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THERMAL INSULATION AND ENERGY CONSERVATION MEASURES FOR BUILDINGS IN KUWAIT

Adnan AL-ADEEB*
Kuwait Institute for Scientific Research

* Not an official paper. The views expressed are those of the author(s) and do not necessarily reflect any views or positions of the United Nations.

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Introduction

Kuwait experienced an economic boom since it began oil production in the early fifties. The majority of the buildings in Kuwait were constructed during the 1960s and '70s. During this period, the major concern was with quantity rather than quality.

Buildings in Kuwait commonly comprised of a reinforced concrete frame walls of dense solid sand-cement blocks faced with sand-lime brick, stone or marble. No insulation of any kind was normally used. Roofs consisted of a reinforced concrete slab, waterproofing membrane, foamed concrete, and terazzo or sand-cement tiles. The foamed concrete was used to provide slopes of about 1% to shed rain water. Windows are normally of the sliding type with an aluminum frame and singleglazed 6 mm plain glass. Most of the residences in Kuwait consised of a well-built structures with a large building area and large aluminum window areas. No regard was given to local environmental conditions in designing these buildings. Comfort temperatures were achieved by massive central air conditioning systems.

As a result of these construction practices, associated with the construction explosion and the low consumer price of electricity (2 fils/kwh), the building sector became a heavy energy consumer. This necessitated a rapid growth in electric power generation capacity and total energy delivery. The present growth rate represents an increasing drain on the national economy. The consumption of electricity increased by a factor of 100 in the past 25 years. The growth in power-generating capacity, the annual peak and the minimum loads for the period 1957-1983 (MEW, 1984) are shown in Fig. 1. Most of the increase in demand was caused by the steady increase in per capita consumption (Fig. 2). It also shows the rise of per capita electricity consumption from 1000 kwh/yr in 1957 to 7500 kwh/yr in 1983. A high proportion of this load is consumed by summer air conditioning.

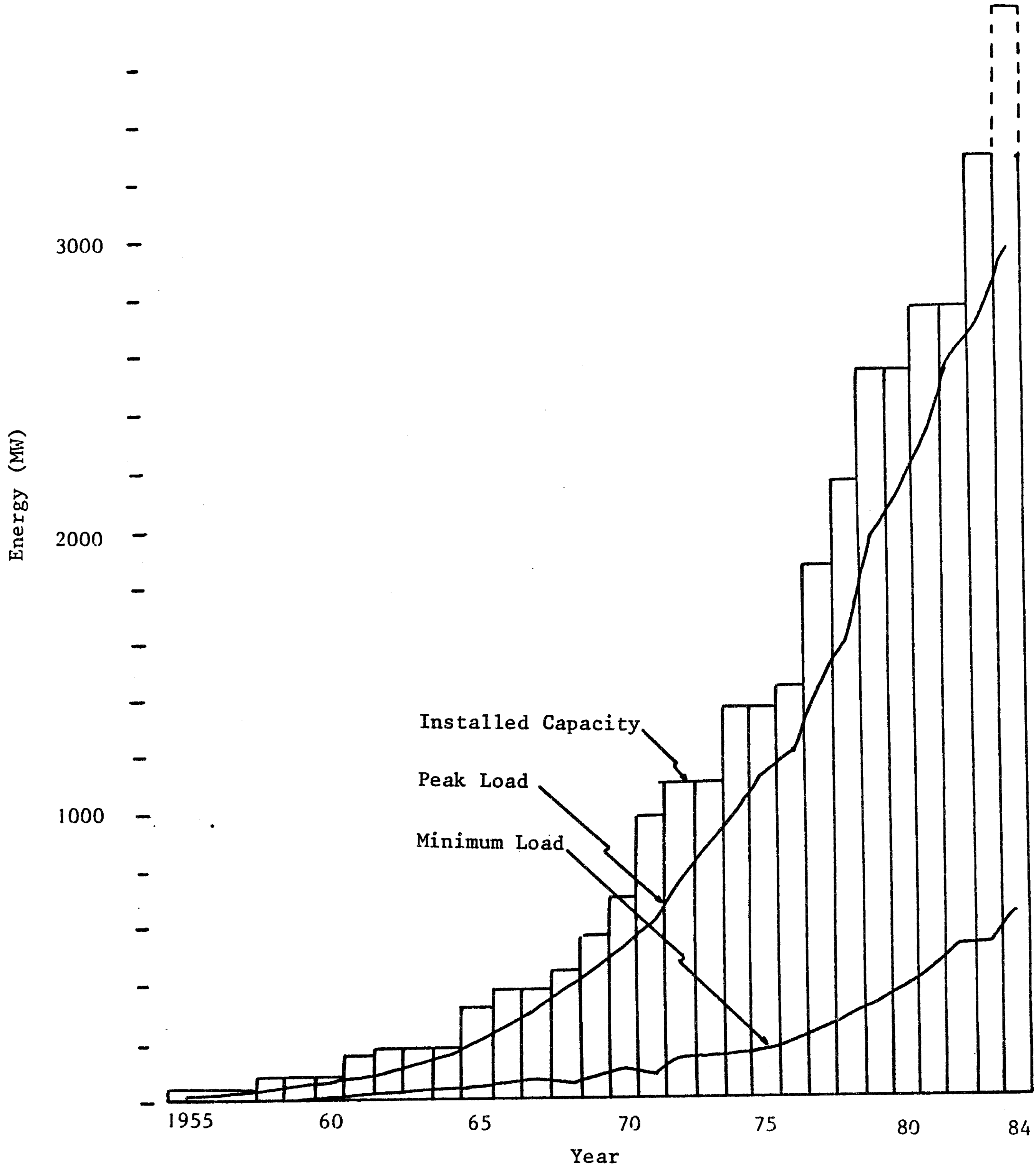


Fig. 1. The growth in installed generating capacity, peak and minimum loads for the State of Kuwait, 1955-1984.

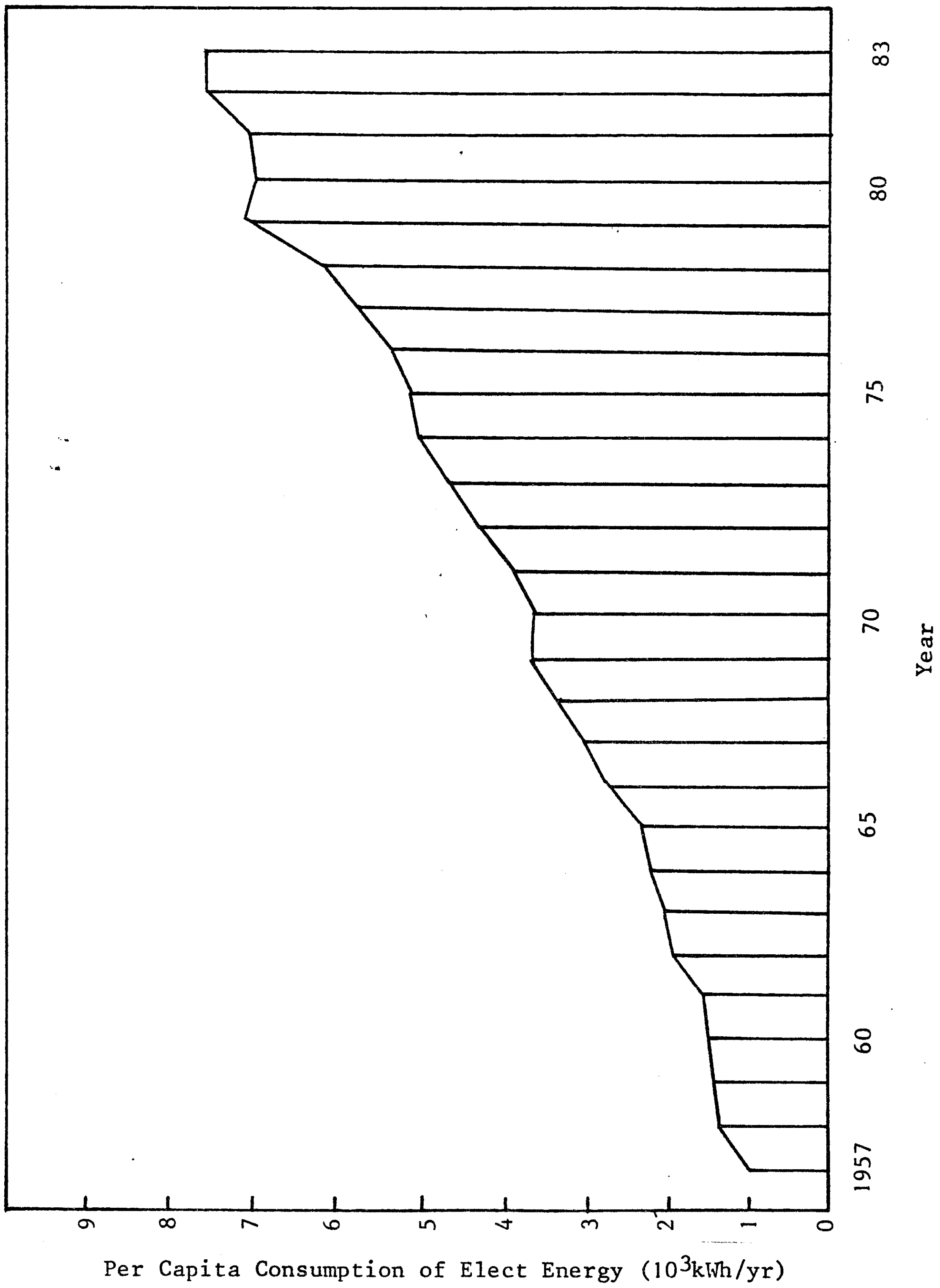


Fig. 2. Growth in annual per capita consumption of electrical energy for the State of Kuwait, 1957-1983.

Kuwait's summer extends from April until October and is characterized by hot dry conditions with maximum temperatures reaching 50°C or more. At night, temperatures drop, but only to around 28-30°C (above the accepted comfort level). During most of this period, therefore, air-conditioning is required 24 h a day. Air conditioning equipment is estimated to account for 60-70% of the peak demand and 50-60% of the annual electrical energy consumption of buildings. If present trends continue, the peak load will increase 2.5 times by 1990 (Fig. 3).

To curb this trend and to reduce the drain on the national economy, the Ministry of Electricity and Water introduced temporary guidelines and regulations for the application of thermal insulation for walls and roofs in 1980. The guidelines also contain various conservation measures for designing energy-efficient buildings. The guidelines were based on limited field experience and test results for thermal properties of construction materials. Later, the Kuwait Institute for Scientific Research (KISR) was engaged by the Ministry of Electricity and Water (MEW) to conduct scientific investigations. KISR's investigation, coupled with practical experience, led to the development of the Code of Practice for Energy Conservation in Kuwaiti Buildings (MEW, 1983). The code limits the peak load requirement for air-conditioning and lighting for different types of buildings and provides information on how the limits could be achieved.

