PROPOSALS · 9

9. Proposals

Introduction

Whilst the previous sections have been largely descriptive and analytical, this section concentrates on proposals, and is divided into three parts.

The first part presents a strategy for the development of Oman. The reason for comment at this level is because the condition of the built environment, which is our particular concern, depends essentially on the social and economic well-being of its inhabitants. We discuss the development of Oman in the light of the governments stated aims, and why these aims are not being fully realised; and we propose an approach that may come closer to achieving these aims.

The second part of the proposals is concerned with a strategy for the development of the built environment. It discusses the reasons why developed and developing countries alike have been unable to provide a satisfactory built environment, and in this context assesses Oman's particular approach to this situation, and finally considers proposals that we believe to be both consistent with the Government's aims as outlined in the Whitehead Report, and capable of achieving them.

The third part sets out specific proposals for the built environment. On this level we have confined ourselves to two fundamental aspects: firstly the structure, materials and technology involved, and secondly the health aspect: in a very direct way both can effect the life of the occupants. Standards for both are often defined and used to dismiss local methods of building (see Proposals on the Built Environment).

This section considers the essential requirements of the material fabric of a building and the potential of the major local materials, and compares these with some of the recently introduced materials. There is also a section on roofing, usually the greatest constructional problem in a building.

With regard to the health factor, and bearing in mind that a healthy environment depends on climatic comfort and hygienic conditions, we discuss the physiological effects of climate, and the ability of local materials, methods and elements used in building to achieve a comfortable micro climate. Under the subject of hygienic conditions water supply and sewage disposal are considered in this section and we discuss local conditions and methods, and make proposals for their improvement, particularly for health risk areas, such as main water collection and washing areas, (falaj outlets) food selling areas, sanitation facilities and cooking areas.

9.1 Proposals

On Development

The success of the built environment in the final analysis rests on the socio-economic well-being of its inhabitants. Thus although our immediate interest in the built environment we feel it relevant to outline our ideas on what we believe will promote the general socio-economic well-being of Oman. The proposals on both levels are closely linked and form a unified approach.

We would like to take as our starting point what appeared as the key recommendation of the Whitehead Report:

> "We believe that regional development should be at the heart of the Governments Development Strategy, and should have as its objective the stabilisation of rural society. Development is as much a social as an economic concept, which should mean that people work together to build up their village, rather than become a rootless class of urban industrial workers." *1.

From our observations it appeared that this key recommendation had still to be put into effect; in fact an opposite trend could be seen to be developing. The Batinah, and in particular the Capital area, were developing at a fast pace compared to the rest of Oman; one could easily see a trend towards a regional imbalance between the Batinah and the rest of the country, and also the Muscat/Mutrah/Rui areas developing into an urban concentration, to the detriment of the rural areas. Investment figures for development projects quoted in mid July 1973 show that the Batinah Region received £54,343.000 and the Muscat/Mutrah/Rui areas received £34,443.000 while the figure for the rest of Oman was £21,938.000. *2.

This trend can be explained by the naturally advantageous position of the region. Its strategic location vis-a-vis the Gulf and in terms of international trade relations is obvious. Furthermore the majority of Omanis (34.5% on the Batinah, 5.7% in Muscat and Mutrah *3.) already live here. Finally, most of the cultivated areas are on and around this coastal strip.

On the other hand there are many precedents for the problems that arise when development planning aggravates rather than moderates natural regional imbalances. It is undoubtedly in recognition of this fact that regional development and rural stabilisation are emphasized in the Whitehead recommendations.

Agriculture and Fisheries are stated to be the two main priorities in Oman's Development Strategy. This appears to shift the emphasis away from the question of the nature and type of industrial development. However, we feel that this question is an immediate and critical one to which answers are already implied in current trends. Exactly how agriculture is to be developed is linked to this question. The Fisheries are to be an industrialised undertaking mainly centralised in Sohar. Many of the development projects in the Batinah and Capital regions also indicate the type of industrialisation that could increasingly be relied upon in Oman.

*1. Sultanate of Oman: Economic Survey 1972. The Harold Whitehead Consulting Group. Introduction.

*2. Calculated from Quotation in the Middle East Economic Digest report on Oman July 1973.

*3. Whitehead Economic Survey 1973. Human Resources. section 2.1.1,2.

There is also a discernible trend for Omanis to move from agricultural to non-agricultural employment, more specifically into construction jobs on the Batinah Coast. The prospects for employment after this initial construction boom dies down, and the effects on the rural areas of such a movement is not a comforting one if precedents from other developing countries are considered. Again the key recommendations of the Whitehead Report seem to have this problem very much in mind. Finally in the long term, if agricultural productivity increases as hoped, an increasing number will need to be employed as a result in non-agricultural sectors as a general healthy development trend. What sort of employment they will get, if any, and where this will be, is very closely linked, as are all the above more immediate problems, to the type of industrial development Oman adopts. In the absense of any alternative proposals the present trend seems to rely on capital-intensive, industrialised technology projects in developing Oman. Agriculture and the fisheries are to be developed by three large international firms - Mardela (USA), Del Monte (USA), and the Food Machinery Corporation (USA). Construction for the fisheries has begun in Sohar; in October the American project organizer informed us that prefabricated units were being shipped across to house the US technicians for the project.

The new Mutrah harbour (cost £20m) is to use a completely new design of breakwater units which although expensive is supposed to prove more effective than any used so far. Seeb International Airport (£5m) began operations in November 1973. Six identical 50 bed hospital units, with adjoining schools, (cost £4m) were built and equipped by a Swedish firm in different towns in Northern Oman. Finally the heavy infrastructural expenditure in the Batinah anticipated this type of planned development. (232 kms of road from Muscat to Sohar - cost £10.5m).

The temptation to rely on such an approach is great. Capital-intensive projects using sophisticated labour-saving technologies are associated strongly with the success of developed countries, and in those areas where capital is available for investment but labour is scarce and expensive such methods may be justifiable; but in Oman the situation is quite the opposite.

Firstly, Oman is very short of capital. Furthermore the capital requirements for installing such technologies are even higher in developing countries than in developed ones. The initial capital required per worker in a developing country has been estimated at £13,150 for a cement factory, £3000 for a vehicle assembly plant and £2800 for a plastics factory. Equivalent capital costs for 75% of British industry are all between £1000 and £3000.*4. Once installed, such plants continue to require heavy and recurrent capital expenditure to maintain and replace parts; and more important, for any significant increase in industrial production in such plants the capital input has to be increased. Organisational improvements, quality of labour and management play a limited role.

At present Oman's capital needs are being met by its oil revenues (approx. 85% of all revenue *5.). Oil reserves are expected to last another 20 years. The extent to which this limited capital is already being absorbed is outlined in the Whitehead Report under the heading "Key Points for the Government to Consider".

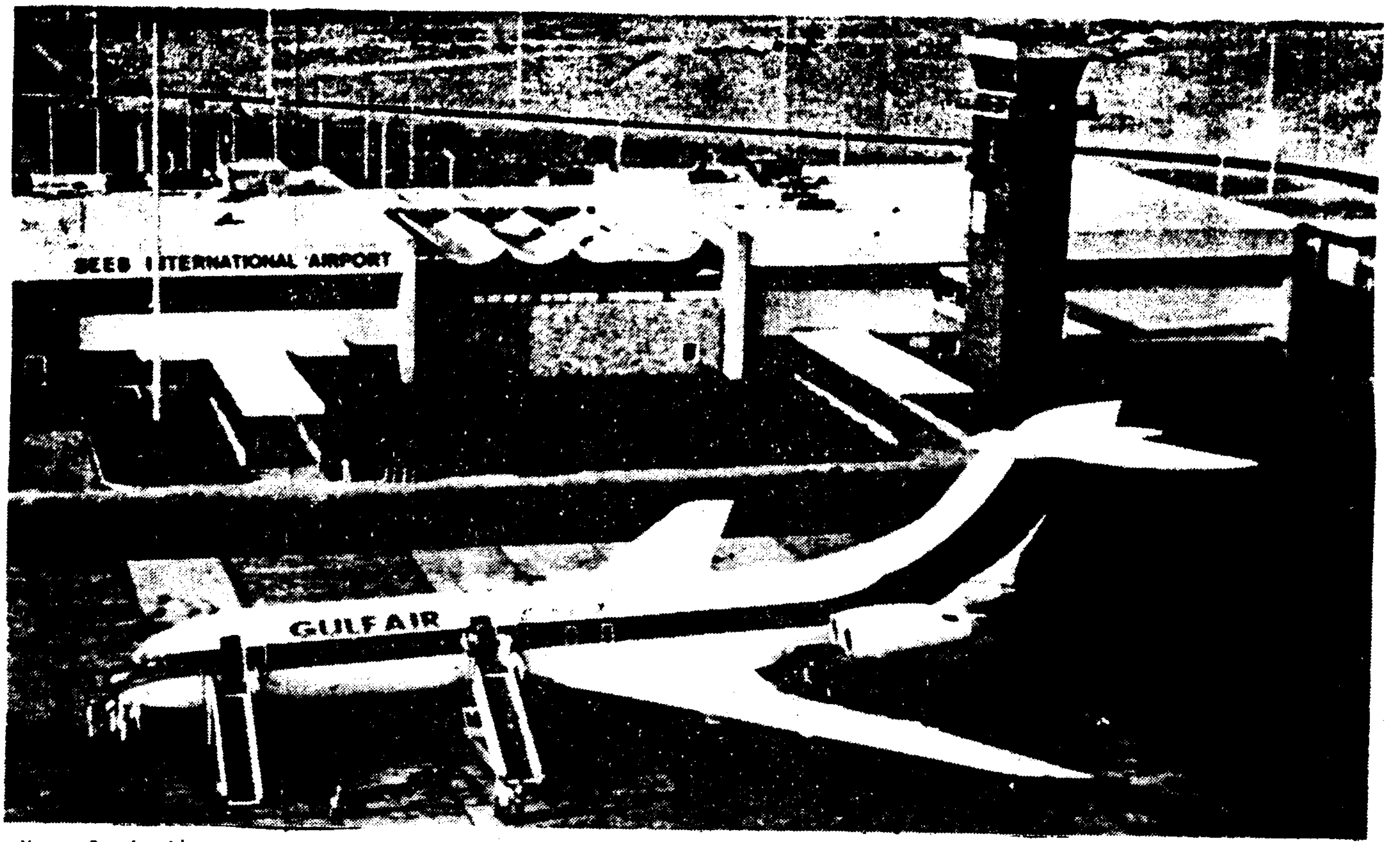
> "The infrastructure projects now being built and planned will require annual recurrent expenditure. There is a danger that if building continues at current rates, within a few years there may be insufficient funds to meet all the consequent expenses."

*4. U.A.C. Industrialisation in West Africa. Statistical and Economical Review 23. As quoted in B W Hodder, Economic Development in the Tropics. Methuen 1973.p172

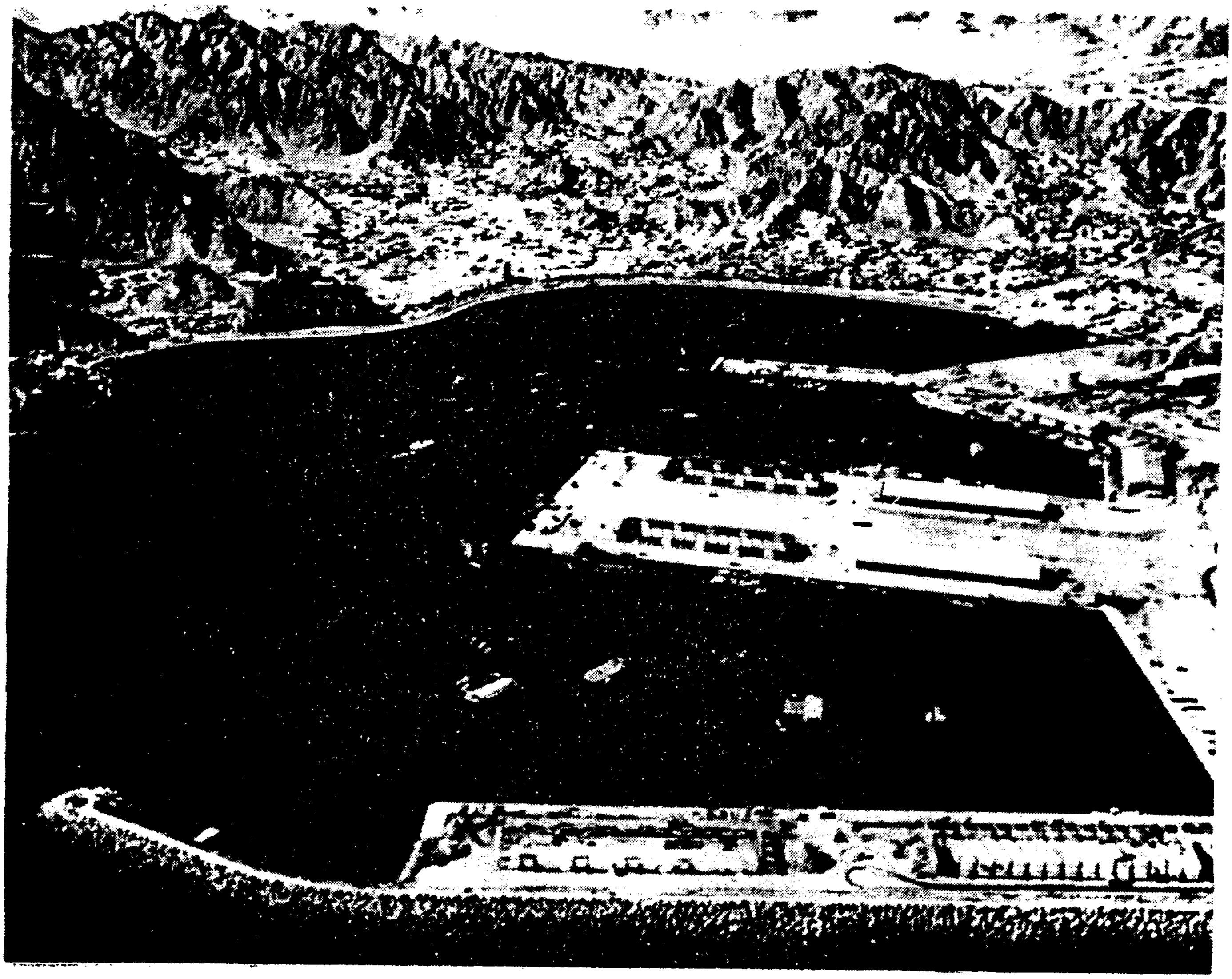
*5. Before price rises. The increased revenue since then does not alter the fundamental argument on how best to use existing capital for Oman's Development.

