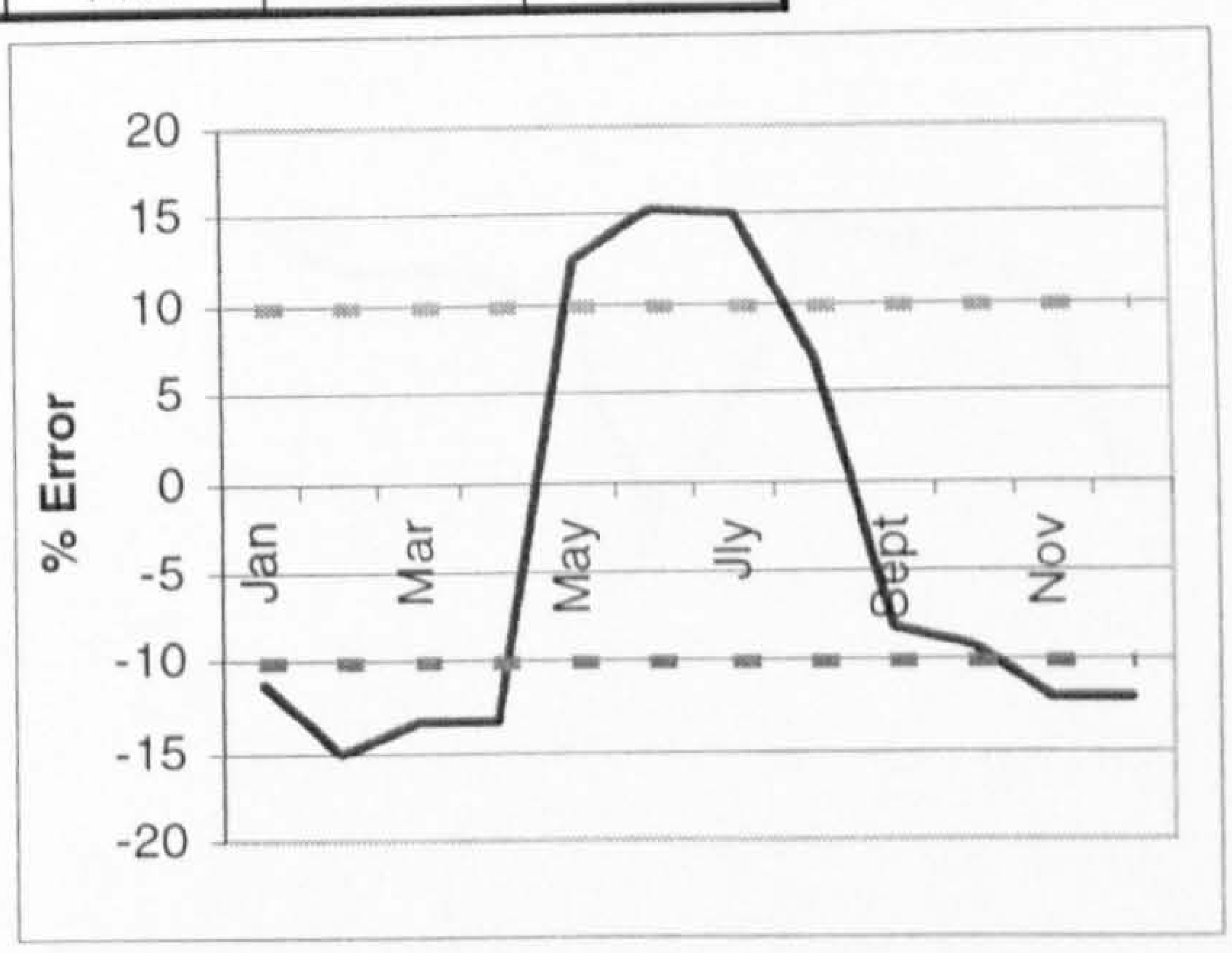
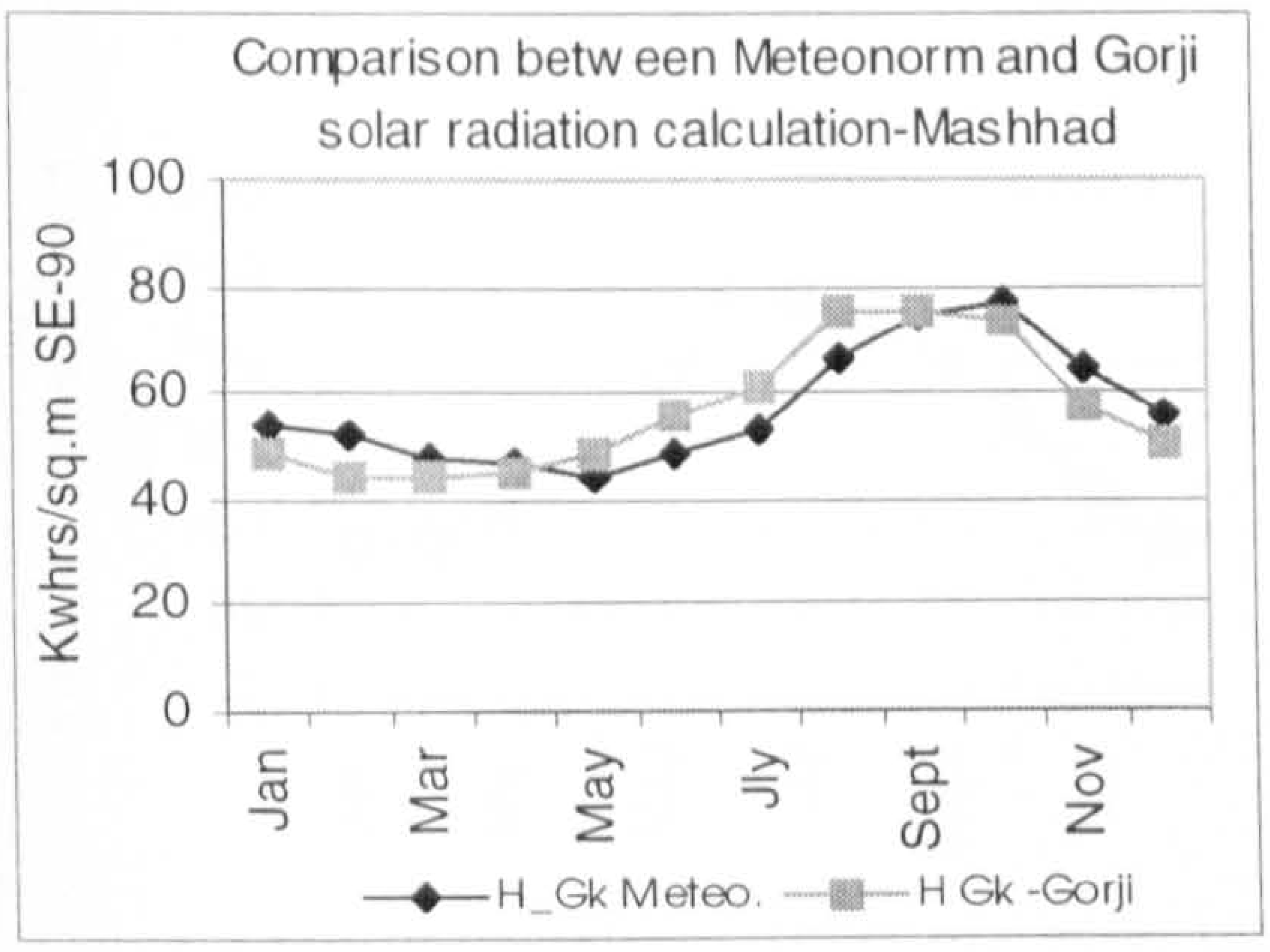


Table and Figures C.26: Comparison between Meteonorm and Gorji solar radiation calculation in south-east surface-Mashhad-Iran Units: Kwhrs/sq.m

SE -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	54	48.40	59.4	48.6	-10.38
Feb.	52	44.52	49.7	46.8	-14.38
Mar.	48	43.86	48.7	43.2	-8.62
Apr.	47	44.70	49.4	42.3	-4.9
May	44	48.36	52.8	39.6	9.91
Jun.	49	55.80	60.7	44.1	13.88
Jly	53	61.07	66.4	47.7	15.23
Aug.	66	75.33	81.9	59.4	14.14
Sept.	74	75.35	82.8	66.6	1.83
Oct.	77	73.54	81.2	69.3	-4.49
Nov.	65	57.87	64.4	58.5	-10.97
Dec.	56	50.07	55.7	50.4	-10.59



