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Note on:

Vernacular Approach to Climatic Variables in Central Saudi Arabia

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Abstract. Human beings have always searched for a livable physical environment. The electronic and mechanical devices that have been introduced during the last few decades have solved this problem to a great extent. Housing and settlement areas designed in accordance with existing climatic variables of that area will not only help to create a comfortable thermal environment but will also have lower initial and operation costs.

Traditional housing demonstrates a wide variety of adaptations to different climatic conditions. The anonymous architects created an environment to cope with extreme climatic conditions without depending on any of the recent mechanical devices. It is found to be beneficial to discuss their achievements that will be helpful in finding solutions for a climatically comfortable environment at a lower cost.

In this paper some examples from the central region of the Kingdom of Saudia belonging to different settlements will be studied and discussed to emphasize the role of architectural design in energy-efficient dwelling units.

Introduction

Human beings, in order to perform their daily tasks and activities efficiently expend a minimum amount of their bodily energy adapting to the thermal environment.

With the coming of modern technology, ingenious electronic and mechanical devices have been introduced to create artificial comfort zones in living and working areas. The use of these devices, which are almost entirely dependent on fossil fuels or water produced electrical energy, has become world wide in a very short period of time. Although it is almost impossible to deny the support given by modern technology in the creation of a livable environment, a restricted use of energy is inevitable. Now and in the future, houses and housing settlements, which are specifically designed to improve energy conservation will require less assistance from these devices that have been favoured because of the freedom they provide for designers.

For centuries the Najdi people have endeavoured to create a physical environment to combat the hot arid climate. The result was a livable environment both in terms of the settlement and the individual dwelling units. Although most of the population is residing in modern villas some are still living in the traditional adobe houses. These houses were and are designed and built without electrical or mechanical heating-cooling devices, and also without the help of architects. The traditional house has developed over many generations and through collaboration between makers and users of buildings [1, p.6]. Since any failure in the house would mean having to face the natural problems personally, they have learned to solve their problems by collaborating with nature [1, p.84].

The imported modernization of the Kingdom has either led to the reconstruction of entire cities or construction of new cities that resulted in the loss of the local architectural traditions. This internationality of architecture sometimes had its "traditional make-up" limited to the exterior appearance only. The contemporary houses which were introduced by western people did neither comply with the climatic conditions nor the socio-cultural needs of the society. The artificial climatic comfort conditions created indoors are provided with mechanical devices that consume energy. Thus one can find an all-glass high-rise in a hot-arid region. As a result of "imported" new rules and regulations, it became more difficult to create a sequence of closed, covered and open spaces which are to be used at different times of the day and days of the year depending on the prevailing climatic conditions. The present regulations enforce a setback of minimum two meters from the boundaries of neighboring plots and one-fifth of the street width from the front. The outdoor space thus created becomes an unused corridor-like outdoor space. The children and the parents can not make use of the outdoor space as the "desired privacy" for outdoor activities can not be provided, due to the fact that the neighbors will be able to overlook into the garden. Despite the fact that there are several disadvantages in adobe houses mostly being in terms of sanitation, parasites and maintenance, in terms of climatic factors the traditional areas have proved to be much more efficient than the fully air-conditioned modern residential areas.

General Climatic Characteristics of the Region

This research has been carried out in Argah, Diraiyah, Garaen and Sadous (Fig. 1). These settlements climatically have a long, hot and almost dry summer with a short cool winter with little rain (Fig. 2). The major characteristics of hot arid areas is the extremely high daytime temperatures and the extremely low night time temperatures. The wide diurnal range, which is about 23°C for this area is indicative of dry weather and clear skies and intensive solar radiation by day and strong outgoing radiation by night [2,pp. 13-14]. As diffused radiation from the sky causes a rise in air temperature, we have the lowest temperatures just before sunrise, and the highest about two hours after noon when the effects of intensive solar radiation and high air temperatures are combined.

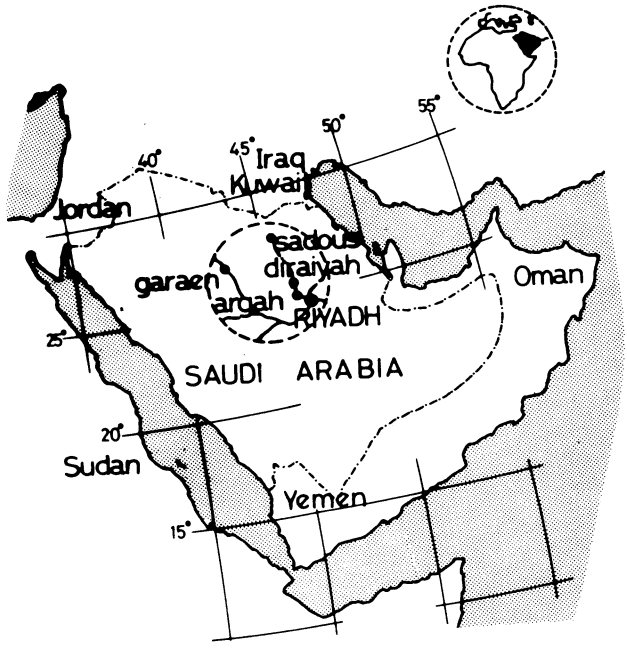

Fig. 1. The location of traditional settlements
(NB. The inset has been enlarged)

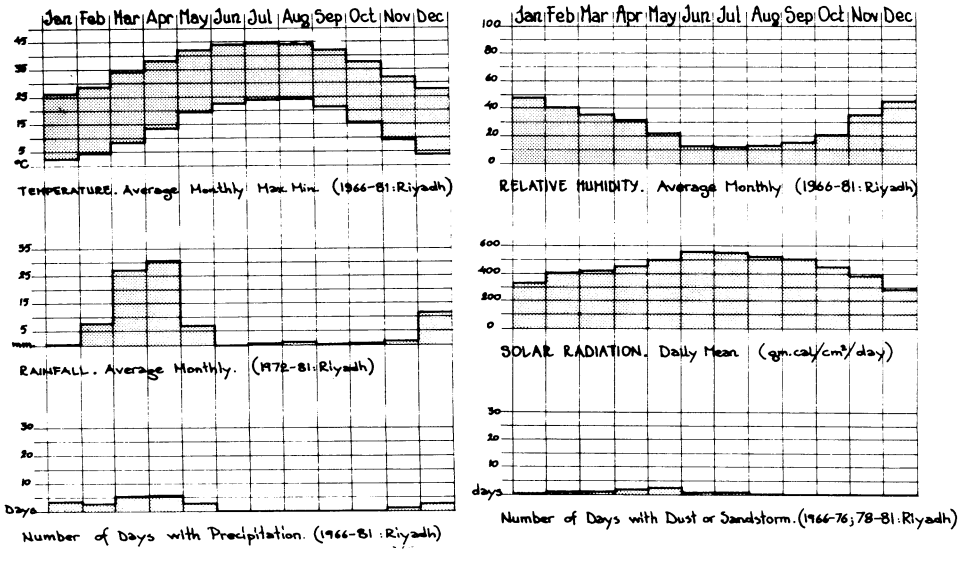

Fig. 2. Climatic data

Since the settlements chosen are located between 24° 46' N and 25° N, on June 21st, at the summer solstice, the sun's rays will be approximately normal to the horizontal (Fig. 3). Therefore, the period of intense solar radiation will be approximately six months, from March 21st to September 21st [3,pp. 185-186].