Fig. 901

Major Development Projects in the Capital Region



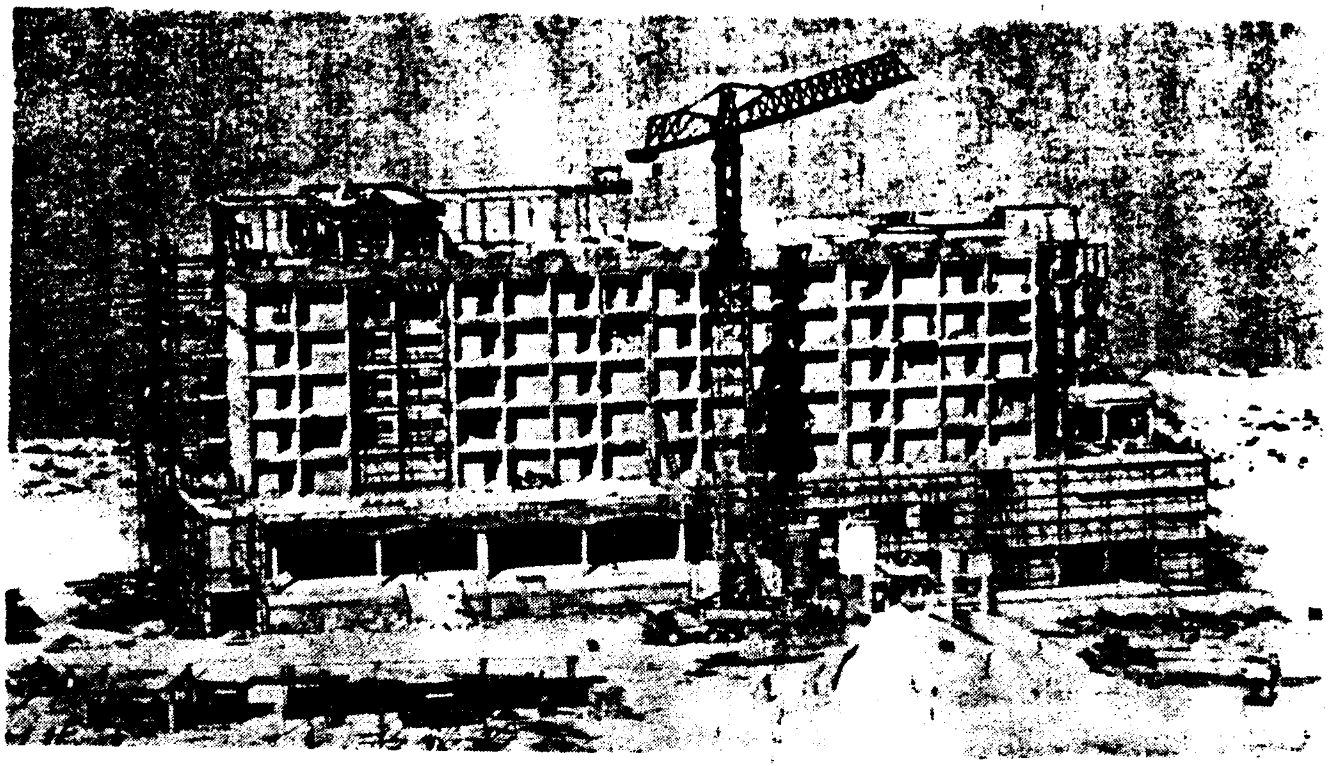
New Seeb Airport



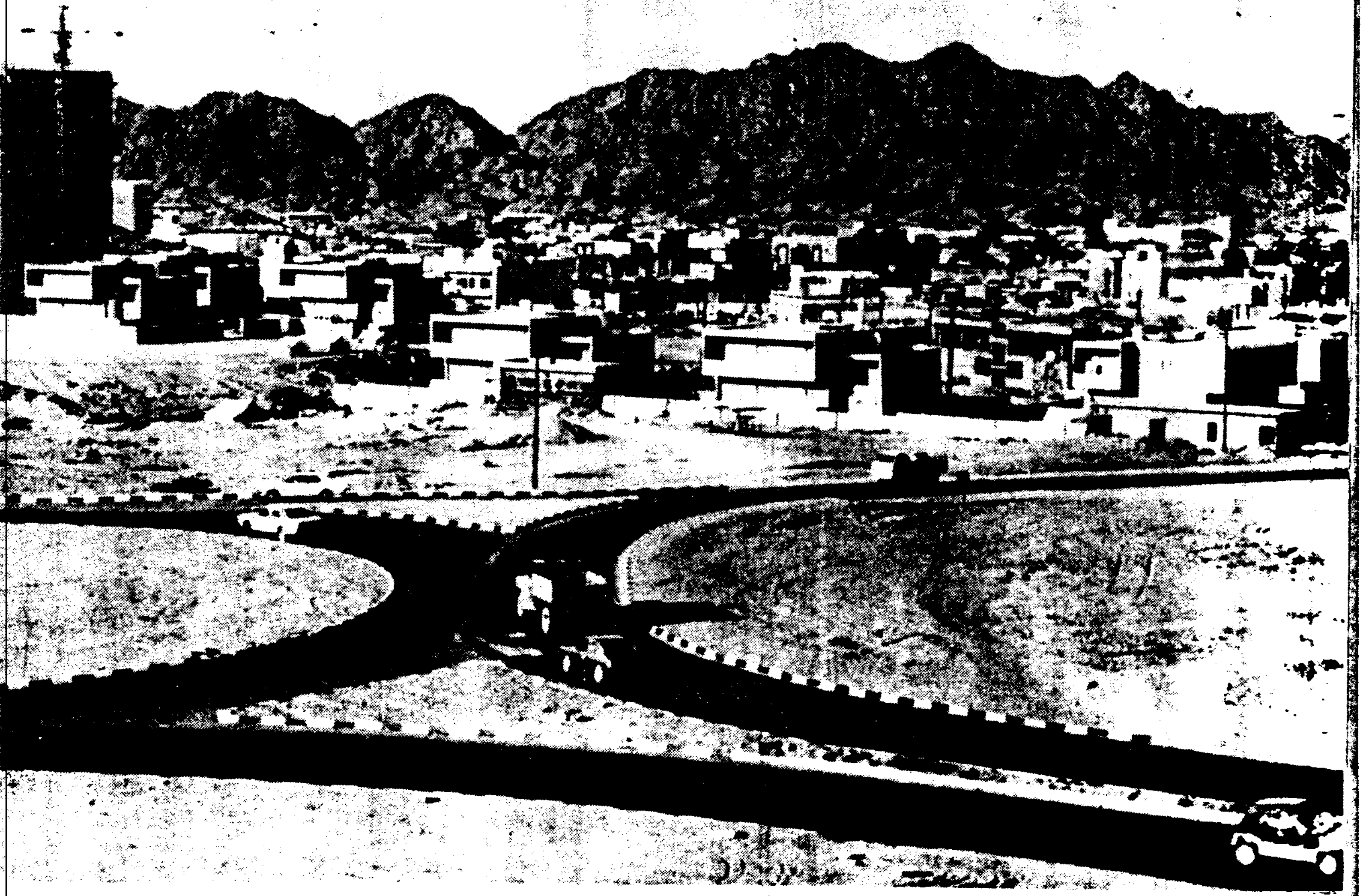
Mutrah Harbour

photos - Min. of Information + Tourism

New Construction in the Capital Region



Hotel at Qurum



Ruwi Valley Development

photos – Min. of Information + Tourism

Unfortunately such heavy infrastructural committments are an accompanying pre-requisite for the seccessful operation of already expensive industrialised technology projects.

To make up this shortfall in capital, domestic and foreign investment is urged by the Whitehead Report. But from the experience of other developing countries we know that this has seldom proved sufficient. Massive 'development loans' have had to be solicited, and from the same experience we know that, above all, these have resulted in crippling debts for the receiving country from which recovery seems impossible. In fact a recent U.N. conference outlining strategy for developing countries proposed that the only way to deal with these debts was to simply cancel them. *6.

Secondly with regard to the labour situation it is true that Oman is not burdened with the teeming millions that so eloquently speak against the use of labour-saving technologies in most developing countries. But at the same time a closer look at the labour availability situation shows that in the unskilled categories there are more Omanis employable than there are jobs. The labour shortage is in the semi-skilled and skilled categories. Thus labour-saving technoligies would have no use for those categories in which labour is potentially plentiful (the unskilled) and would make demands on those categories in which there is a shortage - the skilled and semi-skilled workers. The result would be to leave untapped a potentially productive labour resource (particularly the disguised unemployment situation in the rural areas) and aggravate any unemployment situation among the unskilled category while having to depend on expensive expatriate skills on the other two levels until enough local Omanis can be trained to take over. *7.

Finally, capital-intensive industrialised technology projects introduced into an otherwise underdeveloped economy foster a few swelling urban concentrations to the detriment of other areas. This is because such projects are expensive to install and run and cannot be applied nationally, but must remain situated in a few regions which are already advantaged by reason of their location and other factors. Furthermore, they need to be located within a matrix of infrastructure and service industries as essential supports, if they are to operate successfully. This matrix is already available and taken for granted in developed countries, but in a developing country it often has to be built up from scratch. Thus a large proportion of the available development funds are siphoned off into these few locations. The complementary effect is the siphoning off of the labour resources from the neglected countryside into these few concentrations in search of employment. The final results, as evident in many developing countries, are a few chaotically large cities with underemployed millions living in shanty towns within a general area of rural decay. Oman does not have the population of many such countries, but the model if repeated would be equally damaging.

*6. Mexico for example pays £260m each year in repayment and interest towards its £900m debt. (Quoted in the Guardian 28 Jan '74). The United Nations General Assembly Soecial Session on the problems of raw materials and development held between April 9th and May 2nd 1974. It also discussed how developing countries could form blocks modelled after the OPEC in order to ensure fairer prices for their exports.

*7. "In the unskilled category there are many more people employable than there are jobs. In the semi-skilled and skilled categories, however, there are many more jobs available than Omanis to fill them. Such training as is taking place is wholly inadequate." (Whitehead Employment and Skill 2.2.3)

In 1972 its early signs were noted in the Whitehead Report:

> "Around Muscat and Mutrah an observer sees many such people living by the side of the road, under trees or in the most primitive 'shanties'. Unless this trend is halted it is possible to envisage the growth in a few years of a new class in Oman, a poor, often unemployed, rootless, industrialesed urban proleteriat." *8.

In 1973 they were still there and had undoubtedly increased in number. So as was mentioned at the beginning the situation has already begun to develop, both in the Batinah and Capital areas, and in the rest of the country. The reason can now be largely identified with the type of development projects so far relied upon and more particularly in the level of technology applied.

While it may be true that certain sectors of the economy must rely on industrialised technology, it is also true that these sectors form a small proportion of the total, and affect small proportions of the population and areas of the country. It would be wasteful to sink a major proportion of development resources into these areas with the unrealistic expectation that they would eventually expand to benefit the majority. From the experience of many developing countries that have followed the same 'logic' we can see that this has not happened.

Another strategy has to be developed, one that immediately involves and benefits the majority, and that can be applied uniformly across all regions of the country. If regional development, rural stabilisation and encouraging poeple to work together to build up their villages are the objectives of Omans' development strategy, then we believe the following approach needs to be taken.

Four conditions need to be met:

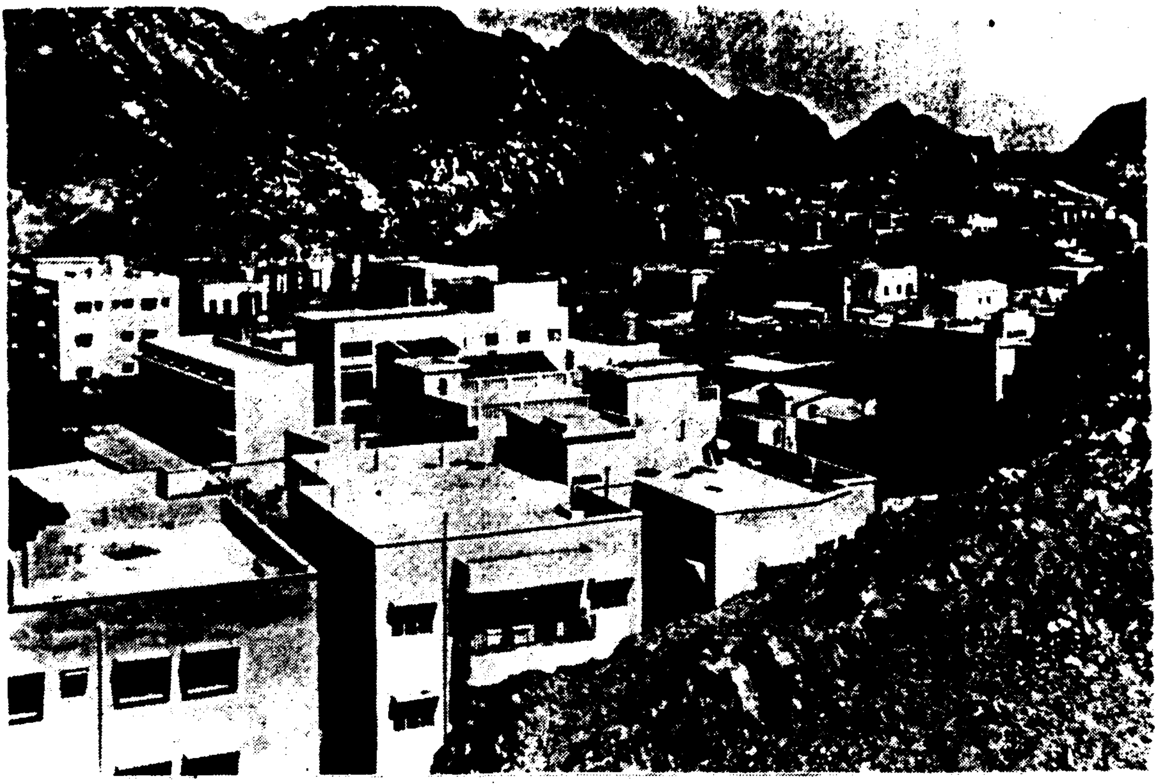
1. Work places have to be created in rural areas.
2. These work places must be cheap enough to be created in large numbers and applied uniformly across all regions.
3. Production methods must be simple enough to be able to make use of existing levels of skill, not only in the technical equipment used, but also in organisation.
4. Production should be largely from local materials and meet local needs.

To meet these conditions, small-scale industries need to be developed using intermediate techniques applied in a regional, decentralised but nationally co-ordinated way. Traditional cottage industries meet the above four conditions, but left exactly as they are such industries are dying out. This is where the emphasis and definition of the term 'Intermediate techniques' must be considered. It requires a fifth and final condition: that the work places must be viable to meet the contemporary situation. That is, the industries must be rationalised on all levels - organisational, technical, economic and social - so that they are feasible and running concerns. This may result in some cases from an upgrading of existing rural industries and traditional practices, in others from a down-grading of fully industrialised methods or a fusion of the two. More often than not a whole new approach may be developed based on a creative understanding of the local situation on the one hand and the demands of a modern economy on the other.

---

*8. Sultanate of Oman: Economic Survey 1972. The Harold Whitehead Consulting Group.

Fig. 902



Urban Concentration in the Capital Region

Decay in towns in Rural Areas

This is not as difficult as it may appear. Where people have made a concerted study along these lines some very hopeful results have emerged. In India for example feasibility studies have been done for a number of production processes, complete with cost analyses. This has been done for the production of agricultural implements, food processing and consumer goods. They were found to be fully competitive with industrialised methods. *9.

Working examples can be seen in Japan where small family units produce a large number of industrialised components. And in Pakistan for example, in Sialkot, the industry in sports goods, cutlery and even surgical instruments rests largely on small independent units using labour intensive methods and yet producing goods fully competitive in the international market. Unlikely as it would seem Britain is one of the importers of the surgical instruments produced this way.

Now let us consider the appropriateness to the Omani situation for such a programme of small-scale industries using intermediate technology compared to the industrialised technology projects discussed before.

Firstly such small-scale industries would require very little capital to initiate and run. Professor Schumacher, a leading exponent of Intermediate Technology approximates a definition of it by saying that equipment cost per work place should be between £70 and £100. Harold Dunkerley, senior adviser to the World Bank, estimates such a workplace to cost up to £160, while for one of a highly industrialised job would cost anything between £600 and £2400. *10. Thus many more workplaces could be provided maximising the use of the share capital resources of Oman to benefit many more people.

Secondly, regarding the labour situation in Oman, the Whitehead Report states:

"In the unskilled category there are many more poeple employable than there are jobs for. These people are not unemployed in the European sense as they go back or remain in their tribal areas and engage in whatever seasonal activities are going on at the time. In the semi-skilled and skilled categories however, there are many more jobs available than Omanis to fill them. Such training as is taking place is wholly inadequate to fill the need within the foreseeable future and very little is being done about it." *11.

The suggested type of industries, by being smaller, easy to get to and integrated into the needs of the villagers, would be far more inviting and more successfully use the underemployed villager than the larger factory in the far off town. They would also be more flexible in response to the seasonal activity demands of the village areas. Because they would be using relatively simple production methods they could use those "many more people employable in the unskilled categories". On the other hand these industries will need to operate on a rationalised basis both in technology and organisation approaching modern plant conditions. Thus over a period of time they could produce the semi-skilled persons needed by the country. They could also be run largely by local people with a minimum of attention from the central government, thus they would not tax the already scarce resource of managerial skills at the centre, while providing a training ground for these skills from within the villages.

---

*9. As cited in "Developing the Third World - the Experience of the 1960's". Ed. R Robinson. C.U.P. 1971 Ch. 7 Section 8.91.

*10 Harold Dunkerley. Paper presented at the conference on Exploding Cities, held at Oxford (UK) in the first week of April 1974.

*11 Whitehead Report. Labour Employment and Skills. 2.2.3.

Thirdly by being cheap and stemming from local potentials and needs such industries could be planned regionally and develop equitably across the nation, and have a direct and immediately beneficial effect on the village economies. Some regional imbalances may still occur but to a scale that a nationally co-ordinated effort could deal with.

Finally one of the major obstructions to industrialisation in Developing Countries often cited is a narrowness of market opportunities for the goods produced. Reasons vary from country to country but most important of all is probably the low purchasing power of the local population. To quote Hodder:

> "Market opportunities and economic prosperity are clearly closely linked and it is perhaps only an analytical convenience to distinguish between the supply and demand sides of the problem of increasing production".*12.

This critical problem would be met as such industries would be directly integrated into local needs and much closer to what people can afford. A domestic market would be immediately available. To summarise in the words of the Cambridge Conference Report on Development:

> "Developing countries tend to feel that the most up to date machinery must always give the best rate of development, that anything simpler must be second best. It is emphatically not the case that intermediate techniques of manufacturing are necessarily less efficient than advanced methods. It may sometimes be just the reverse. In technical jargon, the simplified production may be the optimum technique, given the characteristics of the market, the factor availability and the state of skills." *13.

This we see is the case for Oman.

The types of industries that could be developed along the above lines fall into four convenient headings:

1. Industries producing implements for Agriculture and Fishing.
2. Processing and packaging plants for agricultural and fish products.
3. All varieties of consumer goods, such as textiles, domestic hardware, pottery, glassware, copperwork and footware.
4. Industries related to building such as brick making, glazed tiles, roofing felt, drainage pipes and timber items etc.

Which specific industries Oman could develop in these four categories will emerge from a thorough study of its potentials. The obvious areas would seem to be in agriculture and fisheries, rationalising work methods, providing better implements and in processing and packaging. It would be well worth a serious feasibility study for a system of developing the fisheries including the processing and packaging, but one which would increase the involvement of and benefit to the existing fishermen and provide fish in greater quantities to local Omanis as well as the international market. In its 'Key Facts on the Economy of Oman' the Whitehead Report points out that 'the health of the population is poor due to a protein deficient diet'. A similar problem exists in Argentina, where the beef industry has been highly industrialised and export orientated to the extent that it has been priced out of the range of the majority of the local people. Thus in a protein exporting country the local people continue to suffer from a protein deficiency. The same result may follow with reference to Oman's fisheries. This would be patently contrary to the Whitehead Report's assertion that "Development is as much a social as an economic concept".

*12. B W Hodder. Economic Development in the Tropics. University Paperbacks p. 73

*13. Cambridge Conference Report on Development. U.K. 1965.

Other rural industries are active or were until recently, particularly, but not exclusively, in the Nizwa area. The Whitehead Report listed them as follows:

1. Silversmiths and Goldsmiths
2. Khanjar (Omani daggers) manufacturers
3. Weaving
4. Pottery
5. Copperwork
6. Blacksmiths
7. Tannery
8. Food processing (Halwa and Jaggary production)
9. Cobblers
10. Dyers
11. Masons
12. Carpenters
13. Boat Builders

To these could be added lime burning and limestone quarrying for building. A comment on these two activities, their potential and a comparison with mechanised techniques can be found in section 8 on Salala.

These are the existing rural industries in Oman, some still flourishing, such as the silver and gold smiths and some waning such as weaving, copperwork and shoemaking. But the downhill trend is a product of a situation where such industries are just left to their own devices, as no doubt the 'shanties' of Muscat and Mutrah would increase if left to the unplanned market forces. A thorough study of the existing rural industries in the different regions of Oman needs to be carried out. Here again it must be emphasized that the aim cannot be to preserve such industries purely for their own sake; their feasibility for development along intermediate lines must be clearly identified. Before such a study is carried out it may be premature to write off any one of them. The potentials of new small scale industries must also be investigated. It is perhaps here that the most innovative work will be required. Oman in this endeavour will not be starting alone or from scratch. Work along these lines has already been carried out and is in progress in various parts of the world. In India several organisations are studying and applying such an approach, of which the best known case is probably the Khadi Commission.

In Britain the Intermediate Technology Development Group lead by Professor Schumacher has been involved in this field. The knowledge of such organisations should be drawn upon in evolving a programme of development peculiar to the Oman condition.

We end with a view expressed at the recent Conference on Development problems.

"Major capital schemes like subways and airports have far more political appeal than bus services but they are infinitely less useful - (we need to) - switch away from the grandiose to the practical. In transport this means abandoning the Cadillac approach and actively encouraging the desposed jitneys and pedicabs which actually provide both the jobs and cheap mobility in problem packed places like Djakarta and Bangkok. In housing it means carefully paring down British style middle class suburban design to the much lower standards that people in warmer countries actually need and can afford. In jobs it means forgetting the idea that only the motor car assembly or petro-chemical plants represent real industrial development, and concentrating on providing, organising and enriching the kind of tertiary employment in shops, in distribution, in repair work, in all sorts of services where people actually have some hope of making a living over the next 20 or 30 years.