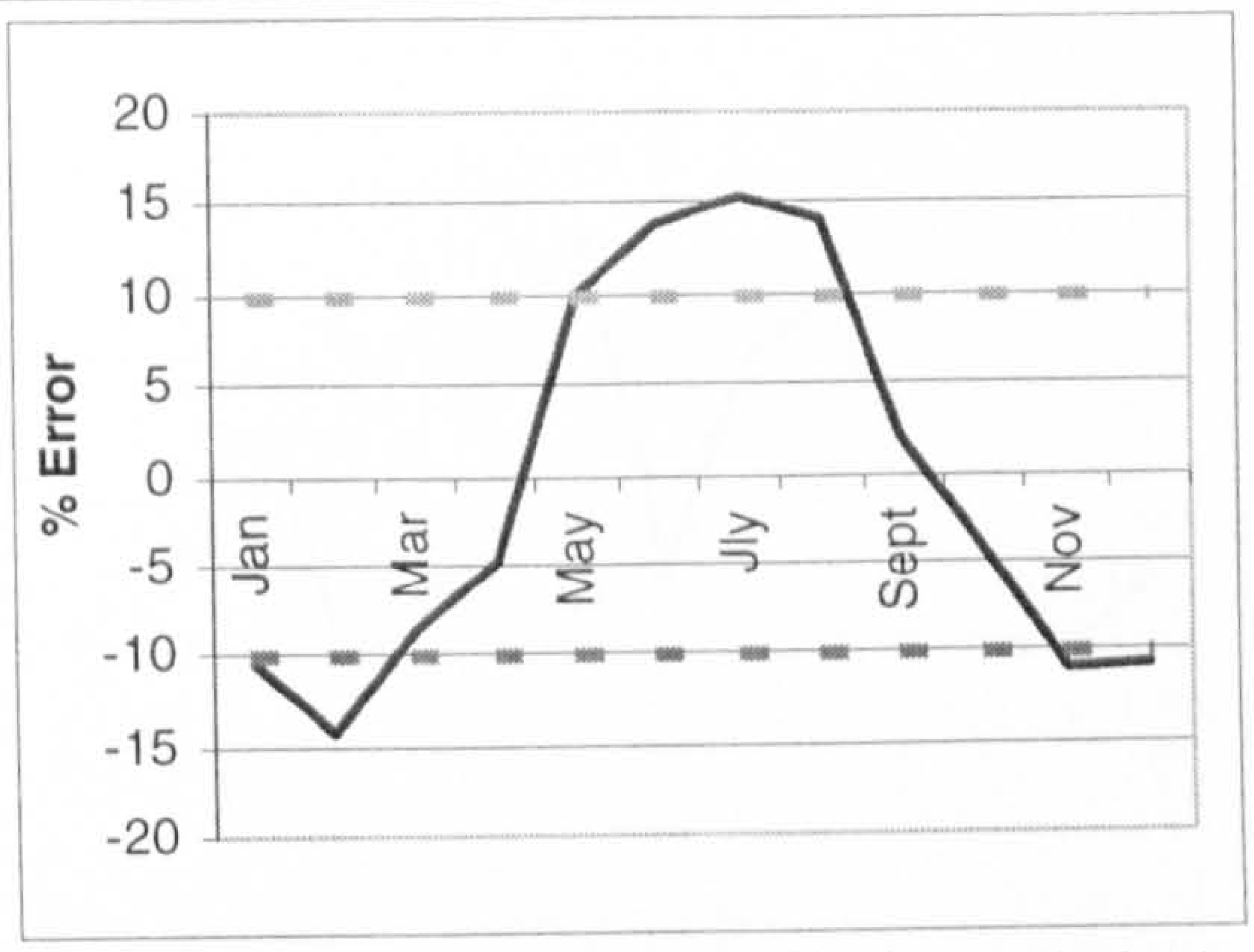
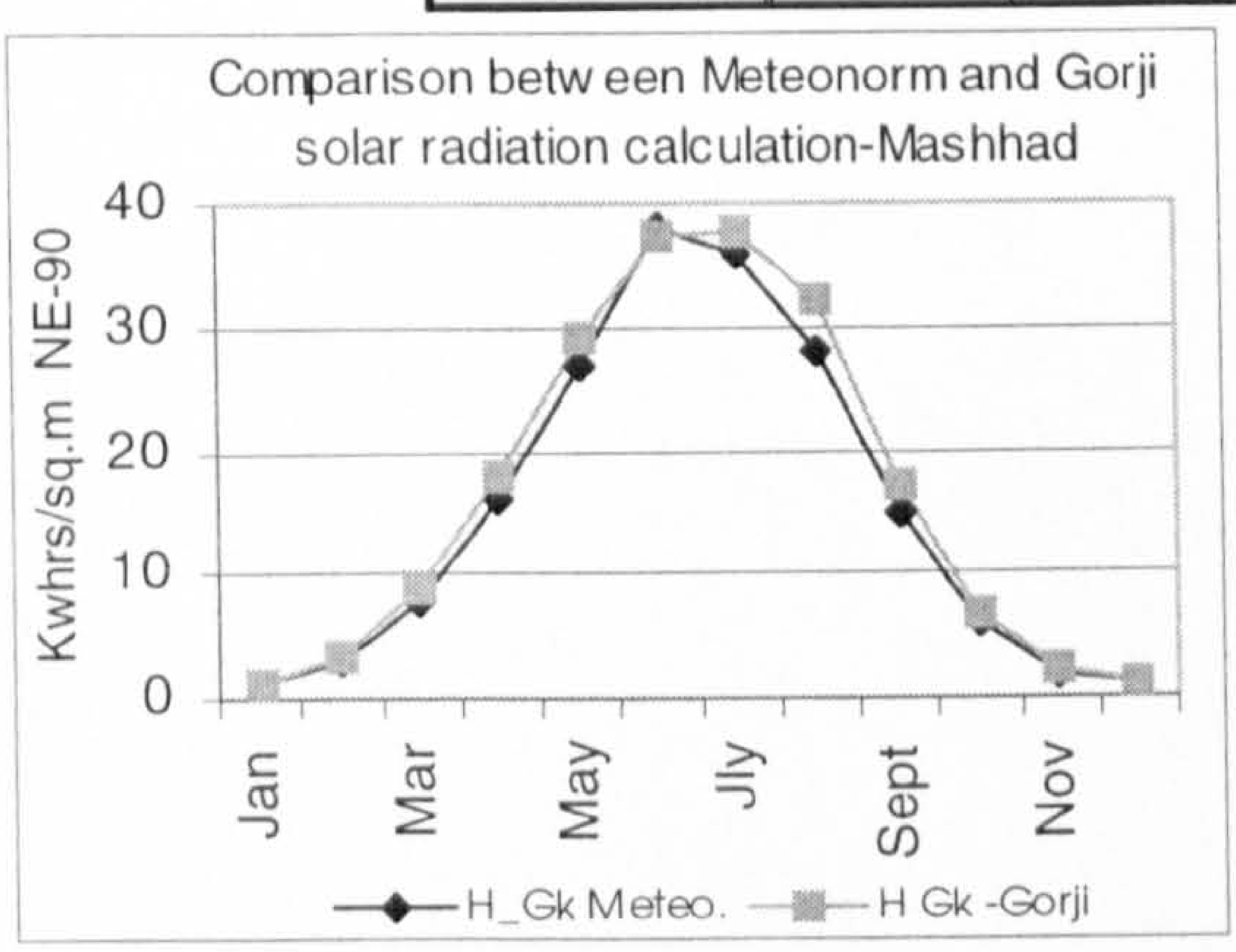


Table and Figures C.27: Comparison between Meteonorm and Gorji solar radiation calculation in north-east surface-Mashhad-Iran Units: Kwhrs/sq.m

NE -90 deg	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	1	1.15	1.1	0.9	14.7
Feb.	3	3.36	3.7	2.7	12.15
Mar.	8	8.98	9.8	7.2	12.24
Apr.	16	17.87	19.5	14.4	11.68
May	27	29.32	32.0	24.3	8.58
Jun.	38	37.20	41.0	34.2	-2.11
Jly	36	37.64	41.2	32.4	4.55
Aug.	28	32.24	35.0	25.2	15.14
Sept.	15	17.10	18.6	13.5	14
Oct.	6	6.76	7.4	5.4	12.67
Nov.	2	2.22	2.4	1.8	11.17
Dec.	1	0.99	1.1	0.9	-0.8



