Preface

In the spring of 1973 we went to Egypt to do research into its indigenous building and planning methods. Part of our work consisted of assessing certain experimental houses in Cairo and a village in Gourna, Luxor, which had been built on traditional design principles. These had been designed and built by Professor Hassan Fathy. Shortly afterwards Professor Fathy, as consultant on Rural Development to the Sultanate of Oman, proposed that a similar study be carried out in Oman. This was accepted and we were invited by the government to do a study of certain traditional buildings and assess what could be learnt from them for application in new building projects. While fulfilling this brief we also had the opportunity to carry out for our own research the extended study presented here. The material covering the original brief has been incorporated within this study.

After a month of preparatory work in London and Egypt with Professor Fathy, we arrived in Oman in the first week of September. We were there as a team until the first week in November, and two of us stayed on to work there for a further three weeks. The period was one of intense work and travel. We had the use of a land-rover. An English speaking Omani, Abdulla Hamadani, joined us to drive and interpret. Language was not a problem to the extent we had anticipated, since one of us knew Urdu and Persian which are spoken along the Northern Coastal Plain, and another spoke Arabic, the national language of Oman.

During our stay in Oman we visited and stayed in some twenty towns and villages in six of the eight major areas of the country. Of the two we omitted, one was the desert interior which has very few settlements, and the other, in the Dhofar Hills of the Salala hinterland, was a guerrilla war zone. We would spend approximately ten days in a major settlement in any one area, during which time we would travel to neighbouring villages if there was something of particular relevance to our study.

We also were able to visit Dubai, one of the neighbouring towns in the United Arab Emirates, where the old town provides a good example of indigenous urban forms in this part of the world.

Not until recently have efforts been made to collate and publish information on Oman in any comprehensive fashion. For each area we visited, therefore, we first tried to understand its physical and economic base: the major occupations of its inhabitants and how these were changing, and how these factors affected the distribution and pattern of the settlements and house forms in the area.

We followed a similar approach in enquiring into the social relationships between the people as a whole and within the family structure. The time factor limited this line of enquiry to some extent, but it was nevertheless of great value in establishing what developed into more than just a contextual framework for our more detailed work. More often than not there were no climatic records available but we were technically well equipped in this respect. We had a comprehensive set of equipment which enabled us to make a climatic profile for each area we visited. This was sometimes augmented by any further information we could obtain from local people, or in certain areas from military bases which had kept records. Details of our findings on the subject appear in the climatic section of the report.

In each area, we had first to contact the local Wali (Mayor), and explain to him what we were doing. Through him we would gain access to the people in his area. The two groups on which our interest centred were the local craftsmen and builders, and the families of the houses we studied. From the craftsmen and builders we learned the construction methods of the area and their views on the changes that are taking place, particularly how they are affecting the built environment and themselves professionally. From the families we learned how the house and its rooms related to their needs, the family structure, at what stages they had built their houses; why in every case they had been built over a period of time, and were still being modified; what they liked about them and what improvements they would like to see brought about.

We developed a basic questionaire, which functioned more usefully as a check-list to ensure that we adequately covered the basic information we needed. Inevitably during the days we were in an area, conversation ranged beyond this, giving us a better understanding of the people and the area as a whole.

It would be impossible to list the very many people who were so helpful and hospitable throughout our stay, and to whom we owe our gratitude. Our particular thanks go to Professor Fathy, whose pioneering work remains a source of inspiration to us: to Mr J Townsend, Economic Advisor to the Government of Oman, to H.E. Karim el Harmy, Minister for Development, to their respective staffs, to the Dhofar Development Organisation, and the Petroleum Development Organisation. Additional thanks to Habib the barasti builder and Abdulla our constant companion. Our thanks to Laura Pinter for the many hours she spent typing the manuscript.

The fourth member of our team, Omar el Farouk was unable to contribute beyond the initial field-work. We owe him special thanks for his invaluable assistance during this stage.

The information from the field-work was collated and this study prepared and written by the three of us, for which we take full responsibility.

Allan Cain
Farroukh Afshar
John Norton

Introduction

1.1 Why study indigenous systems?

This is a study of the indigenous built environment of Oman. It examines how and why the built environment developed and it's potentials and shortcomings for the future. We proposed this study because we believe the potentials of indigenous systems in general have been unfairly neglected in most developing countries. They have been replaced by imported methods, often inappropriate to local conditions and needs on most levels - functional, economic, social, aesthetic or cultural. A relevant basis can be found on which to plan for a countrys' development through an understanding of its indigenous systems. [1].

The visible material success of the industrialised world has made it the obvious model for the developing countries. Consequently, over the years through a combination of imposition and eager acceptance, the objectives and methods of the former have been adopted by the latter in their race for development. This has expressed itself in many ways. Parliamentary form of government has been imported intact into countries with very different indigenous political organisations to those from which it developed in Britain. Western medical methods have been unquestioningly applied, often to the complete neglect of long practiced local methods of healing. The architect from a developing country, schooled into designing for the western prototype, nuclear family, builds to fit his countrymen into housing inadequate for the extended family.

Today there is a growing awareness that such literal transference of solutions often do not work. Nor is it good enough to start with basically imported objectives and methods and then modify them to supposedly apply to local conditions. Many of the developing countries have a very different, physical, social, cultural and economic basis. Today they are also in an international context very different from that in which the industrialised world developed. Thus models drawn from the industrialised world are often innappropriate.

We believe the starting point should not be some external precedent but a thorough understanding of local conditions and indigenous systems. From these, the needs, objectives and methods should be primarily defined, and on the basis of such an understanding can the developing country best select what others can offer her.

This point becomes particularly relevant when we see that today the industrialised nations themselves are having grave doubts about the validity of their own models. The ability, even desirability of sustaining societies based on high consumption and resource use, considering the accumulative effects of such societies on their members and on the world as a whole, is being seriously questioned. Many indigenous systems in developing countries being closely integrated into real needs, based on low resource use and in harmony with the natural environment, could give rise to models for todays' leading nations to follow. Unfortunately the more typical pattern is for developing countries to apply ideas from the industrialised world years after they themselves have rejected these ideas.

Furthermore the assumption that western methods are superior, by people in developing countries has led to a loss of self-respect for their own methods and its strengths, for their own identity as a people, and to a distortion in their minds of what their reality consists of. This is most perceivable in urban areas amongst those who have been longest subjected to western

1. 'systems' used in the general dictionary definition, not as in 'Systems Engineering' etc.

influence. In rural areas where often the majority live, this is a less common phenomenon and indigenous systems still operate.

Oman is one of the most recently emerging nations. Yet such influences were often evident. A schoolboy when asked to draw his mud-brick house drew instead a European bungalow. Several owners of mud brick and palm stem (barasti) houses cited neighbouring concrete block houses as their preference. On the otherhand when questioned further about their own houses, they would outline many advantages in theirs, such as the flexibility of the materials, cheapness and coolness. Prestige and greater permanence remained reasons for preferring the concrete block houses. But for one exception all said they preferred their own houses if they could be made longer lasting.

It is often the educated professionals and policy-makers of developing countries who are most convinced of the superiority of models offered by the western countries over their own systems. Their training and education is often limited to these models. Since the majority of their people however, remain operating within indigenous systems, these professionals are alienated in outlook and what they can offer to the majority. A process of re-evaluation of their indigenous systems would not only help these professionals regain their self-respect and their cultural and social identity, but also realign them with their own people and put them in a better position to be of service.

The common terminology used also reflects such biases. Thus an advanced technology is one that emanates from an industrialised country. Indigenous systems of a developing country are generally termed 'primitive' or 'traditional'. The former by being 'advanced' assumes superiority while the latter suggests backwardness. Such terminology is neither useful nor necessarily accurate. Many indigenous systems are highly sophisticated and efficient. Some of the finest buildings under any criteria, have been achieved in mud brick.[2] On the other-hand a prefabricated dwelling unit of industrialised components, assembled mechanically in the context of many developing countries may prove too expensive, climatically uncomfortable and socially unacceptable in comparison with the indigenous dwelling of the area. A system should not be prejudged by terming it 'advanced' or 'traditional' meaning 'backward'. It must be assessed within its particular context, against all the criteria relevant to what it should achieve. The ancient chinese practice of acupuncture was seriously re-assessed and today plays an increasingly important role in modern medicine.

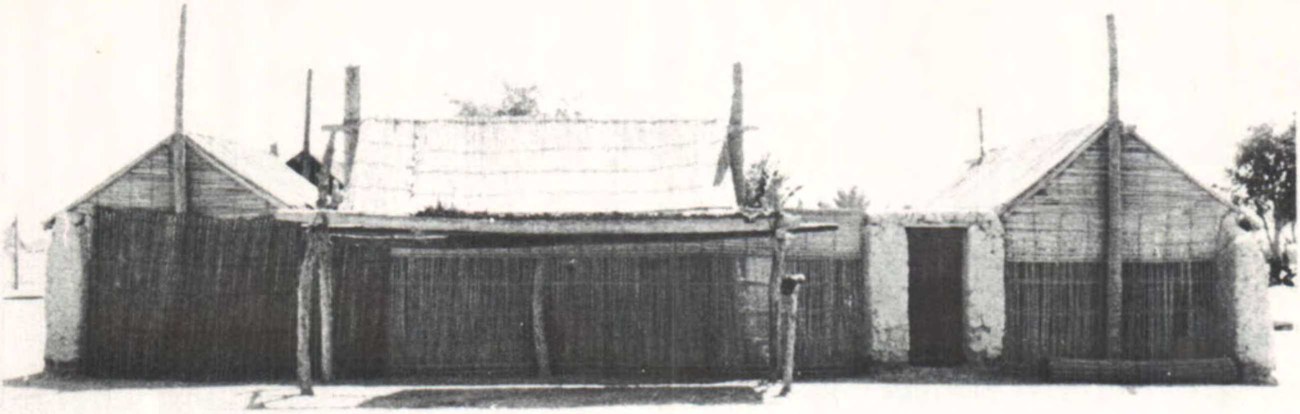
2. The large sunbaked clay domes 7 metres in diameter and 10 metres high in the territory that was formerly the German Cameroons, was found ideally adapted to the elimination of all ring tensions due to the weight of the material. Professor Creswell, remarked on the apparently scientific character of these domes. 'These natives, working with plastic clay - have by experiment found out a particularly safe shape. They are the same shape found in Persia - and furnish proof of the instructive character of these indigenous operations.' As quoted in Pope and Upman.'A Survey of Persian Art'. page 901.