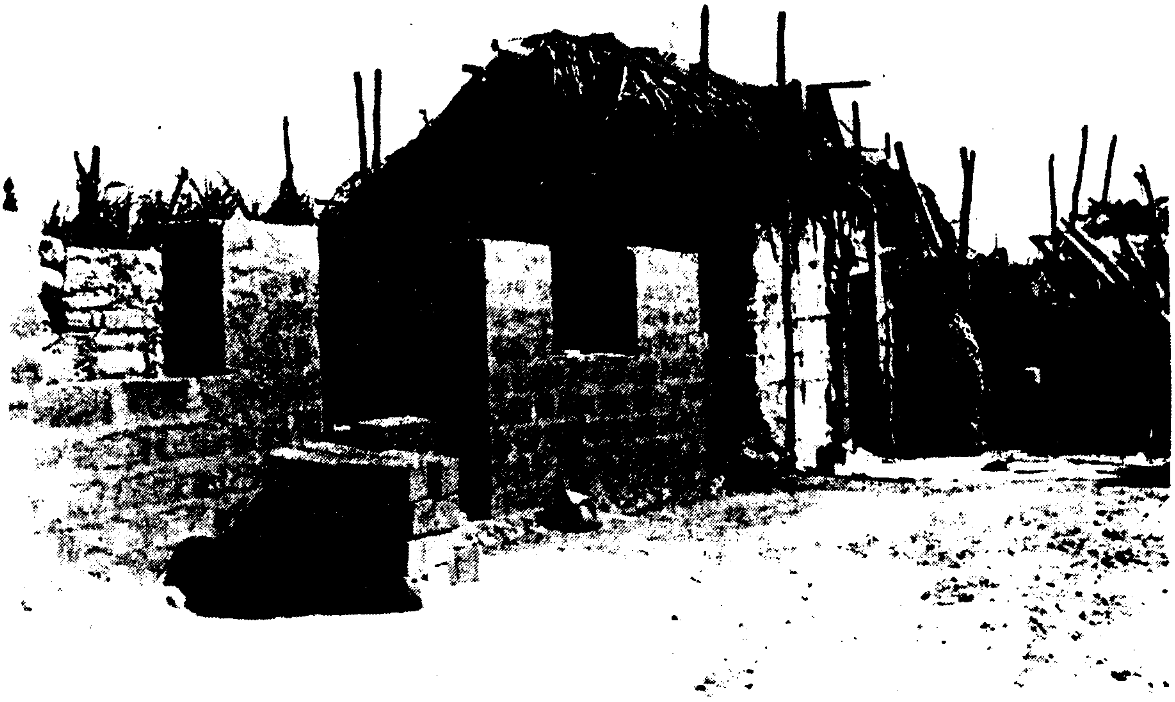
Money, which has been previously lavished in great monolithic dollops on the big projects should now be much more carefully and imaginatively used to set up a multitude of small seedling schemes." *14.

This was the view of Harold Dunkerley, British Economist and Senior Advisor to the World Bank. The World Bank, as a major source of funds for development has in the past financed many large capital intensive industrialised technology projects in developing countries, but as became clear at the Conference, attitudes are now changing. This fact underlines the urgent need for such an alternative approach. In this section we have attempted to discuss its relevance to Oman. In the next section we will try to persue in more detail its relevance to the built environment in Oman.

---

*14. Harold Dunkerley. Paper presented at the Conference on Exploding Cities, held at Oxford (U.K.) in the first week of April 1974, quoted here as reported in the Sunday Times, 7th April, 1974.

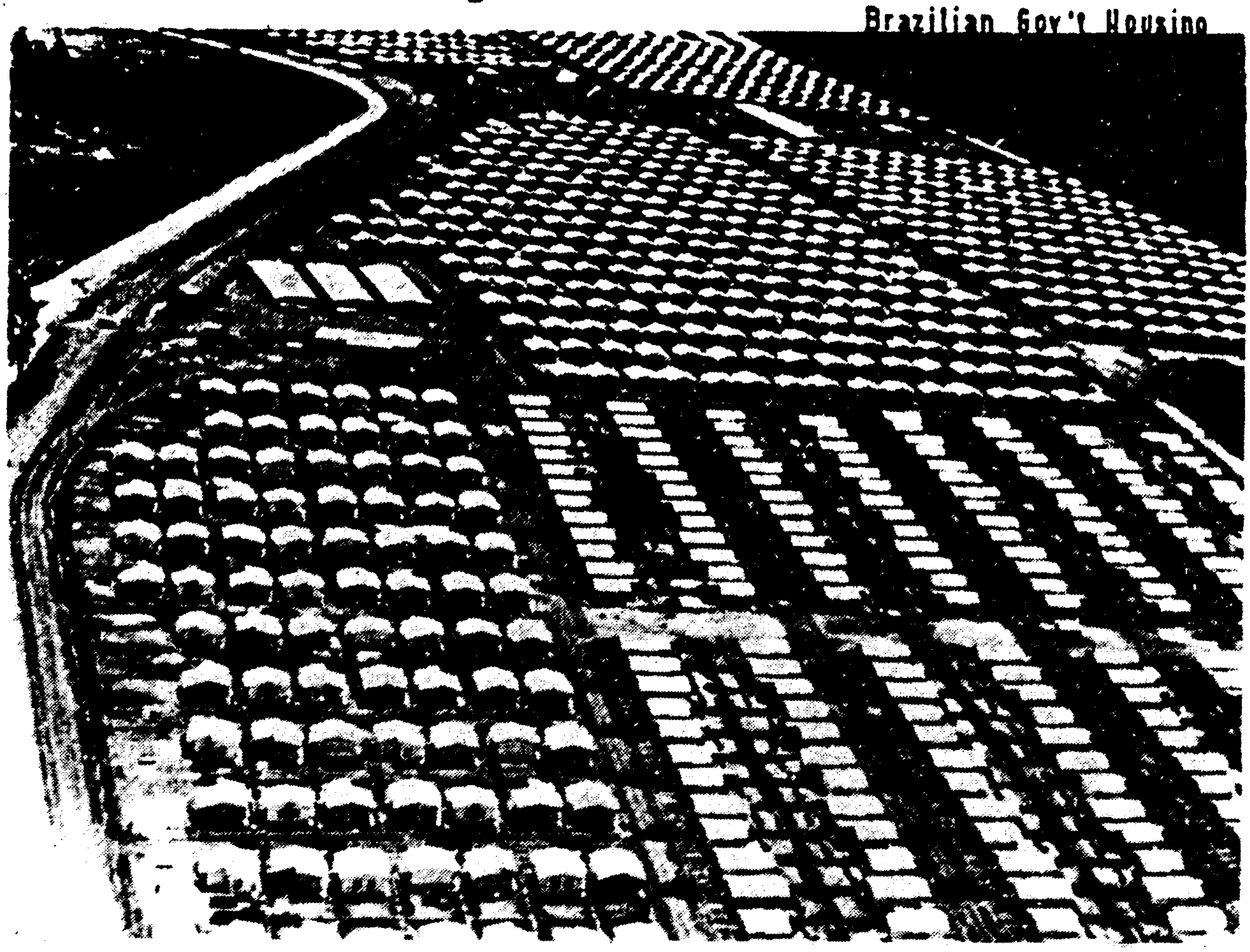
Fig. 904 Housing as a Process



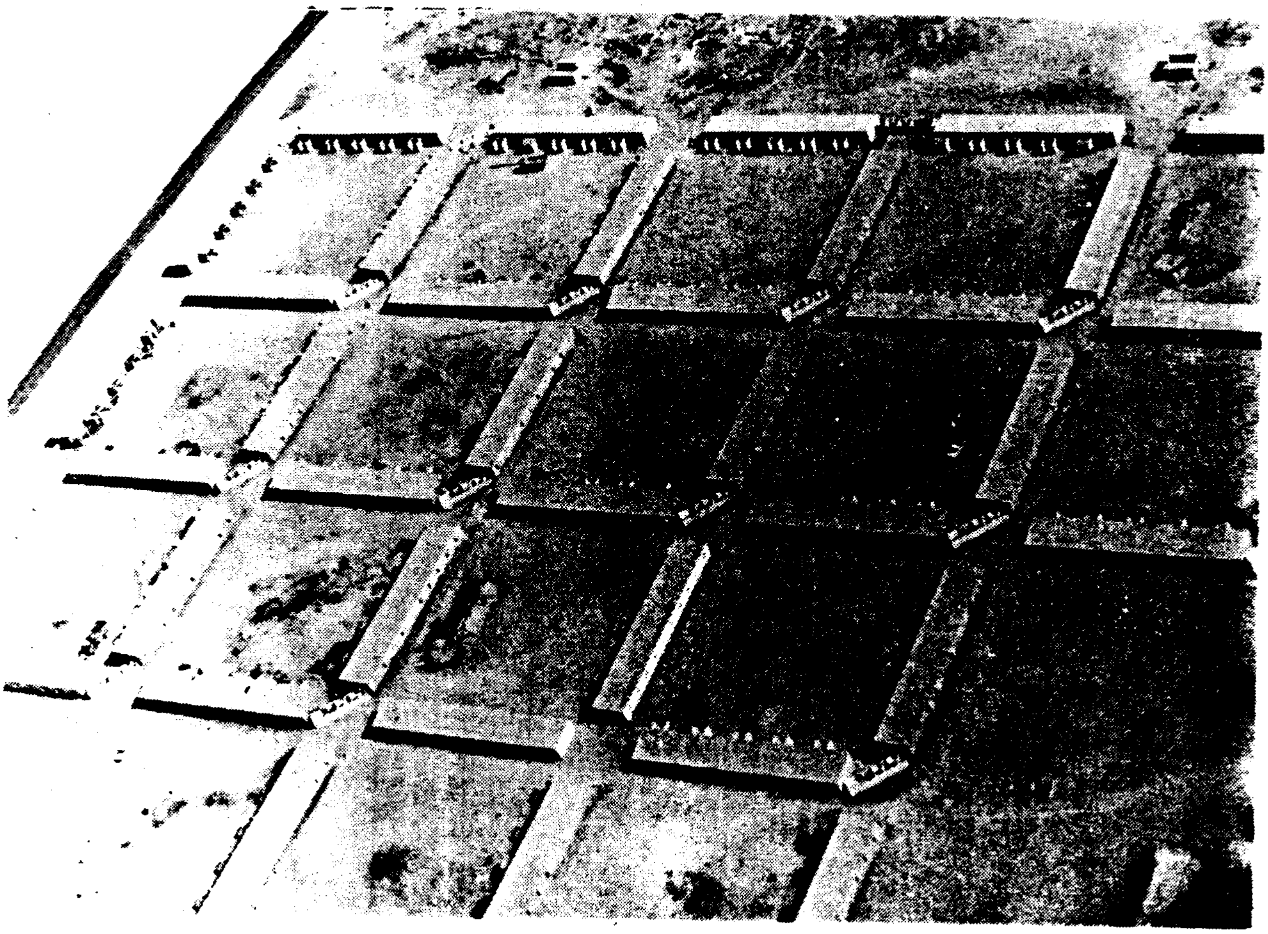
Housing developed by the user begins as a basic shelter and developes into a substantial house, in time, with the users' needs, income, and self-expression.

Fig. 905 Housing as a Product

Brazilian Gov't Housing



Government housing is often built to a standard too expensive for most people / or if built cheaply, lacking quality both functionally and aesthetically.



Refugee housing in Salala

9.2 Proposals

On the Built Environment

Housing forms a major proportion of the built environment and relates most closely to people and their needs. For this reason our comments here will concentrate mostly on housing, although what is said is relevant, to all aspects of the built environment ranging from public to specialised buildings.

Official policies on housing often go wrong because they are based on two fundamental misconceptions: firstly housing is treated as a finite product rather than as an ongoing process. At any moment in time a house reflects its owner's needs - functional, social or economic, and as these needs change so the house changes, bieng one of the main factors helping in meeting these needs. In Salala, examples from both past and present clearly show this to be the case. The old town houses were built stage by stage, floor by floor, as the owner became wealthier and family numbers increased. In 1973, one of the houses studied was having yet another floor added to accommodate a brother and his family returning from the city. (Section 8.)

Similarly in the new allotments one often sees a tent, a palm stem (barasti) shelter and the beginnings of a limestone room all in one plot belonging to one family. An old Arab proverb says "If you complete your house, you die". Obviously this is not some mystical quote but factually reflects what a house is for the majority of the people all over the world; this is clearly the case in developing countries where often at least 80% of the population are rural, and their houses are very much adaptable to change by the owner; and of urban housing at least one third consists of squatter settlements where houses are being constantly added to and changed.*1 Only in developed countries housing as a completed product supplied by the Government and large commercial firms is the norm, and even in these countries, with their chronic housing shortages, a growing number of professionals are citing this confusion between process and product as a major cause.*2.

So what are we saying? Basically that housing is a dynamic process far too intimately related to its occupier's needs to be usurped by professionals, designers and policy-makers, trying to anticipate these needs in a finite and end product manner on behalf of some unknown occupier.

The second related misconception is on the role of standards in housing policies. With the best of intentions policy-makers set some minimum standards in an effort to ensure a decent housing environment for all. However, if the house meeting these standards is one that the majority of the population cannot afford, and the government cannot subsidise to the extent that brings these houses within the reach of the majority, then these 'standards' dictate a policy that is wasteful of funds and obstructive to the housing process. A small quantity (compared to the need) of houses meeting these 'acceptable minimum standards' are built, using up most of the available funds, leaving the majority, most in need of housing assistance, to fend for themselves. Such an approach reflects the tendancy to view housing as a finite product. Many simple shelters over a period of time have developed into substantial houses well beyond any 'minimum acceptable standards'. The imposition of unrealistic standards legally defined to be achieved once and for all or not at all, often preclude such possibilities.

---

*1. Most recent estimate as quoted in the Oxford Conference on III World Cities, April 1974.

*2. J Turner and R Fichter ed. 'Freedom to Build' Collier-MacMillan 1972.

Thus the housing process for the majority must carry on despite, and not because of, official housing policies. Many of the well known conflict situations that have arisen between shanty town dwellers and officials can be traced to this gap between what people need and what official policy makes legally possible.

In this respect the Oman Government has proved more enlightened than many others. In Salala, for example, there is what appears to be a typical squatter situation, but with one crucial difference: the land has been legally allotted to each family group. With this security of tenure the owners, unhindered, are busily building their houses in pace with their needs and abilities. As a result, in a short period some quite substantial houses are already seen to be developing. But of course professionals and policy-makers have to assist far more positively than just to allot land and let the owners get on with building as best they can. A comment in the Whitehead Report, probably the most direct reference to housing in it, may indicate one type of housing policy envisaged for Oman.

> "Housing should provide protection against extremes of weather as well as privacy and facilities for a healthy way of life. This is certainly not provided by barasti and mud houses and to impose such standards here would be quite unrealistic. However the situation is different with new housing projects. We believe the ministry should work out standards for every new Government Housing project, covering at least:-
>
> Lighting (natural and artificial);
> Ventilation;
> Supply of wholesome water;
> Disposal of sewage and waste water;
> Cooking facilities." *3.

It may be prejudging the issue to comment on the above statement, but we feel bound to do so as it seems to imply a form of housing policy that we believe would be inadequate to meet Oman's environmental needs. The main point that we draw from the statement is firstly that Barasti and mud houses do not and cannot 'provide protection against extremes of weather, privacy and facilities for a healthy way of life' and since this is the case, attempts to achieve these basic environmental needs should concentrate on new Government housing projects. Since the vast majority of Omanis live in these Barasti and Mud houses, such a dismissal of their environment and its potentials is, to say the least, unfortunate, especially if these houses are to be their lot for the foreseeable future.

This study shows how several of these factors are provided to an extent far greater than is recognised, often to a level superior to non-indigenous building materials and types. Here we outline some of these ways in the light of the above quote.

Firstly with regard to 'protection against extremes of weather', we found that mud brick walls were a far superior insulator against both heat and cold than concrete or concrete block (common materials used in new government housing projects. See section 3.3.3v). Barasti used as insulation for winter rooms, was found to be marginally better as an insulator than concrete block. Furthermore barasti used as a lattice screen wall has several advantages over the typical solid wall with a clear window opening common to new houses. It allows ventilation in a modulated way through the room. Where there are high temperatures and high humidity with little diurnal variation, such air movement is the only method by which comfort conditions can be approached. (Section 3.1.2, 3.3.2b. Figs. 325-7).

*3. Whitehead Report. 4. Socio-Economic Conditions.
i. Health Services
e. Environmental Sanitation

We saw some examples of concrete used in these ways and as corner supporting members in otherwise barasti houses. Rodent guards designed into the slab would also be useful additions. Thus the calculated and restricted use of such an expensive material may be what is required in many cases rather than the wholesale replacement of indigenous ones.

Finally some idea of comparative costs. A pitched roof barasti room 6m x 4m x 220 would cost approximately 50 R.O., a flat roofed, mud brick room the same size would cost 150 R.O. while a similar concrete block room would cost 400 R.O. *5. We have just mentioned how the life-span of barasti can be increased. 50 R.O. every 15 years relates more closely to the income pattern of the average Omani than 400 once in many more years. It also allows him greater flexibility to make necessary changes in the house. Mud brick well maintained can last indefinitely.

Now it can be argued that houses with air coolers, low level windows with shutters, external louvres and venitian blinds, overhangs and fans can be built into concrete or concrete block houses in new government housing projects, no doubt. But if it is hoped that these barasti and mud houses can then be ignored because their occupants will soon be rehoused in such projects, then, considering the cost involved, we believe this hope to be unrealistic.

Not even the wealthiest nations have been able to cope with their housing shortages and the record for developing countries is painfully clear. Figures were available for two housing projects carried out in Oman by July '73. *6. One was for 250 'low cost' houses which came to £4,000 each. This corresponded to the £4,500 quoted as the price per house by an engineer involved in such projects for the General Development Organisation (now the Ministry of Planning) *7. This was and is clearly out of the reach of the average Omani whose income is probably something less than £30 per month. *8. The second figure was for 700 'low cost units' in Salala costing £700 each. The examples we saw were so clearly limited in any environmental quality, functional or aesthetic, that they could only be viewed as emergency short-term shelters. Thus, for the first project, if we assumed that the householder could get an interest free loan and pay a regular monthly 25% of his income towards his house it would take him 40 years to repay the loan and own the house. In any case, house building at such cost and the offer of interest free loans, all on a nationally effective scale would be an unrealistic burden on the Government. Only a few could be built on such terms. Furthermore even the 25% commonly assumed to be available for household services by most governments running such schemes is proving to be far too high. Most low-income families live on a subsistance income that leaves closer to one tenth or one sixteenth of the regular income available towards house payments. It is no wonder then that the average recovery rate for housing loans in such schemes is about 30%. John Turner, British architect and planner, has spent 8 years working on and advising South American countries on just such 'low-cost housing projects'. His conclusions are worth consideration:

---

*4. Soil samples being tested at Cairo University.

*5. Costs were taken from local builders and house owners in Autumn 1973. A bag of cement then cost 1½ O.R. A year later it had risen to 4½ O.R.

*6. Middle East Economic Digest (M.E.E.D.) report on Oman, July 1973.

*7. He also said there had been some discussion on whether the kitchen was to be of a traditional or European type. The latter was finally decided on, adding to the cost.

*8. This was our impression from talking to many Omanis across the country. We did not abtain any official per capita income figures, which in any case would be misleading, where income levels vary greatly and a comparatively small number may earn a disproportionate amount of the total income.

The typical solid wall with a window in it limits air movement by the location of the window, if, as is usual, sill heights of western houses are adopted. This will introduce ventilation at a height above that which most Omani's, comfortable at floor level, will find useful. Secondly the barasti lattice screen wall modulates the often very bright external light so that it falls evenly inside the room, cutting out glare. In contrast the usual window being a simple opening to the exterior allows the full intensity of the external light through. Finally the barasti lattice screen uses the difference between the external and internal light in a way that allows the occupant to view the outside, without strain to the eyes, while he or more important she, cannot be seen by an outsider. (See section 3.3.3.v. for details). Thus total privacy is maintained behind the barasti lattice screen wall, while allowing a view out, essential ventilation and cutting glare.