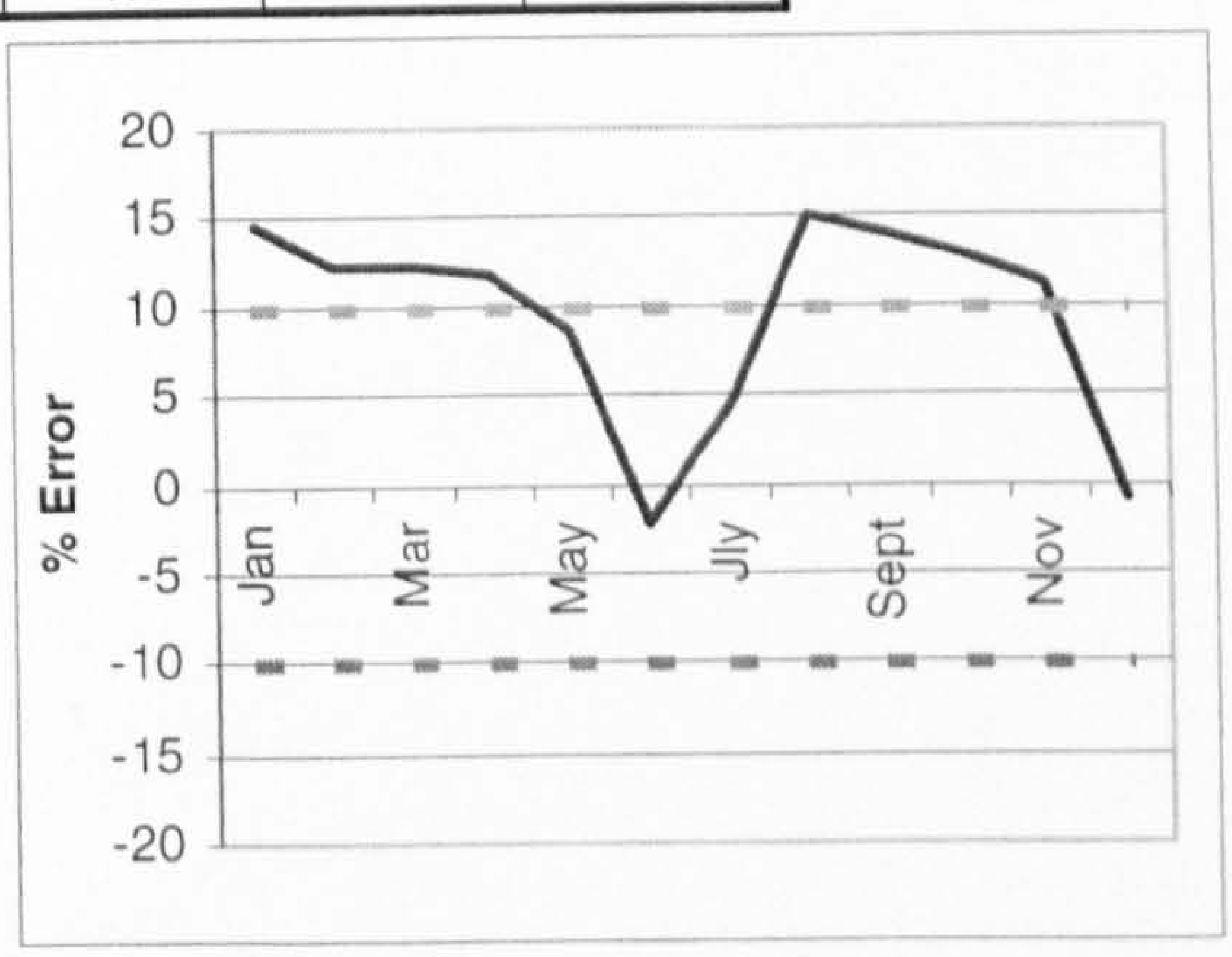
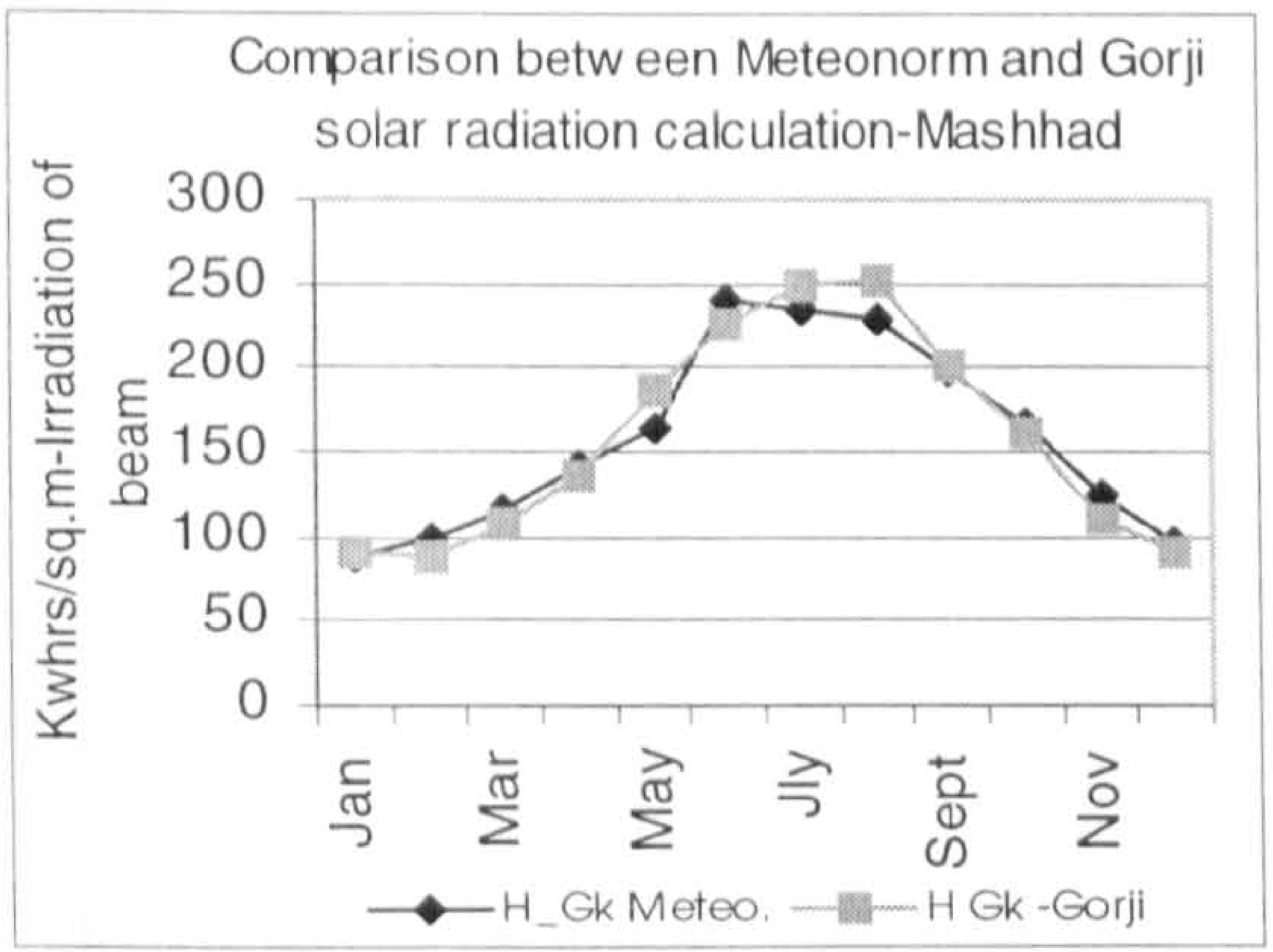
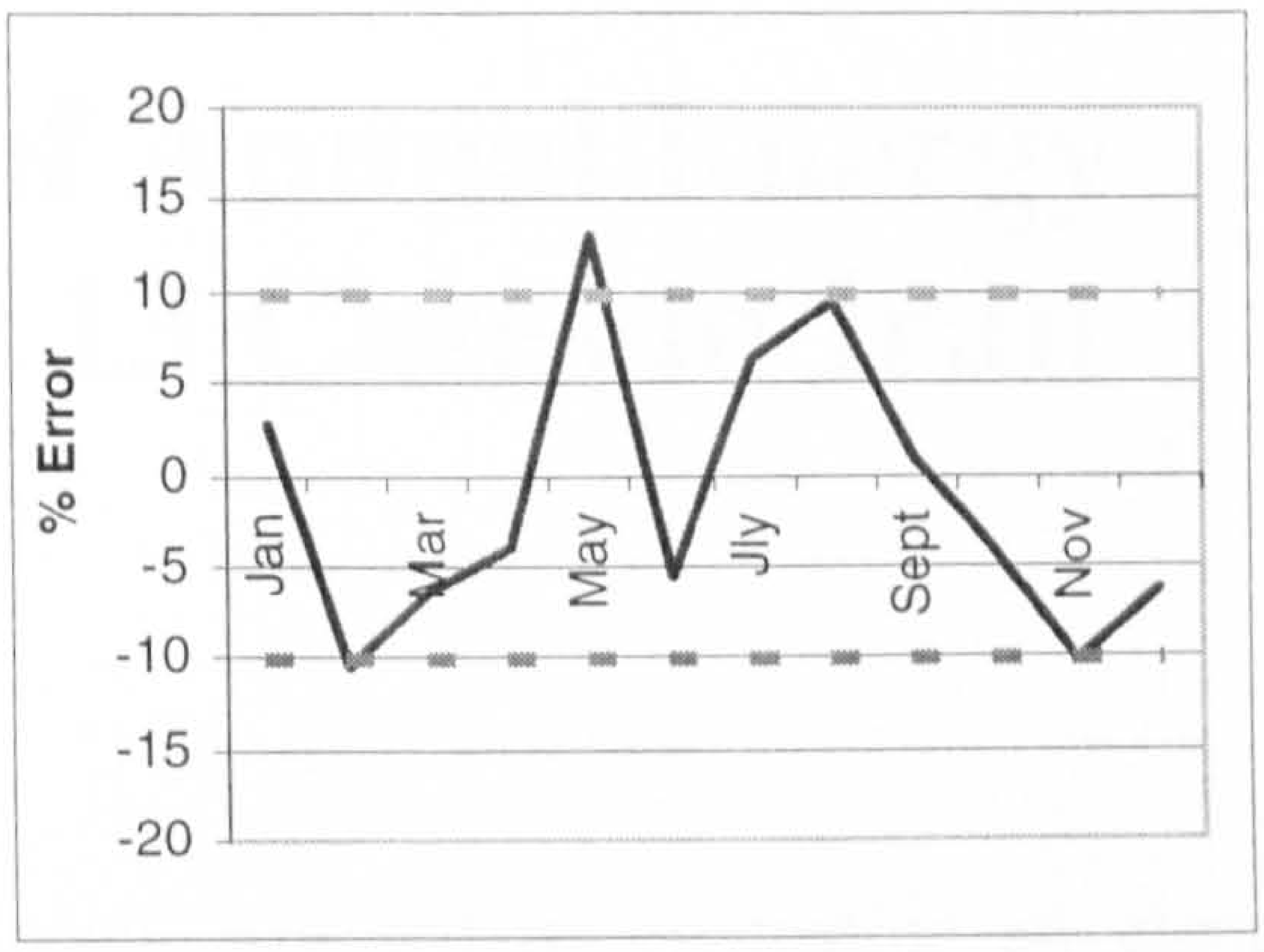


Table and Figures C.28: Comparison between Meteonorm and Gorji solar radiation calculation in irradiation of beam-Mashhad-Iran Units: Kwhrs/sq.m

Irradiation of beam	H-Gh Meteo.	H-Gh Gorji	+10% Error	-10% Error	Actual Error %
Jan.	88	90.35	96.8	79.2	2.67
Feb.	99	88.69	98.6	89.1	-10.41
Mar.	115	107.70	119.2	103.5	-6.35
Apr.	141	135.48	149.6	126.9	-3.92
May	164	185.38	201.8	147.6	13.04
Jun.	241	227.79	251.9	216.9	-5.48
Jly	235	249.93	273.4	211.5	6.35
Aug.	230	251.39	274.4	207	9.3
Sept.	199	200.97	220.9	179.1	0.99
Oct.	168	160.93	177.7	151.2	-4.21
Nov.	124	111.37	123.8	111.6	-10.19
Dec.	97	90.82	100.5	87.3	-6.38





Appendix C

The Calculation of Annual Energy Consumption for 13 Cases in Iran

In order to examine the effect of window size and its orientation on energy demands of spaces, 13 schools are considered. It is assumed that there is no heat flow through internal partitions. Window design of these schools is changed. Different areas of glazing are obtained by changing the window width whilst keeping the height at a constant 1.5 metres.

In all cases windows are located centrally on the external walls with a constant windowsill height of 1.20 metres. The occupancy is assumed zero in all schools.

By changing the width of windows different glazing ratios of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 percent are obtained respectively.

The values of annual energy used for heating, cooling and lighting are calculated by using dynamic separate excel sheet program designed by myself. In this calculation all actual characteristics of each case such as, azimuth angle of building, materials of the roof and walls and the type of window and glazing ratio have not been changed. The scenario 1 (equation 7.8, chapter 7) has been applied for the analysis of the cost of fenestration.

Table C.1: The calculated annual energy consumption
(School No. 1 with single glazing windows)

School No 1	Kwhrs	Glazing ratio % 0	5	10	15	20	25	30	35	40	45	50
North	Heating	137454	138834	140196	141486	142896	144366	145872	147432	149028	150600	152178
	Cooling	5136	5610	6108	6564	7062	7518	8016	8496	8952	9450	9930
	Lighting	77748	75804	70626	69300	68022	67380	65412	64746	62778	58206	52326
	Total	220338	220248	216930	217350	217980	219264	219300	220674	220758	218256	214434
South	Heating	109092	102282	96030	90360	85650	81948	79032	77484	76818	76842	77334
	Cooling	4680	5640	6618	7578	8538	9522	10464	11436	12402	13362	14340
	Lighting	65382	33786	22350	18570	17460	15822	15822	14184	13104	13104	11454
	Total	179154	141708	124998	116508	111648	107292	105318	103104	102324	103308	103128
West	Heating	37966	36772	35856	35020	34440	34018	33742	33568	33536	33600	33792
	Cooling	1602	2254	2906	3558	4210	4862	5518	6172	6816	7474	8126
	Lighting	22382	13062	11388	10828	10070	10070	9898	9516	8956	8390	7090
	Total	61950	52088	50150	49406	48720	48950	49158	49256	49308	49464	49008
East	Heating	38820	38064	37542	37160	36896	36830	36822	36812	36858	36948	37036
	Cooling	1584	1664	1736	1814	1892	1970	2050	2092	2206	2284	2364
	Lighting	22382	17734	15112	14928	14368	14368	13622	12896	11222	10094	7490
	Total	62786	57462	54390	53902	53156	53168	52494	51800	50286	49326	46890
Total		524228	471506	446468	437166	431504	428674	426270	424834	422676	420354	413460

Table C.2: The calculated annual energy consumption
(School No. 2 with single glazing windows)

School No 2	Kwhrs	Glazing ratio % 0	5	10	15	20	25	30	35	40	45	50
North	Heating	12880	13061	13236	13417	13595	13779	13955	14139	14321	14517	14704
	Cooling	487	518	554	585	615	649	680	710	747	778	811
	Lighting	7363	7302	6871	6810	6688	6565	6502	6502	6196	6010	5514
	Total	20730	20881	20661	20812	20898	20993	21137	21351	21264	21305	21029
South	Heating	23906	22467	21141	19949	18959	18152	17551	17225	17081	17108	17196
	Cooling	1022	1258	1490	1726	1962	2195	2430	2663	2899	3131	3367
	Lighting	14431	6977	4330	3730	3492	3254	3012	2782	2536	2055	2055
	Total	39359	30702	26961	25405	24413	23601	22993	22670	22516	22294	22618
West	Heating	6468	6311	6197	6088	6026	5982	5959	5957	5965	5992	6032
	Cooling	272	382	488	601	707	817	924	1033	1143	1253	1359
	Lighting	3828	2328	2076	1948	1819	1819	1819	1819	1819	1660	1532
	Total	10568	9021	8761	8637	8552	8618	8702	8809	8927	8905	8923
East	Heating	6546	6403	6312	6243	6200	6198	6189	6198	6206	6234	6263
	Cooling	269	284	302	314	332	347	362	377	395	407	426
	Lighting	3828	2968	2585	2456	2395	2298	2298	2267	2109	2076	1694
	Total	10643	9655	9199	9013	8927	8843	8849	8842	8710	8717	8383
Total		81300	70259	65582	63867	62790	62055	61681	61672	61417	61221	60953