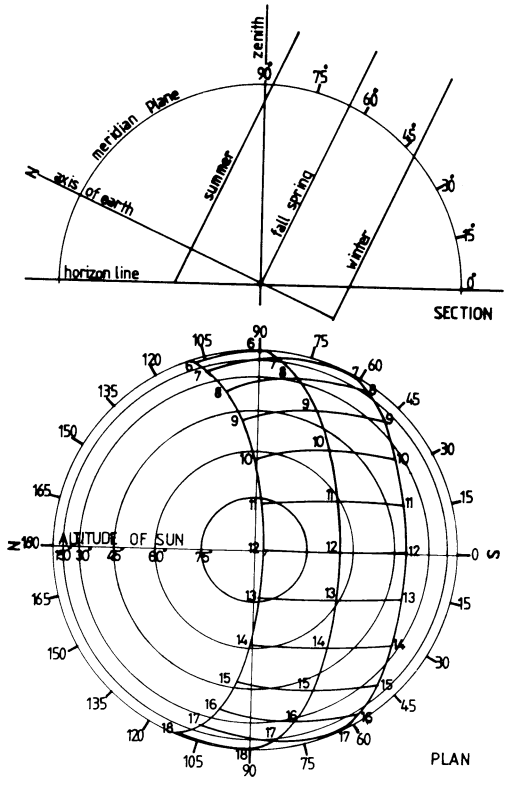

Fig. 3. Orthographic sunpath diagram for 24 N latitude

Although rainfall is mostly seen during March and April, the mean relative humidity (MRH) values reach their peak in January, February and December, which correspond to the coldest months of the year. MRH values are lowest during the hottest period when humidity is needed to avoid discomfort.

Prevailing summer winds are from the N, NNW and NE directions, winter winds being from the SSE, NNE and NE directions. As a result of extreme temperature contrasts, winds are usually strong, raising dust storms from time to time, due to the absence of vegetation and the instability of the sand.

Climatic Responses: Needs, Solutions, Discussions

Urban planning

As the climate is harsh and the resources are limited, site selection is very important for survival. It is a general practice to settle near a "wadi", on hill-tops or the slopes of a hill. All the settlements are surrounded with palm-tree groves and fields which provide food for the community (Fig. 4). When the hot dry air blows through the cool, humid and shady green areas, the water content of the prevailing wind increases while its temperature decreases. Thus, the wind that reaches the settlement is more humid and cooler than it was before. Palm trees also help to reduce the speed and dust content of the wind. Besides vegetation, the site being at a higher elevation helps to reduce erosion by sand as heavier ones will move closer to the ground and mostly settle down in the valley (Fig. 5). Over and above topography and ground cover, the settlement pattern is another factor needed to achieve a better living environment. For hot-dry areas, the basic settlement pattern must provide maximum shade, minimize reflection and the radiation gain, and minimize ventilation during the hot time of the day.

Although all the settlements have compact planning Sadous is especially worth mentioning. It is designed as a single entity, the houses running either side of the main street and the outer walls of the houses form the city wall (Fig. 6). It is, to all intents and purposes one building having a centrally located corridor. Access to the houses is provided by cul-de-sacs which are partially shaded by rooms projecting the entire width of the street.

The winding nature and narrowness of the streets (Photo. 1) when taken into consideration with the height of the surrounding buildings, and the grid pattern being diagonal to E-W axis provides shaded space throughout the day, reduces the effect of stormy winds, and stays relatively warm during cold nights. These shaded streets act as cooling wells for the settlement as they are cooler than the environment. In case of any ventilation, the cool air is carried in to the dwelling units.

Architectural design

There are mainly two types of buildings: residential and religious. This research is mainly concerned with the dwelling units, although the latter has also design considerations in terms of climatic restraints.

The house is an institution, not just a structure. Its form and organization are greatly influenced by the cultural milieu to which it belongs. This form is in turn modified by the physical environment which makes some things impossible and encourages others [1,pp. 46-47].