No such combination of advantageous conditions is achieved by the simple window in the wall. And perhaps most important this sophisticated indigenous solution remains infinitely cheaper. Further sophistications with regard to ventilation are found in the wind-catcher, (Figs. 333-4) the graded openings in windows, (Fig. 611) and several other such devices used indigenously across the country. Such methods should be understood and developed rather than dismissed in favour of others that are inferior and inappropriate to the Omani context.

To achieve a healthy environment requires that the occupants of houses are both climatically comfortable and in hygienic surroundings. We have just outlined how mud brick and barasti houses deal with climatic problems inexpensively.

Indeed it has been argued that the air-cooler, a common solution for those who can afford it, could exert physiological stress because of the wide temperature differential the body is subjected to between the outdoors and indoors, that health-wise indigenous solutions which modulate gentler differentials are better (See section 9.3.2).

Hygienic surroundings have more to do with the other standards mentioned in the quote such as water supply and waste disposal and general health education, than what a house is built of. Except that any money saved on unnecessarily expensive building fabrics can be more usefully employed in these critical areas.

As far as the building fabric is concerned the more crevices there are, the more are the chances of them harbouring insects. Mud brick with mud mortar and mud gypsum or some other lime-based, plaster, if properly applied and maintained can present a particularly smooth, homogenous surface since it is bonded in the same or similar materials. Finishes play the important role in providing a hygienic environment rather than the basic structure. Thus in addition to good surface renders, clay tiles used in kitchen and lavatory areas could contribute greatly towards this. The Nizwa area already has pottery industries and, from all reports, very fine clay.*4. This could be encouraged, extended to include tiles and developed using an intermediate technology as outlined in the previous section (Proposals on Development).

Barasti, like all organic materials, is at a disadvantage as far as harbouring insects are concerned. However since its cheapness and other advantages mentioned earlier are going to continue to recommend it to many Omanis, some solutions must be found. Termites are the most prevalent insects, attacking the stems. We have discussed this problem at some length already (Section 3.3.vii). Isolation of the barasti walls from the soil either using concrete ground beams or floor slabs should deal with termites, since barasti decays quickly and termites are the main cause of this, such measures should at least triple it's lifespan from 5 to 15 years.

> "These centrally administered, packaged deals, built by big contractors, funded by big banks, generate less low income employment than would be demanded through support for traditional systems. They increase the maldistribution of income between classes and religions and accelerate rural-urban migration and the premature sub-urbanization of the cities. They also increase the dependency of poor nations on wealthier ones which finance the programme, or which profit from the business they generate." *9

At one time or another many developed and developing countries alike have placed high hopes on highly automated mass-production methods of house construction to try and achieve the number of houses required at reduced costs. The basic inappropriateness of such methods in the context of a developing country is common to all capital intensive, high technology industries. It makes demands on the scarce resources of capital and skilled labour and needs to operate within a matrix of infrastructural and service supports lacking in developing countries. The implications of these have been discussed in the last section. In the construction industry in particular even in developed countries such methods have not proved as successful when compared to other industries. The economic factor of productivity when isolated can be normally depended on to show an increase when industrialised methods are used. Yet productivity in the construction industry in the United States has been falling away compared to the performance of manufacturing industries in general. *10

To quote Charles Abrams, a leading authority on housing policy in developing countries.

> Industrialised housing techniques have 'been tried by less developed nations with small success and sometimes near disaster - in the less developed world where labour is cheap and plentiful and where standards are simple, the precast house is unessential and premature. Despite the glib sales talk of prefab. pedlars from abroad, the handicraft product is still cheaper, more expandable and more realistic'. *11

Now there may be cases where government housing projects are necessary. For example if a large number of workers are attached to a new industry and urgently need accommodation close to their work. But a housing strategy that concentrated on such projects would have little beneficial effect on the majority of Omani's and their built environment. To achieve this, the essential question to answer would be - "How can the initiative and ability to control and develop his own environment remain with the user - and how can we as professionals and policy-makers aid the user in his attempt to create an adequate built environment for himself?" Less money and effort should be channelled into 'housing projects' that become a drain on both the governments' and the occupants' resources and can only reach a small proportion of the total population in anycase. Instead funds should be concentrated on providing a strategy within which the Omani can continue to build for himself.

Four fundamental variables need to be considered in outlining such a strategy for the built environment of Oman. The first two are to do with the context of the built environment: is it an urban or a rural one? The second two are to do with developing solutions: are they primarily an upgrading of indigenous methods, or a modification of industrialised techniques to make them appropriate to the Omani situation? Our primary pre-occupation was to do with the rural

---

*9 J Turner 'The Fits and Misfits of Peoples Housing'. Royal Institute of British Architect's Journal. February 1974.

*10 See Daniel A Hodes "The Modular Housing Industry". Financial Analysts Journal. May-June 1970. Performance compared using the Manufacturing Index of the U.S. Bureau of Labour Statistics and the Construction Index from tje Economics of the Construction Industry. The Conference Board. 1969.

*11 Charles Abrams 'The Language of Cities' - A glossery of terms - (New York. The Viking Press 1971) pp. 243.

context and the upgrading of indigenous methods, however, since no exclusive approach should be applied, and since all these variables inter-relate and thus must be considered together, we will first outline the urban situation and some potentials connected with industrialised techniques.

In the urban situation for example in places such as Muscat, Mutrah and Salala, problems may arise in the type and availability of building materials. In Salala it is conceivable that after a time the use of limestone and mud may be limited by the effect of causing large pits in the urban area or stripping the surrounding areas of barasti, and if the demand is to be met by transporting these materials, increases in costs will have to be considered. Furthermore urban workers may find themselves in a situation where there is not enough time to build and maintain their houses. Finally there may be a shortage of housing space. The need for proximity to their work and facilities causes people to concentrate on an area, aggravating a series of other problems, such as the need for privacy and security of possessions, fire protection, waste disposal and sanitation and accoustic privacy: one must be aware of all these potential problems that differentiate an urban from a rural environment.

At the same time a closer look at existing situations show that all these conditions do not necessarily arise. First of all, if rural stabilisation is achieved in Oman, then the numbers in urban areas could be moderated before too heavy a demand is placed on building materials in any one area. Secondly, judging from the number of owner built structures going up around Salala and the capital area, and from what can be seen in squatter areas of other developing countries, the immigrant to the city does seem to find more time to build than is often supposed. Problems of privacy and security are often lessened by the existence of socially related groups clustering together and having a mutually understood social code. Thus in the town of Sur one house owner said that the window shutters in one of the walls faced upwards so that he would not overlook his neighbour. Nevertheless these problems are potentially there and they do describe possible limits to the application of rural solutions in the urban context.

What we see in the urban areas of Oman, in the 'shanties' of Muscat, Mutrah and Rui, and the new allotments in Salala are largely the result of occupiers of the land doing their best to provide a decent environment for themselves. Such 'self-help' efforts are now a well recognised phenomenon in most cities of developing countries. The view of official policy-makers has largely shifted from trying to obstruct this process to realising that they cannot provide an alternative method of housing and therefore attempting to assist it. This has been the recommendation of the United Nations for several years now. A more recent convert to this view is the World Bank, which is now putting its support and finances behind self-help housing activity.

The sort of strategy required here would need to include the following:

1. Locating a site close to the major sources of employment or a cheap and reliable public transport system to work areas.
2. Security of tenure so that the owner has the confidence to invest on the land.
3. Basic water supplies and sewage and sanitation services - a site and services scheme for example.
4. Provision of building tools and cheap building materials.
5. Technical advice and training on building methods.

These suggestions form the barest outline of what needs to be done. They are mentioned to recommend the sort of attitude and approach to low income dwellers that is needed in the urban environment of Oman. More details can be found in other sections of this report (Salala Section 8 and the proposals for the rural environment following this section) all of which have relevance to this subject. For more detailed proposals a specific study would be required of the situation.

The potentials in industrialised techniques can be conveniently explored under four problem areas related to the house. *12 Firstly the foundations. A problem arises in attempting to put regularly shaped houses on irregular ground. The slope of the land, the ability of the soil to bear loads without too much sinking over a period of time and similar factors all require consideration and the failure or inability to do so has been a common cause of building collapse throughout the world. This problem can be accentuated when, as observed in Salala, the house in its initial form varies greatly from its final developed form, although in Salala the area generally has a rock base which helps to obviate this problem. However, work has been done in developing various jacking and levelling devices, raft foundations and screw-in footings to name but a few, to tackle these problems. Secondly there is a problem in establishing free standing structures without reliance upon an adjoining stable structure. Work has been done on systems somewhat similar to childrens building kits. Simple components and joints are provided allowing as few as two inexperienced people to erect the structure. *13 Such systems can permit panels of indigenous materials, such as matting to be attached to a frame and to be interchangable to suit the climatic changes, or the system can provide the complete readymade dwelling unit.

Thirdly and particularly important is the supply of water and drainage to settlements, which is normally expensive to carry out, especially where water sources are scarce and if settlements have developed in an irregular layout. Here two related developments may help to ease the problem. Firstly water/waste recycling units are being developed, some no bigger than a refrigerator which take a quantity of water, purify it, distribute it for reuse through the house and then purify it again. Such units would lessen the total demand on water supplies, the reliance of the occupants on centralised water supply sources and cut drainage needs to a minimum. The development of flexible piping will also reduce the cost of laying on water supplies, greatly reducing the need for joints, angles and the problems of laying the pipe.

Finally, the generation of power and its distribution through settlements is another major area of need. In many shanty areas in developing countries unofficial tapping of street power lines is becoming a common phenomenon. For cheap power generation, work is being done on the development of solar energy cells, already used in buoys far out at sea and in space projects. In the forseeable future it will be feasible for a house to have its own solar generator providing its own power supply. Linked to this is the problem of wiring and the National Aeronautics and Space Administration (N.A.S.A.) USA., have developed a sticky tape system of wiring and fittings which are simply stuck to the walls, requiring no labourious fixing process nor a great deal of equipment.

---

*12 These were outlined by Ian Turner in his chapter titled "Technology and Autonomy" in the book "Freedom to Build". What follows is derived from his observations.

*13 See for example. 1. Rita Reief "Building Your Own House : simple as an erector set". The New York Times June 28, 1971. p. 26.
2. John Peter "Tree Houses for Grown-Ups". Look Magazine August 24, 1971 p. 62-63. 3. I Turner and R Herz "Squatter Inspired" Architectural Design Magazine London August 1968. Vol. 38. pp. 367-70.

Most settlements we visited had an existing centre of public building located more or less centrally in the built-up area. These performed a combination of social, economic, administrative and religious functions, which were expressed in their being a cafe, suq, fort and mosque in close proximity. This was the case for example in Nizwa and Buraimi. Another public meeting space was around the communal water collection points where the falaj surfaced. This was particularly the case for the women.

Government buildings in addition to schools and hospitals have included new houses for the Wali, new suqs, municipality buildings, police stations, and experimental farms. These have been built in a way that instead of harmonising with traditional values, have ignored what traditionally exists.

Firstly little has been done to improve existing buildings. Secondly the new buildings have been located not only away from the traditional centres, but also often some way away from the village in general. The immediate effect has been that villagers have to travel some distance to get to schools and clinics. Furthermore, where as before the Wali lived in the village, his new house is also invariably set apart, physically cutting him off from the people.

The conglomeration of new government buildings removed from the village instead of complementing the traditional centre now rivals it. With little improvement aid for the traditional centre or for the village in general, one can foresee the repetition of what has happened in other urban centres in developing countries.

That is, a new town centre develops physically apart and alien in materials and form to the indigenous buildings, to the life style and culture of the indigenous people, and to the physical environment; while the traditional settlement area is allowed to slowly decay and become a slum although often still housing the majority of the population. There is no harmony between the traditional and the new and the many lessons of value offered by the indigenous settlement, are ignored. Examples of such a situation can be seen from Cairo, to Delhi, from Isfahan to nearby Dubai.

The immediate effects of such government buildings were already apparent in several ways. A doctor complained about the new hospitals layout and large windows that exposed it to the dust, glare and heat. One wali at least was busily adding a separate room to his new house to receive guests in (the Maglisse). The living room provided was within the house which was alright for the westernised family but too close to the private quarters for the average Omani.

Finally by using foreign contractors and the materials, techniques and equipment which came with them the advantages to the local people beyond the actual building being constructed, was minimul. The local labour contracted to do the job may have picked up some skills but these bacame promptly useless once the project was completed and materials, the tools and equipment departed with the contractors. The aim to provide 'knowledge for the Omani about his immediate environment and skills to control this environment to a larger extent than before' - remained unfulfilled. One Omani who determined, for prestige reasons, to build a house for himself using the model of concrete structures set for him by the government buildings, bankrupted himself in the process. (See Fig. 408).

Such techniques and others could and will hopefully be developed to the level where they would be widely and cheaply available. However, although it is well to consider the potentials of such advanced techniques, they should be viewed with some reservations. For example, what immediate need is there for 'jacking devices' if communal effort is encouraged and a sufficient labour force could be drawn upon for jobs such as levelling. More important, what may be already commercially viable in a developed country may be far from viable in a developing country such as Oman. For example, the cost quoted for the waste disposal unit *14 is between $50,000 to £1.5 million - working out at $250 - $375 per house. Much more attention will have to be paid to the particular economic and social context before such methods become relevant to Oman.

What we believe to be of more immediate and wide-spread relevance to Oman is the upgrading of indigenous systems. The potentials of indigenous systems as they operate now in Oman and how they can be upgraded have been discussed and will be further detailed in the final part of the proposals section. Here we would like to outline a strategy within which these methods could be used, but first we would like to quote some enlightened principles from the Whitehead Report *15 and comment on Government efforts to develop the built environment.

Three basic principles are outlined:

> "1. Schools must in no circumstances give pupils the impression that education prepares them for a sort of dignified leisure.
>
> 2. Schools must not develop a contempt for manual work.
>
> 3. Schools must not give the impression that education provides a passport from rural areas to Muscat and Mutrah."

Under social and political considerations the report goes on to say:

> "Education should harmonise traditional values with the needs of the modern world - change must be harmonised with customary and traditional way of life."
>
> "If the educational effort is to be successful, it must bear a relationship to the daily life of the pupils. It must give them knowledge about their environment to a larger extent than before. The development of Oman will require numerous changes in every village and every household. Education which is not seen to be an integral part of daily life will do nothing to build the future of Oman".

And in the key recommendation (quoted in the last section), the Whitehead Report calls for 'Rural Stabilisation' and 'people working together to build up their villages'.

Towards this end the government has embarked on building projects, including schools and hospitals, in several rural settlements. While there is no question about the need for such buildings, the way they have been implemented has made them fall short of the aims quoted above and also had some detrimental effects.

*14. Several such systems are becoming commercially viable in the U.S. The Advanced Waste Treatment System Inc. (AWT) Wilmington, Delaware who already market recycling plants for 200-4000 dwellings, look forward to a 'cheap' single dwelling service unit.

*15. Whitehead Report. Section 4.2.2 Basic Educational Policy.

In several cases new buildings will need to occur outside existing settlement areas due to spatial limitations. Similarly some technical assistance, materials, techniques and forms from outside the area may be justified. But the extent to which this was the case in the projects to date, we believe was not necessary, nor did they fulfil the broader aims for rural development set out in the Whitehead Report. We would now like to suggest a strategy within which public buildings could be built which we believe would be consistent with and fulfil these aims.

In keeping with these aims we propose pilot projects in the villages, centred around the upgrading and rebuilding of public areas such as the suqs, water source points (falaj outlets, public washing areas, water collection points etc.) perhaps extended to include buildings like schools, clinics etc. These projects must be integrated as building as well as educational and training operations, and they should be put into effect within the following guide lines.

1. The whole idea of what is being attempted both in principles and in practical aspects should be introduced, thoroughly discussed with local people and developed in practice. A great deal will depend upon agreement on the principles and the willing and enthusiastic involvement of the local people. Therefore no effort should be spared on this aspect.

2. Labour for the building work should be recruited almost entirely from the village. The few exceptions may be some master masons and architects conversant with indigenous building techniques. Their job will be as much to build as to train the local people in the skills of building. The organization of the local labour force and their training will build on the principles of co-operation and communal activity already practiced in the villages. "When the needs of the harvest and other peak activity demands it, the whole community joins in." *16 For this to be successful it is absolutely essential that the villagers believe in the value for themselves of what they are involved in. For some details of how this can be put into practice we refer to Professor Fathy's suggestions as outlined in his book "Gourna - A tale of two villages". *17 In particular the sections relating to 'The Co-op System' and 'In Service Training' (pp. 155-163). His experience has enabled him to develop these ideas to a high level. These suggestions can be used as a model and adapted to suit local conditions. The aim is to leave the villagers with a set of skills, organisational, technical and in design, that make them capable of meeting most problems relating to their built environment by themselves.

3. The materials, techniques and design of the buildings should use and develop the potential of those available locally to the maximum. Where these have been used well locally, they should be adopted. Where shortcomings are present they should be improved upon, borrowing from indigenous techniques practiced in other countries, and where modern technological innovations are needed, they should be integrated with indigenous techniques. The logic behind each of these practices should be discussed with all those involved. The villager will keep his confidence in age old methods that are sound. Where they have shortcomings he will see how they can be improved using techniques he can himself develop and practice or where it is essential to get something from further afield.

*16. Whitehead Report. Labour, Employment and Skills. 2.2.1.

*17. Now available under new title "Architecture for the Poor". University of Chicago Press 1973. Pages quoted here are numbered from limited Cairo edition.

9.3 Specific Proposals

9.3.1.Proposals - Materials

Indigenous materials have been used in the past in Oman for the construction of civic buildings, forts, market places as well as residential buildings. Their use continues today primarily in owner built housing. The use of some of these materials, particularly mud brick, has developed to a sophisticated level especially in the interior towns such as Nizwa and Al Hamrah where buildings of two and three floors are the rule.

In recent construction of public buildings indigenous materials have been superceded by imported materials. The idea that indigenous materials cannot be used in modern building projects has been introduced on the grounds that they tend to produce environments which are physiologically unhealthy and structures which are unsafe.

Before indigenous materials are discounted their properties should be analysed and compared with the the properties of other materials. Every building material has its advantages and disadvantages and its appropriate uses. Materials should be analysed and compared with reference to their properties and strengths, environmental responses, economic implications, ease of use, effective lives, availability and aesthetic qualities.

9.3.1. (i) Structural Standards for Dwellings

Safety in buildings can be looked at in two ways: firstly, structurally the elements of a building must withstand forces and loads inherent within their construction and those imposed from the outside; and secondly, environmental health standards must be met by the design.

Structurally a building must of course be self-supporting. In effect this means that materials used in the construction must be able to support the total weight on the materials used above them. In structures with load bearing walls and heavy roofs this is the primary consideration, and is more important than the consideration of external or applied loads.

The lower portions of a building must support a greater load than the upper portions, of primary inportance in the design of the foundations upon which the whole mass of the building will rest. The bearing capacities of soils below any major building must be known before it can be estimated whether or not they will support the proposed structure.