Fig. 101

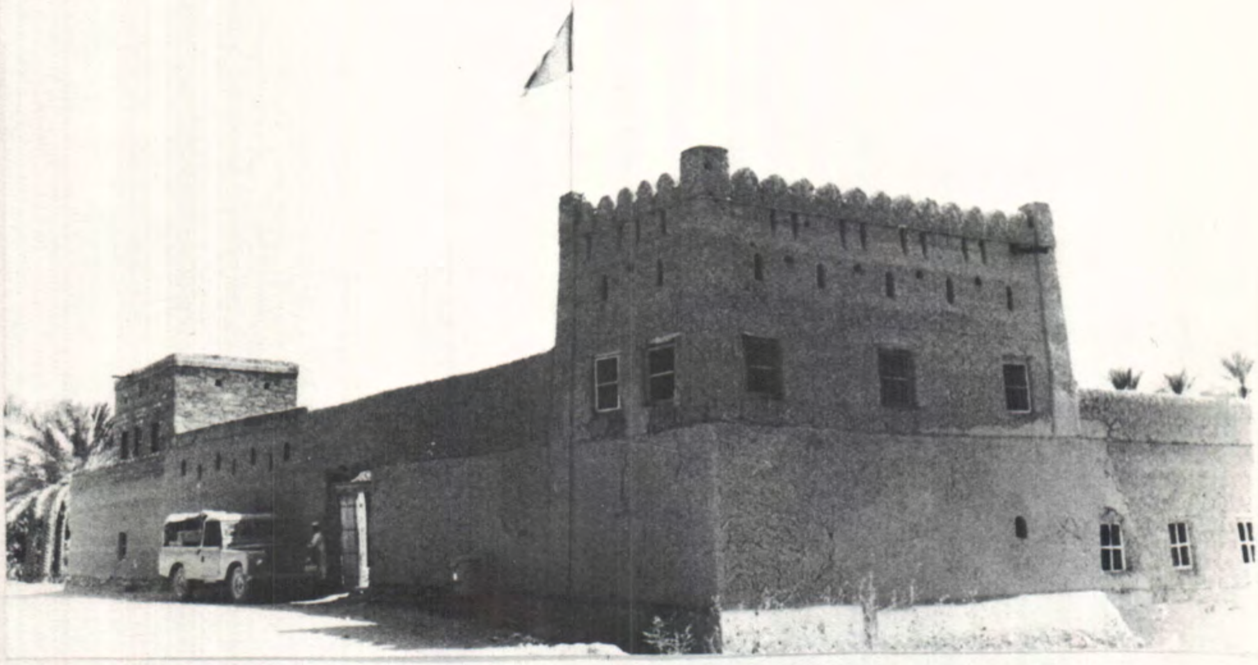
School boy 'Salim', age 11, from Nizwa, draws his house with a pitched roof and a front lawn or garden. The child's clothing in the drawing is also inspired by the European model.

Salim's house in Nizwa.

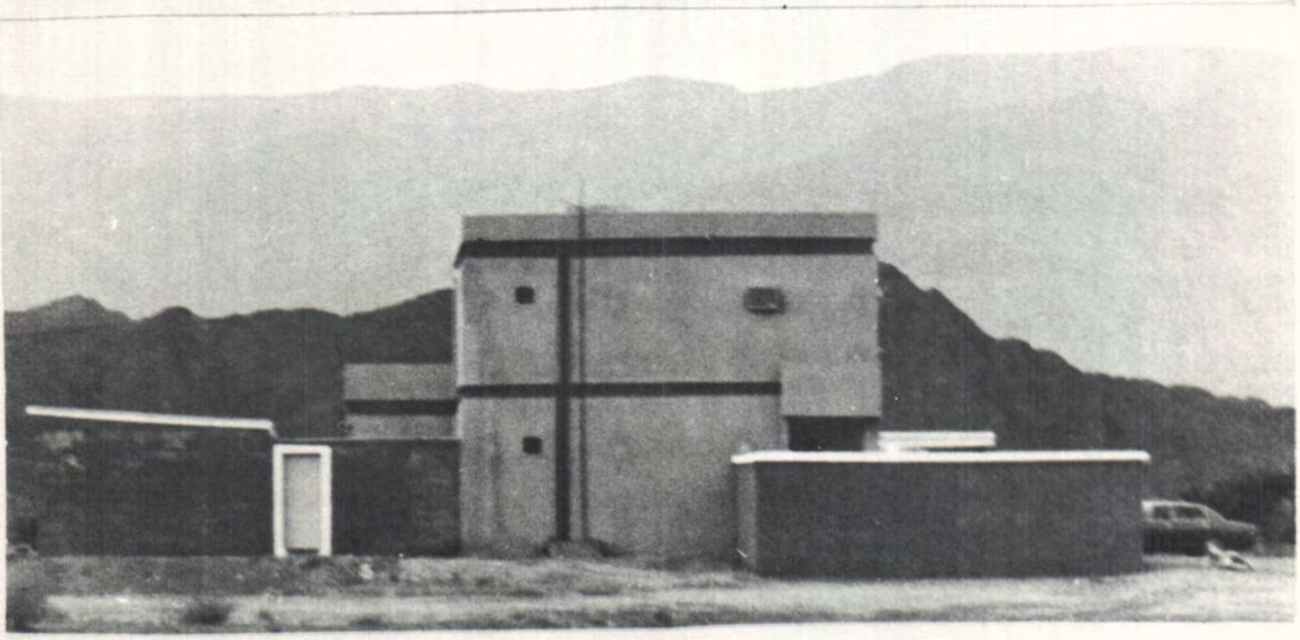
Fig. 102



Indiginous Rural Housing in Muladah



Wali's House and Headquarters in Iski.



Recent building, such as Wali's house in Nizwa, set new models and new aspirations

Why Study the Indigenous Built Environment? [3]

Our particular interest is with the indigenous built environment. In its relationship to housing, Amos Rappaport has this to say: [4]

'All housing needs to achieve four objectives in order to be successful.

1. It needs to be socially and culturally valid. (Here traditional housing possibly works best).
2. It should be sufficiently economical to ensure that the greatest number can afford it. (In primitive contexts most if not all people have houses).
3. It should ensure the maintenance of the health of the occupants.(In relation to climate traditional housing succeeds. In relation to sanitation and parasites it usually fails.)
4. There should be a minimum of maintenance over the life of the building. (Here the evidence is equivocal.

- traditional housing may therefore be much more acceptable if not in fact desirable - than has been assumed, and housing attitudes in developing countries should be adjusted accordingly. At the very least this offers a fruitful field for research.'

In our study we investigate the above assertions. Housing is the most important aspect of the built environment. It most closely relates to mans' needs and it relates to all mens' need for shelter. But the potentials could extend to most aspects of the built environment - to communal and more specialised buildings, to infrastructure such as layout, access and orientation. The one man who has most clearly illustrated this point is Professor H Fathy. In designing and building Gourna Village in Luxor, Egypt, he demonstrated in physical terms how a whole range of the built environment from housing to markets and school can be developed from the indigenous. [5]

Having said this we are also aware that there are contemporary problems that require either the fusion of the indigenous with the borrowed, more recent solutions, or entirely new ideas. However the extent to which this is the case can best be judged on a thorough evaluation of indigenous methods.

Another set of variables to consider are those implied in whether the context is a rural or an urban one. In a rural situation the work rhythm is such that house building can be more easily allowed for than in the more frantic pace of the urban environment. Communal mutally-supporting effort in a long established close-knit rural community in such matters as building, can happen more easily than in the more fragmented work for money oriented city.

Rural settlements are not as restricted for space. This helps ease a variety of problems than urban concentrated settlement has to face. The problems of privacy, and security, waste disposal and sanitation, and fire risks are all easier to handle. [6]

3. We use the phrase 'Indigenous Built Environment' which although not entirely satisfactory, hopefully describes the subject of the study free of associated value judgements. Words such as 'primitive' or 'traditional' have derogatory associations, 'vernacular architecture' can be vague and 'shelter' too confining.

4. A Rappaport. 'House, Form and Culture'. Prentice Hall Inc. 1969 pp 129.

5. H Fathy. 'Architecture for the Poor.' University of Chicago Press. 1973

6. For a fuller account see 'Manual of Tropical Housing & Building'. O H Koenigsberger. T G Ingersoll. Alan Mayhem. S V Szokolay. Longmans 1973 p. Introduction.