Table C.3: The calculated annual energy consumption
(School No. 3 with single glazing windows)

School No 3	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	36512	36868	37216	37566	37928	38326	38724	39112	39516	39920	40338
	Cooling	1360	1386	1422	1452	1482	1520	1510	1580	1616	1648	1678
	Lighting	20616	20616	20100	19408	19238	19068	18552	18206	17860	17174	15432
	Total	58488	58870	58738	58426	58648	58914	58786	58898	58992	58742	57448
South	Heating	57870	54376	51202	48352	45988	44016	42564	41590	41232	41228	41290
	Cooling	2468	3218	3976	4726	5478	6236	6986	7738	8488	9246	9996
	Lighting	34752	16898	10120	8706	8124	7264	6394	5810	4950	4654	3498
	Total	95090	74492	65298	61784	59590	57516	55944	55138	54670	55128	54784
West	Heating	42588	41924	41510	41138	40874	40728	40668	40724	40798	40904	41066
	Cooling	1748	2340	2938	3536	4128	4732	5330	5922	6518	7116	7708
	Lighting	24738	17112	14654	14232	14028	13818	13818	13008	10320	9280	8470
	Total	69074	61376	59102	58906	59030	59278	59816	59654	57636	57300	57244
East	Heating	42242	40614	39330	38390	37754	37202	36828	36566	36404	36362	36444
	Cooling	1790	1942	2092	2236	2388	2532	2682	2828	2972	3122	3274
	Lighting	24738	15662	15056	13410	12994	12790	12790	12172	10946	9096	7844
	Total	68770	58218	56478	54036	53136	52524	52300	51566	50322	48580	47562
Total		291422	252956	239616	233152	230404	228232	226846	225256	221620	219750	217038

Table C.4: The calculated annual energy consumption
(School No. 4 with single glazing windows)

School No 4	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	14838	14992	15173	15364	15557	15757	15965	16183	16388	16603	16821
	Cooling	2214	2260	2312	2364	2413	2462	2511	2560	2612	2664	2713
	Lighting	11486	11293	10816	10525	10431	10336	10048	9852	9375	8791	8023
	Total	28538	28545	28301	28253	28401	28555	28524	28595	28375	28058	27557
South	Heating	28496	26642	25040	23872	23104	22766	22680	22700	22784	22958	23208
	Cooling	4774	5912	7062	8214	9358	10508	11652	12796	13948	15098	16248
	Lighting	23560	11774	7860	6492	5902	5508	5312	4522	3934	3538	2948
	Total	56830	44328	39962	38578	38364	38782	39644	40018	40666	41594	42404
West	Heating	10413	10368	10317	10314	10324	10357	10417	10488	10563	10645	10735
	Cooling	1650	1976	2302	2628	2951	3277	3600	3929	4252	4578	4903
	Lighting	8246	6116	5361	5087	4948	4885	4814	4334	3919	3304	2481
	Total	20309	18460	17980	18029	18223	18519	18831	18751	18734	18527	18119
East	Heating	11650	11090	10689	10346	10089	9942	9841	9801	9853	9958	10063
	Cooling	1921	2116	2308	2500	2699	2890	3086	3278	3473	3664	3862
	Lighting	9424	5813	5031	4950	4873	4631	4554	4323	4007	3691	3147
	Total	22995	19019	18028	17796	17661	17463	17481	17402	17333	17313	17072
Total		128672	110352	104271	102656	102649	103319	104480	104766	105108	105492	105152

Table C.5: The calculated annual energy consumption
(School No. 5 with single glazing windows)

School No 5	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	46122	46344	46664	47040	47428	47838	48292	48738	49216	49698	50188
	Cooling	6852	7012	7176	7342	7502	7668	7838	8004	8156	8328	8488
	Lighting	35340	34156	32094	30910	30910	30336	29742	28858	27692	25602	22996
	Total	88314	87512	85934	85292	85840	85842	85872	85600	85064	83628	81672
South	Heating	60220	56368	53108	50684	49088	48412	48236	48272	48408	48688	49140
	Cooling	10060	12580	15100	17608	20128	22648	25168	27704	30224	32732	35252
	Lighting	49476	25568	17336	15252	12788	12408	10748	9496	8668	7852	7852
	Total	119756	94516	85544	83544	82004	83468	84152	85472	87300	89272	92244
West	Heating	15078	15020	14960	14944	14952	14978	15036	15098	15178	15274	15366
	Cooling	2344	2766	3186	3606	4020	4434	4848	5270	5684	6098	6518
	Lighting	11780	9616	8058	7662	7368	7368	7270	6778	6100	5012	4230
	Total	29202	27402	26204	26212	26340	26780	27154	27146	26962	26384	26114
East	Heating	14614	13792	13164	12610	12226	11966	11796	11752	11810	11912	12044
	Cooling	2436	2692	2948	3210	3466	3734	3978	4240	4508	4764	5020
	Lighting	11780	7368	6288	5702	5500	5500	5400	5400	5206	4520	4028
	Total	28830	23852	22400	21522	21192	21200	21174	21392	21524	21196	21092
Total		266102	233282	220082	216570	215376	217290	218352	219610	220850	220480	221122

Table C.6: The calculated annual energy consumption
(School No. 6 with single glazing windows)

School No 6	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	19196	19474	19746	20032	20322	20626	20924	21214	21518	21802	22106
	Cooling	5292	5638	5980	6316	6652	6992	7340	7676	8018	8360	8702
	Lighting	18848	17744	16646	15858	15696	15396	15236	14914	14298	13824	13518
	Total	43336	42856	42372	42206	42670	43014	43500	43804	43834	43986	44326
South	Heating	28934	26478	24598	23410	22862	22662	22772	22972	23190	23540	23944
	Cooling	8990	10238	11472	12714	13950	15194	16432	17676	18912	20156	21394
	Lighting	30628	16594	10740	8928	8928	8188	7926	7152	6646	6132	6132
	Total	68552	53310	46810	45052	45740	46044	47130	47800	48748	49828	51470
West	Heating	9056	8754	8590	8550	8562	8652	8766	8898	9018	9164	9292
	Cooling	2778	3444	4104	4764	5422	6082	6742	7406	8060	8732	9386
	Lighting	9424	5736	4636	4318	4086	4006	4006	4006	3926	3768	3378
	Total	21258	17934	17330	17632	18070	18740	19514	20310	21004	21664	22056
East	Heating	10576	10352	10238	10168	10120	10116	10126	10140	10156	10206	10278
	Cooling	3060	3236	3418	3596	3778	3954	4130	4308	4490	4668	4838
	Lighting	10602	8832	7516	6984	6892	6806	6714	6456	6014	5310	4776
	Total	24238	22420	21172	20748	20790	20876	20970	20904	20660	20184	19892
Total		157384	136520	127684	125638	127270	128674	131114	132818	134246	135662	137744

Table C.7: The calculated annual energy consumption
(School No. 7 with single glazing windows)

School No 7	Kwhrs	Glazing ratio % 0	5	10	15	20	25	30	35	40	45	50
North	Heating	71752	72600	73472	74344	75228	76112	77044	77968	78900	79808	80768
	Cooling	19468	20504	21520	22556	23584	24608	25648	26672	27708	28736	29772
	Lighting	69504	67192	62548	60232	59660	57880	57880	57308	54404	50924	45744
	Total	160724	160296	157540	157132	158472	158600	160572	161948	161012	159468	156284
South	Heating	78510	71598	66354	62922	61278	60462	60480	60720	61308	62052	62886
	Cooling	24534	28104	31632	35184	38712	42246	45810	49356	52908	56442	60006
	Lighting	83052	43602	26994	22890	21492	21492	19392	18012	16626	15942	13842
	Total	186096	143304	124980	120996	121482	124200	125682	128088	130842	134436	136734
West	Heating	49176	47596	46716	46388	46372	46708	47224	47812	48428	49080	49780
	Cooling	15008	18496	22028	25516	29008	32528	36020	39512	43004	46532	50024
	Lighting	50656	29980	24924	24492	23640	22776	22360	21536	20688	18988	16468
	Total	114840	96072	93668	96396	99020	102012	105604	108860	112120	114600	116272
East	Heating	50808	49356	48444	47760	47236	46940	46668	46500	46472	46652	46896
	Cooling	14860	15784	16700	17624	18560	19460	20412	21324	22248	23188	24112
	Lighting	50656	37976	33368	32084	31652	31264	31264	27472	25340	21580	18180
	Total	116324	103116	98512	97468	97448	97664	98344	95296	94060	91420	89188
Total		577984	502788	474700	471992	476422	482476	490202	494192	498034	499924	498478

Table C.8: The calculated annual energy consumption
(School No. 8 with single glazing windows)

School No 8	Kwhrs	Glazing ratio % 0	5	10	15	20	25	30	35	40	45	50
North	Heating	13950	14090	14240	14398	14568	14738	14902	15072	15242	15418	15582
	Cooling	3816	4072	4334	4596	4848	5116	5378	5628	5890	6152	6416
	Lighting	13548	12980	11852	11282	11178	10950	10950	10504	10390	10048	9606
	Total	31314	31142	30426	30276	30594	30804	31230	31204	31522	31618	31604
South	Heating	26262	23970	22182	21050	20478	20276	20314	20436	20622	20918	21244
	Cooling	8204	9306	10392	11488	12592	13688	14786	15876	16974	18070	19168
	Lighting	27684	14306	9544	8998	8070	8070	7400	6700	6234	6006	5542
	Total	62150	47582	42118	41536	41140	42034	42500	43012	43830	44994	45954
West	Heating	25012	24034	23496	23290	23288	23442	23708	24010	24312	24608	24928
	Cooling	7678	9494	11318	13132	14958	16778	18590	20410	22240	24032	25856
	Lighting	25916	14262	12310	11462	11020	10798	10798	10364	9494	8854	8204
	Total	58606	47790	47124	47884	49266	51018	53096	54784	56046	57494	58988
East	Heating	26144	25582	25238	25030	24882	24798	24768	24752	24728	24776	24888
	Cooling	7546	7966	8368	8794	9202	9616	10030	10444	10852	11272	11686
	Lighting	25916	20742	18154	17292	16850	16636	16002	15338	12766	11674	9310
	Total	59606	54290	51760	51116	50934	51050	50800	50534	48346	47722	45884
Total		211676	180804	171428	170812	171934	174906	177626	179534	179744	181828	182430

Table C.9: The calculated annual energy consumption
(School No. 9 with single glazing windows)