In calculating the forces of compression that a wall must sustain, weights of materials are added starting at the roof and working down floor by floor. The compressive strengths of materials and the thickness of the wall are two factors which must be considered when designing the wall to resist the loads.

A building's weight, as well as other loads applied to it can be seen as forces. The distribution of these forces or loads through the building's structure determines the shape, location and size of elements such as posts, beams and bearing walls. For instance, a roof's weight can be carried by a number of methods. A normal roof is composed of beams supported between two walls and covered with some material which acts as waterproofing and insulation. In this case the whole of the weight is shared by the two side walls. End walls need not be load bearing, and may be of a light material. (illustration on next page).

4. Public education in health and hygiene should be closely incorporated with the design and building of health sensitive areas such as the falaj, water collecting and washing points and the suq, food selling - meat and fish areas. Such health education should involve the local medical personal.

5. Experimental housing units should also be built under the same conditions, teaching and demonstrating to the villagers how they could both technically and in the organisation of the spaces, improve their own homes. Here direct education and skills could be taught regarding critical health areas such as the washing, kitchens and waste disposal areas.

Projects carried out in this way would thus certainly contribute to the physical improvement of the villages; they would leave the villagers with both the skills and knowledge with which they could continue to improve their lot after the initial government assistance was reduced.

We have done work on some ideas for the development of centres for 2 of the settlements we visited - particularly for the upgrading and extension of the suqs, and for the falaj water collection points. [*18] To develop these ideas further at this stage would be contrary to the approach outlined above.

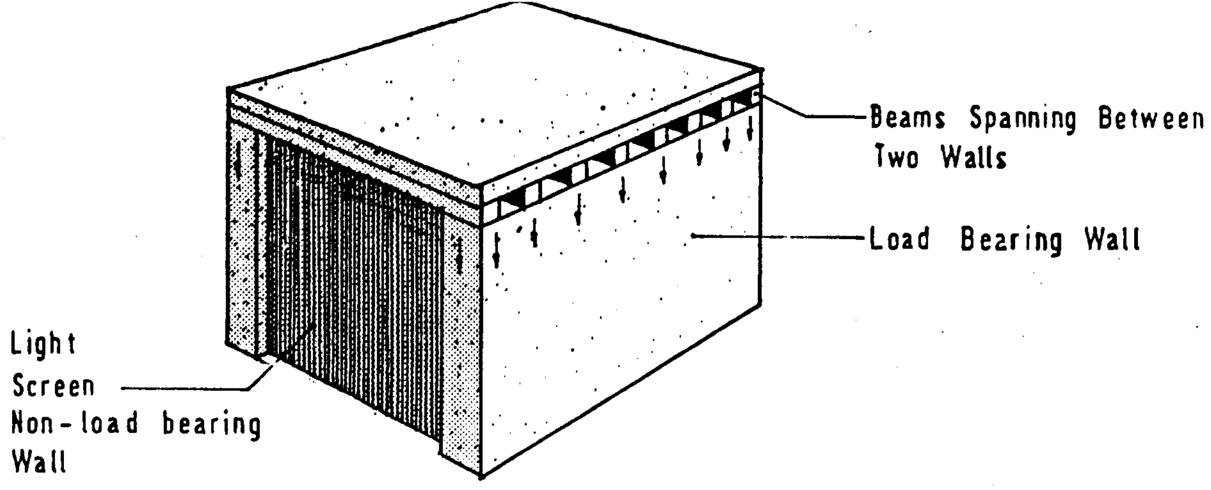
Furthermore the success or failure of such a project will rest largely on how it is implemented and much of the mechanics of implementation will be learnt from the experience itself. In the absence of such experience in the immediate context, it may be counter-productive to anticipate more details at this stage.

We therefore propose a pilot project in one village, in which the above is implemented. From the resulting experience a regionally applicable programme could then be attempted.

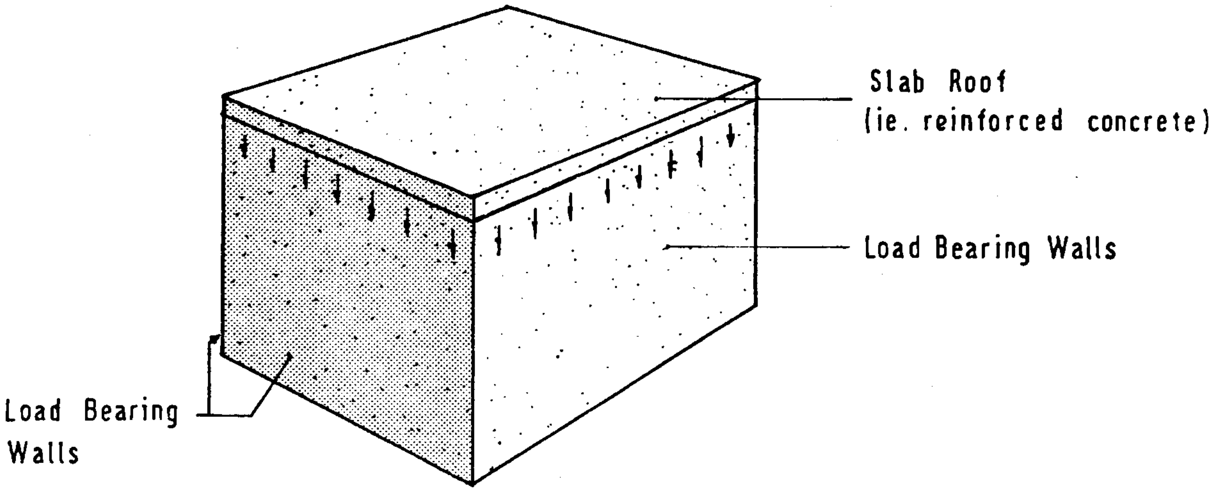
---

*18. Preliminary proposals on these 2 centres were presented to the Government in November 1973 during our field work there.

materials + technology



In the case of a new concrete slab roof, loads can be taken by four walls, which will all be load bearing, the roof's weight distributed evenly between all four walls. (below)



The use of post and beam construction elliminates the need for massive load bearing walls. In this case the roof must be supported by four posts. Posts must be ablt to take large loads since their cross section area is much less that the previous examples. Walls become non-structural infill pannels such as barasti daams. (below)

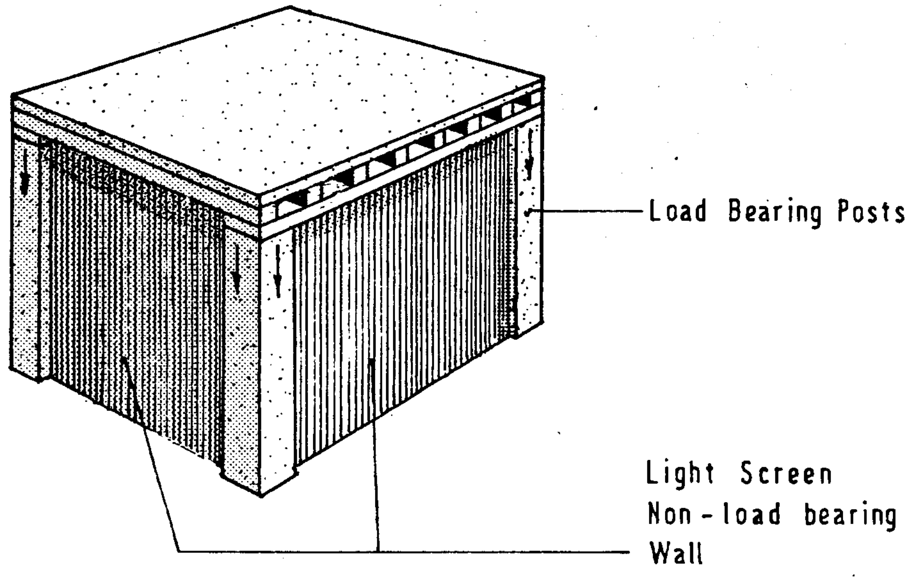
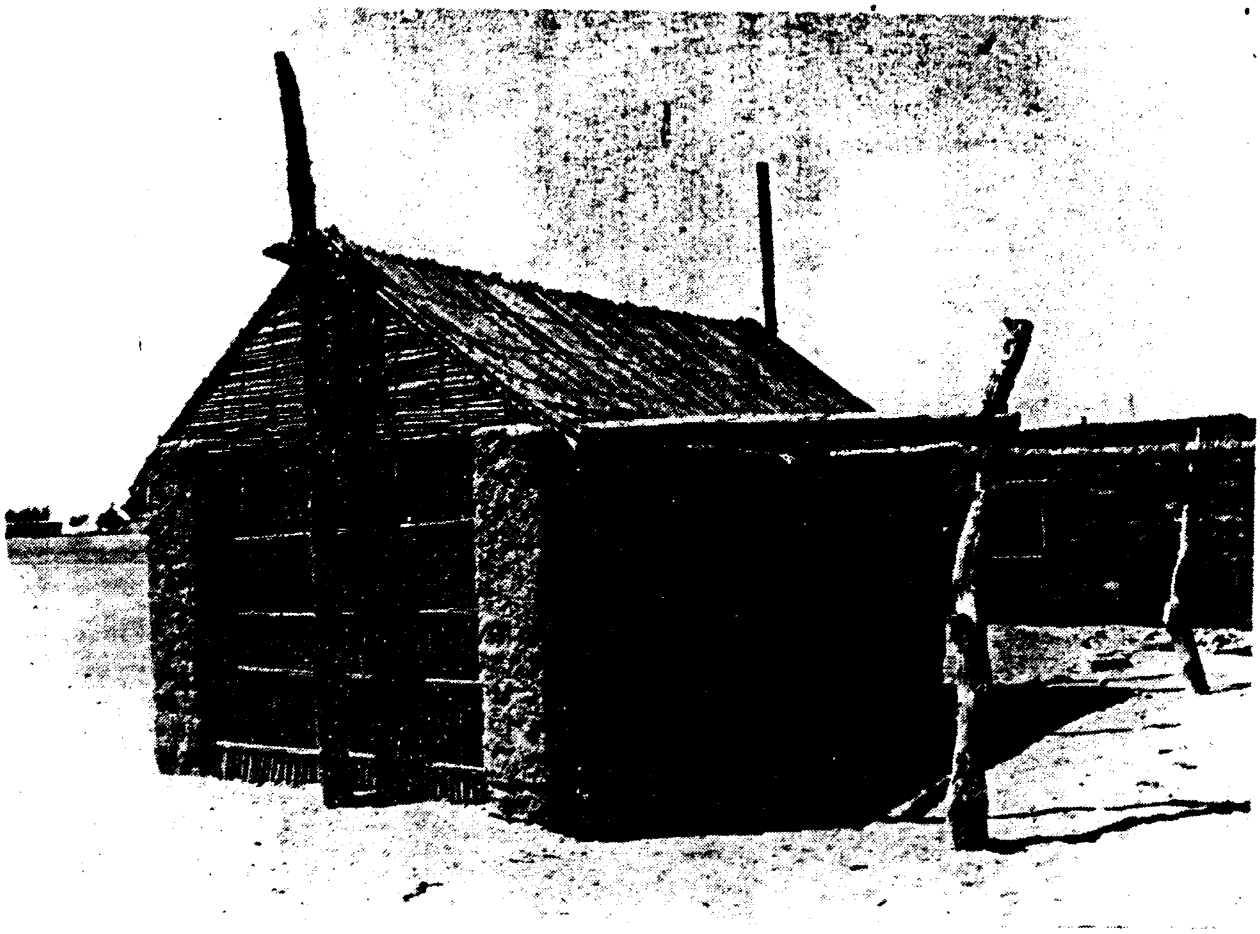
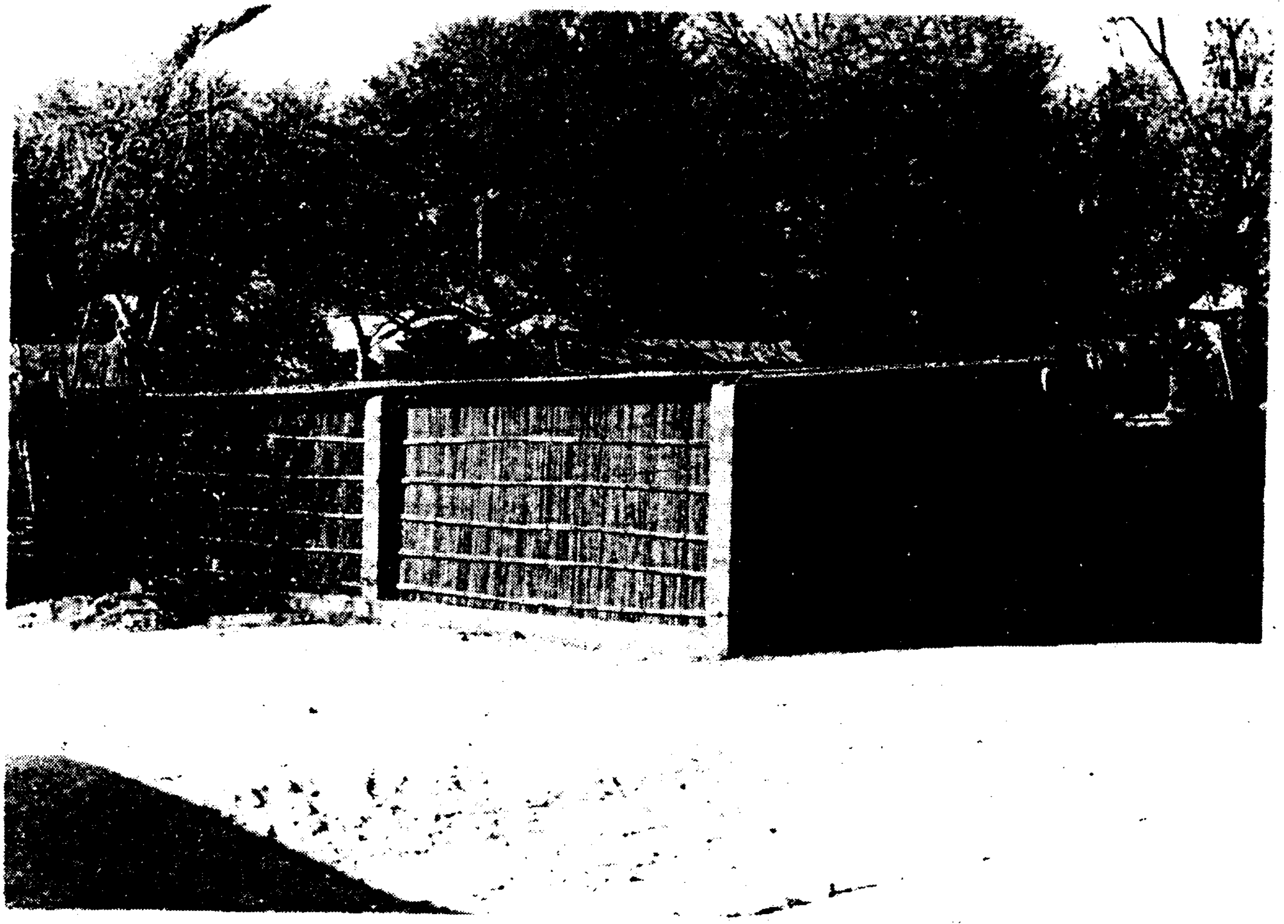


Fig. 907



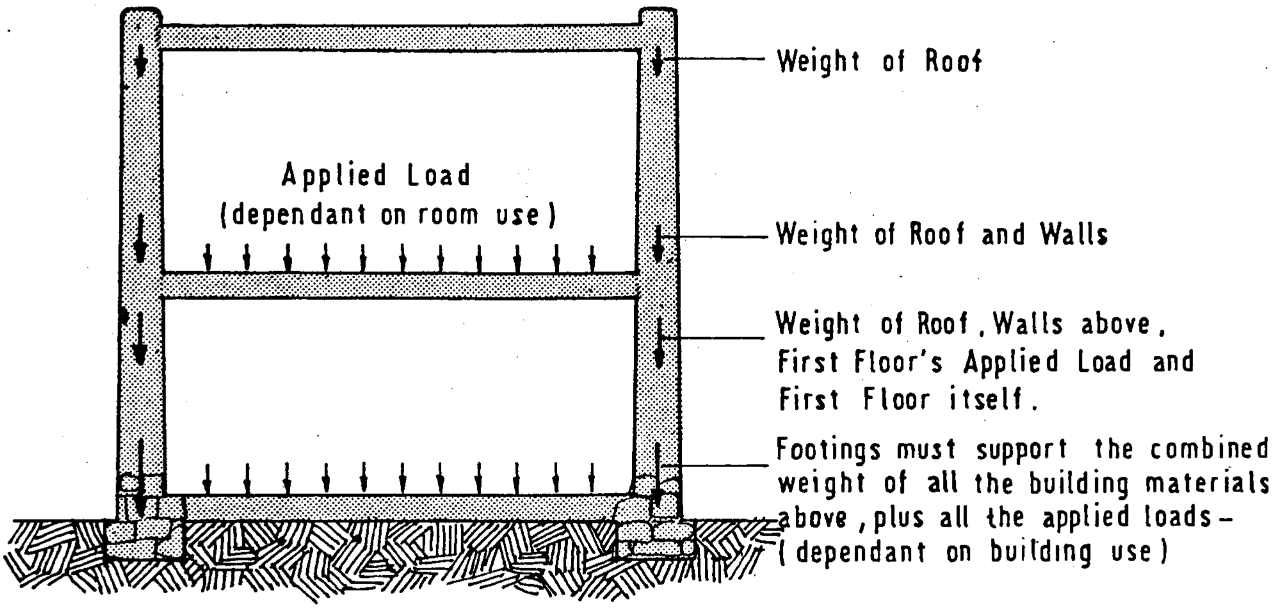
Mud Brick posts, supporting barasti screen walls.



Concrete posts and barasti screening.

Buildings are also subject to loadings determined by their use. Various load intensities are associated with different uses, i.e. the intensity of load distributed over the floor area of domestic dwellings is estimated at about 150 kg/sq meter while class rooms in schools which are used to a greater extent have to bear more weight (load) at 300 kg/sq. meter. In calculating loads that walls or other structural elements must bear these distributed loads must be calculated and added to leads due to the weight of materials.