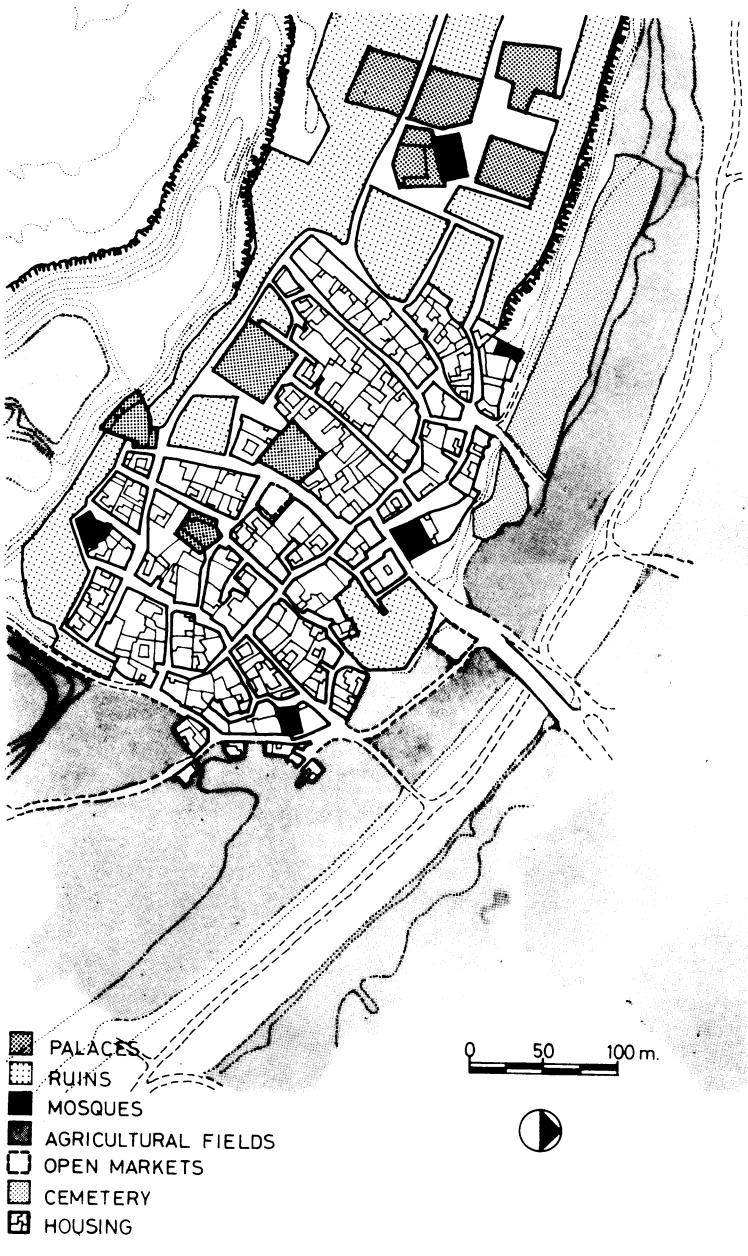

Fig. 4. Land-use plan

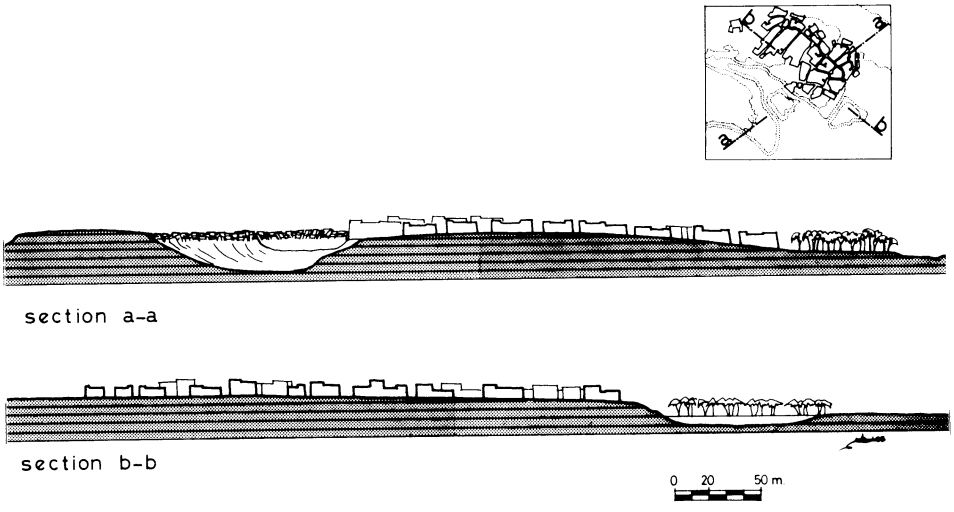

Fig. 5. Sections of the site-Diraiyah

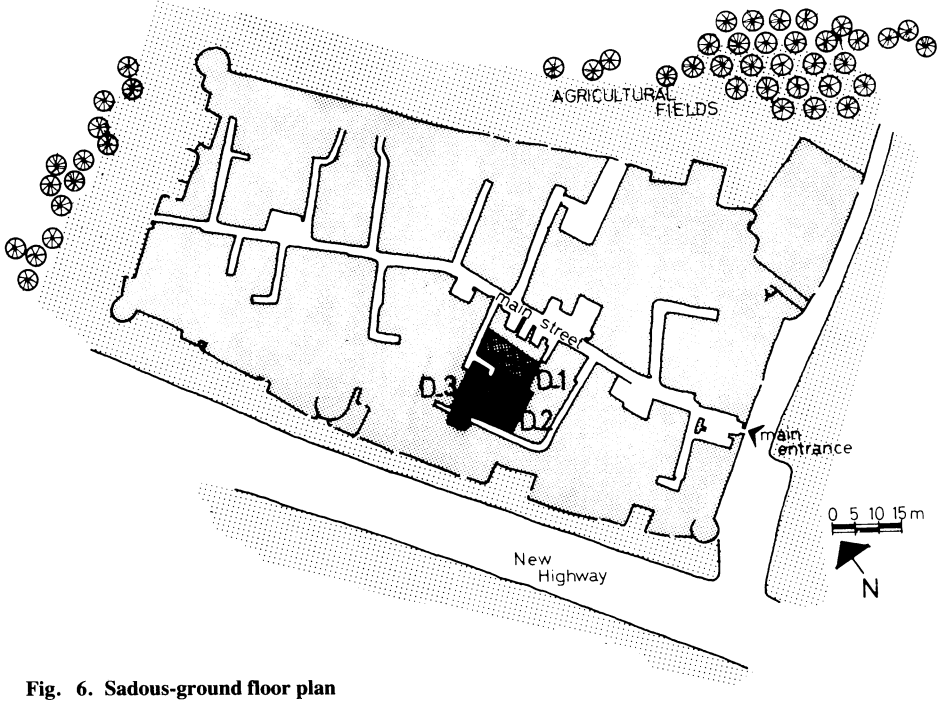

Fig. 6. Sadous-ground floor plan
K.S.A. Ministry of Education, Dept. of Antiquities & Museums.

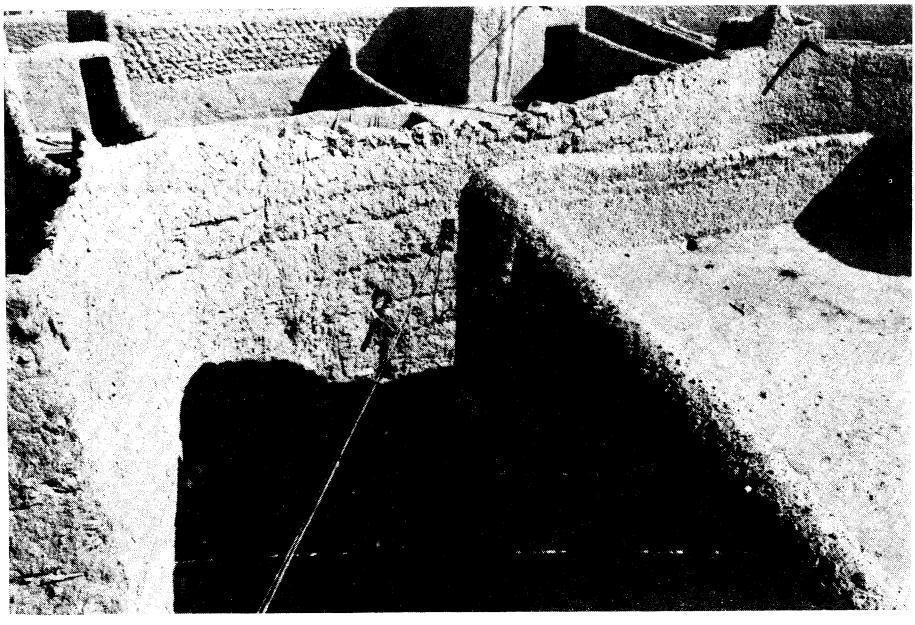

Photo 1. A winding street in Diraiyah

The architectural responses of buildings to climatic conditions can be summarized as: compact geometry; separating cooking; reducing the number and size of windows and placing them high up; painting the house white; and providing a courtyard [1,pp. 89-90].