Some of these apparently inherent problems in the urban environment can be modified. For example judging by the large settlements built by the urban poor, (often entirely unaided by officialdom) time is somehow found for building often in a communal-mutually supportive manner. A tacit code of conduct helps overcome problems of privacy and security. Nevertheless such contextual differences need to be kept in mind particularly if indigenous solutions from rural areas are to be applied to an urban situation. In a country like Oman which does not have a well developed urban tradition, indigenous solutions are bound to stem largely from rural areas. Since Oman is also urbanising this poses certain problems. However to conclude therefore that one must draw solely on the urban principles of the west is not justified.

To quote Dr Koenigsberger:

> "Some of the countries of the arid belt of the Northern Hemisphere notably Iraq, Egypt and the Maghreb countries, Iran, Rajastan, the Punjab and Southern China have townhouse traditions from which new urban building forms could develop." 7.

Some of these countries share many similarities with the Omani context. Their indigenous urban planning principles are exemplified in the older parts of Dubai, Cairo and Isfahan if creatively understood and applied could be very beneficial to urbanising Oman. Thus there is great potential in the sharing of indigenous systems between similar countries. To illustrate this point on a more particular level, we can anticipate that greater building activity in Oman is going to deplete her timber resources. It may not be possible for people to construct flat roofs with wooden beams, matting and mud which is the common method. The only alternative however is not reinforced concrete slab roofing. Vaults and domes could provide a far more economical, climatically more comfortable and generally more consistent alternative.

Finally let us summarise the main reasons why we believe Oman should approach its modern building programmes on the basis of a thorough re-evaluation and development of its indigenous built environment.

1. Oman is in a situation today where the traditional faces modernisation. The indigenous built environment of Oman closely represents the social and economic roots, and lifestyles of its poeple. To understand and develop it to meet contemporary needs would be to achieve a modern built environment that would bridge the transition effectively and in a manner consistent and appropriate to Oman.

2. Oman is also at a stage in its development where its comparatively limited financial resources are being severely taxed by the many demands placed on them. This is within an international context in which countries are becoming increasingly aware of the finite nature of the worlds natural resources and in which the cost of importing goods is rapidly rising. The indigenous built environment expresses hundreds of years of accumulated expertise on how to use what is locally available to meet local needs economically in monetary, resources and energy terms. To realise this potential would give Oman a greater self-sufficiency and a sounder basis on which to decide what is really essential to import. In todays' world such an approach to planning is perhaps the most realistic.

7. Dr Koenigsberger is head of the Development Planning Unit, School of Environmental Studies, University College, London. (He was housing adviser to the U.N. Economic Commission for Africa. Director of Housing for Government of India and consultant to many developing countries.)

A Structure for the Study

The following is a basic structure for the study of the indigenous built environment that we developed during our work. It must of course recognise and allow for many overlaps and exceptions. Its primary use is as an aid to organising work in the field and in analysing it afterwards.

We found that the major influences that shape the built environment can be divided into three.

1. Social and Economic.

This includes kinship patterns, family tribal relationships, roles of particular members, social and religious customs in the social factors. It also includes the economic base of the area, type and pattern of work, etc. We need to investigate how the built environment meets the socio-economic needs of the Community/Family, particularly with reference to how these needs may be affected by rapid changes such as those in many underdeveloped countries. Also how changes meeting higher environmental standards could be developed consistent with the socio-economic conditions.

2. Climate

This includes the major climatic forces in the area such as heat, cold, humidity, air movement, glare and dust. We need to study how these forces are expressed in the built environment and to what extent they meet comfort conditions. How they could be developed inexpensively to better meet comfort conditions.

3. Materials and Technology

We need to investigate the materials used and the way they have been used, ie. the type of technology. What are the problems and potentials here, particularly to define where indigenous methods can be developed on their own, where they could be usefully combined with some imported method.

Although the study can be divided in terms of these three influences, all three closely inter-related. Their inter-relationships form a most important part of the study.

Similarly the built environment can be studied on two inter-related levels.

1. The Settlement.

This would include how it relates to its' immediate surroundings, physical siting, communication routes etc. Within the settlement, how it is laid out in terms of its infrastructure, socio-economic groupings of its' inhabitants public and private buildings, and major climatic forces.

2. The House.

The single building unit: how it is oriented in terms of access and climate, what shapes and spaces are formed and why, what materials are used, how and to what effect?

If the study is to be carried out over a large region, this could be divided into smaller areas defined by a common settlement or house type. This would indicate similarities in the three major influences outlined above, in the areas so described. Any proposals could also be geared accordingly for each of these areas.

The report falls short of our structural model. This is simply explained by the fact that the model was developed during our experiences in Oman and not prior to going there. Thus as we became increasingly aware of the importance of social and economic factors and attempted to study them we also became aware of our inadequacies in this field. On the regional breakdown of Oman six areas emerge.

1. The Desert Interior
2. The Oasis
3. The Northern Coastal Plain
4. The Northern Uplands
5. The Southern Coastal Plain
6. The Southern Uplands

These are based more on geographical ground than on particular settlement or house types, of which there are too many overlaps to generalise. Nevertheless the geographical divisions are described by similarities relating to the three major factors.

We were however unable to visit the Desert Interior and the Southern Uplands. We include two other areas, Muscat/Mutrah/Ruwi and'Sur', two places we did spend time in and hopefully can comment on in a useful way. Both are areas where large scale development is underway. Thus the central part of the study is still divided into six parts, and comes in under sections 3 to 8 in the body of the report.

Northern Coastal Plain - Batinah

Northern Uplands

Oasis - Buraimi

Muscat/Mutrah/Ruwi

Sur

Southern Coastal Plain - Salala

For each of these sections an introduction describes the physical area and summarises the three major factors. It then goes into them in more detail for the area. Finally settlement patterns and house forms are discussed in the light of the three factors. The final part of the study is concerned with proposals.

The proposals are divided into three sections. The first is on a general development strategy for Oman that we believe is relevant to our whole approach. The second part deals with a general policy for the Built Environment within which we locate this particular contribution of ours. The third part makes specific proposals on use of materials, technology, climatic design, water supply and sewage disposal and the design and organisation of health risk areas such as water collection and washing points (falaj), food selling in markets, cooking areas and lavatories. We hope that this work will contribute on a level directly involving and benefitting the majority of Omanis. We also hope that in some modest way it adds impetus towards similar evaluations by others of their indigenous systems.

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1.4 Climate

Introduction

When planning or designing in a country like Oman, where one finds a severe climate one must consider the effect of that environment on the ways of living and ways of building of the inhabitants. For hundreds of years the inhabitants of any particular area have been building up a collective knowledge and way of dealing with their local conditions. This knowledge and experience is there for anyone to share and learn from, standing in the local architecture and living patterns of each particular region. The problem presented is how to extract the principals of design, inherent in the vernacular building and apply them to modern design and the projects of rural and urban development in this country.

The advantages of employing this knowledge in modern building are apparent. The added expense in air conditioning could be avoided or at least drastically reduced if some thought was given at the design stage to sight orientation, the consideration of the sun path and wind direction. The glare that hurts ones eyes in building with large expanses of badly designed window openings can be avoided if, when designing, one firstly looks to the methods for reducing glare, sizing and placement of openings of local buildings of traditional design. When comparing imported building materials with those used locally one is likely to find that in terms of heat transfer and thermal comfort the local materials are superior, and when one compares the material costs, the local materials will likely prove the most economic. In any contemporary design if the structural performance of a local material meets the standards required in the design and is superior climatically there is no question but that it should be employed.

By a thorough analysis of the behaviour of certain traditionally used building materials and ways of building we hope to find ways of improving on their use and of course develop ways of improving services and standards in new buildings using these materials, thus evolving a modern architecture truely in harmony with the climate, the local environment, the changing ways of life embodied in improved standards of living.

For the designer we hope to provide information and design tools for building in a way responsive to the climate.

Before entering into a detailed description of Oman's climate, terms and principles commonly referred to in the report will be defined, and the approach that was taken to the study of the built environment in relation to climate will be explained.

Explanation of Terms

1. Temperature

Temperature is a measure of the degree of hotness. In this report temperature is measured in metric units (°C).

Heat is a form of energy; a calorie being a unit quantity of heat required to raise the temperature of one gram of water by one degree centegrade (°C). Heat can be transmitted by radiation, convection or conduction.

Radiation is a transfer of heat energy through space from a warm body to a cold body by waves travelling at the speed of light, in much the same way as light travels. Examples of radiant heat are the transfer of the sun's energy through space to heat the earth and the warming effect of an open fire on ones skin.

Convection is the principal of heat being transferred by a fluid medium such as air or water by induced area of flow from an area of higher to a lower pressure. Hot air is light and will rise while cool denser heavier air will tend to collect at a lower level.

Conduction is the transfer of heat through a solid from one molecule to the next. Thus the molecular structure of a particular material is a determining factor in conduction. In the context of this report conduction is concerned with the heat transfer through walls of buildings.

2. Ralative Humidity

Relative humidity represents the percentage of water vapour in the air. 100% relative humidity indicates that the air is completely saturated with water vapour. The quantity of water vapour in the air influences the human body's perception of temperatures. When air temperatures are high a person is more likely to feel thermally comfortable if the air is dry(ie. a low relative humidity) than if there is a high relative humidity and the air contains a large proportion of water vapour. The reason for this being the physiological function of perspiration or the secretion of water, at the surface of the skin. This water on the skin's surface evaporates into the air at a rate depending on the degree to which the air is already saturated with water (or its relative humidity).