Development of the Code of Practice

The main sources of heat gain in buildings, which affect the peak load and total energy for the air-conditioning of a building, are as follows:

- Thermal conduction gains through exterior surfaces, i.e., roof, walls, floors, windows and exterior doors.
- Solar radiation gains through glass windows and doors.
- Air infiltration gains due to gaps in window seals, air openings, porous walls and exterior doors.

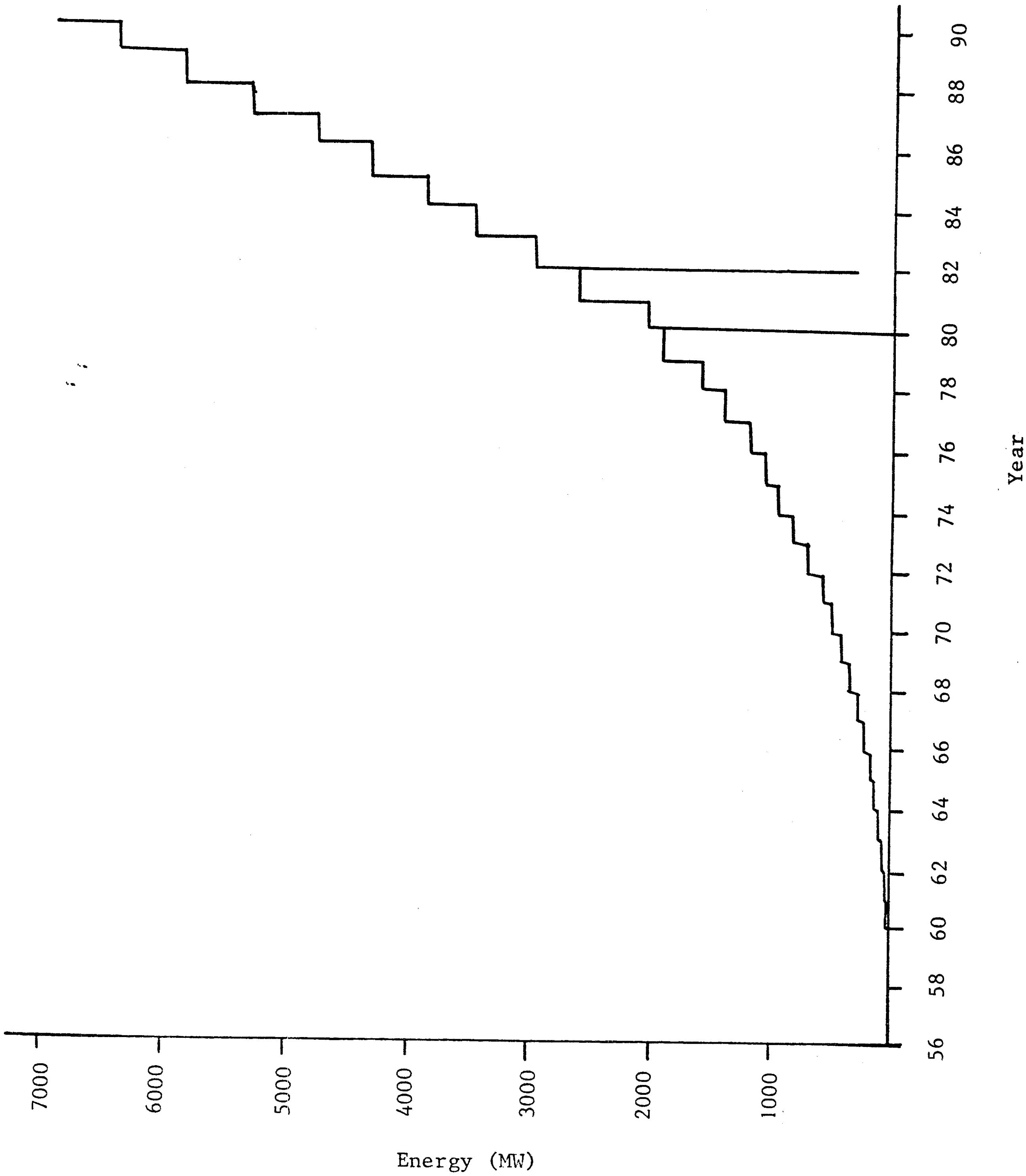


Fig. 3. Projected peak demand up to 1990.

- Interior loads due to lighting, kitchen equipment, office equipment, people and other causes.
- Additional loads due to the operation of the A/C systems, fans, exhaust fans, and fresh air intake by the A/C system.

To analyze the main sources of heat gain to determine the most effective conservation measures, a breakdown was made during the peak load during the summer, through components of typical buildings in Kuwait. Fig. 4 shows the breakdown of a typical two storey villa, one of the most common structures in Kuwait. Internal loads and loads through the ground floor are negligible. Most heat gain is through the walls, roofs and windows either by conduction, solar gain or ventilation. Reducing peak loads, therefore, can be best achieved by insulating walls and roofs and improving windows designs.

The approach used in the development of the code consists of the following:

- Selection of base case buildings that are considered typical of residential, commercial and institutional buildings constructed in the traditional practice without any conservation measures.
- Energy requirements for each base case were calculated.
- Single conservation measures were introduced and energy requirements for each measure were assessed, including different amounts of walls, roofs, floor insulation, changes in the type and size of window area, air infiltration and variable air-volume control.
- The energy requirement was analyzed for combinations of conservation measures.
- The optimum level of insulation was determined using an optimization modelling technique using economic data on prices of thermal insulation materials, electricity and installation and maintenance.

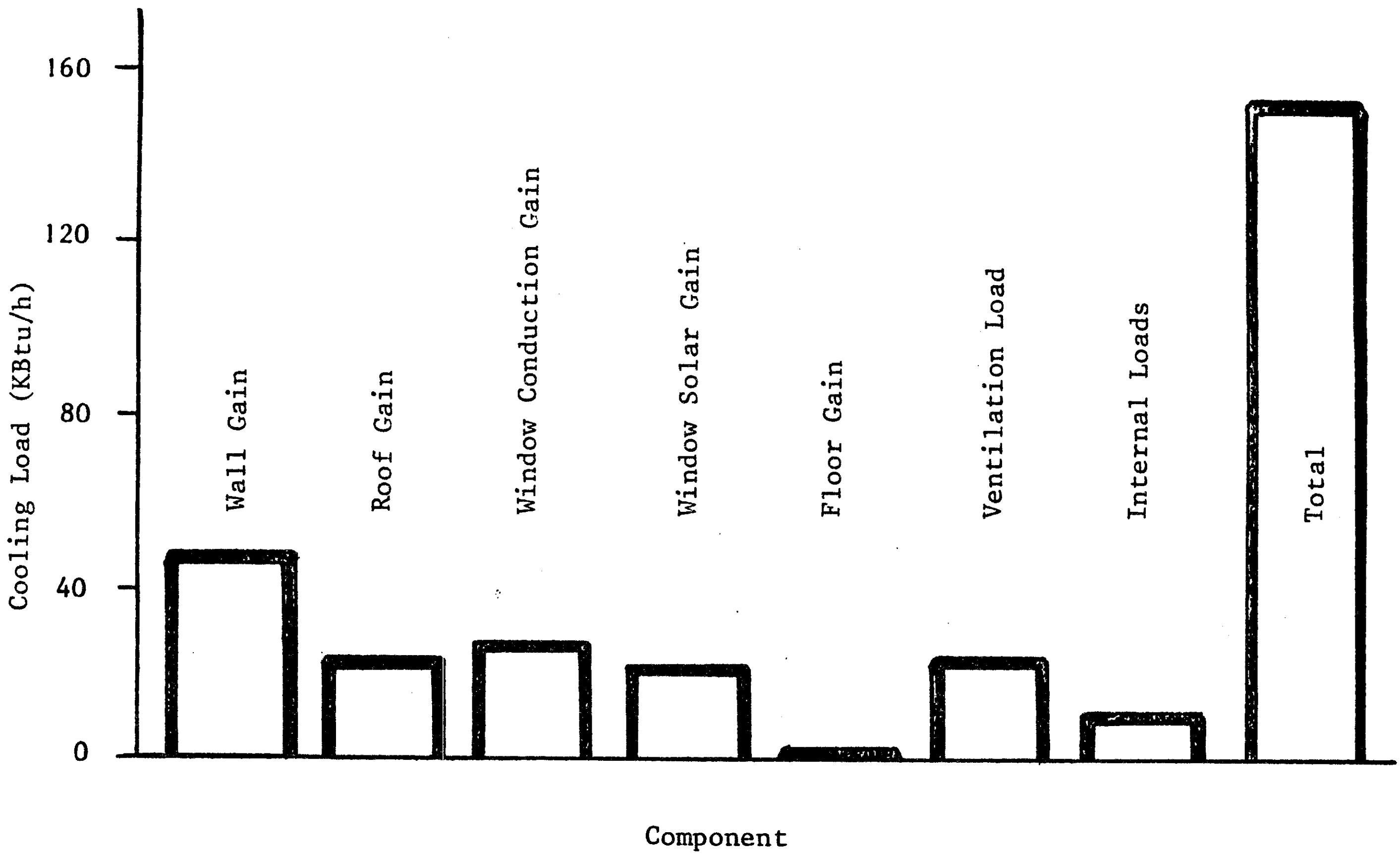


Fig. 4. Peak Load Component breakdown for two Storey Villa (space living area 264 m^2, wall area 360 m^2, wind speed 20-23 knot).

In the analysis of energy use in buildings, an advanced computer program developed by the U.S. Department of Energy (DOE-2) program was used. The program was developed at Lawrence Berkeley Laboratories (1980). The program was further developed by KISR and a mathematical model was input into the program. The developed program was named KESB (Kuwait Energy Use Simulation for Building). Optimization modelling was employed using economic data on prices of materials, electricity, installation and maintenance to determine the optimum levels of insulation and energy conservation measures. The optimization was based on maximization of national benefits while ensuring that the consumer would also financially benefit even with the subsidized price of electricity (2 Fils/kwh). All the conservation measures in the code have a pay-back period of less than five years at the consumer level.

Energy Conservation Code Requirements

The code specifies limits on the peak load requirements for air-conditioning. Table 1 presents the peak load limits for air-conditioning and lighting for different types of buildings. Tables 2 and 3 present the minimum standard for energy conservation measures to be adhered to. These standards may or may not guarantee that a building will meet the basic energy conservation requirements specified in Table 1. The building owner has the option to go beyond these minimum standards or use other recommended measures such as using variable air-volume devices or double-glazing and reflected glass as specified in Table 4.

Lightweight structures with less thermal mass will have a higher peak demand, even if overall energy requirements are the same. To compensate for this, the code recommends an increase in insulation requirements for light construction. The code classifies building construction into three basic types: light, medium and heavy. This is indicated by the weight per unit area of wall and roof construction (Table 5). Table 6 presents the U values for walls and roofs for light and medium construction.