None of the buildings are white in color, but finished with mud plaster. The major reasons are:

1- The streets get relatively warmer due to reflected radiation from the walls,
2- Its produces glare,
3- The dulling of reflective surfaces due to ever-present dust requires frequent painting to maintain reflectivity [4,p. 44].

The houses are approximately rectangular in design, the ratio of the long wall to the short in the houses examined ranging from 1:1.04 to 1:1.6 (Figs. 7,8,9,10]. Although some of the houses in Sadous have ratios exceeding 1:1.6, as the settlement is very compact in design, it can be treated as a single entity. V. Olgyay, in his book "Design with Climate" accepts 1:1.3 as the optimum shape elongated on E-W axis, the range being from 1:1 to 1:1.6. Nevertheless, these houses would be efficient in terms of heat gain and loss even if they were not within these limits as two or three exterior walls are shared between neighbors. In Sadous, 4/6 to 5/6 of the total

exterior walls are shared between the neighbors, leaving out a maximum of one-third of the exterior walls for external climatic conditions (Fig. 11). Even the exposed exterior walls are under shade either due to very narrow winding streets or orientation being diagonal to E-W axis where the impact of radiation is minimum. Thus, the amount of radiation received does not exceed a certain limit, a limit that suits the time-lag properties of the materials used.

Another feature is the windowless exterior walls, the only opening to the outside being the doors (Photo. 2). This reduces the heat caused by penetrating sunlight, reflected radiation and conduction. It might be argued that this is to provide privacy for the Muslim community rather than for climatic reasons. In any event, this is an efficient solution as both factors are satisfied at the same time. Openings are only towards the interior courtyard, placed high above the ground level, sizes being kept to a minimum. Some areas have no windows at all, and as a result stay cooler than the others throughout the day.