During the process of evaporation, or the change of state from liquid to vapours, a great deal of heat is required, and is drawn from the surroundings (the skin's surface) cooler. The rest of the body is cooled in turn through blood vessels carrying cooled blood from the skin's surface to internal organs. The higher the percentage of water vapour in the air the less ready is the air to absorb evaporated water from the surface of the skin, hence the less the cooling effect. In summary, if the relative humidity is low the body can cool itself by perspiring, but it cannot do so as readily if the relative humidity is high.

3. Air Movement

Air moves from areas of high pressures to low pressure areas. The effect of air movement on thermal comfort is related to the previous explanation of evaporative cooling. If there is no air movement the layer of air next to the skin tends to become saturated with water vapour which has evaporated from the skin's surface. Air movement causes the air next to the skin to be continually replaced by new less saturated air. Air movement can be seen to aid evaporation from the skin's surface. Therefore, the degree of air movement corresponds to the degree of aid to evaporative cooling.

4. Thermal Comfort Conditions

This may be defined as a physiological state at which an individual feels neither too warm nor too cold. There are several factors determining the limits of this condition: the air temperature, the relative humidity, the degree of air movement and finally the degree of acclimatisation or the degree to which one becomes used to one's local climate. The first three factors: air temperature, humidity and wind speed can be combined into one value being called the "effective temperature" which relates to what one feels as a temperature on the skin due to a combination of all three factors. Therefore, if the effective temperature at a particular time falls within the range that one feels acclimatised to, it is said to fall in the "comfort" zone.

Example

If for certain conditions of air temperature and relative humidity the effective temperature is found to be higher than the maximum comfort zone temperature, comfort conditions may be maintained if air movement is induced. In this way the effective temperature can be brought into the comfort zone. The relationship between air temperature relative humidity and effective temperature can be calculated using a psychrometric chart while the effect of air movement on effective temperature can also be obtained from a related chart.

Effect of Air Movement on Maintaining Comfort Conditions with Increasing Air Temperatures:

Air Temp.	Velocity- Air Movement m/s	Effective Temperature
26	0.00	26
27	0.01	26
28	0.05	26
29	0.60	26
30	1.20	26
31	2.20	26
32	3.80	26
33	6.00	26

Note Relative Humidity constant 70%

(Ref. Manual of Tropical Housing and Building Part One - Climatic Design - Dr Koenigsberger 1974 Chapter 2.3).

The comfort zone is a range of temperatures which was calculated statistically for each climatic zone and simplified to a workable formula.

(Ref. C T Mahoney AA Dipl. ARIBA D.P.U. Handbook Climate and Design of Buildings).

Physiological Reaction to the Thermal Environment

The human body is involved in a temperature-regulation mechanism; the production of body heat, as well as the regulation of heat loss, provide an adjustment whereby the body temperature is maintained at a constant level quite independent of climatic conditions, ensuring that internal processes are, to a large extent, indipendent of variations in the temperature of the environment.

The body temperature of a healthy person varies within very narrow limits. Interior 'core' body temperature is usually $37^{o} \pm 0.5^{o}C$ while the temperature of the skin and tissues in the limbs is lower and also appears to vary over quite wide limits ($28^{o}C \pm 15^{o}C$) without any after effects being noticed by a healthy person.

Body temperature is controlled by the regulation of the flow of blood from extremities to the interior. As a result of the drop in temperature of the skin and limbs there is a reduction in the flow of blood through these tissues because blood vessels contract. Heat transfer can be reduced up to 40% in this way. On the other hand, at high temperatures the blood vessels are dilated and the skin temperature may rise somewhat and thus increase the heat loss.

Heat loss is essentially a physical process; the human body, like other bodies, loses heat to the environment through convection, conduction, radiation and evaporation. A normally clad adult at rest experiencing thermal comfort conditions will lose heat through the following mediums: 25% due to evaporation, and 50% due to radiation. Heat loss due to radiation decreases with air movement velocity, while heat loss due to convection increases. (Fig104).

Fig. 104 HEAT LOSS BY CONVECTION AND RADIATION AT VARIOUS AIR VELOCITIES *

Air velocity (m/sec)	Percentage of heat loss by		Thermal insulation of the air (clo**)
	Radiation	Convection	
0.09	52	48	0.85
0.25	39	61	0.64
0.36	35	65	0.57
0.49	31	69	0.25
0.81	26	74	0.43
1.21	23	77	0.37
2.25	18	82	0.29
4.00	14	86	0.23

* Data from Burton & Edholm (1955). Based on an air temperature of 25 °C.
** The clo is an arbitrary unit of thermal insulation used with reference to clothing. One clo represents approximately the insulation provided by a 0.5-cm thickness of wool.

Heat Loss by Evaporation and by Radiation

There is a considerable loss of water from the human body by evaporation. The latent heat of evaporation of water is high: to convert 1 gram of water to 1 gram of water vapour requires the expenditure of 584 cal. of heat. When exterior temperatures become high the mechanism of sweat secretion becomes important. Under normal comfort conditions perspiration amounts to 40 grams per hour, corresponding to a heat loss of about 20 k. cal/hour. This represents about 20% of the total of 100 k. cal/hour produced by the body. The activity of sweating increases with the rise in temperature. The rate at which sweat evaporates may be very high; quite frequently individuals in hot workshops or in the desert may secrete as much as one litre of sweat per hour. If all this moisture were to evaporate directly from the body surface, a heat loss of as much as 600 k. cal/hour could occur. This may not always be the case. The rate at which sweat evaporates into the air is governed by the relative humidity of the air. The higher the percentage of water vapour in the air the less ready is the air to absorb evaporated water from the skin's surface, hence the less the cooling effect.

Air movement also has an effect on the rate of evaporative cooling. If there is no air movement the layer of air next to the skin tends to become saturated with water vapour due to perspiration. Air movement causes the air next to the skin to be continually replaced by new less saturated air. Air movement can be seen to aid evaporation from the skin's surface. Therefore the degree of air movement corresponds to the degree of evaporative cooling.

Man can discern and react to even small changes in the temperature of the walls and surrounding objects in the environment. There is a sensation of coldness even when the heat loss is only 0.03 to 0.045 cal/sec and this becomes pronounced at 0.1 to 0.2 cal/sec. These facts explain the unpleasant sensation experienced in a room, the walls of which are appreciately cooler than the air in the room. Heat loss by radiation increases rapidly when the temperatures of the surrounding surfaces decrease. Even a slight increase in the loss of heat by radiation of 3 cal/cm^2/hour causes a sensation of cold in man and a drop of almost 2 degrees C in skin temperature. On the other hand when wall temperatures of a room are only 1.0 degrees C. above air temperature (ie. 23^oC wall surface temperature and air temperature 22^oC) persons will describe the room as hot; while wall temperatures if the same as air temperatures (22^oC) will be described as pleasantly warm. Figure 103 shows graphically the relationship between wall surface temperature or temperature of the surroundings and the corresponding heat loss due to radiation of the human body. It must be remembered that the human body at equalibrium experiencing comfort conditions loses heat by radiation at about 50 k. cal/hour. Loss of heat by radiation from the body at a rate less than this will result in the body building up heat and becoming hotter, hence a feeling of discomfort, while an increase in the loss of heat by radiation to the surroundings above the 50k. Cal/hour level will result in the feeling of coolness.

The area of the source of radiant heat is naturally of great importance; the larger the area, the greater the sensation of heat. If the surroundings are at a low temperature heat is lost, not only from the skin surface, but also directly from the deeper tissues, principally the muscles and blood vessels. When heat exchange by radiation is very high, skin temperature is no longer the principal index of thermal comfort, because a proportion of the radiant heat penetrates the skin. In this situation, there is no longer a correlation between the skin temperature and the thermal condition of the individual.

1.5

Analysis of the Climatic Response of the Built Environment

The approach to the study of the indigenous buildings of Oman is regional. Of course the defining factors for each region include social and cultural determinants and the physical topography and climate. These are all inter-related to various extents to influence the form of the built environment of a particular region.

Climate is an important consideration in understanding the reasons for the physical organization of the community or its pattern of settlement as well as being a determining factor in individual house or building design. Not only does climate have a direct influence on built form, but it also affects such things as economic organization, particularly in agricultural communities where growing seasons are linked to climatic cycles.

The study of the built environment, including settlement organization as well as the organization and features of individual buildings and dwellings, in its climatic context can be broken down into several different stages:

i) the understanding of the region's macro climate, which is done most simply by studying climatic data and organizing it into graphs and charts.

ii) the evaluation of individual buildings or groups of buildings and their response to their particular micro climates, through field tests using portable testing apparatus and personal observations from inhabitants and researchers.

iii) laboratory tests carried out to evaluate individual features, the advantage being that particular conditions can be isolated and the response of certain features quantified.