Table 1. Peak Load Requirements for Air-Conditioning and Lightening in Buildings

Type of Building or Space Within the Building	Peak Load Requirement for Air Conditioning (W/m^2)		Peak load Requirement for Internal Lighting
	Air-Cooled Units	Water-Cooled Units	(W/m^2)
Residential			
(Single and multiple family residences)	65	45	15
Commercial			
- Offices	70	50	30
- Shops			
a) With no electrical equipment	90	60	60
b) With Electrical equipment (e.g., in grocery shops)	Add the equivalent cooling requirement for the heat generated by the equipment		
c) Shopping centers (malls)	80	56	60
- Supermarkets (with basement)	80	56	60
Institutional			
- Mosque	120	80	30
- School (classrooms)	100	65	30
- Community halls, dining halls, theaters	145	100	30
Special (industrial warehouses, sheds, factories, workshops, etc.)	No peak load (W/m^2) criterion will be applied; the minimum energy conservation requirements (Table 3) will be used.		

Table 2. Maximum Thermal Transmittance (U-Value) Allowed for Walls and Roofs of Heavy Construction, Medium/Light External Color

	Maximum Overall U - Value	
	Btu/h $ft^{2o}F$	w/m^2K
Wall	0.10	0.57
Roof	0.07	0.40

Note: For medium and light construction and different colors, the overall U-value should be decreased to obtain the equivalent thermal gain. It is left to the designer and building owners to decide the measures to be taken.

Table 3. Minimum Glazing Requirements

Glazed Area as % of Total Wall Area	Type of Glazing to Be Used
0 - 10%	Any type
11 - 15%	Any type of double glazing

Note: For higher glazing percentages, the type of double-glazing to be used to obtain the required W/m^2 is left to the designer and building owner.

Table 4. Alternative Double Glazing Types

Glazing Area as % of Total Wall Area	Types of Glazing to be Used
15 - 20%	All Types of Double Glazing
20% and above	Double Tinted or Double Reflective Glazing

Table 5. Classification of Building Construction

Building Construction Type	Wall (kg/m^2)	Roof (kg/m^2)
Light	50 - 240	25 - 120
Medium	245 - 480	125 - 240
Heavy	485 - 730	245 - 370

Table 6. Maximum Thermal Transmittance (U-value) Allowed for Walls and Roofs of Medium and Light Construction

Description	Wall (Btu/hft2oF)	Wall (W/m2K)	Roof (Btu/hft2oF)	Roof (W/m2K)
1. Heavy Construction, Dark External Color	0.075	0.42	0.045	0.26
2. Medium Construction, Medium/Light External Color	0.085	0.48	0.06	0.34
3. Medium Construction, Dark External Color	0.075	0.42	0.035	0.20
4. Light Construction, Medium/ Light External Color	0.075	0.42	0.05	0.28
5. light Construction, Dark External Color	0.065	0.36	0.03	0.17

Insulation Materials

Insulation materials are divided into four categories, each with a standard value of thermal resistance. This value is lower than that quoted by most manufacturers and is supposed to allow for deterioration in service conditions and variation in manufactures (Fig. 5). The insulation materials accepted by the code are defined as follows:

1. <u>Perlite</u>

   Perlite (volcanic glass) expanded by exposure to heat to form lightweight angular particles, normally between 0.5 and 5.0mm in length.

2. <u>Vermiculite</u>

   Vermiculite (micaeous mineral flakes) exfoliated by exposure to heat to form lightweight cubicle particles, normally between 5 and 10 mm in length.

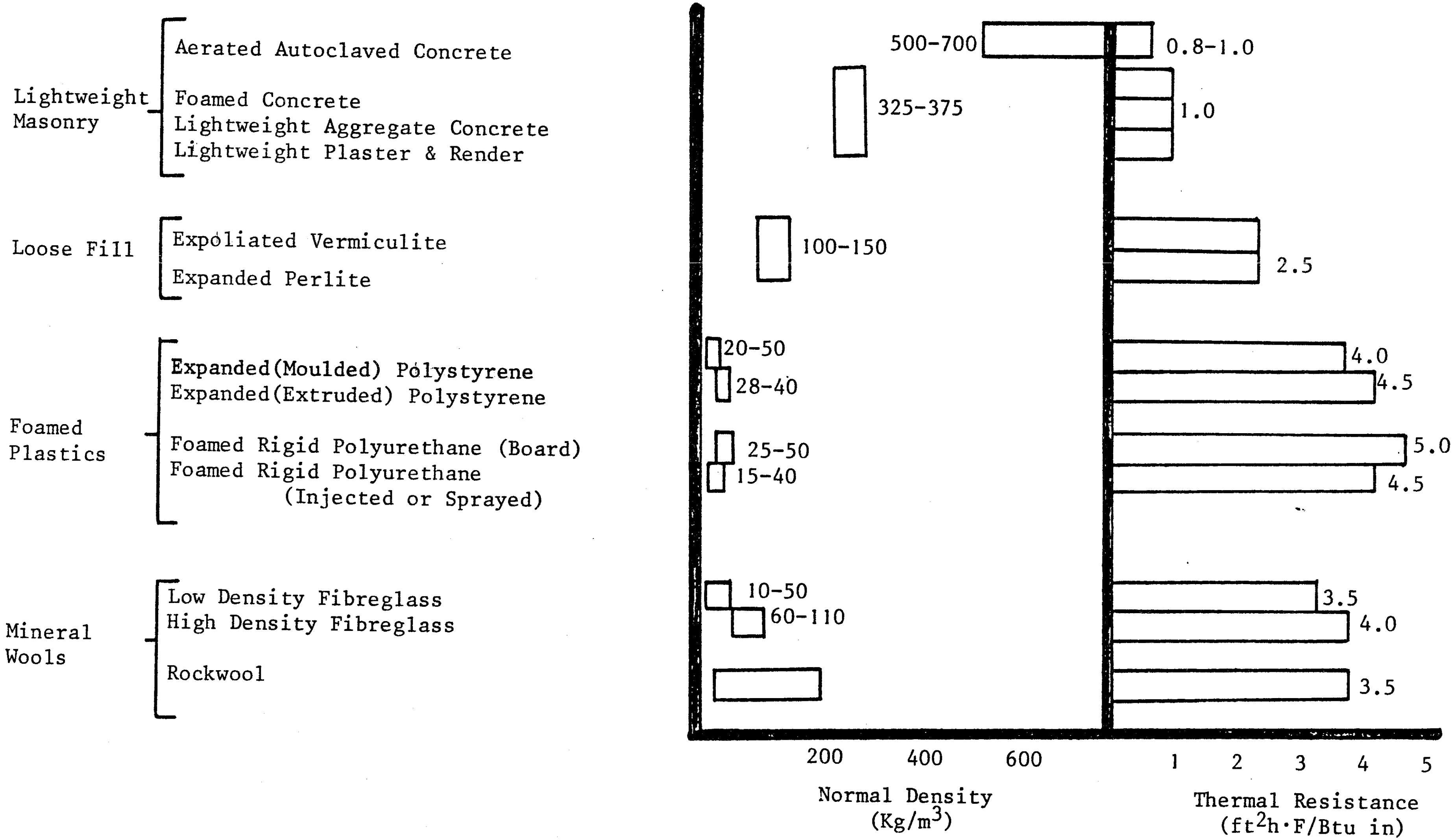


Fig. 5. Classification & Thermal Resistance of Selected Insulation Materials.

3. Foamed Concrete

Concrete made from a mixture of cement, water and chemical foam.

4. Perlite Concrete and Mortar

Concrete and mortar made from a mixture of cement, water and expanded perlite.

5. Vermiculite Concrete and Mortar

Concrete and mortar made from a mixture of cement, water and exfoliated vermiculite.

6. Aerated Autoclaved Concrete

Masonry units from a mixture of sand, lime, cement, gypsun and water, aerated by aluminum powder.

7. Foamed Glass

Glass aerated by a foaming agent during manufacture.

8. Expanded (moulded) Polystyrene

Rigid lightweight sheet formed by the expansion and partial fusion of polystyrene beed, heated in moulds and cut to size.

9. Expanded (extruded) Polystyrene

Rigid lightweight sheet formed by the direct extrusion of foamed polystyrene into sheets.

10. Expanded (Moulded) Polyurethene

Rigid lightweight material made by reacting an isocyanate with a polyol in the presence of foaming agents. The product may be formed into a mould and subsequently cut to size, sprayed directly on the surface to be insulated or injected into cavities.

11. Fiberglass

Fibers formed by the spinning of molten glass, resin-bonded to form a flexible or rigid mat usually faced with building paper or metalized foil.

12. Mineral Wool

Fibers formed by drawing or spinning molten rock and/or clay, resin-bonded to form flexible or rigid mats usually faced with board, paper or metalized foil.

Other materials have been omitted because there is less experience in their behavior unde Kuwaits conditions or because they are controversial. These include urea and phenol formaldehydes and cellulose fibers.

Application of Insulation Materials to Walls

With the exception of a few precast concrete structures, the majority of Kuwaiti walls are 200 mm thick solid sand-cement blocks, plastered internally with sand-cement and faced externally with sand-lime brick, natural stone, marble or cast concrete tiles. When the exterior facing is self-supporting brick, it is not difficult to put a layer of insulation between the block and the facing brick. When the facing is stone or marble, the normal practice of mortaring the stone directly onto the block is no longer possible. Mechanical fixings have to be employed, or a cavity has to be created within the blockwork. Because of the local practice of cutting channels in the inner face of the blockwork to accommodate pipes and conduits, however, the inner leaf of the block has to be a minimum 15 cm thick. If one adds 10 cm of outer-leaf, 5 cm of insulation, 4 cm of natural stone or marble finish and 2 cm of internal plaster, one ends up with a 36 cm thick wall.

Insulation can, of course, be fixed internally, provided clearances have been allowed around doors, windows, electrical points and switches. Although giving less overall efficiency, internal insulation can be useful in rooms occupied intermittently, e.g., meetingrooms, since they can be left without air conditioning for long periods, but cool quickly when an A/C is switched on. Fire departments will not allow foamed plastics to be used in this way, limiting the choice of insulation material to one of the mineral wools. Even the densest of these is somewhat compressible so finishing should preferably be a dry lining such as gypsum board or wood panelling rather than a wet plaster.

By using lightweight masonry, it is possible to construct a simple block wall with built-in isulating properties. Although unit thermal resistance is only about 20% of foamed plastics or mineral wool, the thicknesses used are greater. Lightweight blocks (autoclaved aerated concrete) commercially called Azel Block, is produced by the National Industries Co. The products has a density of 500 kg/m^3 with a compressive strength of 30 kg/cm^2. The product has a thermal conductivity of 0.98 Btu in/ft^2h^oF. Several firms are now licenced to manufacture lightweight masonry units incorporating expanded perlite, exfoliated vermiculite or expanded polystyrene bead. Cavity walls filled with loose perlite, vermiculite, expanded polystyrene bead, or polyurethane foam are also possible.