School No 9	Kwhrs	Glazing ratio % 0	5	10	15	20	25	30	35	40	45	50
North	Heating	47409	47862	48324	48795	49236	49716	50178	50676	51177	51666	52200
	Cooling	3819	3957	4095	4221	4368	4506	4635	4773	4911	5049	5187
	Lighting	40644	40644	39279	38607	37581	36909	36228	34875	31800	27732	24714
	Total	91872	92463	91698	91623	91185	91131	91041	90324	87888	84447	82101
South	Heating	53865	49548	46653	44985	44109	43821	43707	43854	44142	44589	45099
	Cooling	5175	6696	8208	9720	11232	12741	14253	15774	17277	18798	20307
	Lighting	50361	26454	15111	12993	10527	9267	8007	7161	6330	6330	5916
	Total	109401	82698	69972	67698	65868	65829	65967	66789	67749	69717	71322
West	Heating	41253	40068	39417	39288	39522	39852	40269	40701	41157	41604	42096
	Cooling	3756	5040	6345	7641	8925	10230	11526	12819	14106	15402	16689
	Lighting	37110	25035	21351	21351	18564	17637	17637	16707	13329	10839	10521
	Total	82119	70143	67113	68280	67011	67719	69432	70227	68592	67845	69306
East	Heating	41508	39531	38055	36909	36036	35478	35154	35049	35070	35286	35604
	Cooling	3783	3990	4200	4419	4626	4854	5061	5280	5487	5697	5913
	Lighting	37110	26598	22587	22587	22281	22281	19197	16422	14247	13644	9930
	Total	82401	70119	64842	63915	62943	62613	59412	56751	54804	54627	51447
Total		365793	315423	293625	291516	287007	287292	285852	284091	279033	276636	274176

Table C.10: The calculated annual energy consumption
(School No. 10 with single glazing windows)

School No 10	Kwhrs	Glazing ratio % 0	5	10	15	20	25	30	35	40	45	50
North	Heating	26106	26292	26484	26682	26906	27146	27394	27654	27914	28194	28472
	Cooling	2108	2164	2212	2254	2316	2366	2420	2462	2518	2566	2628
	Lighting	22384	22384	21824	21262	20888	20142	20142	19022	18264	15822	13986
	Total	50598	50840	50520	50198	50110	49654	49956	49138	48696	46582	45086
South	Heating	41588	38492	36568	35592	35072	34856	34892	35112	35356	35628	35992
	Cooling	3996	5356	6712	8056	9424	10780	12148	13496	14852	16208	17576
	Lighting	38876	19460	11656	9740	9076	8756	7784	6180	5540	4556	3912
	Total	84460	63308	54936	53388	53572	54392	54824	54788	55748	56392	57480
West	Heating	23146	22654	22368	22252	22342	22506	22712	22912	23144	23386	23642
	Cooling	2060	2678	3290	3910	4522	5140	5758	6372	6990	7608	8214
	Lighting	20616	14958	12542	11862	11692	11692	11176	9124	7734	7234	5688
	Total	45822	40290	38200	38024	38556	39338	39646	38408	37868	38228	37544
East	Heating	22820	21472	20410	19588	19034	18690	18668	18730	18858	19064	19292
	Cooling	2126	2278	2436	2592	2750	2908	3060	3222	3374	3532	3694
	Lighting	20616	12876	11692	11176	10660	10660	10314	8942	8256	6544	6198
	Total	45562	36626	34538	33356	32444	32258	32042	30894	30488	29140	29184
Total		226442	191064	178194	174966	174682	175642	176468	173228	172800	170342	169294

Table C.11: The calculated annual energy consumption
(School No. 11 with single glazing windows)

School No 11	Kwhrs	Glazing ratio % 0	5	10	15	20	25	30	35	40	45	50
North	Heating	43206	43386	43590	43851	44178	44523	44895	45339	45765	46239	46683
	Cooling	3519	3591	3684	3756	3840	3921	3993	4086	4161	4242	4326
	Lighting	37110	36804	35253	34005	33699	33699	32148	31221	28719	24393	22239
	Total	83835	83781	82527	81612	81717	82143	81036	80646	78645	74874	73248
South	Heating	62466	58104	55446	54240	53730	53628	53682	54012	54486	54942	55488
	Cooling	5976	8160	10344	12546	14730	16926	19110	21294	23478	25674	27858
	Lighting	58314	30138	19422	15090	14592	13632	11676	10716	9738	7794	7314
	Total	126756	96402	85212	81876	83052	84186	84468	86022	87702	88410	90660
West	Heating	16974	16686	16542	16470	16479	16581	16725	16899	17046	17217	17373
	Cooling	1494	1890	2286	2679	3075	3480	3873	4269	4674	5058	5463
	Lighting	15021	12021	9765	9393	9267	9138	8898	7770	7014	6144	4770
	Total	33489	30597	28593	28542	28821	29199	29496	28938	28734	28419	27606
East	Heating	16539	15456	14568	13929	13497	13329	13392	13458	13620	13773	13965
	Cooling	1551	1689	1821	1950	2085	2214	2340	2487	2613	2748	2877
	Lighting	15021	9510	8142	7890	7767	7509	7386	6891	6390	6012	5268
	Total	33111	26655	24531	23769	23349	23052	23118	22836	22623	22533	22110
Total		277191	237435	220863	215799	216939	218580	218118	218442	217704	214236	213624

Table C.12: The calculated annual energy consumption
(School No. 12 with single glazing windows)

School No 12	Kwhrs	Glazing ratio % 0	5	10	15	20	25	30	35	40	45	50
North	Heating	60630	61281	61914	62559	63183	63816	64449	65103	65718	66378	67023
	Cooling	0	0	0	0	0	0	0	0	0	0	0
	Lighting	22971	22971	22398	21816	21816	21249	21246	20478	20097	19326	17583
	Total	83601	84252	84312	84375	84999	85065	85695	85581	85815	85704	84606
South	Heating	111528	106005	100677	95619	91080	86961	83697	80751	78384	76701	75669
	Cooling	0	0	0	0	0	0	0	0	0	0	0
	Lighting	44178	23193	13257	11019	8856	8127	7398	6645	5916	5916	5916
	Total	155706	129198	113934	106638	99936	95088	91095	87396	84300	82617	81585
West	Heating	40980	40116	39375	38802	38427	38175	37986	37824	37755	37776	37872
	Cooling	0	0	0	0	0	0	0	0	0	0	0
	Lighting	15903	11136	9150	9150	9150	9015	8883	8883	7293	6636	6237
	Total	56883	51252	48525	47952	47577	47190	46869	46707	45048	44412	44109
East	Heating	40980	40116	39240	38484	37929	37491	37236	37110	37005	36978	36996
	Cooling	0	0	0	0	0	0	0	0	0	0	0
	Lighting	15903	11535	9681	9681	9681	9678	9549	9282	7557	6771	6372
	Total	56883	51651	48921	48165	47610	47169	46785	46392	44562	43749	43368
Total		353073	316353	295692	287130	280122	274512	270444	266076	259725	256482	253668

Table C.13: The calculated annual energy consumption
(School No. 13 with single glazing windows)

School No 13	Kwhrs	Glazing ratio % 0	5	10	15	20	25	30	35	40	45	50
North	Heating	9094	9198	9308	9410	9514	9634	9732	9840	9962	10058	10174
	Cooling	32678	33436	34180	34938	35684	36442	37194	37946	38702	39448	40206
	Lighting	29452	29452	27726	26504	26010	25516	25030	22340	20356	19854	18638
	Total	71224	72086	71214	70852	71208	71592	71956	70126	69020	69360	69018
South	Heating	10564	10408	10312	10228	10288	10372	10456	10544	10676	10796	10924
	Cooling	44552	48368	52156	55960	59776	63564	67392	71196	74996	78800	82592
	Lighting	38876	21404	14928	10724	8756	7452	6800	5184	3892	3560	3240
	Total	93992	80180	77396	76912	78820	81388	84648	86924	89564	93156	96756
West	Heating	10194	10334	10478	10630	10776	10920	11072	11224	11376	11534	11678
	Cooling	40496	43882	47256	50642	54022	57402	60782	64162	67536	70922	74308
	Lighting	35342	21510	19440	18274	17078	16486	16194	16194	13842	10576	9128
	Total	86032	75726	77174	79546	81876	84808	88048	91580	92754	93032	95114
East	Heating	10320	9972	9760	9620	9582	9614	9654	9694	9734	9798	9906
	Cooling	40386	43240	46094	48942	51778	54626	57474	60328	63170	66020	68862
	Lighting	35342	24456	20616	20616	20616	20616	20324	16494	14706	11470	8554
	Total	86048	77668	76470	79178	81976	84856	87452	86516	87610	87288	87322
Total		337296	305660	302254	306488	313880	322644	332104	335146	338948	342836	348210

Table C.14: Fenestration cost analyses assuming scenario 1 applied with single-glazing windows
(cop = 2.5, f = 0.7, N=4.5, equation 7.8, chapter 7)

Unit: ACF*		Glazing ratio % 0	5	10	15	20	25	30	35	40	45	50
School No. 1	North	345750	345078	338601	338880	339492	341260	340767	342663	342224	337139	329675
	South	282113	217230	189465	176281	169276	162805	160331	156918	155761	157523	157017
	West	97463	80153	77003	75973	74953	75523	76000	76241	76346	76603	75711
	East	98651	89348	84011	83274	82029	82075	80865	79620	76877	75116	70699
	Total	823978	731809	689082	674409	665751	661663	657963	655442	651208	646381	633102
School No. 2	North	32548	32753	32292	32497	32586	32689	32883	33200	32976	32978	32412
	South	62001	46951	40708	38348	36929	35766	34894	34433	34209	33799	34350
	West	16629	13903	13477	13294	13164	13299	13459	13652	13862	13812	13830
	East	16735	15010	14223	13913	13775	13624	13638	13622	13382	13384	12772
	Total	127914	108617	100700	98053	96453	95378	94874	94908	94429	93973	93363
School No. 3	North	91769	92325	91958	91267	91533	91865	91487	91545	91565	90965	88481
	South	149750	113966	98592	93321	90246	87243	84951	83860	83150	83976	83334
	West	108576	94965	91025	90810	91131	91631	92622	92309	88650	88006	87845
	East	108156	89765	87108	83061	81676	80778	80514	79289	77110	73990	72127
	Total	458251	391021	368683	358459	354586	351517	349573	347004	340475	336937	331787
School No. 4	North	45878	45834	45328	45171	45366	45569	45436	45483	45011	44361	43379
	South	91750	69933	62667	60608	60507	61384	62968	63633	64769	66375	67740
	West	32703	29392	28547	28636	28982	29502	30042	29871	29813	29410	28642
	East	37081	30131	28495	28205	28057	27755	27825	27697	27554	27479	27006
	Total	207413	175290	165037	162619	162911	164210	166270	166685	167147	167625	166768

ACF = Annual Cost Factor

Table C.15: Fenestration cost analyses assuming scenario 1 applied with single-glazing windows
(cop = 2.5, f = 0.7, N=4.5, equation 7.8, chapter 7)
Continue