Section Showing Loads Within a Building



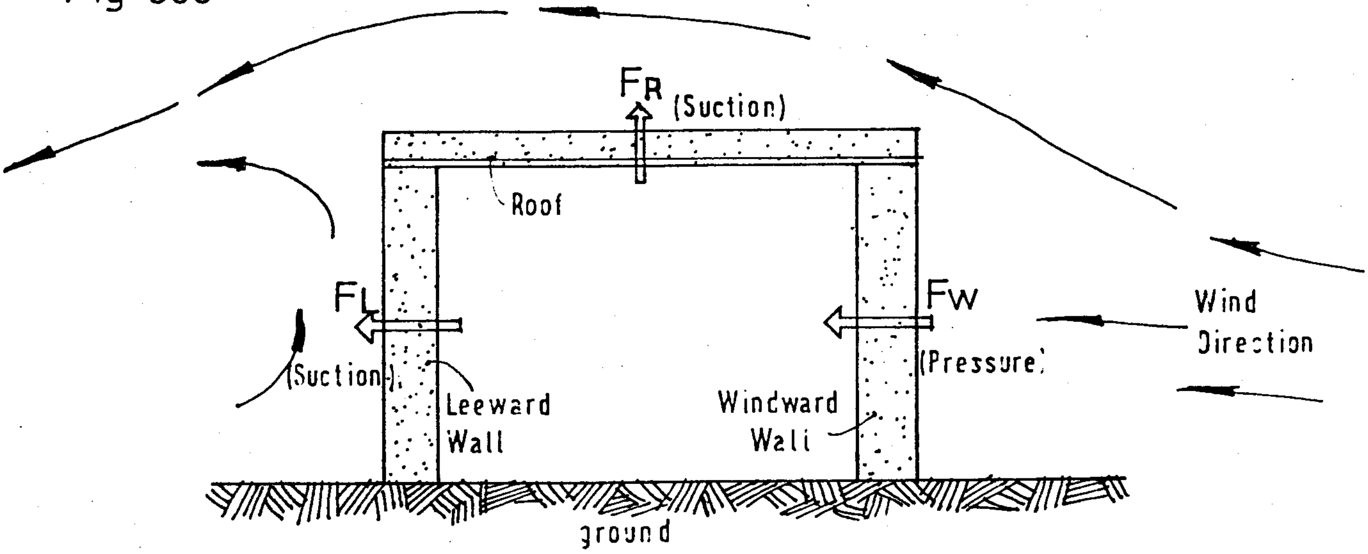
Environmental forces, particularly wind, also apply loads to buildings. Wind loading is a problem especially along coastlines where storms may occur. While all other loads duscussed above apply forces directed toward the ground and can be taken by the compressive strength of the particular material used in the walls or posts, wind loads act on walls often at right angles to the walls.

Increasing wind velocities apply increasing pressures to the walls and structure (See Fig.308). The magnitude of these pressures depends not only on the wind's velocity but also on the geometrical form of the building, its orientation in the wind stream, the friction effect on the surface of the building and to a limited extent on the size of the object. It is very difficult to determine the effect of wind upon a structure before it is built, though studies of models in wind tunnels often prove useful. It is known that winds often produce upward suction forces which sometimes pull light roofs off a building in gales. Lightly constructed buildings are particularly susceptable to wind damage.

Materials vary greatly in their strengths or their ability to resist certain kinds of loads. Many materials are termed "load bearing"; these are able to resist principally compression, and are used in walls or posts that must support stubstatial weights. Materials such as mud brick and concrete are load bearing. A mud brick (50% clay to 50% sand) has a compressive strength of about 20 kg/cm^2 while concrete block's (mixed 1:3:4) compressive strength is about 53 kg/cm^2. This compressive strength for mud brick is sufficient for most normal building needs. If necessary mud brick can be designed to increase its compressive strength. The same strength can be achieved in both a mud brick and a concrete wall if the mud brick wall is about two and one half times thicker. Mud brick still remains a viable alternative to concrete block because it is much cheaper, and because the thickness of the wall ensures that its thermal properties are enhanced.

Other materials are able to resist tension and bending loads as well as compressive ones. Indigenous organic materials such as timber beams and palm trunks and stems are able to span distances between two fixed points and are thus used for roofing or lintols over doors and windows. New imported materials such as steel or reinforced concrete fall into this category.

Fig. 908



Building Section in Wind Stream

F = kg/m²

WIND		F_W	F_L	F_R
Wind Condition	Wind Velocity m/sec.	Pressure on windward wall	Suction on leeward wall	Suction on roof
strong	10	4	-2·5	-4
gale	25	36	-22	-36
hurricane	45	95	-58	-95

Chart of Wind Loadings

mud brick

9.3.1.(ii) Mud Brick Construction

Mud brick is used as one of the principal building materials in many parts of Oman. Its use depends to a large extent on the availability of lateritic (clay) soils. These are present in most parts of the country. Mud brick although was not found to be extensively used in the Dhofar coastal region. This is probably due to the limestone bed rock condition. Clay is used here although,as a mortar for limestone block as well as for rendering barasti houses.

Mud brick has been used in the past in Oman for the construction of civic buildings, forts, market places as well as residential buildings. It continues today as one of the primary materials in owner built housing. The use of mud brick in building has developed to a high artistic level especially in the interior towns such as Nizwa and Hamrah, where multi-storied buildings of two and three stories are the rule.

In recent construction of public buildings mud brick has been superceded by concrete. The idea that mud brick and other indigenous materials cannot be used in modern building projects has been introduced on the grounds that these indigenous materials tend to produce environments which are physiologically unhealthy and structures which are unsafe.

Before mud brick or any other material is discounted its properties should be analized and compared to properties known about other materials. Every building material has its advantages and disadvantages and its appropriate uses. Materials should be analized and compared with reference to their physical properties and strengths, environmental responses, economic implications, ease of use, effective lives, availability, and aesthetic qualities.

Physical Properties of Mud Brick

Composition of Soils

In choosing soils suitable for the making of mud bricks its physical properties must be analized. Soils of various compositions produce bricks with differing properties and strength and resistance to water damage.

Soils are usually graded into four divisions according to the size of particles, as gravel, sand, silt and clay.

	Particle Size
Gravel	2.0 mm
Sand	0.2 - 0.02 mm
Silt	0.02 - 0.002 mm
Clay	-0.002 mm

The soils cohesion properties (ability to hold together in a mass) are directly due to particle sizes. Coarse soil particles are not cohesive and rely on friction between particles for stability while a fine grain soil (i.e. with a high proportion of clay) is cohesive.

The presence of a high water content reduces the cohesive strength, and thus its plasticity, resistance to deformation and its compressive strength.

The presence of organic material such as humus in the soil is not favourable for brick making and in preparing a site for qyarrying clay for brick making the top soil or organic -ayers in which biological activity takes place, must be cleared away.

In making bricks of a sand-clay soil, the clay provides the cohesive strength and the sand lowers the moisture absorption and gives resistance to abrasion.

Soils having a high proportion of clay swell up increasing their volume when wet and shrink and crack badly when drying. Sandy soils on the otherhand do not have sufficient cohesive strength to prevent crumbling.

Soils which are either predominantly sandy or have a high proportion of clay will not produce good mud brick for building. If soils are found in these conditions they must be mixed in the proper proportions to make a good brick. The clay and sand content of soils very even within short distances, physical properties of soil from one area may be quite different from soil taken from a neighbouring area.

Fig909 shows that the reduction of clay percentage will cause an accompanied reduction in strength of the brick. This is attributed to the consequent decrease in cohesion which in turn is the reason for brumbling and breaking of bricks having a low percentage of clay.

The water absorption rate of bricks varies directly with the amount of clay present. When submerged in water bricks absorb at least their own wieght of water after half an hour and show signs of disintegration.

Fig909 shows that when mud bricks are exposed to a saturated atmosphere they absorb water to only about 4% of their weight. Bricks with a high proportion fo clay absorb slightly more. Moisture absorption stops at about 4% after 12 to 15 days.

In donsidering the effects of rain it is found that bricks having a greater proportion of sand are more resiliant. Rain damage varies in inverse proportion to the amount of sand present in the brick.

Water Content of Mud Brick

Brick making relies on the properties of clay in the soil when saturated with water to become plyable but still plastic. This allows the mud to be moulded into a block shape and to keep its shape when the formwork is removed. The proper proportion of water to obtain this state is usually between one quarter to one half the eirght of dry clay.

There are two stages in drying of the brick. As most of the water evaporates shrinkage of the brick corresponds to the amount of water evaporated. At a point when the brick contains 7-10% water shrinkage ceases and the brick has become hard, though remaining a dard colour due to the presence of water. Soil particles are in contact at this point and the remaining water removed is replaced by air. With drying the brick gains a lighter colour.

This means that water content of 7-10% is tolerable in mud brick construction and will not result in damage. On the other hand when water content exceeds that limit it breaks down the cohesive strength between clay particles and consequently the strength of the brick.

Climatic Response - Heat Transfer

The response of mud brick building to thermal conditions experienced in Oman has been tested in a series of experiments at various locations in the country (see sections 3and 8). The thick mud brick walls insulate the interior of buildings from extremes of heat and cold, in a way that no other material has shown. Exterior surfaces of mud brick walls which are exposed to solar radiation heat up to a lesser extent than wall surfaces of many other materials, becuase mud walls especially those rendered with a mud plaster have a light colour. These wall surfaces therefore reflect solar radiation rather than absorb it. Mud walls varying in thickness from 40cm to 60cm delay the transfer of heat built up on exterior wall or roof surfaces due to solar radiation from reaching interior surfaces for twenty four to thirty hours. Very little of the heat from outside surfaces reaches interior surfaces which remain roughly at a constant temperature which is an average of the daily range of outside surface temperatures.

The mud brick walls action of insulating the interior from heat and cold is not only die to its thichness but also its low coefficient of thermal conductivity. (i.e. the higher the coefficient of thermal conductivity the more ready the material is to transfer heat through a wall).

The coefficient of thermal conductivity for mud brick varies with the composition of the mud brick. The coefficient increases with a higher proportion of sand to clay. See fig .

In comparison to other structural materials mud brick has a relatively low coefficient of thermal conductivity at 0.50 W/M^{o}C while concrete is approximately 1.2 W/M^{o}C and limestone is 1.5 W/M^{o}C.

Mud Brick Making

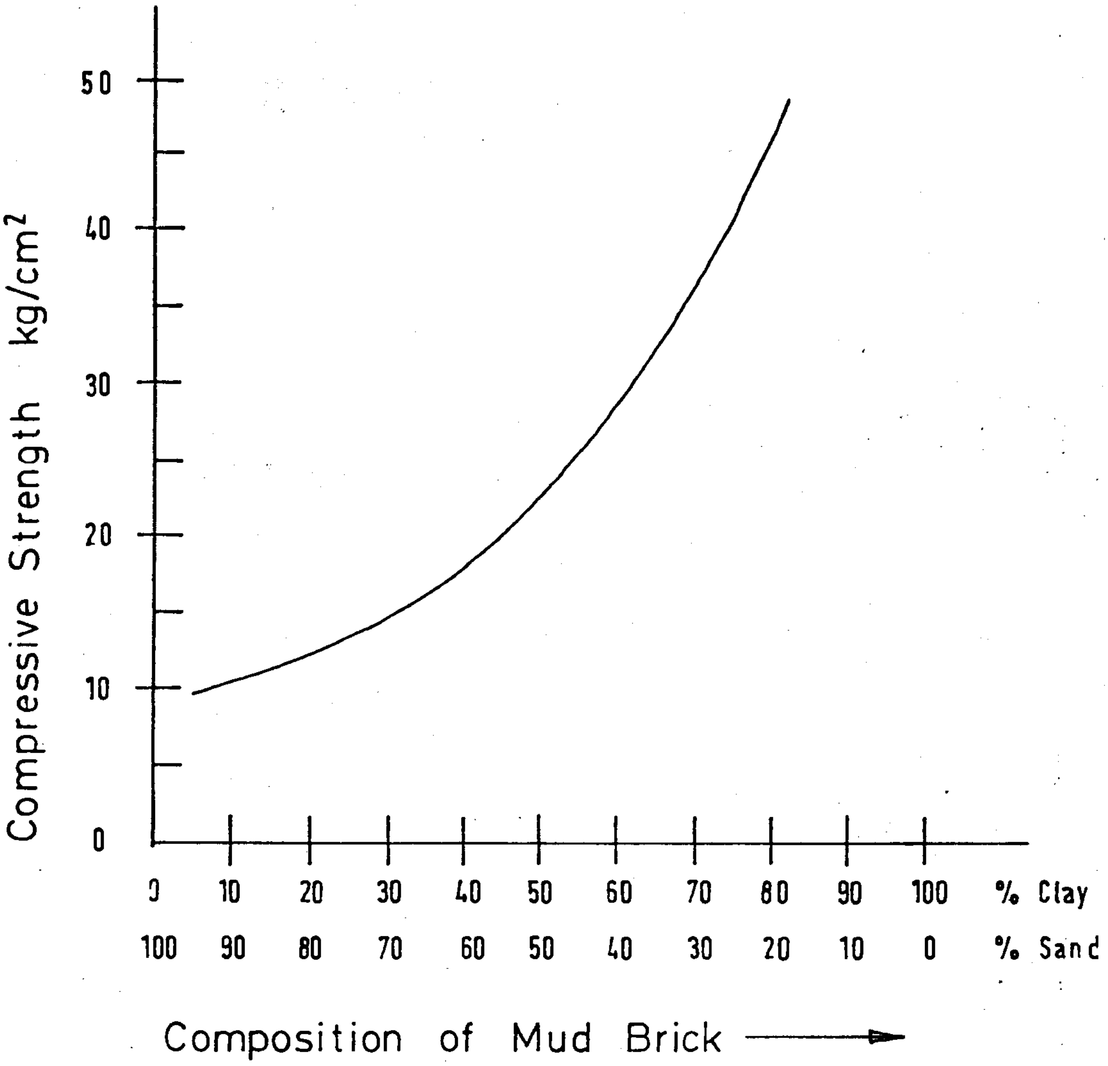
Choosing soils for mud brick making.

The demands of modern construction require a scientific appraoch to the selection and composition of building materials. Individual materials must be uniform in their properties and strengths and these properties and strengths must be clearly understood. Mud brick as a material must also meet these requirements.

Builders in the past cannot be dismissed as unscientific and the reason for their successes and ingenuity put aside to intuition. What we have today has evolved over many years of testing and experimentation. It is the accumulated knowledge of many people building in response to similar problems and environments. On the other hand when new tools and techniques make themselves available they should be taken up if they prove themselves to be improvements on existing systems. Improvements have always been made and must continue. When more than one material or grade of material is available the choice of building material or system of construction must rely on the requirements of the building and the environmental factors.

We can see from fig.909 that mud brick's properties of strength and resistance to water damage vary depending on the composition of the brick. Therefore the mud brick can be designed to fit individual building's requirements. Compressive loads experienced by bearing walls in the building must be determined and the amount of moisture in the environment known in order to choose the optimum proportions of sand and clay to produce the best brick. A further non structural consideration can be made at this point. It is known that the insulation or heat transfer value of the brick (i.e. its coefficient

Fig. 909



Graph showing Strength of Mud Brick in relation to its Proportional Composition of Clay and Sand of thermal conductivity) composition of the material. Knowing the location and orientation of the building the optimum coefficient of thermal conductivity can also be attained by choosing the proportion of sand and clay.

Ideally one would like to find soils of appropriate quantities of sand and clay near the building site. Water in considerable quantities is also required nearby. If mud can be quarried near the building site and mud brick making carried out nearby there will be a great saving in time and transportation costs. This of course is not always possible. On the other hand a site may be found where there is a large deposit of soil which produces a high quality brick and a mud brick making yard established here to produce bricks for a large project or for general community use. In choosing a site not only the soil quality and economicy of transporting bricks must be considered but the eventual use of the excavated depression which is left behind.

It is not always possible to find soils of the proper composition for mud brick making in the desired area. Soils may vary in their composition even over relatively short distances. Soils from various sites may be mixed to provide the correst proportions of sand and clay for the production of suitable bricks. It therefore becomes very important to make a thorough soil survey of areas where mud brick production is proposed.

(A) In the past the mud brick mason would clear away the top soil from a number of sites and test examples of the sub soils using simple tests. Colour of the coil would be noted, black soils tend to indicate unwanted organic material, and other colours indicate presence of various chenicals and minerals. A musty smell is a good indicator of the presence of organic material. Larger particles can be graded visually and soils having gravels or very course sands will be rejected. Grain size can be determined by 'touch'. Soil if tested between the teeth can be graded (the tongue and mouth being extremely sensitive to small particles). Sandy particles will feel sharp and will grate against the teeth. Silt particles will be finer but still grate somewhat. While clay will feel powdery or even soapy. Wet samples of soil rubbed between the fingers will give similar sensations. When a vall of soil is manipulated in the hand its texture becomes apparent. If it folds together and is very plyable it has a high proportion of clay, if it crumples easily it has a high proportion of sand. If the ball of soil swells up in water it is clay, if it falls apart in water is it sandy. Many qualitative tests such as these give important information on the uses of soils for mud brick making.

Quantities of various particles in the soil can be roughly graded visually. Soil samples must be dried and pulverized. All particles which can be seen by the naked eye are separated and set aside. These are sands and gravels, the remainder being silt and clay. Two piles are made and the proportions can be estimated visually or measured.

The accuracy of the above 'traditional' tests of course depends on the experience and patience of the mason. This kind of knowledge will prove advantageous even to modern builders.

(B) The newly developed field of 'soil science' and 'soil engineering' has provided new techniques that the mud brick builder can employ to upgrade his methods of soil selection and testing.

Bore holes can be dug in various places and core samples removed. These samples indicate soil conditions at various levels below the surface at each test location. Maps and cut away sections (profiles) can be drawn showing the different soil stratta. Bearing strengths of these various stratta can also be taken. Soil samples are individually tested for chemical composition and particle size. Some of these tests must be done in the laboratory but others can be 'field tests'. The test for grain size requires drying and pulverizing the sample. The soil particles are then screened or sieved through a series of wire meshes having sizes corresponding to the various particle demensions - gravel, sand, silt and clay. The material collected in each sieve-tray is weighed and the proportion of each particle size is determined. This gives very accurate information to the brick maker.

For example:

> It is determined after calculating the required compressive strength and resistance to moisture that a brick with a composition of 50% sand and 50% clay is desired for a particular building. After a comprehensive set of bore tests, it is found that there are not deposits of soil in the vacinity with the above proportion of particles, although there is a site with 20% sand and 80% clay and another with 60% sand and 40% clay. Mixing is therefore required to obtain the proper composition in the brick. In this case if soil from the first site was mixed with soil from the second site in a proportion of 2 to 1 the proper composition of 50% sand and 50% clay would be obtained.

Fig 911

Traditional
mud brick making

Preparing earth
for mortar

Forming bricks
using frame mould

Traditional Brick Making

Brick making: mud is collected from the supply pit and placed in a banked up enclosure size where it is mixed with water until the consistance is suitable for brick making.

This mixing process is usually carried out by foot though machines can be used, if available. At this stage care must be taken to ensure that the mud put into the brick mould has the correct moisture content. Too much water at this stage will result in bricks shrinking and cracking excessively in the drying process. This in turn results in a loss of strength and density in the bricks. As a rough rule of thumb if the mud sticks to the mould on removal, then the mix is too dry, and equally if the brick does not retain a firm shape when unsupported the mix is too wet.

Too much moisture in the mix will dry out in the brick leaving voids which weaken the bricks compressive strength and allow further moisture absorption. The mud must stand for a day or two before brick making to allow all the small lumps to break up into a consistant mix,

When the mud is finally ready a level space is cleared, over which a layer of sand or dust in sprinkled to stop the brick sticking to the ground. A hand mould consisting of four wooden sides with no top or bottom to it, and of the required size of the brick is then placed on the ground and filled with the mud mix, which is tamped down to ensure a compact neat brick. The top is cleaned off and the mould is then carefully raised up to leave the formed brick to dry. Bricks should be left to dry in a shaded place for the first three days. This prevents excessive shrinkage and cracking. In fact the slower a brick takes to dry the stronger it becomes. The best bricks are therefore made during the winter. After three days bricks are turned on end so they dry evenly and lift in the sun. Bricks should not be used before they have thoroughly dried out, which usually takes at least thirty days, when they will attain a constant weight.