Application of Insulation to Roofs

Placing of foamed screed on top of traditional flat roof slabs has been a common practice in Kuwait for many years; it provides a small amount of insulation and assists run off, but it is impractical to supply sufficient thickness to meet modern insulation codes. It has, therefore, to be supplemented by a more efficient insulator and, although few people use their roofs, roof access is usually a requirement and whatever insulation system is used must be able to withstand foot traffic; rigid foam plastic boards are likely to perform better than more compressible fiberglass and rock wools, and the most convenient place to put them is below the foamed concrete screed, where loadings are spread, and the waterproofing membrane remains above the insulation. Alternatively, insulation can be added above the foamed concrete and waterproof membrane; a procedure most suited to retrofit operations where these layers are already in place. In this case, the best material to use is extruded polystyrene, because of its lower water absorption characteristics. Other materials will require an additional waterproof layer.

The so-called 'upside down' roof is one in which the waterproof membrane is placed directly on the roof slab, with slabs of extruded polystyrene placed on top and held in place by paving slabs or gravel. This roof is meeting resistance in Kuwait from engineers who are dissatisfied with the complete absence of a slope and by users who are accustomed to a smooth finish, but the speed of installation is attractive.

Additional insulation can, of course, be added below the roof slab. The insulation, in this case, is protected from the weather and from wear and tear and is likely to be more durable. In this case, the mineral wools are preferred to foamed plastics because of their fire-resistant properties.

The recommended thermal resistivity and conductivity of insulation materials and common building materials are given in Tables 7 and 8. The skin resistance of the outer and inner surfaces and the air spaces contained within the section contribute to the total resistance of the wall and roof. The values are given in Table 9. The proposed code recommended standard wall and roof sections, incorporating common insulation materials and prohibited the use of other materials until tests could be made to determine their effectiveness. The code gives somewhat conservative figures of thermal resistance for design purposes; amendments will undoubtedly be made with experience. The recommended wall and roof sections proposed in the code are given in Appendix I.

Table 10 presents the peak electrical load requirement for the base cases without any conservation measures and those which employ the conservation measures in accordance with 1983 code requirements. Adherence to the 1983 Code of Practice produces significant reductions in the peak electrical load and annual energy consumption over the base case.

Windows

Typically, about 40% of the total heat gain comes through the windows for the following reasons:

- They are transparent and admit direct solar radiation.
- They are thin and conduct heat readily from the outside air.
- They are the principal openings in the fabric and the principal causes of infiltration.

It is therefore just as important to reduce heat gains through windows as it is through walls and roofs. Some methods of doing this are given below:

Table 7. Thermal Resistivity and Conductivity of Insulation Material

Insulation Material	Thermal Resistivity ($ft^2h^oF/Btu\ in$)	Thermal Conductivity ($Btu\ in/ft^2h^of$)
Loose Fill		
Perlite	2.5	0.4
Vermiculite	2.5	0.4
Lightweight Masonry		
Foamed Concrete	1.0	1.0
Foamed Glass	2.5	0.4
Aerated Autoclaved Concrete	0.8 - 1.0	1.25 - 1.0
Foamed Plastics		
Foamed Polyurethane Board	5.0	0.2
Foamed Polyurethane Spray	4.5	0.22
Expanded (extruded) Polystyrene	4.5	0.22
Expanded (moulded) Polystyrene	4.0	0.25
Mineral Wools (fiberglass)		
Density 10 - 48 kg/m^3	3.5	0.29
Density 60 - 110 kg/m^3	4.0	0.25
Mineral Wool (rockwool)	3.5	0.29

Table 8. Thermal Resistivity and Conductivity of Building Materials

Building Material	´R´ Value (ft^2h^oF/Btu in)	´K´ Value (Btu in/ft^2h^of)
Dense Mortar Screed	0.157	6.38
Terrazzo Tiles	0.120	8.32
Concrete Tiles	0.097	10.33
Waterproofing Material	0.288	3.47
Cast Concrete Slab	0.097	10.33
Corrugated Galvanized Steel	0.009	104.00
Corrugated Asbestos Cement	0.144	6.93
Mineral Wool Tile	1.449	0.69
Stone/Marble	0.096	10.40
Rendering/Roughcast	0.250	4.00
Sand-lime Brick or Block	0.206	4.85
Sand Cement Block	0.160	6.24
Wood	0.160	6.24
Gypsum Board	0.313	3.19

Table 9. Thermal Resistivity and Resistance of Air Space Within Structures in Kuwait

Surface	'R' Value ($ft^2 h ^oF/Btu$ in)
<u>External Wall Surface</u>	
Non-metallic	0.278
Un-painted met	0.369
<u>Internal Wall Surface</u>	
Non-metallic	0.698
Unpainted metal	1.374
<u>External Roof Surface</u>	
Non-Metallic	0.233
Metallic	0.290
<u>Internal Roof Surfaces</u>	
Non-metallic	0.857
Metallic	2.152
cavity within wall	1.000
cavity lined on one side with aluminum foil	2.000
Air space above false ceiling	2.000
Air space lined on one side with aluminum foil	4.000

Table 10. Summary of Peak Electrical Load for Space Cooling According to Different Energy Conservation Standards

Building Type	Peak Electrical Load for Air-Conditioning (W/m^2) Base Case	1983 Code of Practice Limits
Residential		
Single Storey Villa	123.7	65
Single Storey Villa with Courtyard	152.4	65
Two Storey Villa	108.1	65
Limited Income House	79.6	65
Medium Income House	108.4	65
Five Storey Apartment	100.4	65
Commercial		
Offices	53.5	50 *
Shops	178.0	121 +
Institutional		
Mosque	269	120
School (Classroom	110	65 *
Community Hall, Hospital, etc.	Special buildings. No peak load (W/m^2) is applied. Minimum conservation requirements must be included.	

* Employing water-cooled A/C equipment (1.4 kW/t). All other cases are for air-cooled A/C equipment rated at 2 kW/t.

\+ Includes 31 W/m^2 cooling requirement for heat generated by equipment.

Limitation in Number and Size of Windows

The fashion, in general, is to over-fenestrate to produce interior light and create an illusion of space. But because windows waste in energy, there is now a tendency (especially in recent Kuwaiti buildings) to restrict window size. This can be counterproductive if overdone; insufficient windows mean insufficient daylight so that artificial light has to be used. This wastes energy not only because power is needed to activate the light, but extra cooling is needed to remove the heat it produces. Proper design with regard to the building's intended function is required to produce the correct balance.

Correct Positioning

If the main function of the window is introducing daylight, they should be placed high on the walls so the light they admit can be spread across the room; if it is outlook, they should be placed at eye level. East and west facing windows should be kept to a minimum. Most day-lighting should be achieved by north or south facing windows, which can easily be shaded.

Design

The prime consideration of design should be to provide the maximum light:heat transmission ratio. Frames should be as narrow as possible consistent with strength and rigidity. A frame with thermal brick will reduce heat gain through the frame effectively.

Multiple Glazing

Double-glazed windows are effective in conserving energy compared with single-glazing. They reduce conduction gains by about 50%, but with a loss of about 12% light transmission. Triple-glazed units are not readily available. The saving is an additional 17%, but with a further 8% loss of light.

Solar Glass

'Tinted' glass whether 'body tinted' or 'surface modified' is not particularly effective in reducing heat gains. It absorbs some of the sun's infrared rays but also blocks some of the visible light. These absorbed infrared rays, heat the glass and some of this heat is re-radiated or convected to the outside. The remainder eventually moves into the building, but the net effect is not significant.

New surface coated glass, in which metallic deposits are applied during manufacturing, are being made developed in a variety of colors and coating thicknesses to produce a wide range of properties. All are to some extent, heat-absorbing and get hotter than ordinary clear glass. In Kuwait, this will require adequate clearance between the glass and the frame to allow for expansion. The principal property is their ability to selectively reflect some of the infrared and ultraviolet rays; visible light is also lost, but the light:heat ratio is usually more favorable than it is for clear glass.

Double- glazed units made of solar reflective glass are the most effective: unfortunately, they are the most expensive. Computer analysis made for typical buildings in Kuwait indicate that despite this, they are cost-effective in terms of lower air conditioning plant requirements.

Some of the larger glass-making companies are experimenting with double-glazed units having all glass surfaces metal-coated. These not only selectively reflect infrared and ultraviolet light, but also utilize low emissivity properties of metallic coatings on the inner faces to optimize the cavity effect and reduce the radiation of stored heat to the interior. Some are said to have U-values similar to a normal brick or block wall.

The order of magnitude of heat gains from the typical types of glazing is shown in Fig. 6. The properties of solar glazing can vary from one type to another.

Control of Infiltration

Infiltration is mostly caused by poorly fitted and badly designed windows. As long as sliding windows remain popular, it is difficult to see how this can be remedied. Sliding windows do not get in the way of curtains or flyscreens and are cheaper to produce than the hinged variety, but because the latter are more efficient, their use for energy conservation purposes should be considered. There is a case for a special design to suit Kuwait's condition, (Fig. 7a) where the air is directed to the lower part of the room when needed, but the glass can be shut tight against hot air and dust during hot weather. Centrally hinged designs (Fig. 7b, c) would be suitable for deeply recessed windows. Whatever type of window is employed, it should at least fit snugly into its frame and the frame into the window opening. A silicone caulk is recommended if any air movement can be detected around the window edges.

Shading Devices

It is best to prevent, as far as possible, direct sunlight coming through the glass for most of the summer. Permanent external screens can be effective in north or south-facing windows where the sun's angle of incidence is acute; east and west-facing windows aspects are more difficult to deal with. The commonest policy is to recess the window as far as possible to at least reduce the time during which the direct sunlight will strike the glass (Fig. 8). External canvas screens or wooden shutters are obviously more effective than curtains in blocking the sun's rays. Sunscreens in the form of heavy concrete or ceramic grill work are more common. These may enhance the appearance of the building, but whatever sunlight they block is matched by the useful light prevented from entering the building. At night, the stored heat radiated towards the wall and their presence blocks much of the cooling effect that could be achieved by night radiation.

Curtains normally delay the passage of heat into the room, but light or, preferably, metallic linings can direct some solar radiation back through the glass. Padded curtains can be effective in reducing total heat gains, but only if sealed against the window space. It is difficult to achieve this without spoiling their aesthetic effect.

There is a case for installing built-in insulated shutters that, when the room is not being used, can be drawn across the window space negligibly reducing the heat gains.