Unit: ACF*		Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
School No. 5	North	141900	140374	137416	136121	136964	136816	136702	136047	134905	132142	128440
	South	193279	149273	134329	131626	129445	132330	133626	135989	139229	142675	147857
	West	46985	43766	41632	41652	41880	42662	43314	43277	42916	41840	41320
	East	46487	37831	35449	34074	33622	33733	33749	34157	34374	33745	33509
	Total	428651	371244	348826	343473	341910	345540	347390	349470	351424	350402	351127
School No. 6	North	70902	69935	68964	68559	69287	69794	70558	70998	70940	71108	71608
	South	112688	86161	75157	72432	73873	74494	76408	77540	79166	80981	83787
	West	34914	29042	28016	28574	29358	30531	31882	33266	34471	35605	36263
	East	39715	36526	34322	33584	33678	33834	33999	33875	33430	32555	32003
	Total	258219	221665	206458	203149	206196	208652	212848	215680	218006	220248	223660
School No. 7	North	262755	261671	256387	255330	257415	257319	260523	262658	260629	257513	251427
	South	305924	231456	200413	194512	195995	201189	203850	208092	212832	219026	222853
	West	188517	155319	151317	156349	161078	166340	172614	178258	183898	188120	190871
	East	190584	167347	159397	157771	157929	158427	159752	154328	152113	147295	143187
	Total	947780	815793	767515	763962	772417	783275	796740	803336	809471	811954	808338
School No. 8	North	51204	50842	49498	49170	49679	49994	50700	50591	51100	51208	51122
	South	102153	76779	67605	66976	66475	68159	68984	69860	71264	73250	74857
	West	96236	77129	76130	77574	80062	83159	86801	89728	91887	94384	96955
	East	97618	88257	83830	82748	82475	82715	82276	81803	77873	76732	73383
	Total	347211	293007	277063	276467	278691	284027	288761	291981	292125	295574	296316
School No. 9	North	147828	148724	147177	146867	145916	145641	145308	143833	139263	132888	128468
	South	176992	130524	108688	105212	102242	102278	102569	103994	105616	108993	111693
	West	132551	111432	106219	108367	105997	107149	110078	111349	108238	106728	109175
	East	132964	111588	102635	101391	99964	99577	93935	89184	85671	85273	79431
	Total	590334	502268	464719	461837	454118	454645	451890	448360	438787	433881	428767
School No. 10	North	81417	81784	81137	80484	80243	79333	79785	78216	77325	73416	70620
	South	136640	99712	85355	82929	83453	85009	85773	85627	87265	88323	90147
	West	73916	64140	60484	60210	61134	62481	62959	60657	59599	60158	58832
	East	73568	57982	54617	52793	51357	51149	50768	48679	47901	45398	45393
	Total	365541	303619	281592	276417	276187	277972	279286	273179	272089	267295	264992
School No. 11	North	134917	134753	132420	130677	130745	131384	129254	128387	124628	117665	114574
	South	205048	152025	132867	127308	129614	131692	132180	134855	137704	138809	142657
	West	54000	48901	45347	45282	45781	46423	46905	45836	45414	44784	43263
	East	53480	42260	38766	37630	37034	36562	36657	36125	35682	35463	34631
	Total	447445	377939	349399	340897	343173	346061	344996	345204	343428	336722	335125
School No. 12	North	128049	128980	128853	128728	129620	129505	130405	129958	130151	129707	127492
	South	239005	193335	167831	156569	146185	138983	133003	127435	122738	120331	118855
	West	87227	77411	72776	71957	71421	70817	70309	70078	67117	65964	65384
	East	87227	78129	73539	72458	71664	71033	70436	69775	66520	65066	64374
	Total	541508	477854	442999	429712	418891	410338	404153	397245	386526	381069	376105
School No. 13	North	124838	126352	124741	124052	124654	125301	125920	122586	120550	121127	120468
	South	165277	140473	135497	134657	138069	142661	148498	152562	157265	163686	170119
	West	151086	132483	135036	139250	143390	148614	154390	160691	162748	163190	166884
	East	151068	136113	134035	138961	144011	149184	153842	152142	154096	153493	153514
	Total	592269	535421	529310	536920	550125	565759	582649	587981	594660	601496	610986

ACF = Annual Cost Factor

Table C.16: The calculated annual energy consumption
(School No. 1 with double glazing windows)

School No 1	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	137454	137364	137328	137256	137238	137340	137484	137646	137844	138024	138204
	Cooling	5136	5610	6090	6564	7062	7560	8034	8514	8994	9468	9948
	Lighting	77748	75804	70626	69300	68022	67380	65412	64746	62778	58206	52326
	Total	220338	218778	214044	213120	212322	212280	210930	210906	209616	205698	200478
South	Heating	109092	101124	93690	86928	81222	76560	72966	70716	69444	68982	68592
	Cooling	4680	5640	6618	7578	8538	9522	10500	11460	12420	13380	14358
	Lighting	65382	33786	22350	18570	17460	15822	15822	14184	13104	13104	11454
	Total	179154	140550	122658	113076	107220	101904	99288	96360	94968	95466	94404
West	Heating	37966	36380	35052	33836	32904	32138	31510	31012	30654	30464	30312
	Cooling	1602	2260	2908	3564	4216	4868	5520	6176	6822	7480	8132
	Lighting	22382	13062	11388	10828	10070	10070	9898	9516	8956	8390	7090
	Total	61950	51702	49348	48228	47190	47076	46928	46704	46432	46334	45534
East	Heating	38820	37646	36738	35950	35334	34902	34506	34116	33818	33514	33236
	Cooling	1584	1664	1736	1814	1898	1978	2050	2134	2212	2284	2364
	Lighting	22382	17734	15112	14928	14368	14368	13622	12896	11222	10094	7490
	Total	62786	57044	53586	52692	51600	51248	50178	49146	47252	45892	43090
Total		524228	468074	439636	427116	418332	412508	407324	403116	398268	393390	383506

Table C.17: The calculated annual energy consumption
(School No. 2 with double glazing windows)

School No 2	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	12880	12907	12942	12972	13005	13026	13069	13102	13150	13195	13237
	Cooling	487	518	551	585	615	649	683	713	747	781	811
	Lighting	7363	7302	6871	6810	6688	6565	6502	6502	6196	6010	5514
	Total	20730	20727	20364	20367	20308	20240	20254	20317	20093	19986	19562
South	Heating	23906	22179	20566	19114	17873	16831	16069	15567	15301	15147	15095
	Cooling	1022	1258	1494	1729	1965	2198	2433	2669	2902	3138	3374
	Lighting	14431	6977	4330	3730	3492	3254	3012	2782	2536	2055	2055
	Total	39359	30414	26390	24573	23330	22283	21514	21018	20739	20340	20524
West	Heating	6468	6232	6042	5862	5729	5616	5536	5463	5428	5378	5357
	Cooling	272	382	491	598	711	820	927	1037	1147	1253	1363
	Lighting	3828	2328	2076	1948	1819	1819	1819	1819	1819	1660	1532
	Total	10568	8942	8609	8408	8259	8255	8282	8319	8394	8291	8252
East	Heating	6546	6330	6155	6013	5913	5829	5754	5692	5638	5597	5565
	Cooling	269	284	302	317	332	347	362	380	396	411	429
	Lighting	3828	2968	2585	2456	2395	2298	2298	2267	2109	2076	1694
	Total	10643	9582	9042	8786	8640	8474	8414	8339	8143	8084	7688
Total		81300	69665	64405	62134	60537	59252	58464	57993	57369	56701	56026

Table C.18: The calculated annual energy consumption
(School No. 3 with double glazing windows)

School	Kwhrs	Glazing ratio %										
No 3		0	5	10	15	20	25	30	35	40	45	50
North	Heating	36512	36492	36472	36440	36440	36456	36480	36498	36540	36564	36612
	Cooling	1360	1384	1416	1452	1482	1520	1510	1586	1618	1654	1684
	Lighting	20616	20616	20100	19408	19238	19068	18552	18206	17860	17174	15432
	Total	58488	58492	57988	57300	57160	57044	56542	56290	56018	55392	53728
South	Heating	57870	53766	49968	46526	43630	41132	39298	37976	37342	36900	36602
	Cooling	2468	3218	3976	4734	5484	6242	6988	7744	8496	9252	10010
	Lighting	34752	16898	10120	8706	8124	7264	6394	5810	4950	4654	3498
	Total	95090	73882	64064	59966	57238	54638	52680	51530	50788	50806	50110
West	Heating	42588	41472	40614	39818	39132	38576	38124	37762	37428	37168	36896
	Cooling	1748	2340	2938	3536	4134	4732	5330	5928	6526	7124	7716
	Lighting	24738	17112	14654	14232	14028	13818	13818	13008	10320	9280	8470
	Total	69074	60924	58206	57586	57294	57126	57272	56698	54274	53572	53082
East	Heating	42242	40172	38448	37090	36048	35074	34344	33694	33186	32820	32606
	Cooling	1790	1942	2086	2242	2388	2538	2682	2834	2984	3128	3280
	Lighting	24738	15662	15056	13410	12994	12790	12790	12172	10946	9096	7844
	Total	68770	57776	55590	52742	51430	50402	49816	48700	47116	45044	43730
Total		291422	251074	235848	227594	223122	219210	216310	213218	208196	204814	200650

Table C.19: The calculated annual energy consumption
(School No. 4 with double glazing windows)

School	Kwhrs	Glazing ratio %										
No 4		0	5	10	15	20	25	30	35	40	45	50
North	Heating	14838	14816	14822	14841	14859	14886	14922	14961	14994	15043	15088
	Cooling	2214	2257	2303	2352	2398	2444	2492	2542	2585	2630	2676
	Lighting	11486	11293	10816	10525	10431	10336	10048	9852	9375	8791	8023
	Total	28538	28366	27941	27718	27688	27666	27462	27355	26954	26464	25787
South	Heating	28496	26280	24346	22850	21852	21290	20956	20702	20562	20538	20546
	Cooling	4774	5906	7050	8188	9320	10478	11610	12748	13892	15030	16176
	Lighting	23560	11774	7860	6492	5902	5508	5312	4522	3934	3538	2948
	Total	56830	43960	39256	37530	37074	37276	37878	37972	38388	39106	39670
West	Heating	10413	10232	10067	9945	9835	9746	9692	9650	9606	9579	9566
	Cooling	1650	1976	2296	2619	2942	3265	3585	3911	4230	4553	4876
	Lighting	8246	6116	5361	5087	4948	4885	4814	4334	3919	3304	2481
	Total	20309	18324	17724	17651	17725	17896	18091	17895	17755	17436	16923
East	Heating	11650	10948	10399	9926	9551	9274	9063	8943	8899	8895	8915
	Cooling	1921	2113	2302	2497	2683	2875	3067	3262	3451	3646	3832
	Lighting	9424	5813	5031	4950	4873	4631	4554	4323	4007	3691	3147
	Total	22995	18874	17732	17373	17107	16780	16684	16528	16357	16232	15894
Total		128672	109524	102653	100272	99594	99618	100115	99750	99454	99238	98274