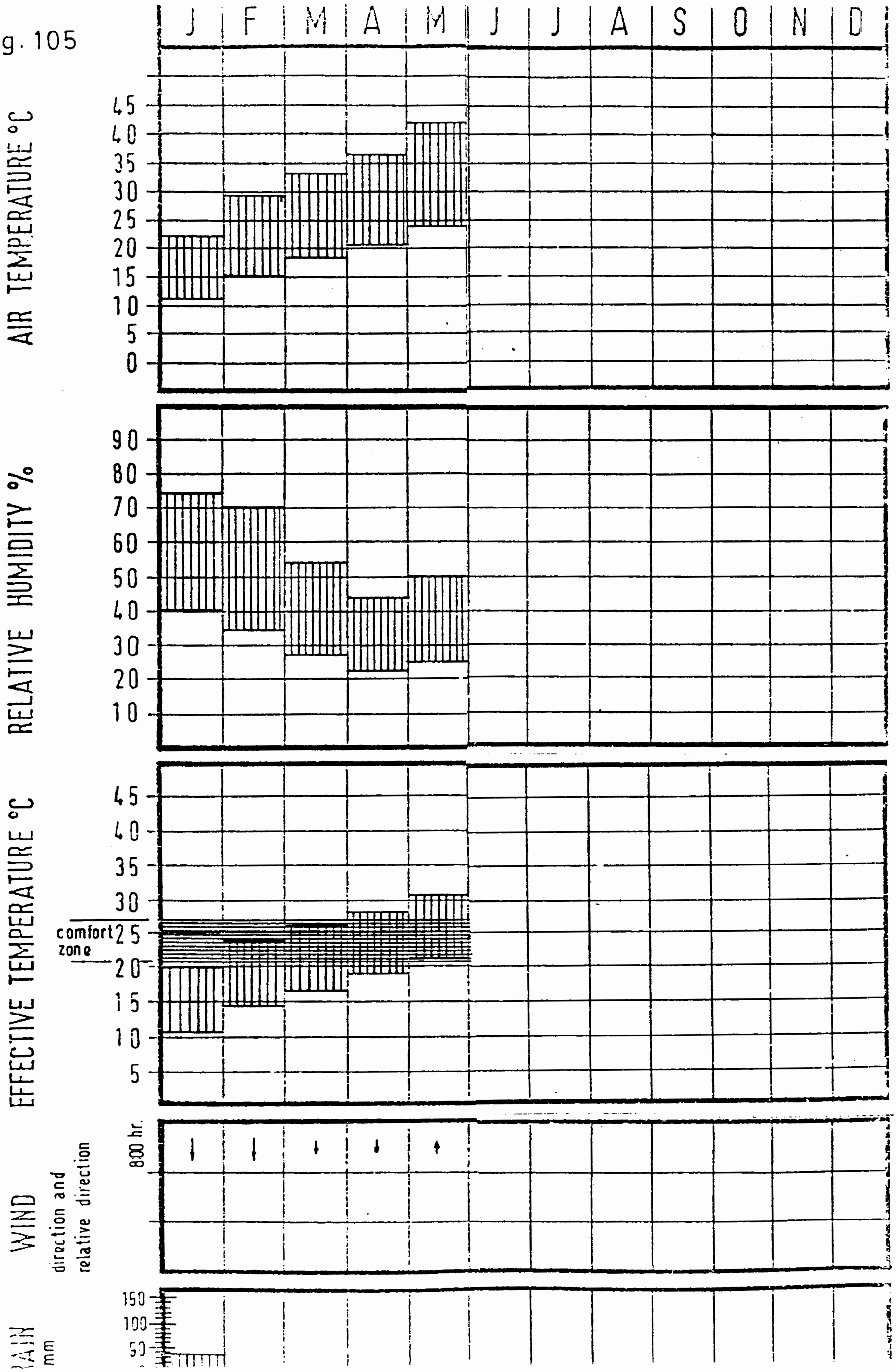
iv) the summation of all the information obtained from above and its analysis to form a clear picture of the response of particular aspects of the built environment to the climatic forces, and finally the integration of this information with social, economic and other material considerations in order to have a clear understanding of the response of the built environment to the forces which influence it.

i) Use of Graphs and Charts

In this report meteorological data is listed for each region in chart form to provide a climatic profile for every area studied. Since the method of presentation is kept uniform information should be relatively easy to find and the climatic variations between each region easily compared. Information presented on these graphs has been obtained from various sources. Permanent meteorological stations have existed for a number of years at Salala, Masirah Island, and Muscat. Statistics for temperature, relative humidity and precipitation are published, in the form of averages taken over a number of years, by the Meteorological Office, H.M.S.O. London. This is the only truely dependable information which is available for the area, since it discounts chance variations which may occur and represents what one may expect to be average conditions.

In recent years some climatic data has been collected in the course of petroleum exploration by P.D.O. Stations have been set up in Fahud, Izki and Mina al Fahal among others. Hydrological survey teams are also now beginning to collect meteorological data for such locations as Sohar. None of these stations has been in existence for long enough to produce conclusive statistics showing yearly averages, but what information is available is presented in this report. It must be understood that much of the information shown on these stations represents information collected in what is assumed to be a typical year. Data from these recently introduced stations has been measured against what one would theoretically expect from a station in that given geographical location and the data has been found to be acceptable in most cases.

Fig. 105


J F M A M J J A S O N D
AIR TEMPERATURE °C
45 40 35 30 25 20 15 10 5 0
RELATIVE HUMIDITY %
90 80 70 60 50 40 30 20 10
EFFECTIVE TEMPERATURE °C
45 40 35 30 25 20 15 10 5
comfort zone
WIND
direction and relative direction
8:00 hr.
RAIN
mm.
150 100 50

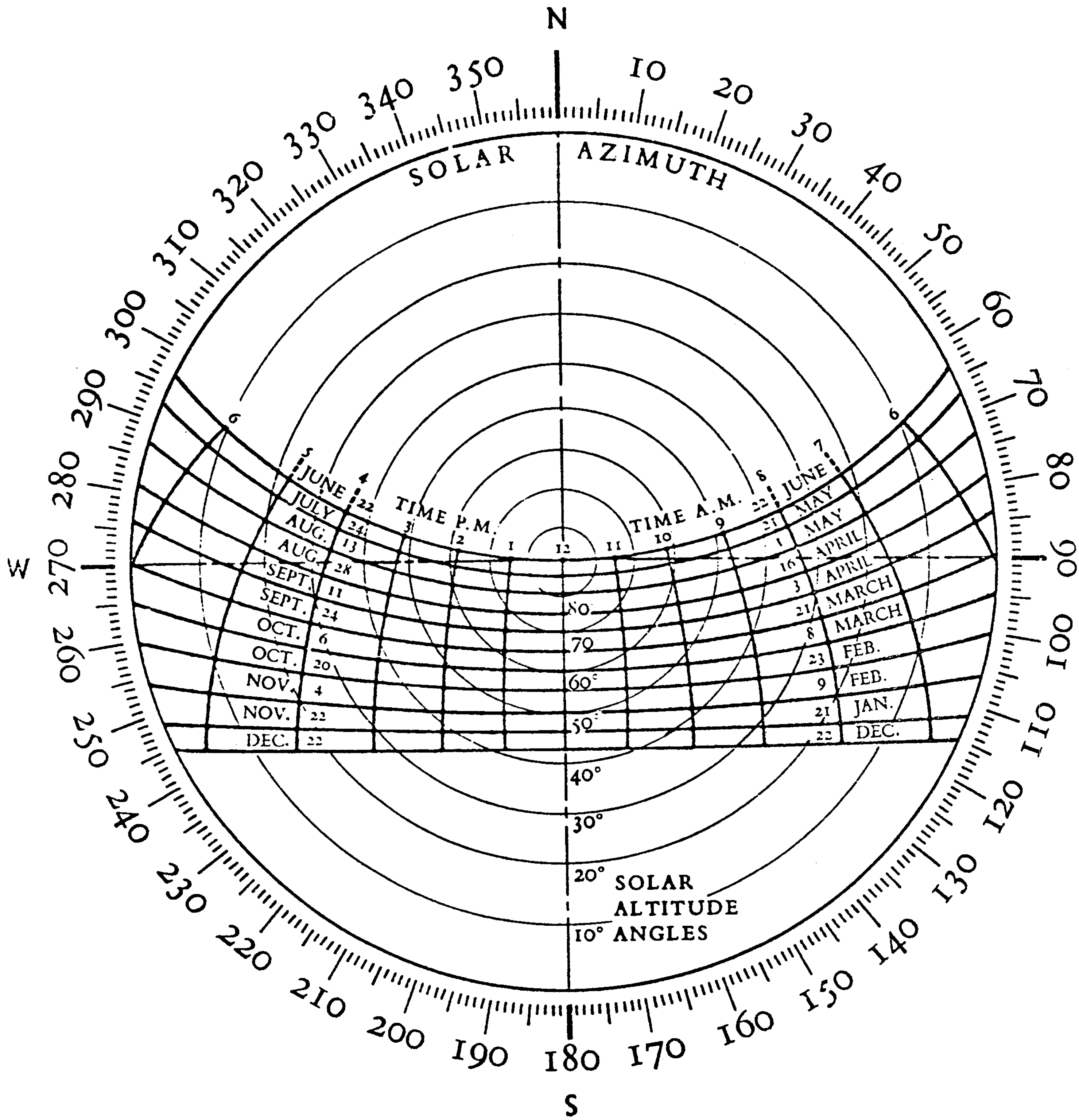


Fig. 106

Solar Chart

(sun path diagram)