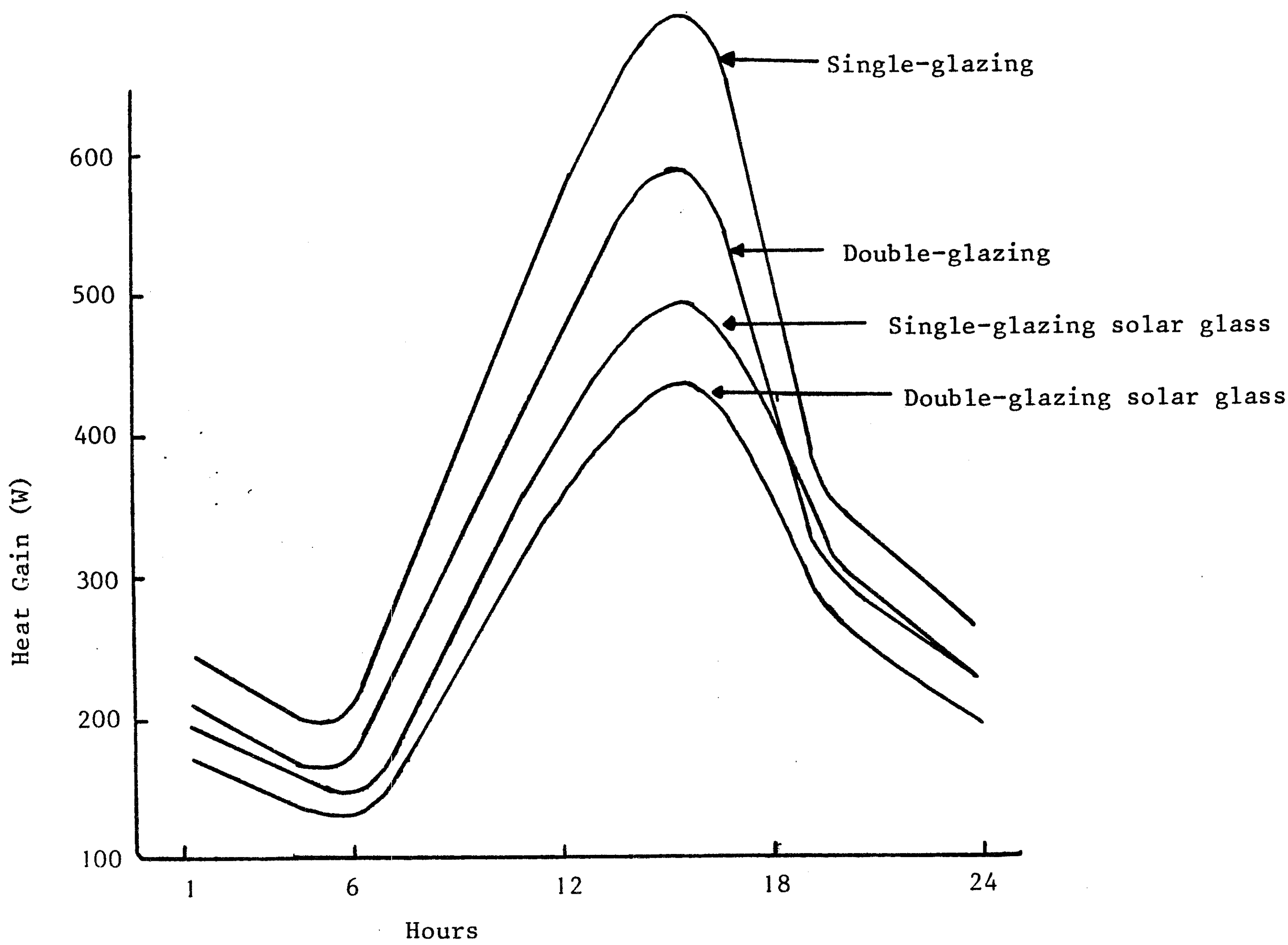


Fig. 6. Heat gains through windows due to radiation, convection and infiltration.

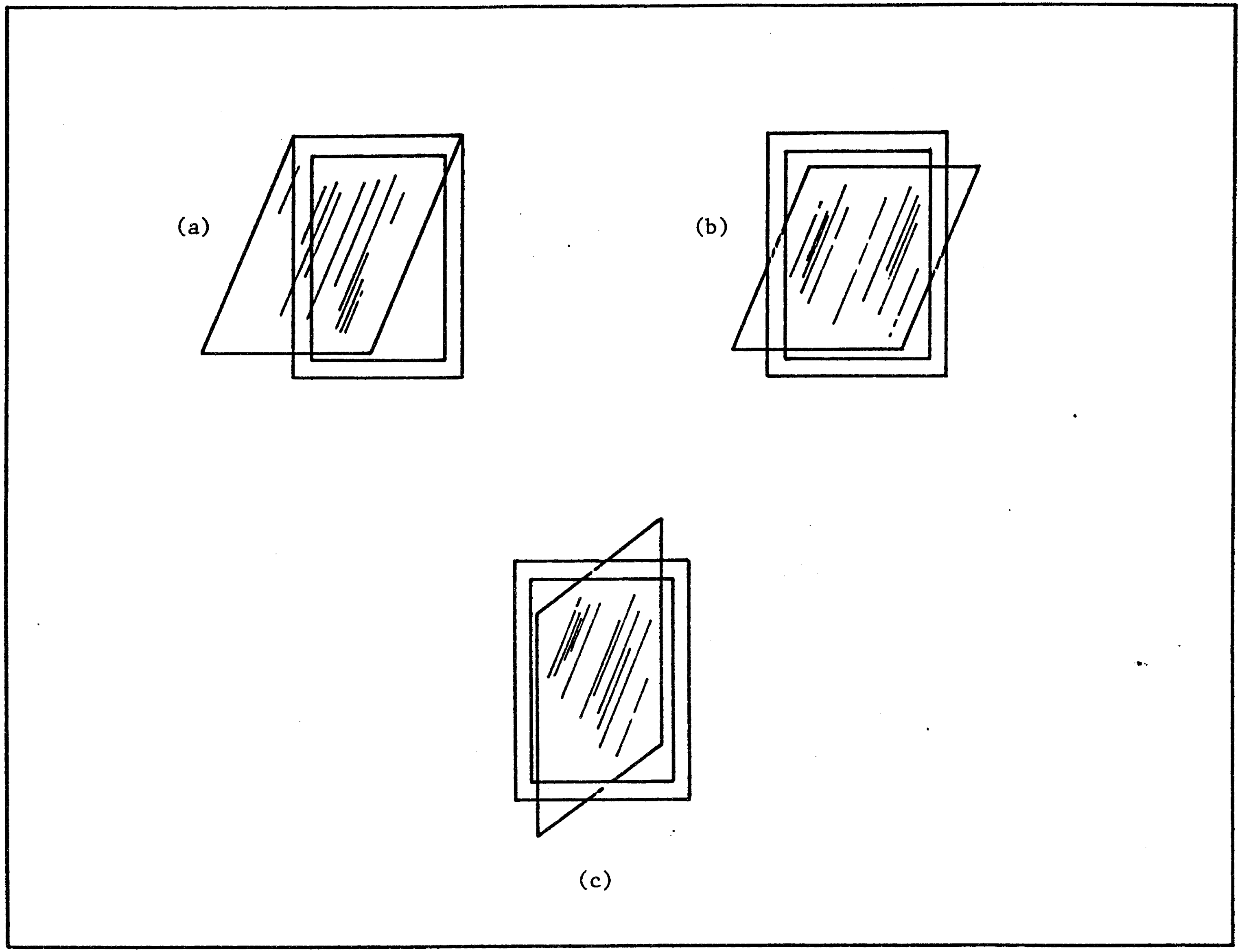


Fig. 7. Various pivot points for opening windows.

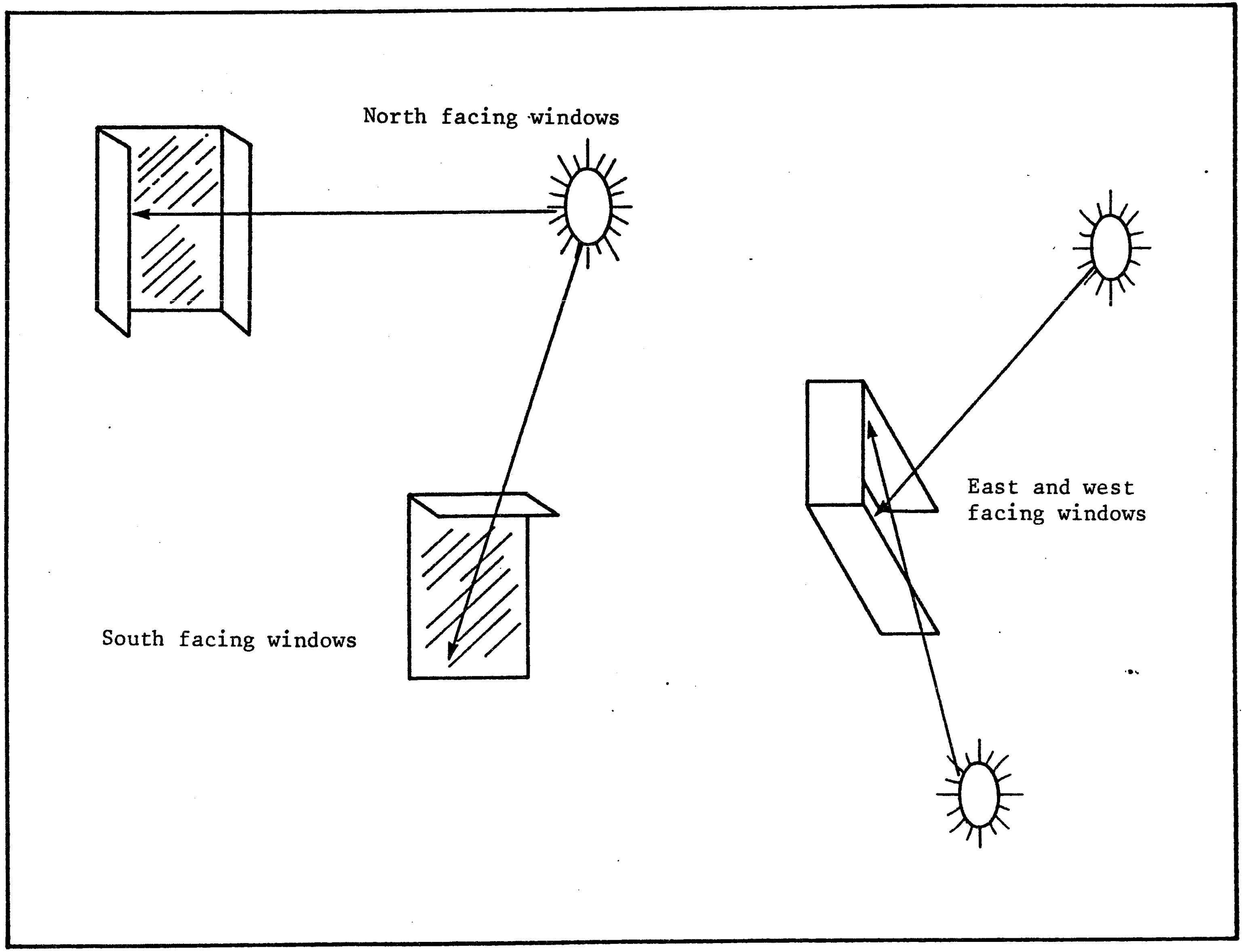
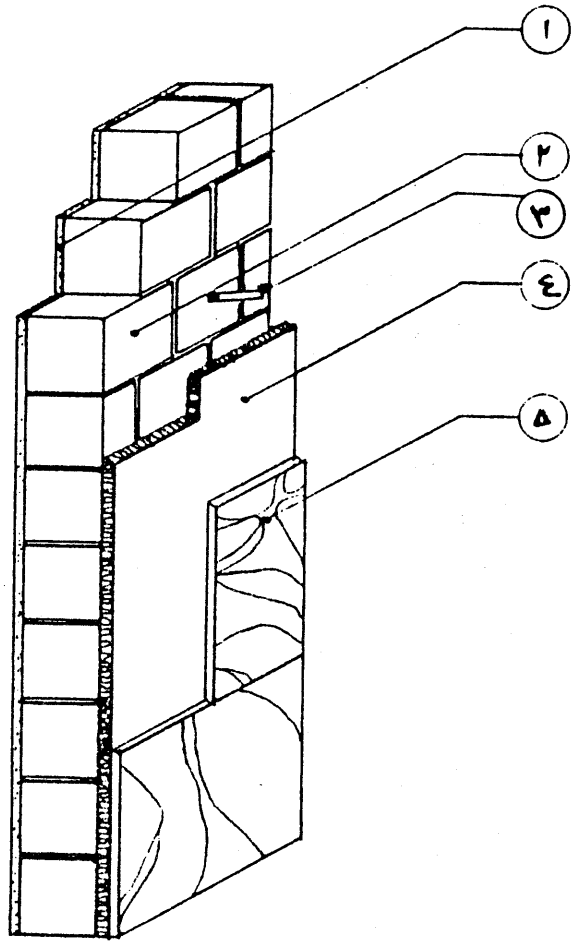