Table C.20: The calculated annual energy consumption
(School No. 5 with double glazing windows)

School No 5	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	46122	45866	45704	45570	45492	45418	45382	45364	45344	45350	45394
	Cooling	6852	7000	7152	7306	7460	7612	7772	7912	8072	8224	8378
	Lighting	35340	34156	32094	30910	30910	30336	29742	28858	27692	25602	22996
	Total	88314	87022	84950	83786	83862	83366	82896	82134	81108	79176	76768
South	Heating	60220	55668	51776	48748	46692	45580	44920	44448	44088	43996	43996
	Cooling	10060	12556	15076	17560	20068	22576	25084	27568	30088	32596	35092
	Lighting	49476	25568	17336	15252	12788	12408	10748	9496	8668	7852	7852
	Total	119756	93792	84188	81560	79548	80564	80752	81512	82844	84444	86940
West	Heating	15078	14838	14640	14460	14318	14186	14074	14002	13950	13882	13804
	Cooling	2344	2766	3174	3588	4002	4416	4830	5238	5658	6074	6482
	Lighting	11780	9616	8058	7662	7368	7368	7270	6778	6100	5012	4230
	Total	29202	27220	25872	25710	25688	25970	26174	26018	25708	24968	24516
East	Heating	14614	13628	12844	12138	11628	11228	10936	10802	10758	10756	10778
	Cooling	2436	2692	2942	3198	3460	3710	3966	4216	4472	4734	4990
	Lighting	11780	7368	6288	5702	5500	5500	5400	5400	5206	4520	4028
	Total	28830	23688	22074	21038	20588	20438	20302	20418	20436	20010	19796
Total		266102	231722	217084	212094	209686	210338	210124	210082	210096	208598	208020

Table C.21: The calculated annual energy consumption
(School No. 6 with double glazing windows)

School No 6	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	19196	19244	19276	19324	19386	19446	19502	19568	19642	19704	19770
	Cooling	5292	5626	5944	6280	6602	6926	7262	7592	7920	8244	8568
	Lighting	18848	17744	16646	15858	15696	15396	15236	14914	14298	13824	13518
	Total	43336	42614	41866	41462	41684	41768	42000	42074	41860	41772	41856
South	Heating	28934	26096	23896	22404	21604	21190	21004	20944	20968	21082	21232
	Cooling	8990	10208	11422	12646	13872	15086	16310	17530	18750	19962	21180
	Lighting	30628	16594	10740	8928	8928	8188	7926	7152	6646	6132	6132
	Total	68552	52898	46058	43978	44404	44464	45240	45626	46364	47176	48544
West	Heating	9056	8638	8388	8224	8162	8148	8160	8202	8226	8262	8298
	Cooling	2778	3432	4086	4738	5392	6052	6712	7364	8012	8670	9318
	Lighting	9424	5736	4636	4318	4086	4006	4006	4006	3926	3768	3378
	Total	21258	17806	17110	17280	17640	18206	18878	19572	20164	20700	20994
East	Heating	10576	10232	9978	9774	9606	9476	9364	9246	9152	9098	9062
	Cooling	3060	3248	3412	3574	3742	3918	4088	4246	4422	4594	4764
	Lighting	10602	8832	7516	6984	6892	6806	6714	6456	6014	5310	4776
	Total	24238	22312	20906	20332	20240	20200	20166	19948	19588	19002	18602
Total		157384	135630	125940	123052	123968	124638	126284	127220	127976	128650	129996

Table C.22: The calculated annual energy consumption
(School No. 7 with double glazing windows)

School No 7	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	71752	71824	71888	71984	72084	72216	72352	72488	72632	72780	72904
	Cooling	19468	20472	21436	22412	23404	24376	25368	26344	27332	28308	29288
	Lighting	69504	67192	62548	60232	59660	57880	57880	57308	54404	50924	45744
	Total	160724	159488	155872	154628	155148	154472	155600	156140	154368	152012	147936
South	Heating	78510	70710	64668	60450	58194	56790	56142	55842	55800	55944	56232
	Cooling	24534	28032	31542	35022	38478	41988	45480	48978	52452	55926	59406
	Lighting	83052	43602	26994	22890	21492	21492	19392	18012	16626	15942	13842
	Total	186096	142344	123204	118362	118164	120270	121014	122832	124878	127812	129480
West	Heating	49176	47028	45636	44780	44324	44200	44268	44372	44552	44744	44912
	Cooling	15008	18472	21952	25408	28864	32344	35812	39268	42748	46204	49684
	Lighting	50656	29980	24924	24492	23640	22776	22360	21536	20688	18988	16468
	Total	114840	95480	92512	94680	96828	99320	102440	105176	107988	109936	111064
East	Heating	50808	48792	47308	46080	45036	44172	43376	42716	42292	42020	41768
	Cooling	14860	15748	16628	17528	18428	19304	20204	21080	21992	22884	23748
	Lighting	50656	37976	33368	32084	31652	31264	31264	27472	25340	21580	18180
	Total	116324	102516	97304	95692	95116	94740	94844	91268	89624	86484	83696
Total		577984	499828	468892	463362	465256	468802	473898	475416	476858	476244	472176

Table C.23: The calculated annual energy consumption
(School No. 8 with double glazing windows)

School No 8	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	13950	13938	13944	13938	13952	13976	13982	13996	14020	14034	14052
	Cooling	3816	4072	4310	4560	4816	5066	5324	5574	5824	6074	6312
	Lighting	13548	12980	11852	11282	11178	10950	10950	10504	10390	10048	9606
	Total	31314	30990	30106	29780	29946	29992	30256	30074	30234	30156	29970
South	Heating	26262	23666	21606	20226	19442	19066	18856	18790	18806	18896	18996
	Cooling	8204	9282	10360	11434	12512	13598	14670	15748	16828	17906	18980
	Lighting	27684	14306	9544	8998	8070	8070	7400	6700	6234	6006	5542
	Total	62150	47254	41510	40658	40024	40734	40926	41238	41868	42808	43518
West	Heating	25012	23756	22964	22490	22258	22184	22218	22260	22326	22392	22446
	Cooling	7678	9482	11282	13078	14878	16686	18488	20290	22084	23886	25686
	Lighting	25916	14262	12310	11462	11020	10798	10798	10364	9494	8854	8204
	Total	58606	47500	46556	47030	48156	49668	51504	52914	53904	55132	56336
East	Heating	26144	25298	24664	24166	23728	23370	23076	22786	22504	22302	22192
	Cooling	7546	7942	8338	8740	9136	9532	9916	10322	10718	11108	11516
	Lighting	25916	20742	18154	17292	16850	16636	16002	15338	12766	11674	9310
	Total	59606	53982	51156	50198	49714	49538	48994	48446	45988	45084	43018
Total		211676	179726	169328	167666	167840	169932	171680	172672	171994	173180	172842

Table C.24: The calculated annual energy consumption
(School No. 9 with double glazing windows)

School No 9	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	47409	47364	47253	47169	47094	47022	46956	46920	46911	46884	46884
	Cooling	3819	3954	4095	4233	4371	4506	4644	4785	4923	5061	5187
	Lighting	40644	40644	39279	38607	37581	36909	36228	34875	31800	27732	24714
	Total	91872	91962	90627	90009	89046	88437	87828	86580	83634	79677	76785
South	Heating	53865	48894	45438	43266	41919	41160	40590	40299	40146	40167	40197
	Cooling	5175	6696	8199	9720	11241	12741	14265	15786	17292	18807	20328
	Lighting	50361	26454	15111	12993	10527	9267	8007	7161	6330	6330	5916
	Total	109401	82044	68748	65979	63687	63168	62862	63246	63768	65304	66441
West	Heating	41253	39588	38463	37953	37761	37698	37701	37713	37734	37800	37881
	Cooling	3756	5049	6345	7641	8937	10230	11526	12831	14118	15411	16716
	Lighting	37110	25035	21351	21351	18564	17637	17637	16707	13329	10839	10521
	Total	82119	69672	66159	66945	65262	65565	66864	67251	65181	64050	65118
East	Heating	41508	39042	37095	35487	34194	33222	32487	32028	31722	31620	31602
	Cooling	3783	3990	4209	4428	4635	4854	5073	5280	5499	5706	5934
	Lighting	37110	26598	22587	22587	22281	22281	19197	16422	14247	13644	9930
	Total	82401	69630	63891	62502	61110	60357	56757	53730	51468	50970	47466
Total		365793	313308	289425	285435	279105	277527	274311	270807	264051	260001	255810

Table C.25: The calculated annual energy consumption
(School No. 10 with double glazing windows)

School No 10	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	26106	25996	25892	25794	25726	25684	25634	25610	25586	25574	25568
	Cooling	2108	2158	2212	2262	2316	2366	2420	2470	2524	2574	2628
	Lighting	22384	22384	21824	21262	20888	20142	20142	19022	18264	15822	13986
	Total	50598	50538	49928	49318	48930	48192	48196	47102	46374	43970	42182
South	Heating	41588	37996	35624	34260	33400	32784	32520	32304	32188	32116	32076
	Cooling	3996	5356	6712	8068	9424	10780	12140	13496	14852	16208	17576
	Lighting	38876	19460	11656	9740	9076	8756	7784	6180	5540	4556	3912
	Total	84460	62812	53992	52068	51900	52320	52444	51980	52580	52880	53564
West	Heating	23146	22382	21854	21484	21350	21284	21242	21230	21230	21238	21270
	Cooling	2060	2678	3298	3910	4528	5140	5754	6378	6996	7608	8228
	Lighting	20616	14958	12542	11862	11692	11692	11176	9124	7734	7234	5688
	Total	45822	40018	37694	37256	37570	38116	38172	36732	35960	36080	35186
East	Heating	22820	21194	19872	18802	18036	17510	17306	17158	17108	17120	17148
	Cooling	2126	2278	2436	2588	2750	2902	3066	3224	3380	3538	3694
	Lighting	20616	12876	11692	11176	10660	10660	10314	8942	8256	6544	6198
	Total	45562	36348	34000	32566	31446	31072	30686	29324	28744	27202	27040
Total		226442	189716	175614	171208	169846	169700	169498	165138	163658	160132	157972

Table C.26: The calculated annual energy consumption
(School No. 11 with double glazing windows)