Two guides as to the quality of the finished brick give an indication whether it will be adequate for any load bearing commonly found in house building. Firstly, whilst small surface cracks are permissable in the brick, if these cracks extend from one side to the other the brick should be rejected. Secondly, the bricks should be uniform in size, free of voids and should stand up to stacking, handling and movement without appreciable breakage or srumbling at the corners. The surface of the brick should give good resistance to abrasion when rubbed with the hand.

A detailed description of the traditional mud brick production methods which have been rationalized and approached in a systematic scientific manner can be found in Professor Hassan Fathy's book, Architecture for the Poor. Here he recounts his experiences in rural Egypt and shows how mud brick production can be carried out very economically to produce a consistantly good material. These experiences can be adapted and used as models for working out similar production problems in Oman.

Rammed Earth Bricks

Mud bricks of a strength greater than those made using the traditional method can be made employing brick ramming-form devices and the same basic material. These rams use a lever action to form bricks under compression. A somewhat dryer clay sand mixture is put into the mould and a stronger brick requiring less drying time is produced.

The most common brick ram machine is the man powered 'Civca Ram' produced in Columbia, South America. It requires a crew of two men to operate plus men to mix and carry the mortar. The Civca Ram can produce about 400 pressed blocks per day while Professor Fatby's experience shows that a crew can produce 3000 traditional moulded blocks per day. Other automatic or semi-mechanized techniques can produce 1500 to 2000 pressed blocks in a working day but at greater expense.

It must be remembered that high strength pressed blocks are not always necessary. The compressive strengths taken by traditionally made blocks are sufficient for most one and two storey building projects.

Improvements

Mud brick as it is used now has a relatively low strength when compated to limestone, concrete and red brick. It can only be used in campression. Even with its relatively low compressive strength substantial two and three storied buildings are the rule in many areas of Oman. Extensive multi-storied mud brick buildings have been built in many other parts of the world. Mud brick has a low resistance to water damage, this is why mud buildings tend to be found in areas of little rain, though very fine mud buildings have been built in the past in Europe as well, as far north as Britain. In areas that experience rainfall or flood damage mud construction has been adapted to respond to wet conditions.

Several methods have been employed to improve mud brick systems.

i) Firstly, the use of mud brick in conjunction with other materials can be advantageous. Limestone footings for mud walls are employed extensively in Oman where water damage to the bases of walls due to flooding is a problem.

Substantial footings for mud brick walls are advisable in almost every condition. Damage to walls due to cracking or movements of the surface of the ground can largely be prevented by proper footings. Limestone, red brick or concrete can be used for footings, and these should be set below the surface for stability.

Damp proofing courses are also advisable in areas where dampness rising from the ground can damage mud brick. Commercial roll-out materials and felts are usable but the simplest method is the use of a layer of bitumen spread continuously over a levelled course on top of the footing wall. The damp proofing course must be above ground level. The mud brick construction starts above it.

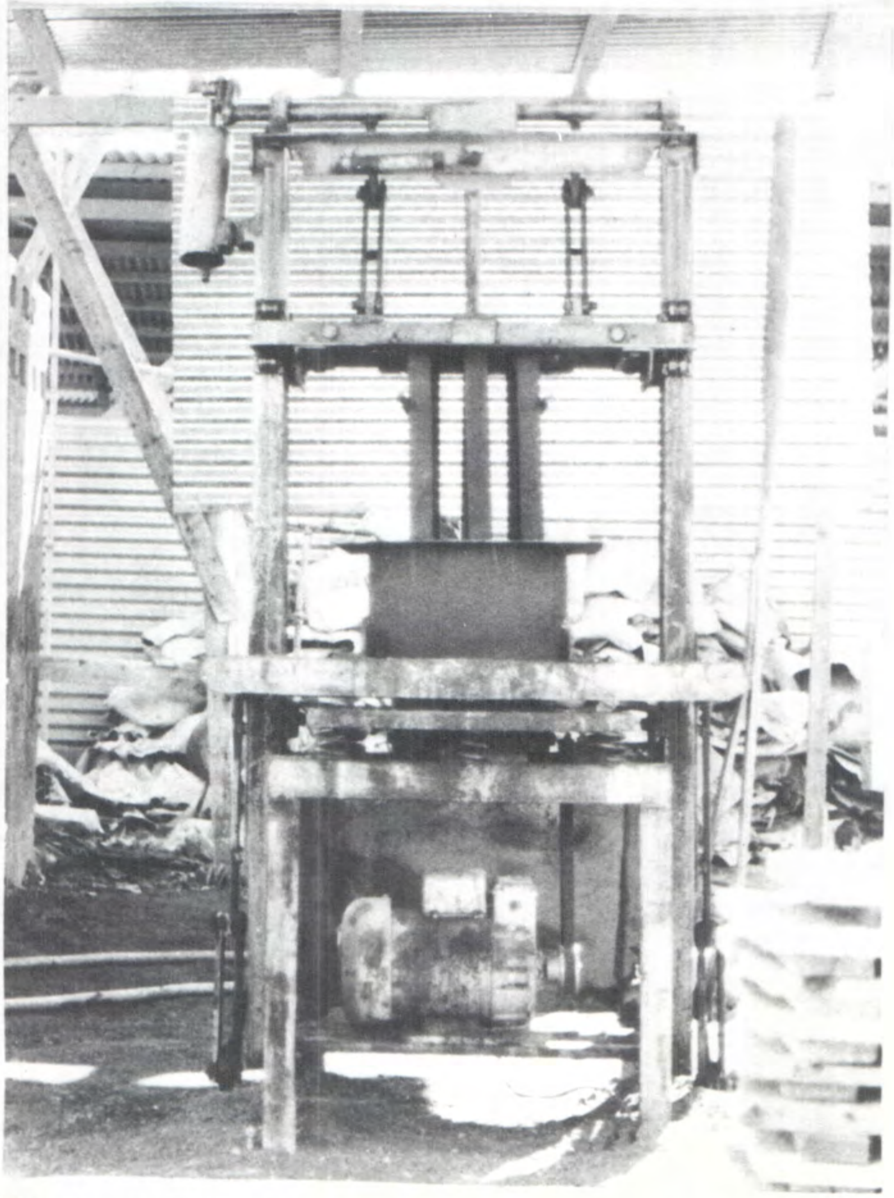
Reinforcement can be introduced into the mud brick wall when additional strength is needed, such as in an earthquake zone. Vertical reinforcement can be introduced in the form of hardwood sticks or steel running through the wall. Horizontal reinforcement can take the form of a ring beam (refer to Fig) which may be as substantial as a continuous reinforced concrete member running around the walls of a structure.

ii) The second method used to improve mud brick systems is rendering or plastering wall surfaces. Surface rendering prevents water from damaging the brick structure and also helps keep down dust from the mud surface in the interior. There are a number of materials which can be used for rendering. They vary in their ability to bond with the mud brick surface, their ability to resist the penetration of water, their durability and their availability and cost.

Fig 912.

Bricks drying in the sun.

Fig 913.



Brick or block making press.

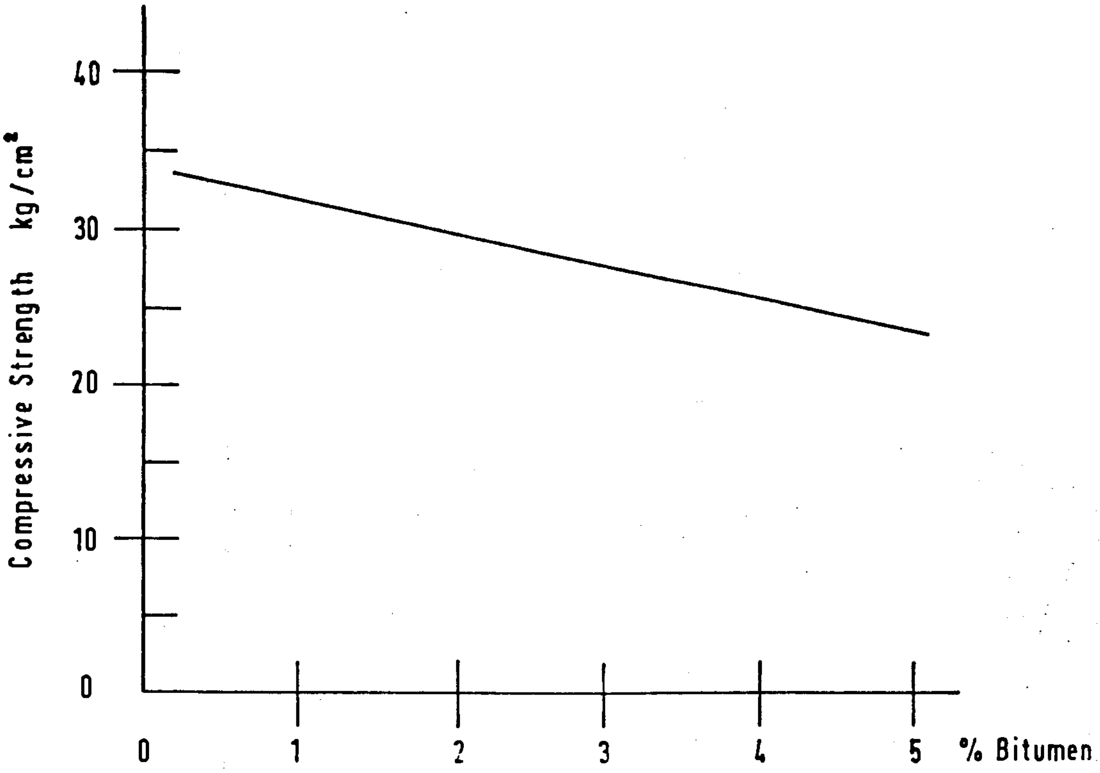
The simplest and most readily available material is a type of clay plaster. Special high grade clays more resistant to abrasion are used to render the walls of mud brick buildings. This is the most common type of rendering and is used universally in indigenous construction. The clay is generally of a lighter colour than the brick clay and reflects solar radiation well. Its actual composition varies from area to area but its production generally requires a period of fermentation in water. It is sometimes mixed with straw to help stop cracking. This material has the advantage of binding readily to the mud surface. Replastering is generally required every three years.

Recent experimentation has shown that a very hard rendered surface which will not tend to crack can be obtained by simply using a clay-sand mixture with a high proportion of sand i.e. two parts sand to one part clay. The wall surface in this case will be darker than the one above and absorb more solar radiation.

Lime, gypsum, cement and other materials with oil or chemical bases can be used for rendering walls. These solutions may prove to be expensive and costs must be weighed against effectiveness and durability. The wall construction must be completely dried out before plastering, further settling of drying will cause cracking or flaking of the new surface.

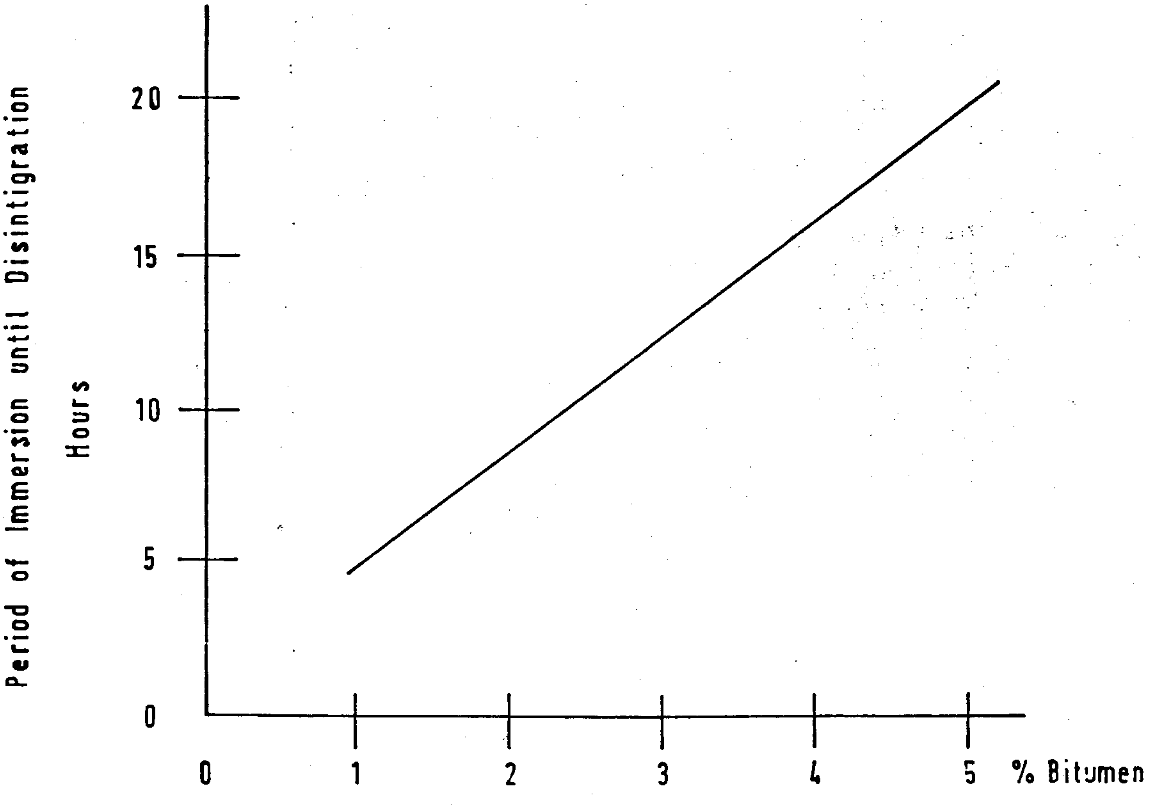
Surfaces must be prepared. Rendering materials adhere well to rough surfaces and are less likely to crack. Walls must be dry and free from loose material. A thin wash of portland cement and water will help plaster adhere to the wall. Plastering material can be trowelled on, spread by hand, thrown or mechanically sprayed. These rendering materials tend to last 5 to 10 years, then must be replaced.

Fig. 914
Bitumen Stabilized Mud Brick



Graph showing Compressive Strength of Mud Brick corresponding to amount of Bitumen.

Note - Mud Brick approximately 60% Clay + 40% Sand



Graph showing Brick's Resistance to Water Damage corresponding to amount of Bitumen.

(iii) Stabilization of Mud Brick

Mud bricks can themselves be improved by adding various substances to the mud mixture before the brick is formed.

In Egypt indigenous mud brick makers added straw to the brick mixture to help stop cracking of the brick during the drying process. Recent experimentation has shown that substances can be added to the mud mixture to make the brick stronger and or more resistant to water damage.

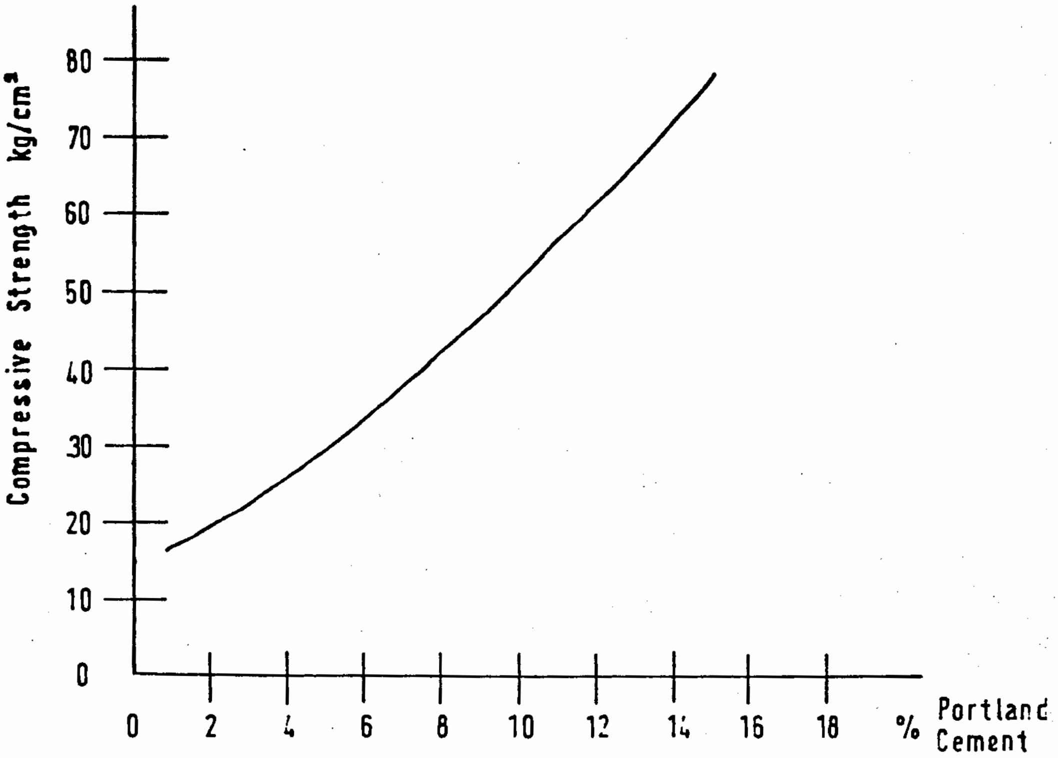
Bitumen as an addative has proved to make mud bricks more water resistant and crack resistant, but is also lowers the compressive strength of the brick. (See Fig.914). When adding oil based substances such as bitumen to the mud brick mixture it is found that they will not readily mix since they are insoluable in water. To overcome this difficulty emulsifying agents must be added to render the oily substance immiscible in water. Such emulsifying agents are alcohols, soaps, and proteins. A 2% soda solution or 1% soap is sufficient as an emulsifying agent for the brick mixture. In the brick making process itself, bricks stabilised with bitumen tend to take longer to dry and cure than unstabilized bricks.

Bitumen or other secondary by-products of the oil industry may prove to be economical brick stabilizers, especially in a country having oil resources.

Portland cement is the most commonly used mud brick stabilizer. A relatively small precentage of Portland cement in the mud brick mix makes bricks which are not only more water resistant but also stronger in compression. Figure 915 shows the relation of the various proportions of sand, clay and portland cement to compressive strength. Increasing the percentage of cement certainly improves the strength of the brick; but in light of the costs of Portland cement it is found that the best percentages, which may not increase the cost to an uneconomic degree and will still give sufficient strength, are from 6% to 8%. Portland cement has been found useful for stabilizing most soils except those with very high percentages of clay.