Fig. 8. Shading devices for different window orientation.

Appendix I
Details of Wall and Roof Sections

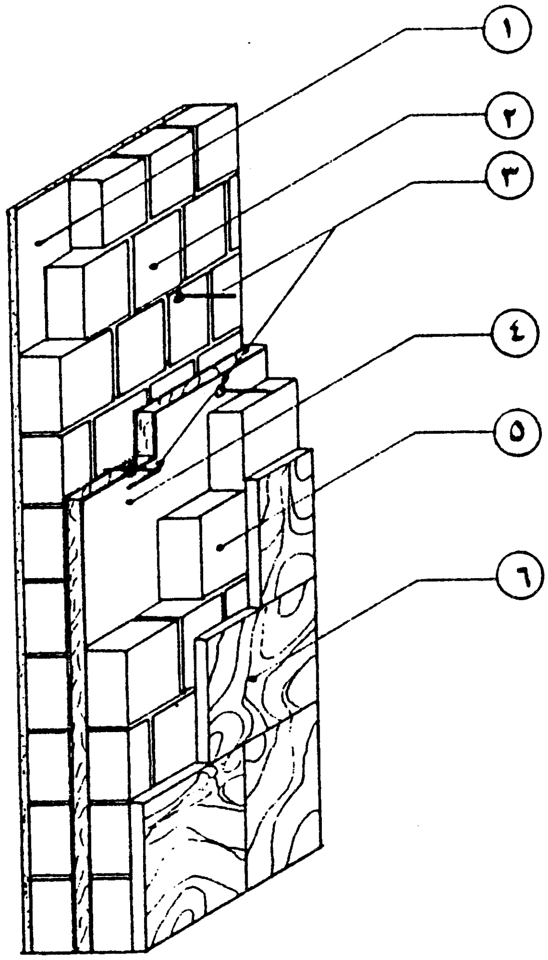
WALL 1



1. Sand cement plaster (2 cm)
2. Sand cement block (solid) (20 cm)
3. Mechanical fixings
4. Extruded polystyrene (5 cm)
5. Marble (3 cm)

١- مساح رمل / اسمنت (٢ سم)
٢- طابوق اسمنتى (٢٠ سم)
٣- روابط تشبيت
٤- بوليسترين منبثق (٥ سم)
٥- رخام (٣ سم)

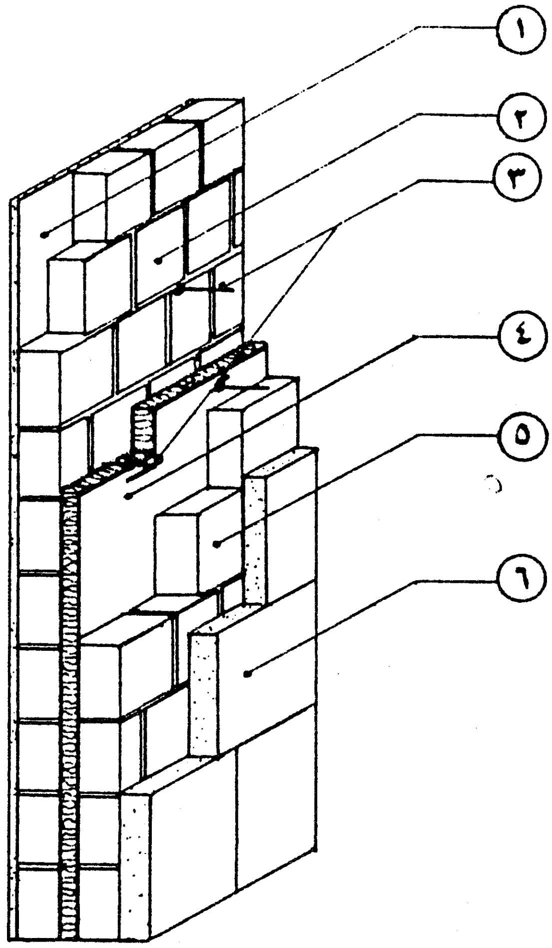
WALL 2



1. Sand cement plaster (2 cm)
2. Sand cement block (solid) (10 cm)
3. Wall ties
4. High density mineral wool (faced both sides with reinforced aluminium foil) (5 cm)
5. Sand cement block (10 cm)
6. Marble (3 cm) (solid)

١- مساح رمل / اسمنت (٢ سم)
٢- طابوق اسمنتى (١٠ سم)
٣- روابط تشبيت
٤- صوف معدنى كثيف (مغطى بالالمنيوم المقوى من الجهتين) (٥ سم)
٥- طابوق اسمنتى (١٠ سم)
٦- رخام (٣ سم)

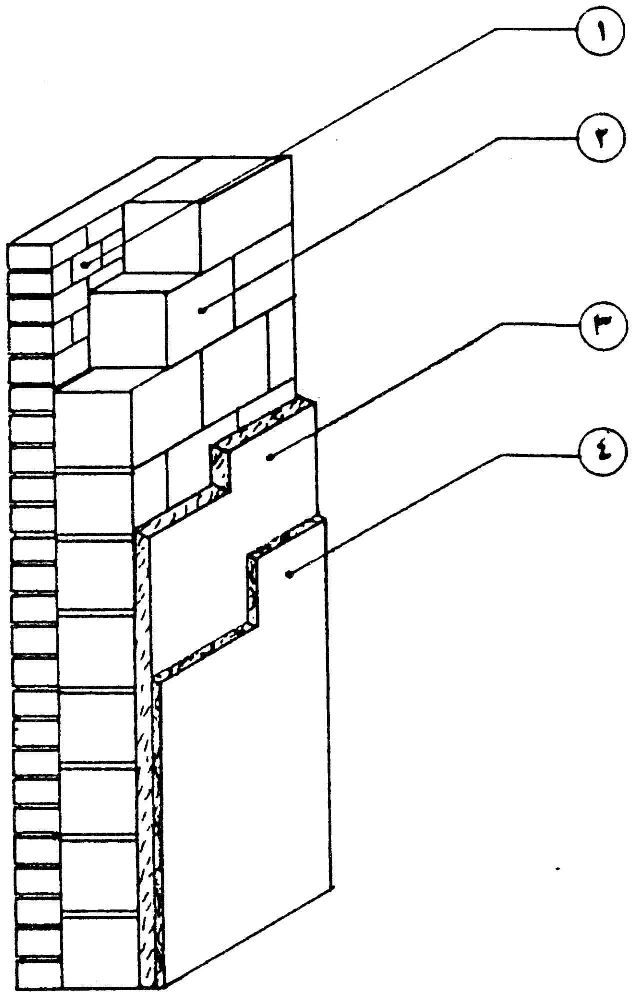
WALL 3



1. Sand cement plaster (2 cm)
2. Sand cement block (solid) (10 cm)
3. Wall ties
4. Expanded Polystyrene (faced both sides with reinforced aluminium foil) (5 cm)
5. Sand cement block (solid) (10 cm)
6. Natural stone (3 - 8 cm)

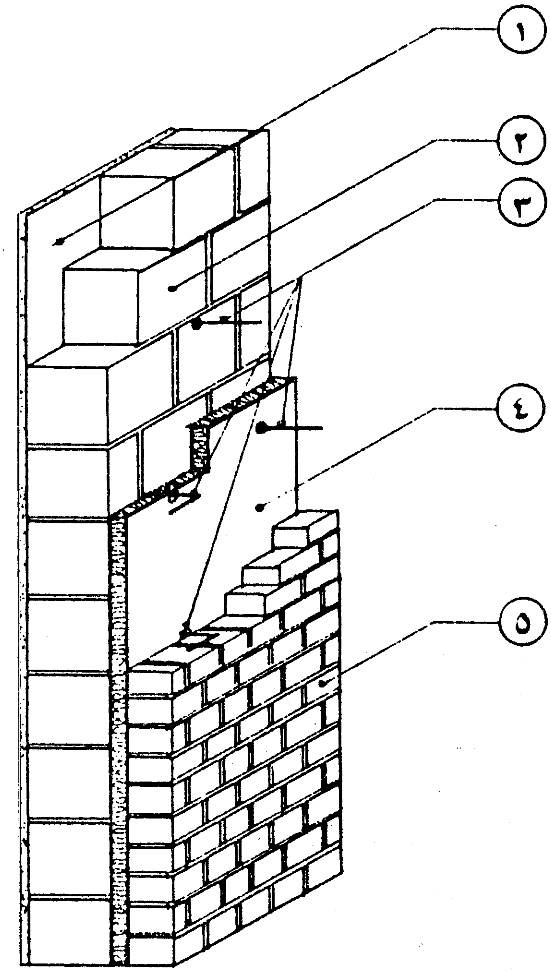
١- مساح رمل / اسمنت (٢ سم)
٢- طابوق اسمنتى (١٠ سم)
٣- روابط تثبيت
٤- بوليسترين ممدد بصفائح المنيوم المقوى من الجهتين (٥ سم)
٥- طابوق اسمنتى (١٠ سم)
٦- حجر طبيعى (٣ - ٨ سم)