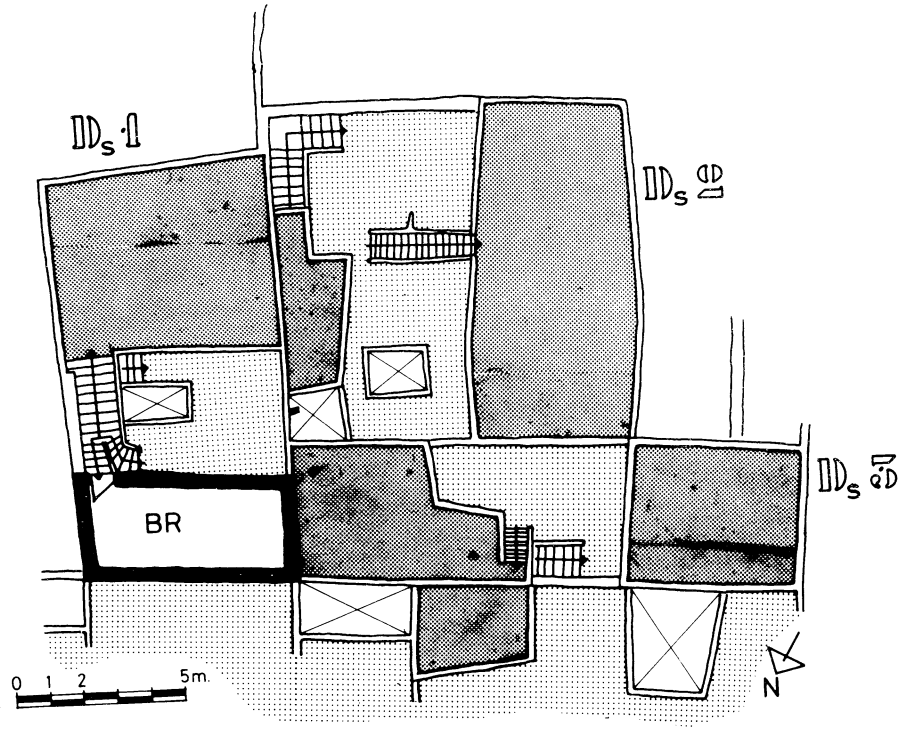

Fig. 7. Roof plans of a cluster of houses-Sadous

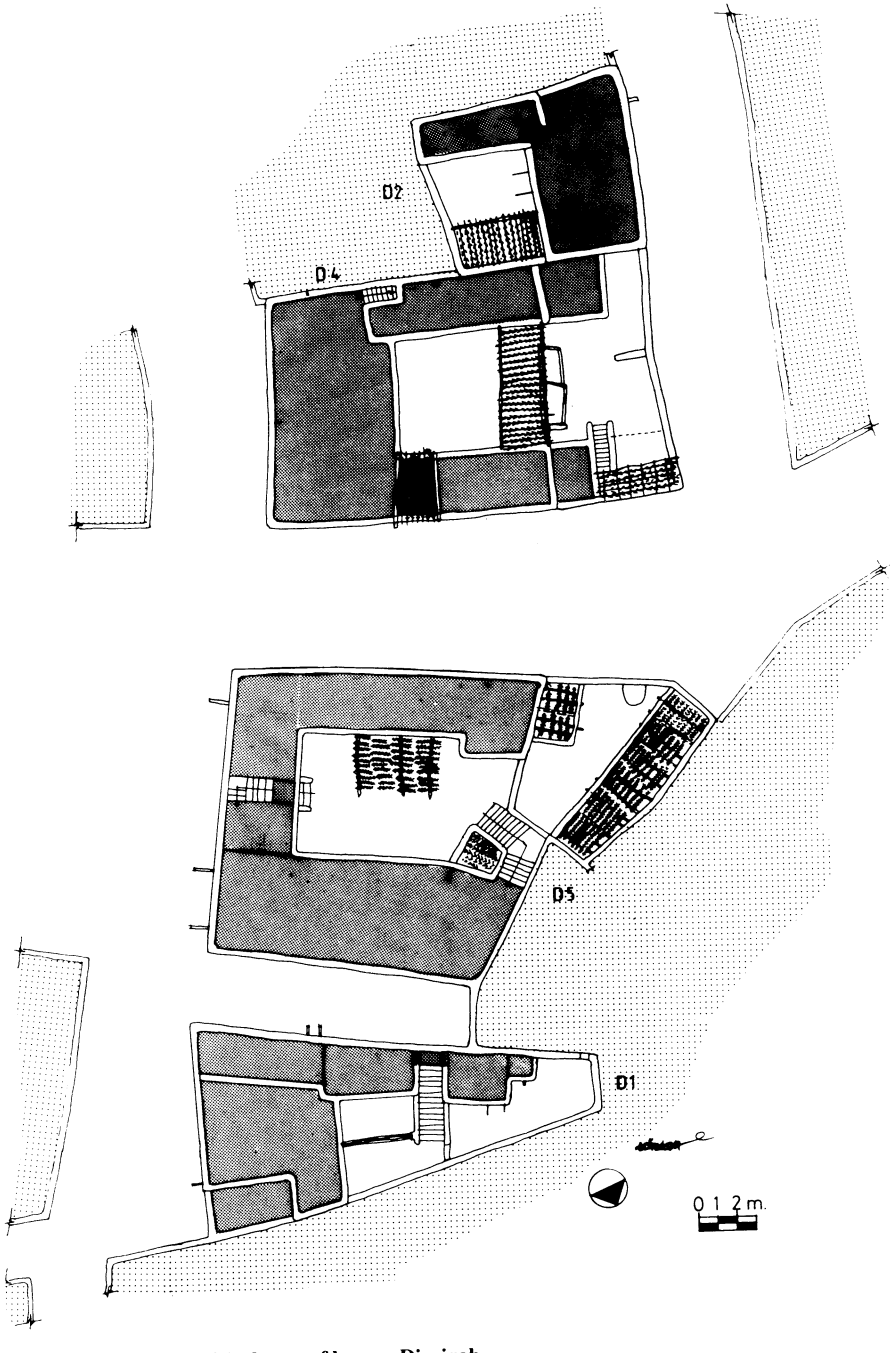

Fig. 8. Roof plans of A cluster of houses-Diraiyah

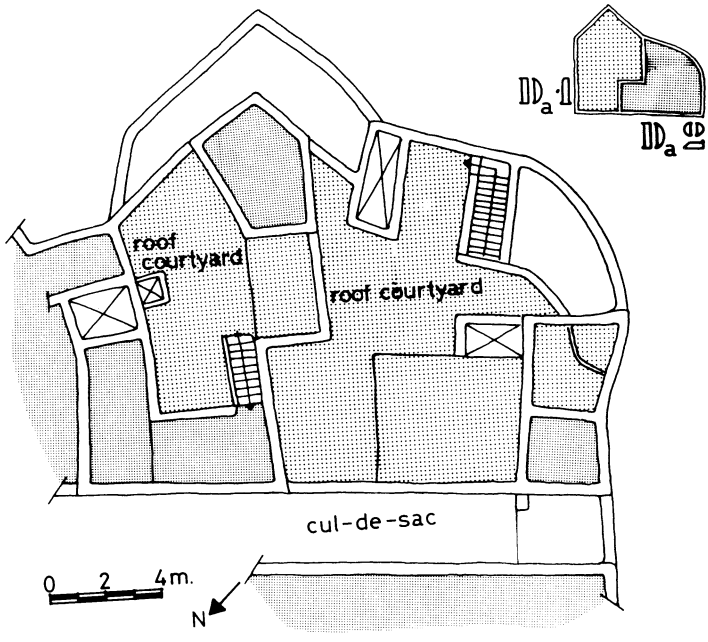

Fig. 9. Roof plans of two houses-Argah

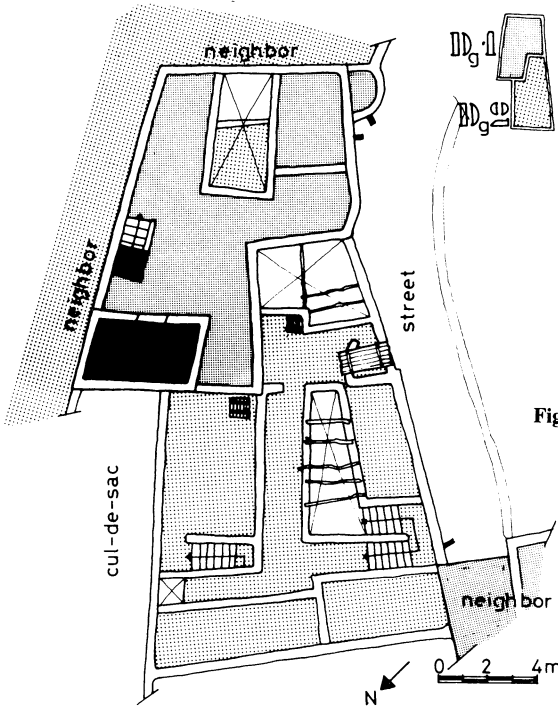

Fig. 10. Roof plans of two houses-Garaen

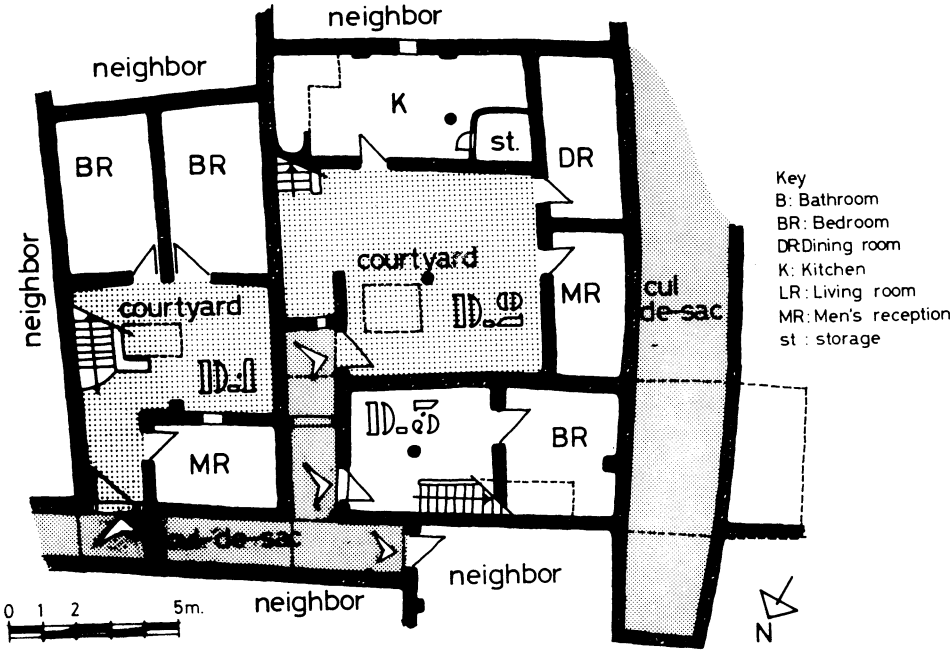

Fig. 11. Ground floor plans of A cluster of houses-Sadous

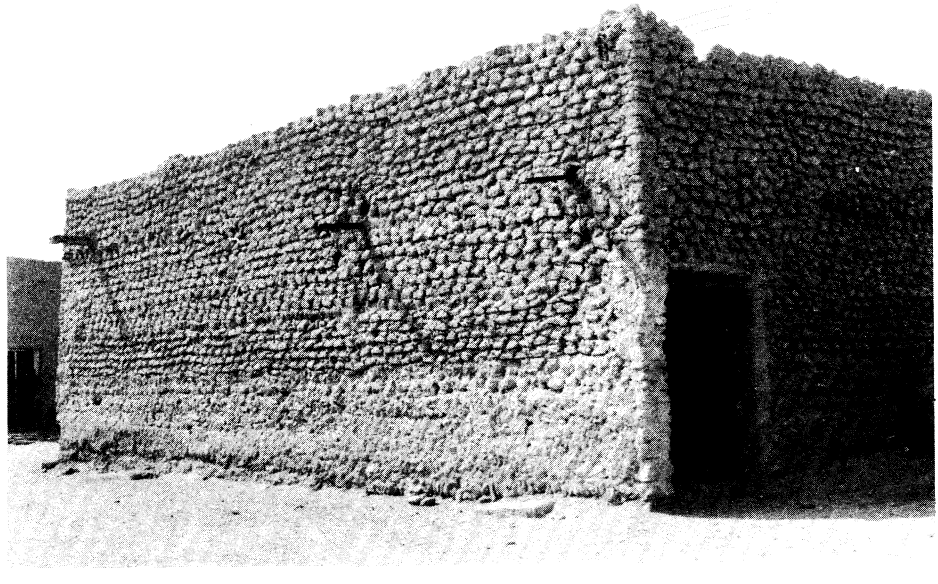

Photo 2. The houses have almost no openings towards the outside except the doors

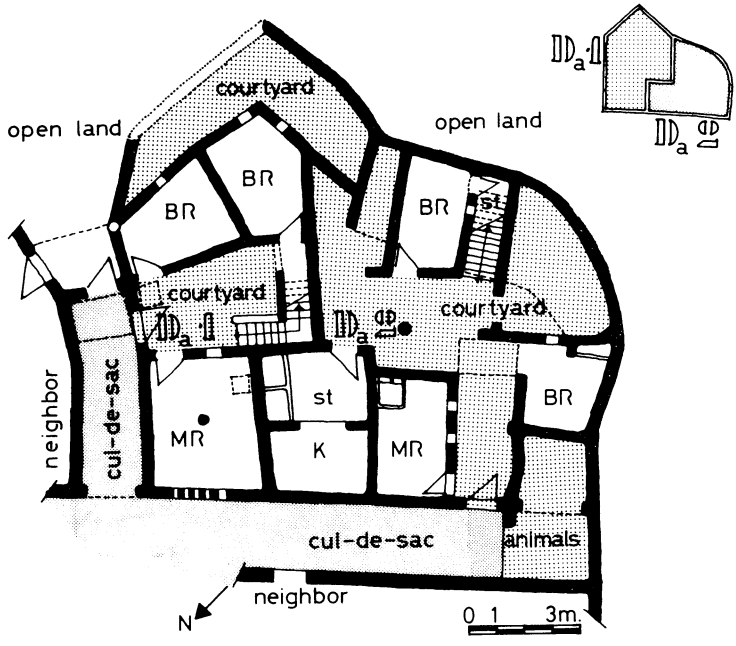

Fig. 12. Ground floor plans of two houses-Argah

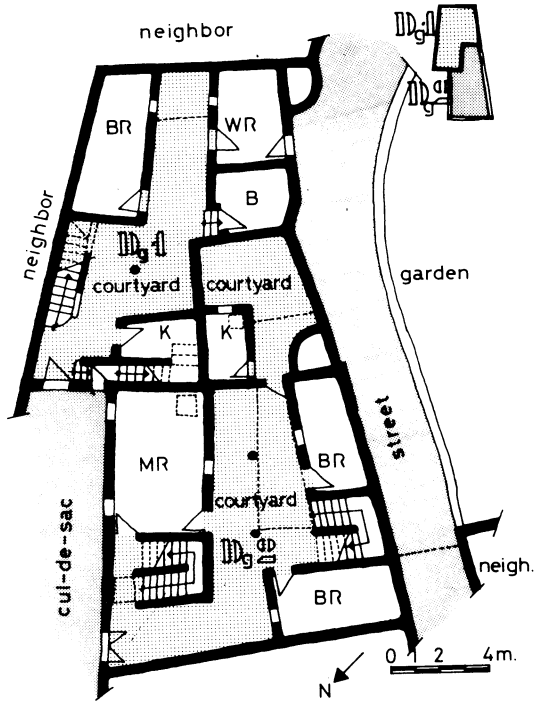

Fig. 13. Ground floor plans of two houses-Garaen .

The window-floor area percentage in the houses examined in all four locations ranges from 0.00 to 7.66. Interior spaces serving many people, such as the reception rooms for male guests, have the maximum amount of openings as they were mostly used at night when it was cool outside and the need for fresh air was more than the other rooms due to the number of users.

The courtyards are of great value in terms of climatic implications, as well as the social and psychological implications. The family courtyard acts as an extension of the surrounding rooms giving a sequence of spaces: open, covered, and enclosed (Figs. 11,12,13). This gives a variety of choice of space use at different times of the day and days of the year.