School	Kwhrs	Glazing ratio %										
No 11		0	5	10	15	20	25	30	35	40	45	50
North	Heating	43206	42894	42600	42381	42219	42108	42036	41982	41955	41949	41940
	Cooling	3519	3600	3675	3765	3840	3921	4005	4086	4170	4263	4335
	Lighting	37110	36804	35253	34005	33699	33699	32148	31221	28719	24393	22239
	Total	83835	83298	81528	80151	79758	79728	78189	77289	74844	70605	68514
South	Heating	62466	57360	54084	52242	51186	50484	50016	49776	49638	49602	49608
	Cooling	5976	8196	10380	12564	14748	16932	19128	21312	23496	25674	27864
	Lighting	58314	30138	19422	15090	14592	13632	11676	10716	9738	7794	7314
	Total	126756	95694	83886	79896	80526	81048	80820	81804	82872	83070	84786
West	Heating	16974	16503	16152	15897	15735	15690	15654	15627	15627	15621	15612
	Cooling	1494	1890	2286	2679	3084	3489	3885	4278	4674	5070	5463
	Lighting	15021	12021	9765	9393	9267	9138	8898	7770	7014	6144	4770
	Total	33489	30414	28203	27969	28086	28317	28437	27675	27315	26835	25845
East	Heating	16539	15237	14181	13359	12780	12513	12405	12351	12357	12384	12411
	Cooling	1551	1686	1821	1950	2085	2223	2349	2487	2613	2751	2886
	Lighting	15021	9510	8142	7890	7767	7509	7386	6891	6390	6012	5268
	Total	33111	26433	24144	23199	22632	22245	22140	21729	21360	21147	20565
Total		277191	235839	217761	211215	211002	211338	209586	208497	206391	201657	199710

Table C.27: The calculated annual energy consumption
(School No. 12 with double glazing windows)

School	Kwhrs	Glazing ratio %										
No 12		0	5	10	15	20	25	30	35	40	45	50
North	Heating	60630	60666	60714	60756	60792	60837	60861	60903	60939	60990	61053
	Cooling	0	0	0	0	0	0	0	0	0	0	0
	Lighting	22971	22971	22398	21816	21816	21249	21246	20478	20097	19326	17583
	Total	83601	83637	83112	82572	82608	82086	82107	81381	81036	80316	78636
South	Heating	111528	104850	98406	92214	86592	81576	77337	73524	70482	68208	66447
	Cooling	0	0	0	0	0	0	0	0	0	0	0
	Lighting	44178	23193	13257	11019	8856	8127	7398	6645	5916	5916	5916
	Total	155706	128043	111663	103233	95448	89703	84735	80169	76398	74124	72363
West	Heating	40980	39705	38556	37593	36837	36204	35634	35100	34695	34371	34131
	Cooling	0	0	0	0	0	0	0	0	0	0	0
	Lighting	15903	11136	9150	9150	9150	9015	8883	8883	7293	6636	6237
	Total	56883	50841	47706	46743	45987	45219	44517	43983	41988	41007	40368
East	Heating	40980	39696	38412	37257	36309	35511	34929	34416	33966	33588	33285
	Cooling	0	0	0	0	0	0	0	0	0	0	0
	Lighting	15903	11535	9681	9681	9681	9678	9549	9282	7557	6771	6372
	Total	56883	51231	48093	46938	45990	45189	44478	43698	41523	40359	39657
Total		353073	313752	290574	279486	270033	262197	255837	249231	240945	235806	231024

Table C.28: The calculated annual energy consumption
(School No. 13 with double glazing windows)

School No 13	Kwhrs	Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
North	Heating	9094	9138	9192	9240	9288	9336	9386	9440	9468	9536	9584
	Cooling	32678	33216	33766	34298	34848	35392	35930	36474	37012	37556	38106
	Lighting	29452	29452	27726	26504	26010	25516	25030	22340	20356	19854	18638
	Total	71224	71806	70684	70042	70146	70244	70346	68254	66836	66946	66328
South	Heating	10564	10320	10164	9984	9996	9996	10020	10044	10092	10124	10172
	Cooling	44552	48088	51608	55144	58664	62172	65720	69240	72752	76296	79820
	Lighting	38876	21404	14928	10724	8756	7452	6800	5184	3892	3560	3240
	Total	93992	79812	76700	75852	77416	79620	82540	84468	86736	89980	93232
West	Heating	10194	10266	10340	10412	10496	10574	10654	10726	10810	10878	10968
	Cooling	40496	43618	46756	49890	53008	56132	59262	62392	65522	68650	71776
	Lighting	35342	21510	19440	18274	17078	16486	16194	16194	13842	10576	9128
	Total	86032	75394	76536	78576	80582	83192	86110	89312	90174	90104	91872
East	Heating	10320	9900	9626	9408	9332	9292	9272	9232	9224	9234	9286
	Cooling	40386	42982	45582	48174	50778	53362	55966	58564	61150	63748	66340
	Lighting	35342	24456	20616	20616	20616	20616	20324	16494	14706	11470	8554
	Total	86048	77338	75824	78198	80726	83270	85562	84290	85080	84452	84180
Total		337296	304350	299744	302668	308870	316326	324558	326324	328826	331482	335612

Table C.29: Fenestration cost analyses assuming scenario 1 applied with double-glazing windows
(cop = 2.5, f = 0.7, N=4.5, equation 7.8, chapter 7)

Unit: ACF*		Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
School No. 1	North	345750	342976	334468	332831	331402	331288	328805	328702	326307	319188	309725
	South	282113	215574	186119	171373	162944	155100	151721	147283	145248	146315	144548
	West	97463	79603	75857	74291	72768	72846	72812	72593	72236	72130	70746
	East	98651	88750	82862	81544	79806	79333	77553	75840	72541	70205	65265
	Total	823978	726903	679306	660040	646919	638567	630891	624418	616331	607838	590284
School No. 2	North	32548	32533	31867	31861	31743	31612	31622	31723	31302	31093	30314
	South	62001	46539	39893	37159	35381	33882	32780	32073	31669	31008	31358
	West	16629	13790	13261	12965	12746	12781	12859	12953	13101	12934	12872
	East	16735	14906	13998	13590	13364	13096	13016	12904	12571	12480	11779
	Total	127914	107767	99018	95576	93234	91372	90277	89653	88643	87515	86323
School No. 3	North	91769	91784	90884	89657	89405	89190	88278	87818	87313	86177	83164
	South	149750	113094	96827	90724	86885	83130	80284	78703	77602	77798	76655
	West	108576	94319	89744	88922	88650	88554	88984	88084	83845	82677	81896
	East	108156	89133	85836	81212	79236	77746	76962	75193	72530	68936	66650
	Total	458251	388329	363291	350516	344177	338620	334507	329798	321289	315588	308365
School No. 4	North	45878	45577	44810	44401	44341	44291	43910	43703	42969	42069	40834
	South	91750	69404	61653	59100	58648	59220	60427	60690	61490	62792	63804
	West	32703	29197	28178	28092	28266	28607	28978	28641	28405	27841	26922
	East	37081	29922	28070	27599	27259	26773	26678	26441	26150	25926	25311
	Total	207413	174101	162711	159192	158513	158890	159993	159475	159015	158628	156871

ACF = Annual Cost Factor

Table C.30: Fenestration cost analyses assuming scenario 1 applied with double-glazing windows
(cop = 2.5, f = 0.7, N=4.5, equation 7.8, chapter 7)
Continue

Unit: ACF*		Glazing ratio %										
		0	5	10	15	20	25	30	35	40	45	50
School No. 5	**North**	141900	139669	136000	133954	134120	133254	132421	131057	129217	125737	121387
	South	193279	148228	132381	128771	125910	128151	128733	130276	132807	135721	140213
	West	46985	43506	41153	40928	40941	41497	41906	41652	41113	39806	39021
	East	46487	37596	34981	33377	32756	32634	32497	32756	32804	32038	31645
	Total	428651	369000	344515	337030	333727	335536	335558	335740	335941	333302	332266
School No. 6	**North**	70902	69585	68227	67482	67858	67987	68384	68493	68080	67899	68026
	South	112688	85561	74063	70871	71934	72195	73661	74378	75697	77116	79523
	West	34914	28855	27694	28061	28732	29756	30961	32195	33252	34203	34719
	East	39715	36376	33939	32981	32878	32854	32834	32485	31872	30837	30131
	Total	258219	220376	203923	199395	201402	202792	205840	207551	208901	210056	212399
School No. 7	**North**	262755	260504	253971	251696	252595	251330	253310	254231	250989	246693	239310
	South	305924	230057	197840	190685	191163	195474	197053	200436	204134	209362	212258
	West	188517	154464	149636	153855	157891	162422	168013	172899	177894	181330	183298
	East	190584	166476	157643	155196	154545	154188	154670	148477	145675	140124	135199
	Total	947780	811499	759091	751433	756195	763414	773045	776044	778692	777509	770065
School No. 8	**North**	51204	50625	49032	48447	48741	48814	49287	48955	49234	49088	48747
	South	102153	76301	66724	65701	64850	66267	66690	67276	68404	70063	71304
	West	96236	76710	75304	76333	78445	81194	84487	87009	88767	90953	93100
	East	97618	87807	82955	81415	80706	80522	79651	78772	74452	72899	69221
	Total	347211	291443	274015	271895	272741	276797	280115	282012	280856	283003	282372
School No. 9	**North**	147828	148007	145645	144564	142858	141788	140717	138484	133184	126072	120866
	South	176992	129588	106934	102754	99127	98473	98133	98932	99928	102685	104721
	West	132551	110762	104855	106458	103500	104069	106406	107098	103364	101304	103196
	East	132964	110888	101279	99373	97346	96350	90142	84864	80905	80047	73746
	Total	590334	499246	458713	453149	442831	440681	435398	429377	417382	410108	402529
School No. 10	**North**	81417	81350	80290	79229	78555	77243	77268	75308	74006	69684	66467
	South	136640	99003	84005	81046	81062	82046	82367	81612	82734	83301	84547
	West	73916	63751	59763	59112	59727	60734	60850	58263	56873	57086	55465
	East	73568	57585	53847	51662	49929	49451	48832	46435	45409	42629	42327
	Total	365541	301689	277906	271049	269273	269473	269317	261617	259023	252700	248807
School No. 11	**North**	134917	134066	130988	128591	127943	127930	125187	123587	119196	111568	107807
	South	205048	151026	130984	124483	126008	127207	126970	128830	130804	131173	134260
	West	54000	48639	44789	44462	44733	45165	45395	44033	43385	42523	40745
	East	53480	41942	38212	36815	36009	35411	35262	34542	33876	33483	32425
	Total	447445	375672	344974	334352	334693	335714	332814	330992	327260	318747	315237
School No. 12	**North**	128049	128100	127137	126150	126201	125245	125274	123952	123317	122003	118955
	South	239005	191683	164583	151700	139767	131282	123908	117100	111438	108186	105668
	West	87227	76823	71605	70228	69147	67999	66946	66182	62741	61095	60034
	East	87227	77528	72355	70703	69348	68201	67137	65922	62174	60219	59067
	Total	541508	474134	435681	418781	404463	392727	383265	373157	359671	351503	343724
School No. 13	**North**	124838	125870	123830	122657	122826	122985	123150	119364	116802	116974	115844
	South	165277	139843	134299	132840	135650	139617	144865	148326	152391	158218	164054
	West	151086	131911	133939	137584	141164	145833	151056	156793	158314	158162	161311
	East	151068	135545	132922	137275	141854	146448	150581	148306	149731	148597	148088
	Total	592269	533169	524990	530356	541495	554884	569652	572790	577237	581952	589298

ACF = Annual Cost Factor