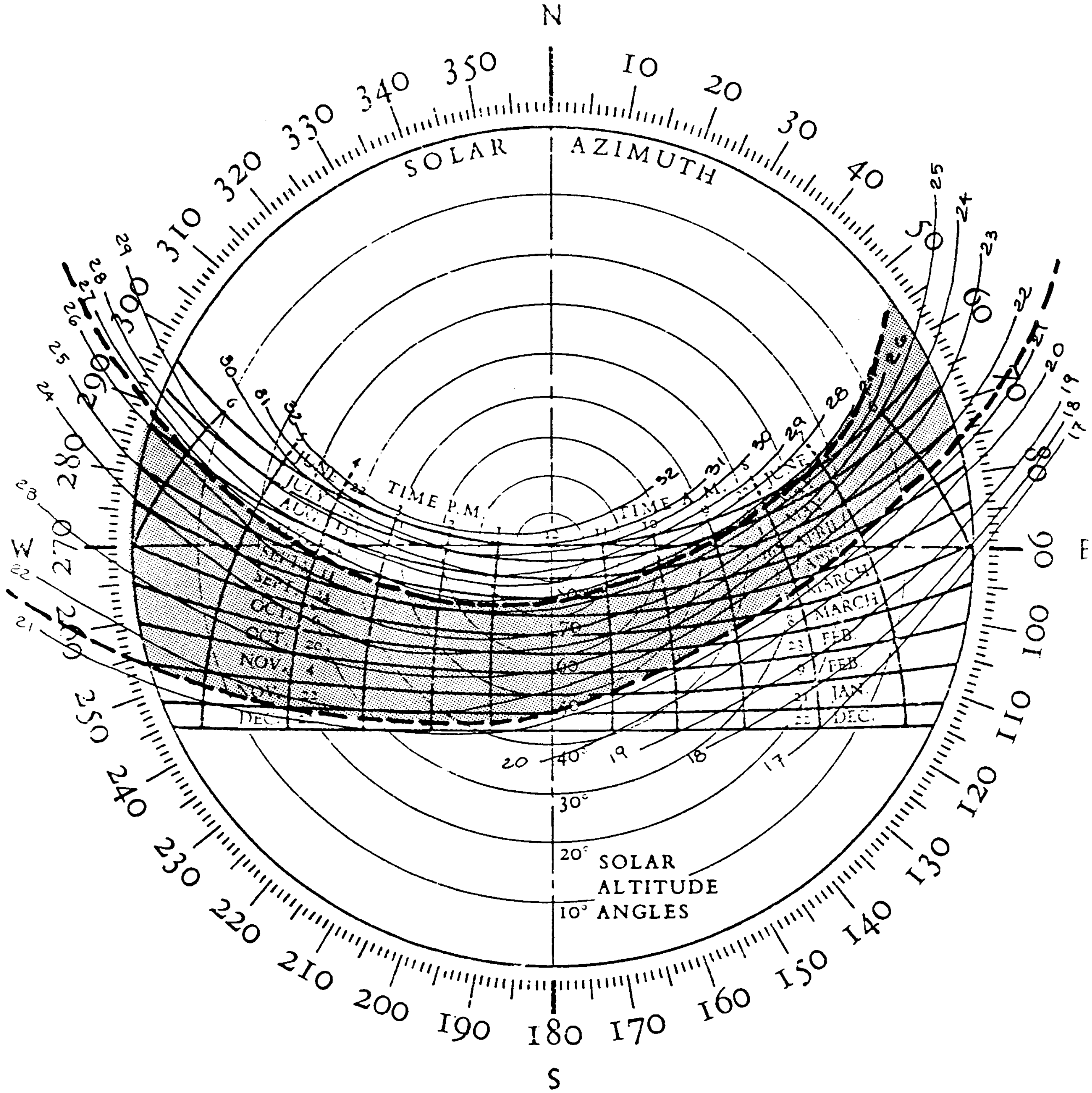


Fig. 107

Solar Chart
with
Temperature Overlay

– comfort zone

Although information on wind speed and direction is not published in the Meteorological Office's tables this data was obtained directly from the permanent stations and the P.D.O. head office at Mina al Fahal provided what information was available from their stations. The H.M.S.O., Meteorological Office's publication Air Flow over the Western Indian Ocean illustrates the changing prevailing wind conditions of the area. In addition to this, discussion with local inhabitants of each area, and direct measurement with portable meteorological equipment in the field provided useful information in establishing a climatic profile of each region.

In reference to Fig 105, a sample of the climatic data chart used in this report, it should be noted that the continuous vertical columns represent months of the year, while the various aspects of the climate are listed down the left hand side, i.e. air temperature, relative humidity, effective temperature, at minimal wind velocity, wind direction and relative velocity and rainfall. The first three, air temperature, relative humidity and effective temperatures are drawn as bar graphs representing the average daily ranges for each month. The upper limit indicating the average maximum temperature, relative humidity or effective temperature that one is likely to experience on an average day in a particular month, while the lower limit of the bar graph indicates the corresponding lowest temperature, humidity or effective temperature. The effective temperature graph also shows the comfort zone in relation to the average daily ranges. Using this graph one is able to discern at which times of day during each month a person will feel either uncomfortably hot or cold. Crytical months which are largely too cold or too hot for human comfort can be seen clearly. It is for these times that design features in buildings must accommodate.

Wind directions and relative velocities are shown as averages for three times per day; firstly night-time and early morning, daylight hours, and evening. Direction is shown by an arrow while the relative velocity is indicated by the length of the arrow.

Rainfall is shown by a bar graph indicating the amount of rainfall in millimetres.

Solar Charts

Solar charts can be used in combination with the climatic data graphs described above as tools in planning or designing with climate. The solar chart itself (Fig 106) can be seen as a map of lines traced by the sun as it travels across the sky each day, projected on a plane. The limits of the chart (circumference) can be seen as the horizon if the chart is oriented in its proper N-S alignment. The degrees from north are found around the circumference. The concentric rings represent angles of altitude as seen from the plane of the earth's surface, (i.e. a point directly above ones head would be 90^{o}).

The times of daylight hours are plotted against the sun paths for different months of the year. Therefore one can determine the precise position of the sun in the sky for a particular time of day for any day of the year. Each chart represents only 6 months, meaning two are needed for a complete year. Different latitudes require correspondingly different solar charts. Thus the basic solar chart for the Batinah Coast region is not the same as that for the Dhofar Coastal Plain.

Over the basic solar charts presented for each region is superimposed a graphic representation of effective temperature conditions experienced over the complete year. This information is derived * from the graph of effective temperatures (Fig 107). This information is presented somewhat like isotherms on a meteorological map, in that lines are drawn each representing a particular effective temperature condition. From these charts one can read the average temperature for any daylight time of the day for any day of the year.

* Ref. Climatic Handbook, Development Planning Unit, London University)

The comfort zone is also represented on these charts.

Of particular interest to the designer is the fact that he can see at a glance during which hours of the day or times of year that comfort conditions are not attained, and for these critical times he can also read the position of the sun in the sky. From this data he is able to describe how to orient his building or establish wall openings to either encourage of discourage sunlight and solar radiation from entering his building. It is a simple matter to design window openings to allow the sun to penetrate into rooms at times when temperatures fall below comfort levels and to be excluded at other times.

When the direction of the wind is known for different times of the day and the year this information can be used in conjunction with solar charts to calculate openings and optimum orientations to provide natural cooling during the hot critical times.

ii) Field Testing - Micro Climate

An understanding of the micro climate which effects individual settlements and buildings can rarely be obtained from published meteorological data. Proximity to physical features such as bodies of water, hills or mountains - other built forms - on the quantities and kinds of vegetation, or the attitude, all have their effects on modifying the macro climate or the climate said to generally affect the region. In fact when meteorological observations are made every attempt is made to isolate the testing apparatus from micro climatic localized influences.

Bodies of water are known to effect the temperatures of areas nearby, because water heats up and cools at a rate much slower than land. The difference in temperatures of the air over the land and water cause pressure differences which in turn induce localized winds. This is known as the onshore, offshore or the land-sea breeze effect and is explained in detail in section 3.1.2.

Mountains or hills have the effect of physically altering wind patterns by simple deflection or the channelling of winds down valleys. Changes in altitude correspond to temperature changes. The stratification of layers of air of different temperatures over a daily cycle induce local winds in the slopes and valleys (Refer section 4.1.2.).

The presence of a moist shaded environment in vegetated areas means that the micro climate within and around the green area is quite different from that outside. (Refer to sections 3.1.2 and Fig 304 on the coastal planted belt and 5.1.2 on the oasis climate.)

The spacing between buildings within the settlement effects wind flow within the settlement and the shading of streets just as does the organization of the spaces within the house. Open spaces can be organized in such a way as to induce air movement when there is no wind. (Refer to section 7.1.2). Materials used in the construction of buildings effect their internal thermal environment.

Particular features within buildings such as wind catchers (badgir) and cleverly designed openings as well as orientation on a site all effect the micro climates within and around buildings.

Because the micro climate which effects the built environment is due to particular conditions which vary from place to place, they can only be understood through field testing, observation and local experience.

Tools

In studying the micro climates of buildings many of the tools used by the meteorologist (of a permanent station) are employed, but these must be light weight, portable and durable.

Measuring apparatus is needed for air temperature, surface temperature, radiation levels, air movement and lighting. Among the portable apparatus used during field surveys in Oman were the following instruments:

1) Whirling Hygrometer - this is an instrument containing both a dry thermometer and a thermometer whose bulb is kept permanently wet. The wet bulb thermometer records a temperature which is influenced by evaporative cooling from the bulb while the dry bulb records simply air temperature. Since more evaporation hence cooling occurs when the air is dry, the degree of cooling of the bulb is controlled by the percentage of humidity in the air. The relative humidity can be computed from the wet bulb temperature and the dry bulb temperature.