When provided with greenery and water, and shaded, courtyards act as a cooling well. As water is scarce in the Najd region, fountains and pools are rarely found, while trees can be seen in almost all courtyards. In addition to trees, horizontal shading elements constructed of wooden posts and beams covered with palm-tree branches were used to provide extra shade (Photo. 3). Many layers of dry palm-tree branches absorb most of the radiation. Moreover, the nature of the shelter enables the hot-air to escape through it avoiding the heat build-up due to trapped air as in the case of solid shelter. In contrast to the large openings above courtyards in Diraiyah; Sadous, Garaen and Argah have courtyards that are mostly covered at the top, the lighting and air ventilation being provided through a small opening ranging between 0.8 to 6.7 sq.m. This treatment provides more shade and thus cooler outdoor spaces when compared to those in Diraiyah.

The courtyard element is very efficient in providing shelter against strong winds, hence the high closed exterior walls function as a barrier against sand and dust storms. To be more effective, the ratio of the long side to the short must be in-between 1:1 to 1:3 [4,p. 52]. If the long side is more than three times that of the width, the building should have the long axis perpendicular to the wind direction [4,p. 52]. The houses examined in all four locations have courtyard ratios ranging from 1:1 to 1:2.7, ensuring protection from strong winds and dust/sand storms.