WALL 4



1. Sand Lime brick (11 cm)	١- طابوق جيرى (١١ سم)
2. Sand cement block (solid) (20 cm)	٢- طابوق اسمنتى (٢٠ سم)
3. High density mineral wool (5 cm)	٣- صوف معدنى كثيف (٥ سم)
4. Gypsum board (1 cm)	٤- الواح جبس (١ سم)

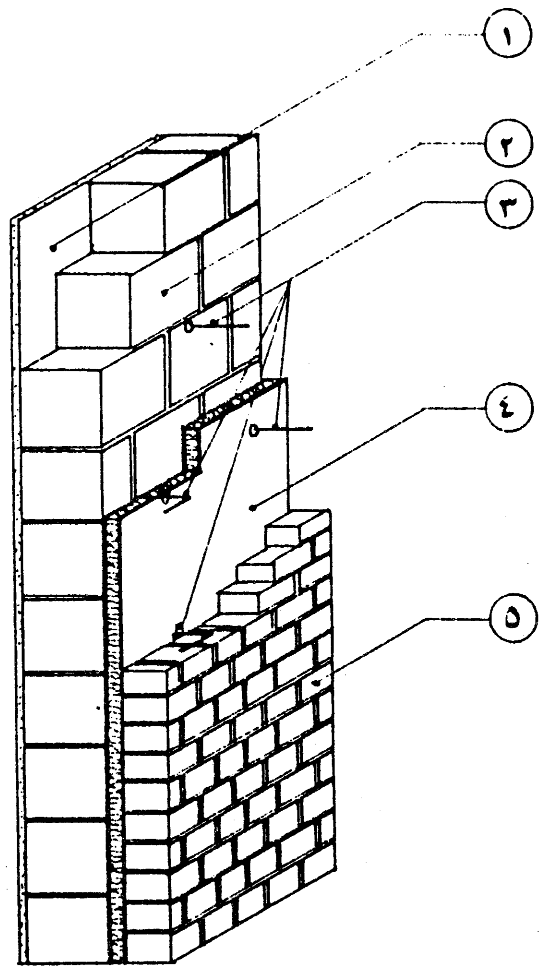
WALL 5



1. Sand/cement plaster (2 cm)
2. Sand cement block (solid) (20 cm)
3. Wall ties
4. Polyurethane (faced both sides with aluminium foil) (5 cm)
5. Sand-lime brick (11 cm)

١- مساح رمل / اسمنت (٢ سم)
٢- طابوق اسمنتي (٢٠ سم)
٣- روابط تثبيت
٤- بوليورثين مغطى بصفائح المنيوم مقوى من الجهتين (٥ سم)
٥- طابوق جيري (١١ سم)

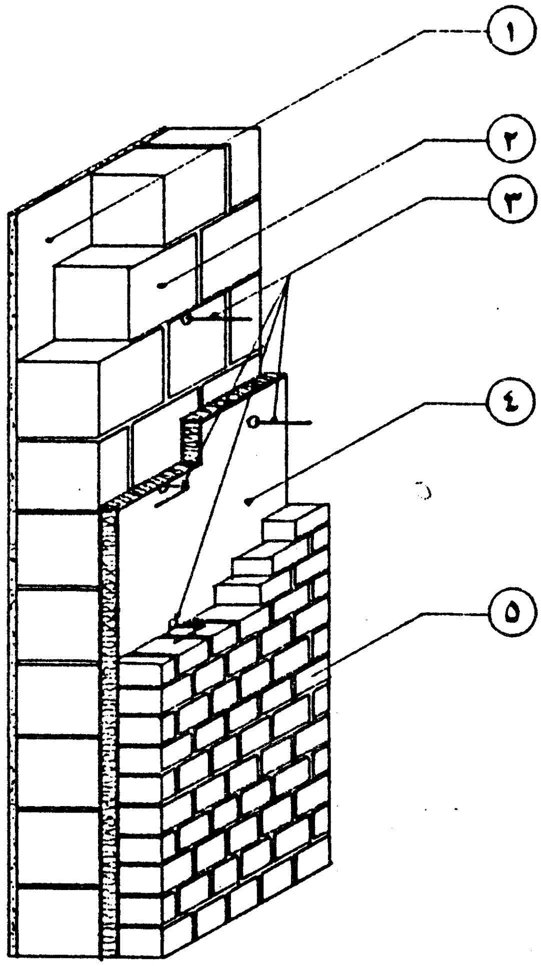
WALL 6



1. Sand/cement plaster (2 cm)
2. Sand cement block (solid) (20 cm)
3. Wall ties
4. Extruded polystyrene (5 cm)
5. Sand-lime brick (11 cm)

١- مساح رمل / اسمنت (٢ سم)
٢- طابوق اسمنتي (٢٠ سم)
٣- روابط تثبيت
٤- بوليسترين منبثق (٥ سم)
٥- طابوق جيري (١١ سم)

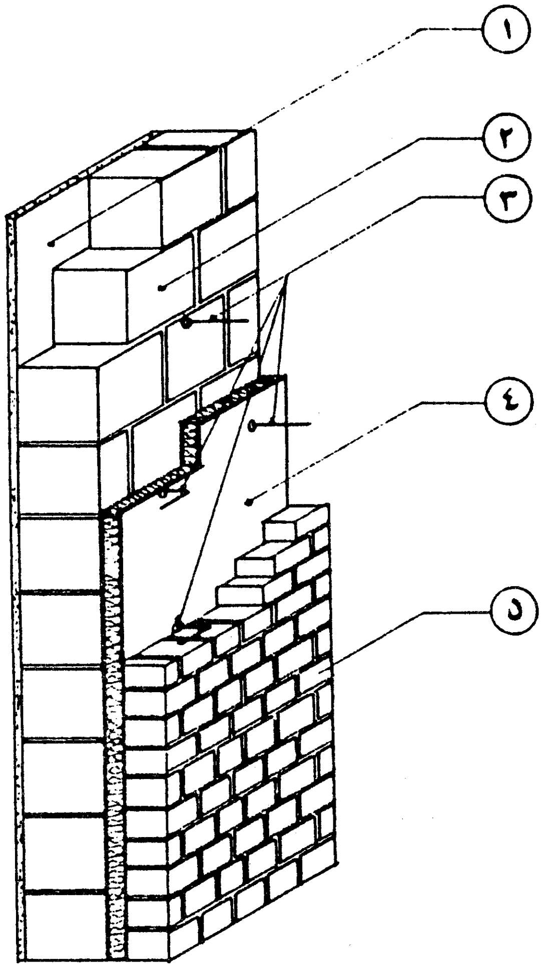
WALL 7



1. Sand/cement plaster (2 cm)
2. Sand cement block (solid) (20 cm)
3. Wall ties
4. High density mineral wool (faced both sides with aluminium foil) (5 cm)
5. Sand-lime brick (11 cm)

١- مساح رمل / اسمنت (٢ سم)
٢- طابوق اسمنتى (٢٠ سم)
٣- روابط تشبيت
٤- صوف معدنى مكثف مغطى بصفائح من الالمنيوم من الجهتين (٥ سم)
٥- طابوق جيرى (١١ سم)

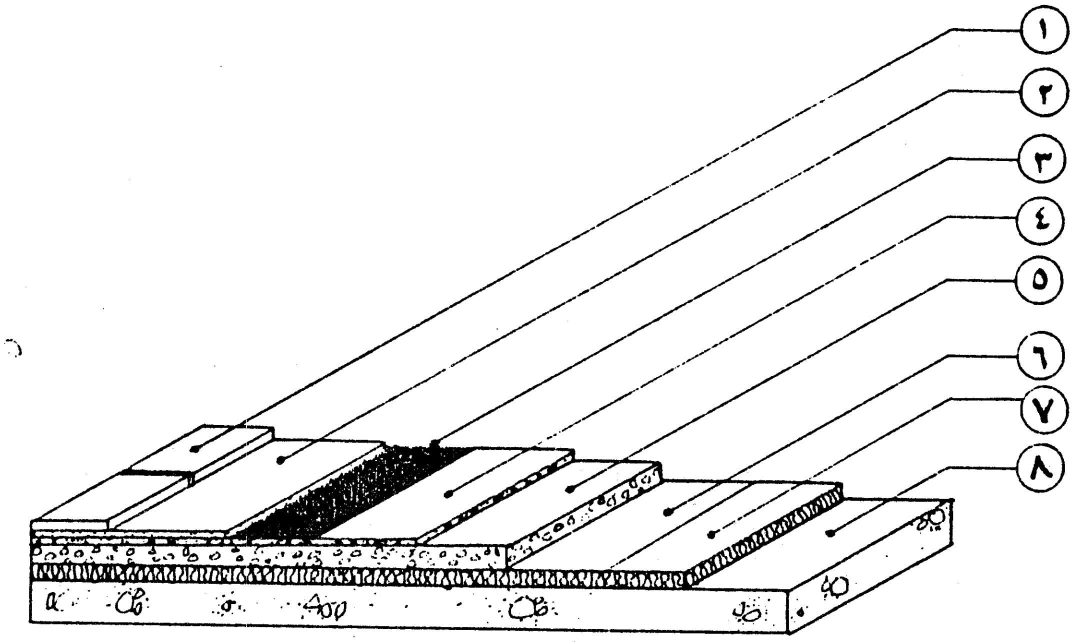
WALL 8



1. Sand/cement plaster (2 cm)
2. Sand cement block (solid) (20 cm)
3. Wall ties
4. Expanded polystyrene (faced both sides with aluminium foil) (5 cm)
5. Sand-lime brick (11 cm)

١- مساح رمل / اسمنت (٢ سم)
٢- طابوق اسمنتى (٢٠ سم)
٣- روابط تثبيت
٤- بوليسترين ممدد (مغطى بالالمنيوم من الجهتين) (٥ سم)
٥- طابوق جيرى (١١ سم)

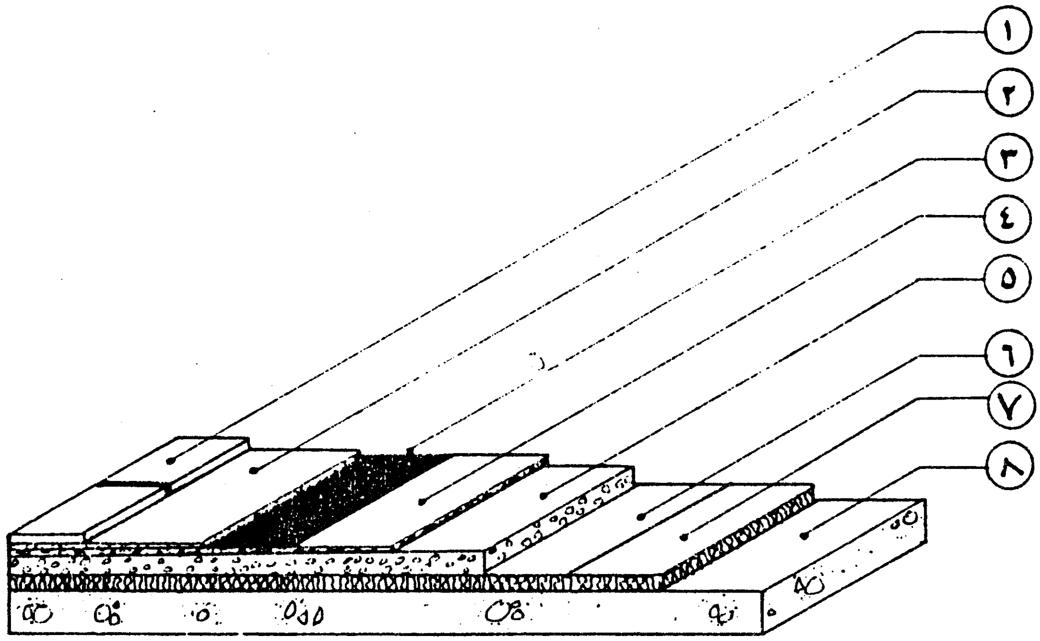
ROOF 1



1. Sand cement roofing tiles (white) (20 x 20 x 2 cm)
2. Motar bed (2 cm)
3. Elastameric waterproofing on bituminous primer
4. Sand cement screed (2 cm)
5. Foamed concrete 2% slope (5 cm at lowest point)
6. 1000 Gauge polythere sheet
7. Extruded polystyrene, insulation (5 cm)
8. Concrete slab (12 cm)