2) Thermo-hydrograph - this apparatus keeps a continuous running record of temperature (thermograph) and relative humidity (hydrograph). Changing conditions are inked continuously onto a graph which is fixed onto a rotating clockwork driven drum. Twenty four hour graphs of air temperatures and relative humidities are therefore obtained.

3) Electronic contact thermometer - this thermometer records on a dial the surface temperatures of objects such as walls on to which the sensor is applied.

4) Globe Thermometer - this instrument records temperature due to radiation. It is composed of a simple thermometer whose bulb is inserted into a black globe. The matt black surface of the globe heats up readily when exposed to solar radiation. The thermometer therefore registers the temperature due to this radiant heat affect.

5) Smoke Tubes - these are glass tubes containing a chemical solution which produces smoke which has the same density as air. This smoke therefore rides on the breeze and will not tend to rise as hot cigarette smoke will. Smoke tubes are useful in establishing wind direction patterns and relative speed. Speed can be estimated roughly by timing puffs of smoke over a measured distance.

6) Velometer - this meter indicates the wind velocity experienced from one particular direction. It is useful in recording air movement when the direction is known and is constant. It is very sensitive and is useful at low velocities.

7) Cup Anemometer - this instrument records total wind velocity irrespective of direction.

8) Kata Thermometer - by indicating the rate of cooling due to air movement this instrument enables one to calculate wind velocity.

9) Mini-Lux Meter - lighting levels are recorded in lux by this meter. It is useful in evaluating brightness or lighting intensities.

10) Photometer - this instrument gives values for the amount of light reflected from particular surfaces. It is useful in measuring glare by taking readings from highly illuminated surfaces and comparing them with their surroundings. It is a delicate and difficult instrument to use.

11) Electronic Photometer - this instrument functions as above but gives more accurate readings and can be read simply.

iii) Laboratory Experimentation

Field testing is essential in the work of analysing the response of the built environemnt to climate because it is only in this way that one can reach an understanding of the relationship of all the environemntal forces influencing the built form. On the otherhand it is essential at times to understand the actions of particular phenomina such as air movement or solar radiation on a particular feature of the building, before it is possible to piece together a picture of the whole building. Much of the necessary apparatus needed to obtain detailed information is not portable and can only be found in laboratories. For these reasons certain experiments were carried out in the laboratory after the innitial field testing was completed.

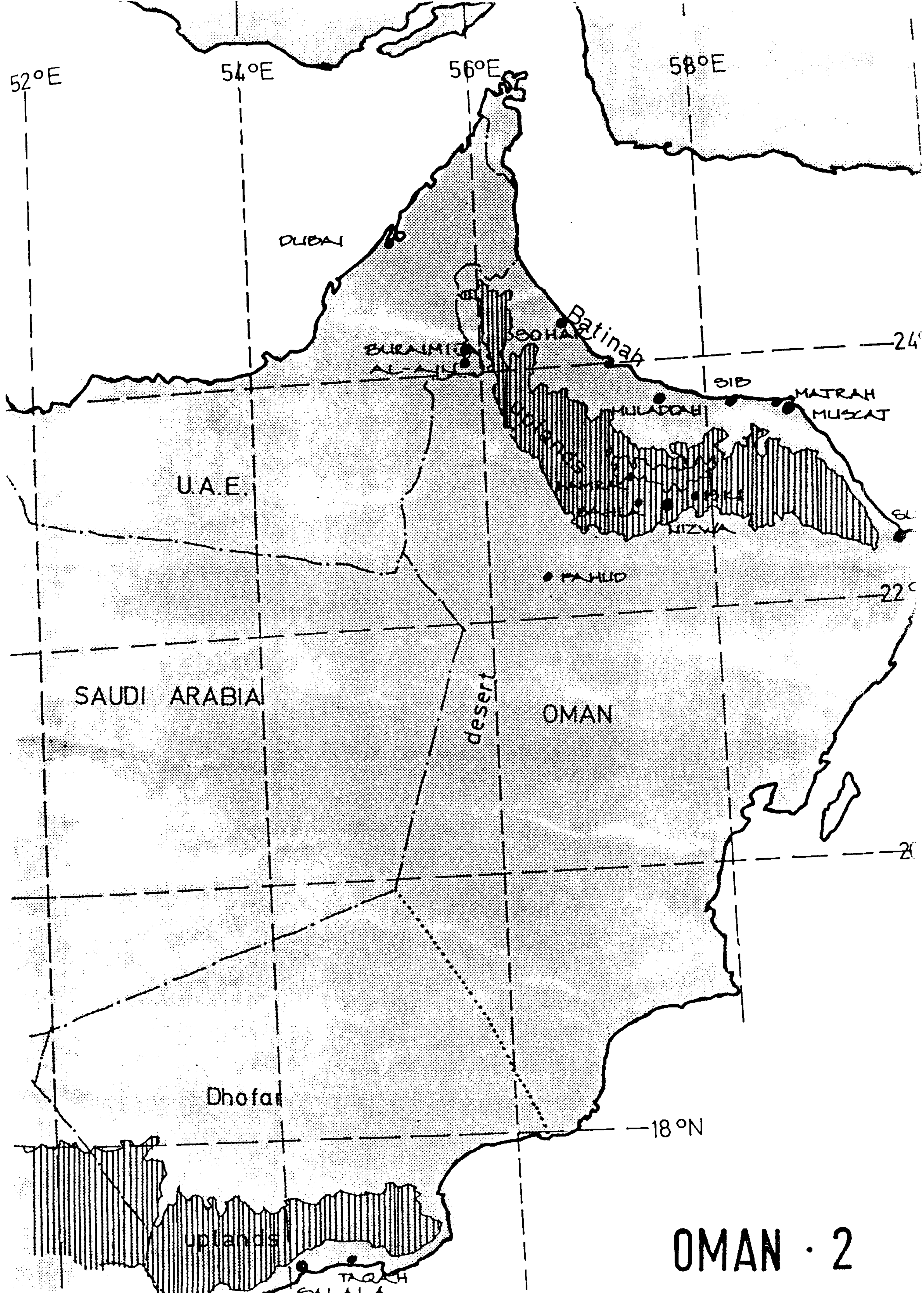
Laboratory facilities were made available at:

a) London University College Engineering Testing Laboratories.
b) Yardsley Testing Laboratories Ltd - Leatherhead Surrey
c) Development Planning Unit - London
d) Cairo University - Dr Saied Yeuseff

Both climatic and structural tests were carried out on building materials and pre-assembled units (such as lattice screens and wall panels).

A local palm stem (barasti) builder in Seeb was approached to help assemble a series of test panels illustrating methods of wall and roof construction. On completion these panels were shipped to the London laboratories where a series of tests including heat transfer, hygroscopic absorption and air movement could be carried out. Structural tests were also undertaken on similar units.

Mud bricks, rendering plasters and other indigenous building materials were also collected from various different regions visited during the survey. These were taken to Cairo where Dr Saied Yeuseff has been responsible for much pioneering work in the analysis of soils for their suitability in mud brick making at Cairo University. At this moment results have not yet been received from these tests, but findings should indicate the strengths, durability and heat transfer properties of mud brick from each area. A detailed account of mud bricks' properties is to be found in Section 9.3.1.(ii).


52°E
54°E
56°E
58°E
DUBAI
BURAIMI
AL-AIN
SOHAR
Batinah
SIB
MATRAH
MUSCAT
MULADDAH
NIZWA
FAHUD
U.A.E.
SAUDI ARABIA
OMAN
desert
Dhofar
uplands
18 °N
TAQAH
SALALA

OMAN · 2

2.1

Introduction to Oman

The area of the country has been estimated at 260,000 square kilometres, (100,000 square miles).

There has never been a comprehensive census in Oman and until recently there was no accurate figure for population. However, recent sample surveys have given a reasonable accurate estimate and the IBRD's figure of 600,000 has now been accepted by the Government for planning purposes.

Most of the population is Arab but in Muscat and Mutrah and along the Batinah coast there are sizeable minorities of Baluchis, Pakistanis and Indians. More than half the population adheres to the Ibadi sect of Islam and the majority of the remainder are Sunni. On the coast there is also a Shia community. About 5% of the total population still lives a nomadic life.

The Sultanate of Oman lies in the South Eastern corner of the Arabian Peninsula. Its northenmost extremity commands the strategic straits of Hormuz. The northermost area, Musandam, is separated from the rest of the country by a strip of land some 80 km wide belonging to the United Arab Emirates. The coast line stretches for more than 1,500 km South and West along the Gulf of Oman and the Arabian Sea. Oman borders the People's Democratic Republic of Yemen on the South-West, Saudi Arabia on the North and West and the United Arab Emirates in the extreme North. Most of the population is concentrated on the narrow coastal plain known as the Batinah in the North and in the valleys of the Hajar mountains running parallel to this plain. There is also a population centre in the southern province of Dhofar around the southern capital Salala.

Muscat is the capital of Oman and is linked to Mutrah, which is the commercial centre of the country. The Muscat-Mutrah area has at present a fast growing population, estimated at some 30,000 people. Other main centres in the north are Sohar, Nizwa, Rustaq, Suma'il and Sur, and in the south Salala.

The official language of Oman is Arabic but some business and government officials in Muscat use English. Arabic is spoken exclusively in the interior.

Climate is marked by very hot summers, even in the highlands of the Al Jebel Al Akhdar plateau, most of which lies at about 2,000 metres in altitude with the peak reaching to 3,000 metres. Summer temperatures have been known to reach 50^{o} Centigrade. The winter climate is very agreeable.