Materials and Methods of Construction

V. Olgyay in his book "Design with Climate" states [5,p. 7] that the envelope of a hemispherical vault is roughly three times the surface of its base, so the radiation of high sun positions is diluted on a rounded surface. This results in lower surface temperatures which are further reduced by wind cooling.

Despite the fact that vaulted or domed roofs are very advantageous in terms of radiation and the provision of extra air-space, these houses have flat roofs. The main reasons for flat roofs are, the scarcity of rain, ease of construction, availability of tensile elements, and provision of extra living-sleeping area on the roof on cool nights

Photo 3. Detail from the shelter showing palm-tree branches

(Photo. 4). The roof, although flat, has some precautions against heat build-up and radiation impact. The roofs of most of the houses examined in all four locations have different levels as the spaces have different heights according to their functions and floor area sizes. Each level on the roof is separated and surrounded by parapets about 60 cm. in height, throwing shadow on the roof (Photo. 5). In addition to it, the materials used in roof construction and detailing perform good insulating capabilities. Athel tree trunks were used as beams to carry the roof, having palm tree branches laid over them (Photo. 6). The mud-layer was placed on the palm leaves which were laid over the branches, finally reaching a total thickness of about 30 cm (Fig. 14). The air spaces between the palm tree branches and leaves act as additional heat insulators, insulation being most effective under steady state conditions.

Large diurnal temperature of hot-dry regions ask for high heat capacity materials that store heat during the day and give it off to the interior space at night. Thus, the main material of construction was sun-dried mud-brick (adobe), the wall surfaces smoothened by the application of mud-plaster. Adobe is inexpensive, easy to make, use and repair and needs no great technical skill or equipment. Other advantages of the adobe are its vermin proof, sound deadening and fire resistant properties [6,p. 11]. Although the values for many properties of adobe varies due to the composition of soil and methods of preparation, generally the thermal conductivity of adobe is four times greater than building gypsum, and twice that of normal weight concrete [7]. Hence the heat insulating property of adobe lies in the thickness of the walls. The high-mass structure serves two purposes: [8] (1) it acts as a heat sink which stores thermal energy (storage capacity), (2) it acts as a large capacitor which resists rapid temperature changes in the structure (moderating effects).

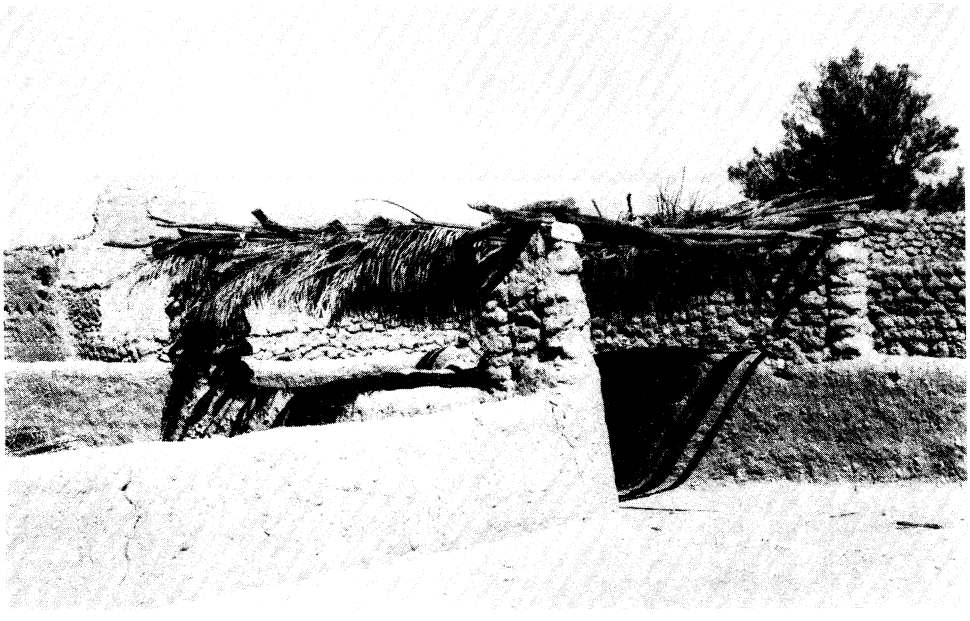

Photo 4. A sheltered sitting area on the roof

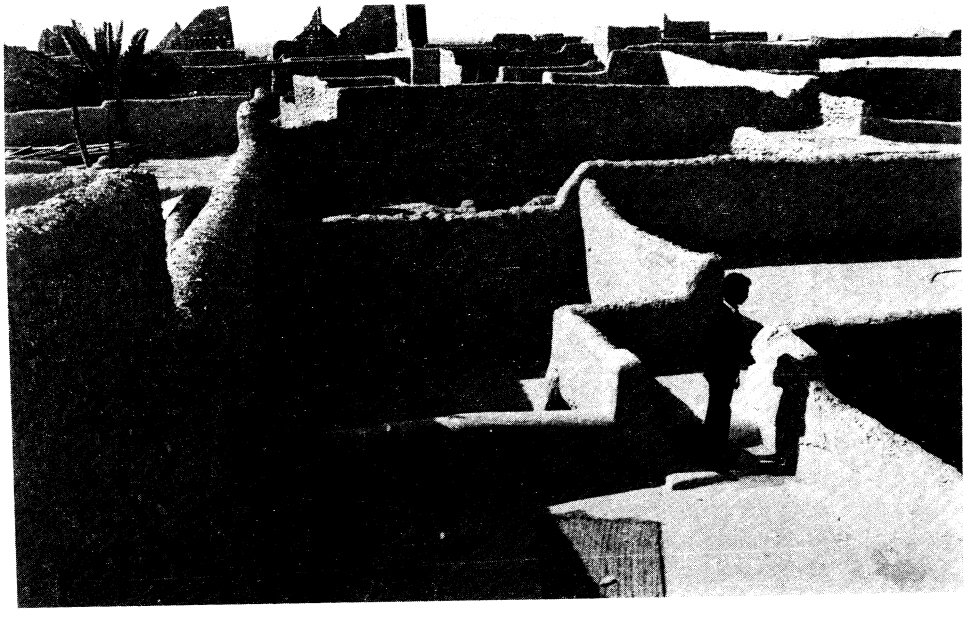

Photo 5. The roof is subdivided by small parapets to reduce direct radiation on the roof