١- بلاط اسمنتى أبيض (٢٠ x ٢٠ x ٢ سم)
٢- ٢ سم مونة
٣- مانع الرطوبه (ممبرين)
٤- ٢ سم مونة
٥- خرسانه رغوية بانحدار ٢٪ (٥ سم فى ادنى نقطة)
٦- ورق نايلون جيج (١٠٠٠)
٧- بوليسترين منبثق (٥ سم)
٨- سقف خرسانه مسلحة (١٢ سم)

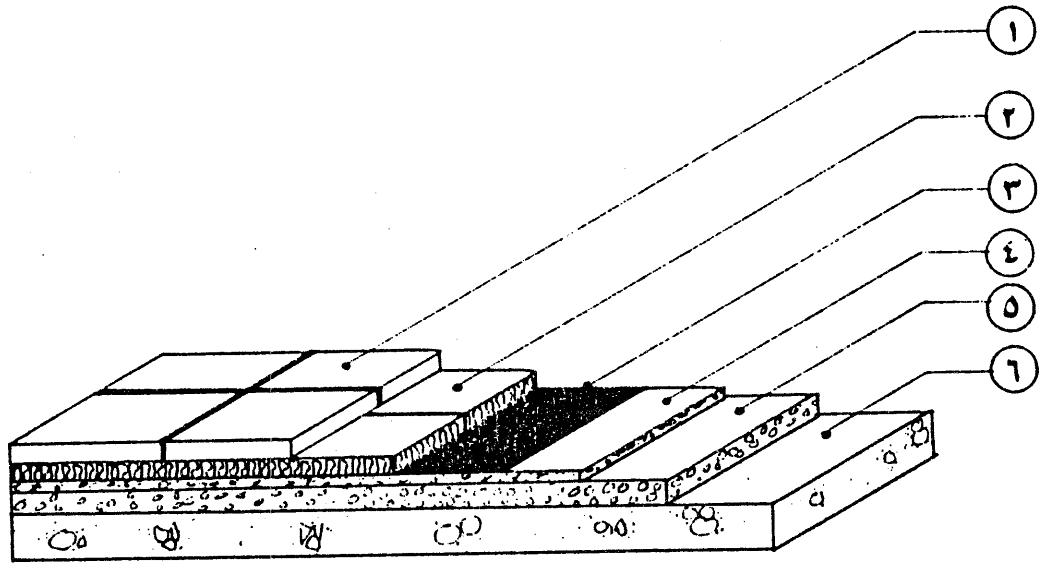
ROOF 2



1. Sand cement roofing tiles (white) (20 x 20 x 2 cm)
2. Mortar bed (2 cm)
3. Elastameric waterproofing on bituminous primer
4. Cement sand screed
5. Foamed concrete 2% slope (5 cm at lowest point)
6. 1000 gauge polythene sheet
7. Polyurethane foam insulation (5 cm)
8. Concrete slab (12 cm)

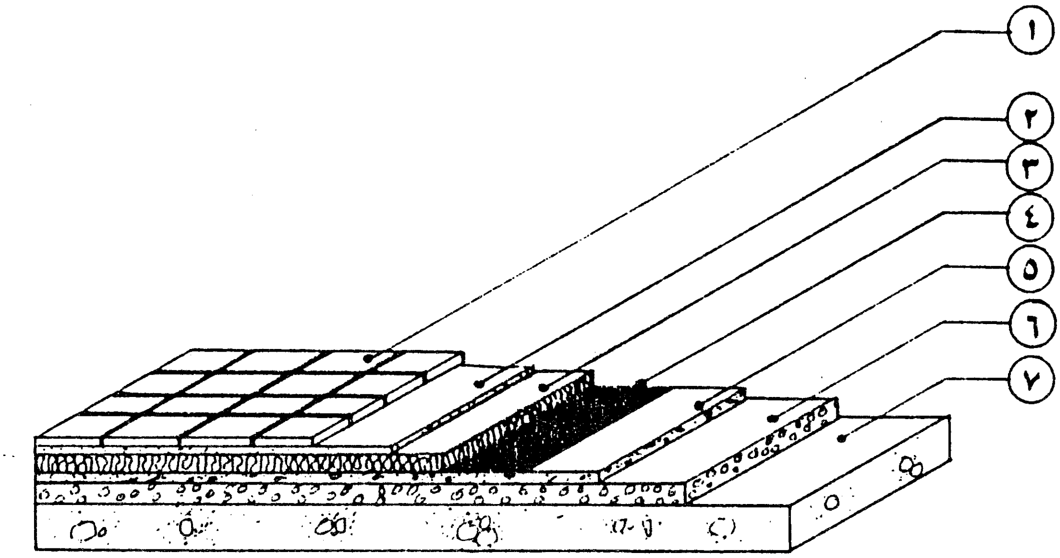
١- بلاط اسمنتى أبيض (٢٠ x ٢٠ x ٢ سم)
٢- مونة سمنت (٢ سم)
٣- مانع رطوبه (ممبرين)
٤- مونة سمنت
٥- خرسانة رغويه بانحدار ٢٪ (٥ سم فى ادنى نقطة)
٦- ورق نايلون كيج (١٠٠٠)
٧- الواح بوليورثين (٥ سم)
٨- سقف خرسانه مسلحة (١٢ سم)

ROOF 3



1. Concrete paving slabs (5 cm)	١- بلاط اسمنتى (٥ سم)
2. Extruded polystyrene (5 cm)	٢- بوليسترين منبثق (٥ سم)
3. Elastameric waterproofing membrane on bituminous primer	٣- مانع رطوبة (ممبرين)
4. Sand cement screed (2 cm)	٤- مونة اسمنت (٢ سم)
5. Foamed concrete 2% slope (5 cm at lowest point)	٥- خرسانه رغويه بانحدار ٢٪ (٥ سم فى ادنى نقطة)
6. Concrete slab (12 cm)	٦- سقف خرسانه مسلحه (١٢ سم)

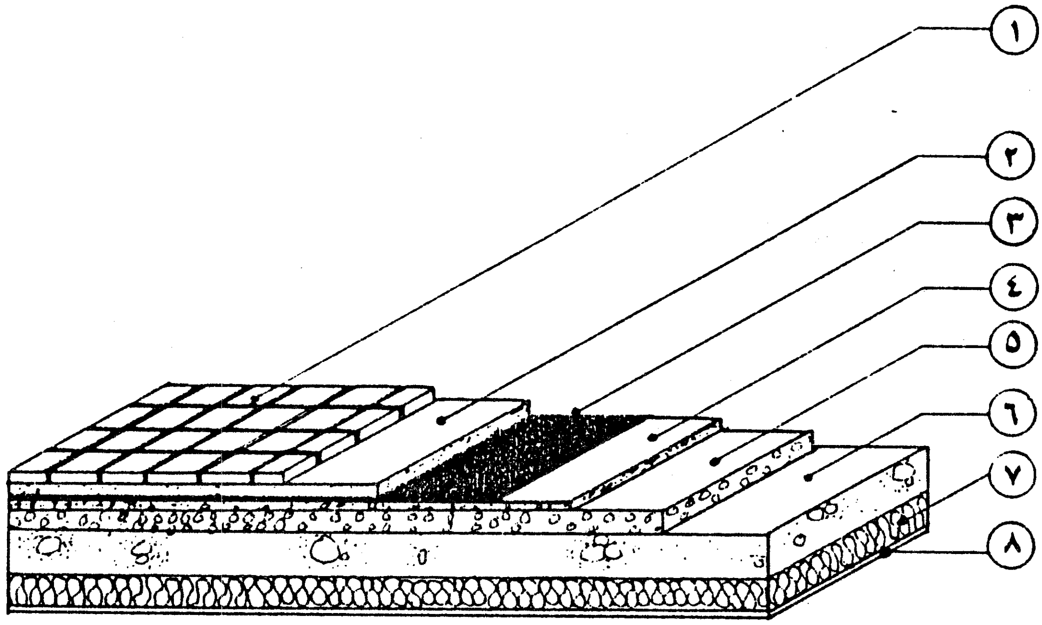
ROOF 4



1. Terrazo tiles
2. Motar bed (2 cm)
3. Extruded polystyrene (5 cm)
4. Elastomeric waterproofing membrane on bituminous primer
5. Sand cement screed (2 cm)
6. Foamed concrete 2% slope (5 cm at lowest point)
7. Concrete slab (12 cm)

١- بلاط
٢- مونه سمنت (٢ سم)
٣- بوليسترين منبثق (٥ سم)
٤- مانع رطوبه (ممبرين)
٥- مونه سمنت (٢ سم)
٦- خرسانه رغويه بانحدار ٢٪ (٥ سم فى ادنىنقطه)
٧- سقف خرسانه مسلحه (١٢ سم)

ROOF 5



1. Sand cement roofing tiles (white) 20 x 20 x 2 cm)
2. Mortar bed (2 cm)
3. Elastameric waterproofing on bituminous primer
4. Cement sand screed (2 cm)
5. Foamed concrete 2% slope (5 cm at lowest point)
6. Concrete slab (12 cm)
7. Mineral wool (high density) rigid (Double faced) (7.5 cm)
8. Decorative finish

١- بلاط سمنتى أبيض (٢٠ x ٢٠ x ٢ سم)
٢- مونه اسمنت (٢ سم)
٣- مانع رطوبه (ممبرين)
٤- مونه اسمنت (٢ سم)
٥- خرسانه رغويه بانحدار ٢٪ (٥ سم فى ادنى منطقه)
٦- سقف خرسانه مسلحه (١٢ سم)
٧- صوف معدنى كثيف مغلف بالالمنيوم من الجهتين (٧٫٥ سم)
٨- ديكور

Relevant Literature

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