Oman is ruled by His Majesty Sultan Qaboos bin Da'id bin Taimur. He came to power in July 1970 after a peaceful coup which ended the reign of his father, Sultan Sa'id bin Taimur bin Faisal. Sultan Sa'id, who reigned for 38 years, was the last custodian of a century long status quo which was almost medieval. Oman, which has for some hundreds of years been recognised as independent, is now a member of both the Arab League and the United Nations, (also the International Monetary Fund).

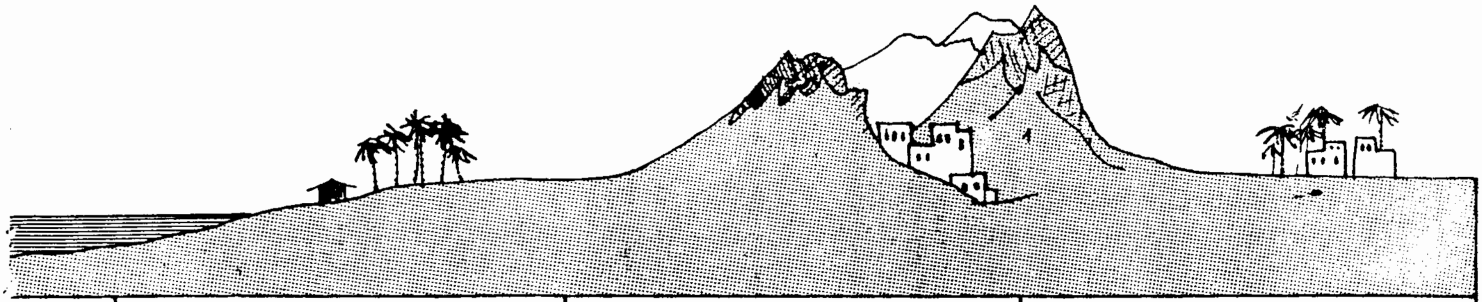
It is a mistake to think of Oman as a Gulf country, for its history, institutions people and above all, the facts of geography, make it distinctly different from the Emirates and Sheikhdoms which adjoin its northern boundaries.

Government in Oman can be considered on three levels, national, regional and local. The national Government is headed by HM The Sultan, as Head of State and the source of all authority.The Sultan has appointed Ministers to be responsible to him for various functions of government. Ministers meet under the Chairmanship of the Hm The Sultan as a cabinet with collective responsibility for government.

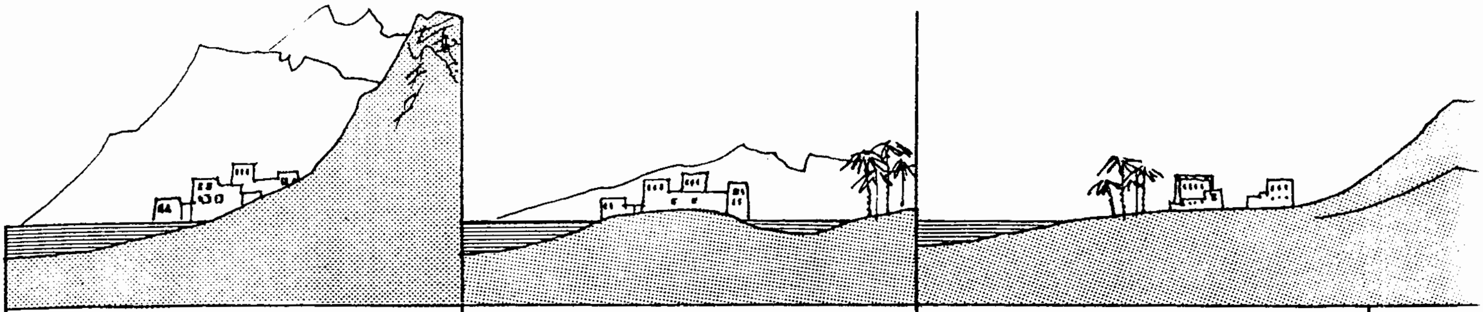
Regional government follows the traditional pattern under appointed provincial governors (Walis). Local government is beginning to develop with municipalities, not only in the capital area stretching from Muscat to Sib, but also in provincial townships (Nizwa, Sur, Sohar, Rostaq, Sumail, Buraimi and 'Ibri). Salala capital of Dhofar province, also has its own Municipal Council.

Up to 1967, the year in which oil production and exports began, Oman was a subsistence economy growing very slowly, if at all. Since then, the gross domestic product has probably risen at an annual rate of about 8 per cent to 10 per cent in real terms. This expansion was led by the oil sector until 1970; subsequently construction was the leading sector. Despite the decline in oil production in 1971 and 1972, the marked rise in crude oil export prices improved Oman's terms of trade and, consequently, increased the real resources available for consumption and investment. From 1967 to 1970, Oman realized budget surpluses and added substantially to its foreign assets. With the change in Government in mid-1970 and the acceleration of the development effort, public investment increased rapidly and public and private consumption expenditures rose at high rates.

* The above section is a direct quote from a Government of Oman publication. Courtesy of Oman Embassy - London 1973



		BATINAH COAST	NORTHERN UPLANDS	DESERT/OASIS
LOCATION		SAHAM, SEEB, SOHAR, SHINAS	IZKI, NIZWA, BAHLA, BAHLA, AL HAMRA	BURAIMI + AL-AIN, FAHUD
ECONOMIC BASE		DATE GROWING FISHING TRADE	DATE GROWING AGRICULTURE CRAFTS METAL WORK	OASIS - DATE GROWING SUBSISTANCE AGRICULTURE DESERT - PETROL
CLIMATE	Critical Times	UNCOMFORTABLY HOT MAY TO SEPTEMBER UNCOMFORTABLY COOL DECEMBER TO FEBRUARY	UNCOMFORTABLY HOT IN DAYTIME MAY TO SEPT. UNCOMFORTABLY COOL NOVEMBER TO FEBRUARY	UNCOMFORTABLY HOT MAY TO SEPTEMBER UNCOMFORTABLY COOL NOVEMBER TO MARCH
	Temperature Range	14°C – 40°C DECEMBER – JUNE NIGHT MID–DAY MODERATE DAILY RANGE	11°C – 42°C JANUARY – JUNE NIGHT MID–DAY LARGE RANGE	12°C – 42°C JANUARY – JULY NIGHT MID–DAY LARGE RANGE
	Humidity	MODERATE TO HIGH % PEAK IN JANUARY AND AUGUST MODERATE RANGE	MODERATE TO LOW % PEAK IN WINTER AND MID SUMMER LARGE RANGE	MODERATE % PEAK IN WINTER LARGE RANGE
	Winds	LAND/SEA BREEZE MODERATE	MOUNTAIN SLOPE WINDS MODERATE	PREVAILING SEASONAL SHIFTS MODERATE
	Rainfall	LOW WINTER & AUGUST	LOW JANUARY & AUGUST	ERRATIC
INDIGENOUS BUILDING MATERIALS	Walls	DATE PALM STEMS (summer use) MUD BRICK - INLAND WINTER USE FIRED BRICK IN PAST	MUD BRICK LIMESTONE	MUD BRICK
	Roofing	DATE PALM STEMS	PALM BEAMS + STEMS + MUD PLASTER	PALM BEAMS + STEMS + MUD PLASTER



		CAPITAL REGION	SUR	DHOFAR COAST
LOCATION		MUSCAT, MUTRAH RUWI, MINA AL FAHAL	SUR, AYQA BILAD AS SUR	SALALA RAYZUT, TAQAH, MIRBAT
ECONOMIC BASE		ADMINISTRATION TRADE – IMPORTS OIL – EXPORT	TRADE (PORT OF CALL)	IMPORTS COCONUT PALM FISHING
CLIMATE	Critical Times	UNCOMFORTABLY HOT APRIL TO OCTOBER COOL NIGHTS DECEMBER – FEBRUARY	UNCOMFORTABLY HOT MAY TO AUGUST HOT DAYTIME APRIL – OCTOBER COOL NIGHT-TIMES DECEMBER – FEBRUARY	UNCOMFORTABLY HOT MAY – JUNE AND DAYTIME SEPTEMBER – OCTOBER UNCOMFORTABLY COOL NIGHTS – DEC – FEB.
CLIMATE	Temperature Range	19°C – 38°C JANUARY – JUNE NIGHT MID-DAY SMALL DAILY RANGE	18°C – 36°C JANUARY – MAY & NIGHT-TIME JUNE SMALL DAILY RANGE	18°C – 32°C JANUARY –MAY & OCTOBER NIGHT MID-DAY SMALL DAILY RANGE
CLIMATE	Humidity	HIGH % PEAK IN AUGUST LITTLE OR NO VARIATION OR RANGE	HIGH % PEAK IN AUGUST SMALL RANGE	HIGH % TO MODERATE EXTREMELY HIGH IN SUMMER SMALL RANGE
CLIMATE	Winds	LAND/SEA & SLOPE BREEZES LOW	LAND/SEA BREEZE MODERATE	LAND/SEA BREEZE MODERATE
CLIMATE	Rainfall	LOW WINTER	LOW	LOW JULY & AUGUST
BUILDING MATERIALS	Walls	LIMESTONE MUD BRICK	LIMESTONE STONE & MUD	LIMESTONE PALM BEAMS - COCONUT PALM
BUILDING MATERIALS	Roofing	IMPORTED TIMBER	IMPORTED TIMBER	LOCAL TIMBER TEMPORARILY UNAVAILABLE