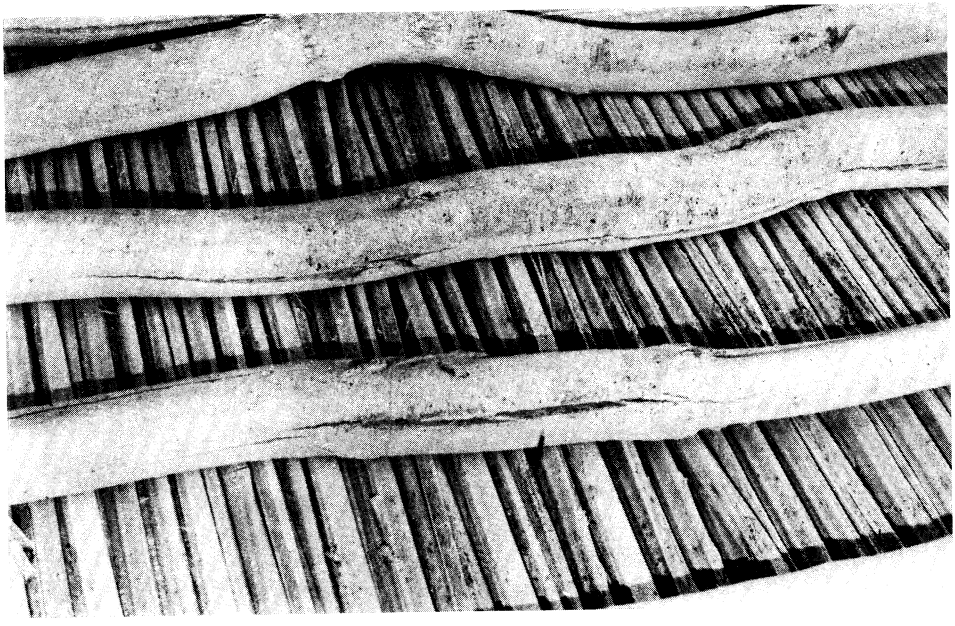

Photo 6. Ceiling detail showing tamarisk (athel) tree trunks and palm-tree branches

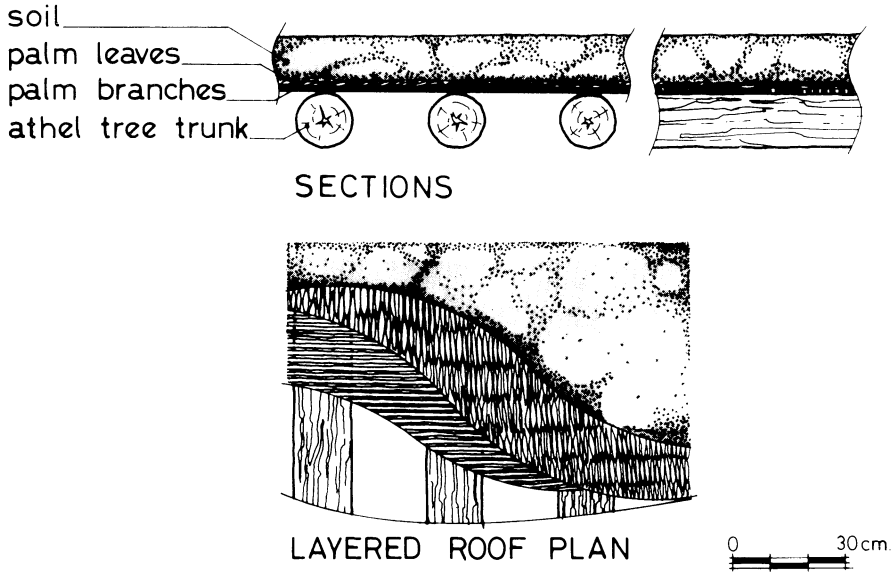

Fig. 14. Roof construction

Thus, it is improper to evaluate adobe in competition with other construction/insulating materials on the basis of thermal conductivity alone. H.A. Fine states that in a recent experiment performed on an adobe building with no contrived solar capability and without any heating all winter, it had a 24-h average inside air temperature of 10.2°C, while the average outside air temperature was 0.6°C [9].

Although the high storage capacity of the adobe brick is an advantage during the cool season, the interior spaces are relatively warmer during cool summer nights, determining the use of outdoor spaces, especially the roof area.

Conclusion

Although the modifications in climatic extremities are minimal, design concepts and architectural responses to climate are very high in quality when compared to contemporary solutions. However, this does not mean that we have to be imitative. The feasible and logical approach should be an understanding and consideration of the traditional design criteria and methods, and to follow the same rational process of input-output in that of traditional design.

The still-valid design criteria, sorted out from the traditonal houses in Argah, Garaen, Diraiyah and Sadous can be listed as follows:

- Narrow and winding streets.
- Grid pattern of streets diagonal to E-W axis.
- Projections above the pedestrian walk-ways.
- Compact planning and grouping of buildings.
- Compact forms, building ratio in plan 1:1.1 to 1:1.6.
- Minimum openings to outside.
- Provision of courtyard with green and water elements.
- Courtyard ratio in plan 1:1 to 1:3.
- Sequence of open, covered and closed spaces to be used at different times of the day and days of the year.
- High ceilings.
- Accessible flat roofs.
- Thick and insulated walls and roof.
- Use of high heat capacity materials.

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البدائل التقليدية والمتغيرات المناخية للمنطقة الوسطى بالمملكة العربية السعودية

عادل أحمد كليجال

قسم العمارة وعلوم البناء، كلية العمارة والتخطيط، جامعة الملك سعود، الرياض، المملكة العربية السعودية

ملخص البحث. ظل الإنسان يبحث عن المناخ المناسب ليوفر له الحياة السعيدة ـ ومما لا شك فيه أن التقدم في الإلكترونيات والأجهزة الميكانيكية خلال العقود الأخيرة قد ساعدت كثيرًا في خلق المناخ الملائم في المجمعات السكنية والتي تم تصميمها بناءً على الاعتبارات المناخية مما أدى إلى تخفيض التكلفة الأولية وتكاليف الصيانة والتشغيل.

المساكن القديمة تعكس لنا نماذج مختلفة من الأمثلة الجيدة عن ملائمة العناصر المناخية المختلفة ـ لقد رأى المهندس المعماري في العهود الماضية الوصول إلى التصميم المعماري الذي يتفاعل مع المناخ الخارجي ليوفر المناخ الحراري الداخلي بدون الاعتماد على الحلول الميكانيكية ـ فلا بد لنا من دراسة وتحليل النماذج القديمة والتي تساعدنا في إيجاد الحلول المناسبة وبأقل تكلفة.

في هذه الدراسة سوف يتم اختيار بعض الأمثلة من المنطقة الوسطى بالمملكة العربية السعودية ودراستها وتحليلها لتوضيح الدور المهم الذي يقوم به التصميم المعماري في إيجاد الوحدات السكنية التي تساعد على تخفيض استهلاك الطاقة.