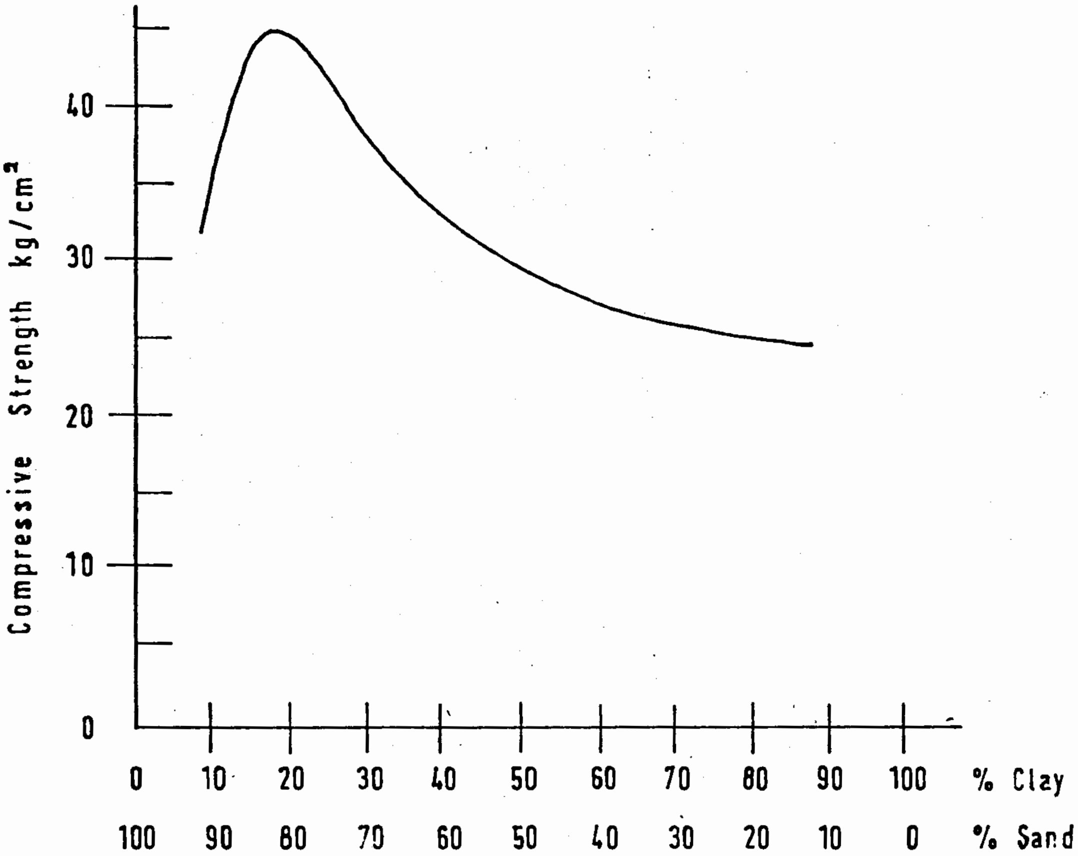
Fig. 915

Portland Cement Stabilized Mud Brick



Note - Mud Brick approximately 40 % Clay + 60 % Sand

Graph showing Compressive Strength of Mud Brick corresponding to poportion of Portland Cement



Note - Portland Cement composition - 6 %

Compressive Strength of Stabilized Brick corresponding to Clay—Sand proportions.

(iv) Fired Brick

Firing is a method that can be used to make brick both stronger and water resistant. Its economic feasibility depends on the availability of fuel. Soils, best used for fired brick making have a higher proportion of clay than sand (as much as 70% to 80% clay). Initially bricks for firing are prepared in much the same way as adobe bricks. Bricks for firing must be free of foreign or organic matter, so soils must be carefully prepared. After bricks are formed and allowed to dry for a few days they can be fired in various ways. The simplest technique is to simply stack bricks so as to form an enclosure around the fuels (if solid). The fuel is ignited and allowed to burn completely. Bricks are left to cool and then unstacked. The bricks that are closest to the fire are generally damaged and those furthest away are not completely fired. Only about 50% of the bricks are usable after firing with this method.

Permanent kilns, though initially more expensive to build, yield a higher percentage of usable bricks and also make more efficient use of available fuels. Fuels need not be expensive. Kilns in rural localities can burn harvest chaff mixed with petroleum wastes on any other locally available fuels.

Mud brick if properly used is suitable for most building applications of one, two and even three storied construction. This is possible in Oman's conditons because there is very little rainfall throughout the year. Rendering of mud-brick wall surfaces reduces exterior maintenance, provides a weather protection and helps prevent fine dust in the interiors. The bases of all wolls in contact with the ground must be protected form rising damp and occasional flooding. In these cases water resistant materials must be used, these include fired brick, stabilized mud brick, limestone and concrete. Walls which have particularly bad exposures to rain or abrasive winds, or walls carrying excessive loads should be made of stabilized brick or some related material. Though mud brick is the most economical of the load bearing materials, each building application has its own requirement and the merits and drawbacks of each available material should be considered.

mestone

9.3.1. (iii)
Limestone

Limestone is the most common indigenous material used in urban areas of Oman, particularly in the coastal towns of the Capital region, and in Sur and Salala. Being a load bearing material of considerable strength, buildings of several stories are common. In rural areas where houses are made of predominantly mud brick, limestone is used for foundations and lower protions of walls, which might be subject to flooding. Some rural mountain settlements use stone exclusively.

In many areas of the country limestone is the bed rock condition. This is particularly true in coastal areas, because limestone is formed by the compression over a long period of time of marine deposits. In coastal areas the limestone obtained near the shoreline, being comparatively more recently formed, is softer and weaker than that obtained further inland. While the stone found near the coast is easier to quarry and work the best material for building is found inland.

Limestone used for building is obtained in a number of ways. In some areas it is simply collected in a loose form from what has been left exposed along the shore or in hilly areas. Stones are usually irregular and small and produce less stable structures. A great deal of mortar (mud or lime based) is used in this type of wall construction.

A better material is the limestone block which must be hand cut from a quarry site. This is a labourious process with only simple tools. The Salala region has the most extensive quarrying systems. In the coastal plain area the top soils must be cleared away to expose the limestone bed rock. Blocks are cut from the bed rock using hand tools such ashammers , pikes and wedges. A number of men work on a quarry site but generally as individuals, each selling the blocks that he himself cuts. Roughly regular blocks of the same size can be produced using this method. These provide an excellent building material for town house construction of several stories. Thick walls are the rule so as to allow for the future building of upper floors. Cut blocks are used as facing for the exterior and interior wall surfaces and less regular stones or broken blocks fill in between. Limestone blocks can be reused many times, so that stone from old walls can be used in new construction.

The demand for building materials has grown tremendously in some urban areas, particularly in Salala where the population has swollen because of the war. The manual quarrying method described above has a limited output, being that a man can cut only about 30 blocks a day. The price of stone has therefore increased greatly and is now more than 30 Rials per 100.

If the use of limestone is to continue for house-building the costs must be brought down. The upgrading of the quarrying system may be an answer. Mechanized limestone cutting has been experimented with in Salala (Fig. 820), but so far production results have not been good, largely due to organizational and technical problems. If mechanization were to be introduced to upgrade the indigenous quarrying system it would necessitate that those men working together in a quarry now as individuals need to establish some sort of system where they can co-operate to run the cutting machine and market their products. By encouraging the upgrading of the indigenous limestone extracting system, a local supply of building materials would be ensured and the money invested in building would remain in the community. Initially capital is required for the purchase of machines and a great deal of organization is needed to upgrade the present system.

palm stem - barasti.

9.3.1.(iv)

Barasti (Palm Frond Stems)

Barasti is used as a primary building material for nearly all of the inhabited Omani coastline, but usually only within a distance of 3 or 4 kilometres from the shore. In the north fronds are taken from date palm trees, whilst coconut palm fronds are used in the Salala area. Although methods of using the stems vary from region to region, their importance as a building material arises from their being both cheap and readily available, and their practicability in terms of coping with many of the house owners needs, both climatically and phusically. Barasti is an attractive and functional proposition for a large number of Omanis, many of whom can only afford a minimal sum of money for housing.

Physical Properties

Date palm frond stems are usually about 2½ metres long, with a gently tapering but robust stem. In comparison the coconut palm fronds taper more rapidly, resulting in a less rigid stem. Although neither stem type is currently used for structural purposes (posts and beams providing the load bearing framework) the date palm stem provides greater rigidity in a wall than that of the coconut palm. The average tensile strength of the date palm stem is 177kg/cm^2; it has a linear compressive strength of 216 kg/cm^2, and an average point load-bearing capacity of 20 kg.

The stem has a potential value of giving tensile strength to load bearing materials when it is used as reinforcement.

Environmental Response

Barasti wall panels made up of stems with their leaves removed allow a relatively free passage of air into the interior of the house, which is advantageous where, both in the north and south of Oman, the summer climate is a combination of high temperatures and humidity, since in these conditions air movement becomes a most important factor in attaining comfort conditions.

A barasti wall panel made up of two layers of stems with the leaves sandwiched in between has a heat transfer time lag of about 2½-3 hours, and the proportion of heat transferred from one surface to the other - ie. from the exterior to the interior in the summer and in reverse during the winter - is about 85%. This figure can be reduced by increasing the thickness of the panel (simply by adding daams to the wall) (Fig 368) or by plastering the exterior with mud (Fig 810).

The qualities of providing shade whilst allowing free air movement do not go hand in hand with insulation, and therefore different panels are required for different times of year depending on the seasonal climatic variations.

Barasti used as a roofing panel, where the leaves are packed tightly together and are also pointing down the slope of the roof, provides satisfactory protection and runoff for the small amount of rainfall that occurs in areas where Barasti is used.

Using stems with the leaves removed, screens are formed which modify the quality of the exterior light as seen by the occupant of the room, so that the view is not a strain on the eyes due to excessive brightness, at the same time permitting a view of the exterior without being seen by people outside.

Barasti panels, due to their porous nature, do not provide accoustic privacy.

Ease of Construction

Barasti construction using either date or coçonut palm frond stems is a relatively simple process. In both cases a basic frame is erected consisting of four corner posts and two larger posts set at the centre point of the two end walls to support the ridge pole. The coconut palm frond is relatively weak and requires a lattice framework along the whole wall to support the stems. The date palm frond is more robust, and after tying the stems together, the resulting panel can be placed in position and only requires fixing onto the main posts. In summary the coconut palm frond requires a 'built in place' method of construction whilst the date palm barasti is used in pre-assembled panels which can be erected or taken down at will according to the annual climatic cariations and the occupants requirements.

Maintenance and Lifespan

The major drawback of Barasti as used at the present time is its short lifespan. Stems used in contact with the ground are subject to termite attack, which eat away the stem, particularly on the beach front where stems may only last as little as two years. If precautions are taken to avoid termite attach the stems can have a lifespan of 20 years or more. Primarily the maintenance required is to ensure that, having been erected with care to avoid contact with the ground, the stems are inspected regularly to ensure that no termite attack has begun, and to deal with it as soon as there are any signs of such activity. Provided that suitable percautions are taken, maintenance can be reduced considerably and the lifespan greatly increased.

Availability and Economics

There are large areas of palm trees in Oman, providing a ready supply of Barasti for building. Away from the coast this supply of raw materials is little used. There is at present no shortage of stems, even for the landless peasant or in the capital region where few palm trees grow.

A barasti panel, usually 4 metres long and 2.20 metres high, known as a da'am, costs 2.000 Rials Omani to buy ready made (supplied with the leaves still on the stems). Where stems are provided by the owner-builder, the cost of binding a da'am is o.600 R.O. A flat roofedroom measuring 6 x 4 metres and 2.20 metres high costs 20 R.O. to build, whilst a pitched roof room costs 50 R.O. These figures apply where the house-owner is having a room built for him, and hence incorporates labour costs as well as material costs, so that the price of a room built by the owner will be considerably lowered. The materials widespread use is greatly effected by its cheapness and easy availability, factors which are most important to a populace with very little money available for house building.

Problems and Potentials

At present the greatest problem in using Barasti is termite attach which severely reduces the lifespan of the stems - careful building ensuring that the stems have no contact directly with the ground, and the use of termite shields to prevent termites approaching elements of the room via supporting posts and floor joists, largely overcomes this problem, since the most destructive termites require a soil link with the ground, without which they die. Preventing the establishment of this link is therefore important.

Unprotected stems easily catch fire and particularly in kitchen areas, present a fire hazard. Fire retardant paints or the use of mud plaster greatly reduce this risk, making the stems harder to ignite. Careful design of areas where there is a natural fire risk will also greatly reduce the likelihood of the whole house being burnt.

Because of the number of cavities in the formation of a Barasti panel, the material harbours a large number of insects, but basically none that represent a health risk. Vermin are a product of the overall environmental quality, and should not be seen as a drawback of this material.

The advantages of Barasti outweigh the disadvantages. It is cheap and readily available and in areas where it is commonly used, responds very well to the summer climate of Oman. Amongst all the materials available in areas where it is used, Barasti houses come closest to achieving comfort conditions during the summer, when the climate out of doors is the most uncomfortable. Particular attention should be paid to its qualities regarding lighting and ventilation.


rooting

9.3.1. (vi)
Roofing

The roof is of prime importance when considering the elements of the house. In almost all building traditions a construction is not considered to be a house until the roof is erected. The completion of the roof is often accompanied by some formal ceremony of symbolic importance.

While wall construction presents few problems to the builder, roof building proves to be technically more complicated and expensive. Roofs must have the ability to span certain distances while walls need only be load bearing and in the case of screen walls bear no load at all.

The roof is responsible for protecting the inhabitants of the dwelling as well as materials below it from the elements. Water must be efficiently shed, the interior must be shaded from the sun, and heat, which builds up through solar radiation, must often be retarded so that interior temperatures will not become excessive. Roofs must, in some cases, double as platforms or terraces for use during summer nights and even at times if the house is to be extended, be strong enough to support the weight of future construction as new floors are added above. This last function is important in the Omani context where house construction is viewed as a process of extensions taking place over a long period of time.

Indigenous Roofing:

Predominantly two types of roof construction are found in the indigenous architecture of Oman; the pitched palm stem roof and the flat mud, timber-palm roof. Their location can be roughly defined regionally; the differing functions being due to the availability of the particular materials and the local climate. Pitched palm stem (barasti) roofs are found in coastal areas, very near to palm groves in most cases, while flat roofs are generally found further inland.

By their shape, pitched roofs (Fig.917) shed rainwater easily, and the construction material (barasti) makes the roof very light. Lightly constructed houses using non-loadbearing barasti walls, and only corner posts for support, generally employ these pitched barasti roofs, as do some coastal mud walled houses. Palm stems with leaves left on are used as shingling (i.e. with leaves pointing down) to shed water efficiently. Such roofs are cheap and easy to construct, some of the structure being prefabricated on the ground. Roofs are usually held firm by ropes which are 'post tensioned' after the roof is in place.

These roofs offer occupants of a dwelling protection from the rain and sun, and a degree of insulation from heat which can be transferred into the interior. On the otherhand, because the roofs are light and because of their shape they can not support building above, and they do not provide usable domestic spaces (platforms).

These roofs are only used in one story construction, or in some cases for temproarily roofing top floors of multi-story buildings.

Improvements in the water proof qualities of the traditional pitched-barasti roof have been recently made by some of the 'barasti' builders on the Batinah Coast. Beneath the outer layer of shingles a waterproof membrane is introduced. Membranes range from sheets of polythene, to standard roofing felts. Building remnants from large scale construction projects in the vacinity are often used.

A combination of mud, timber and palm flat roofing (Fig918) is usually found in inland locations and built-up urban areas. Their weight necessitates the use of load bearing supporting walls below. The basic structure of these roofs

Fig. 917

Improved Pitched Roof

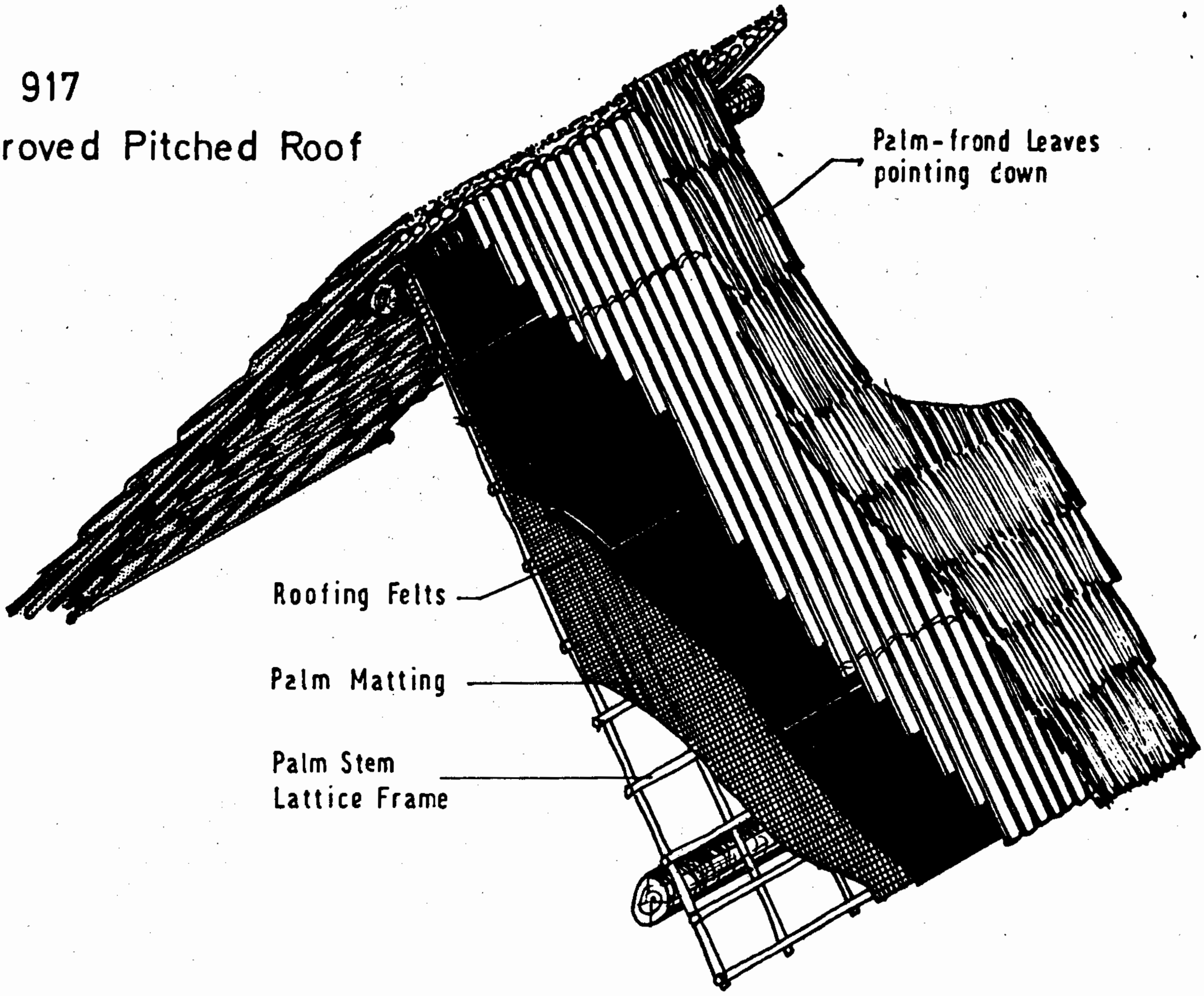
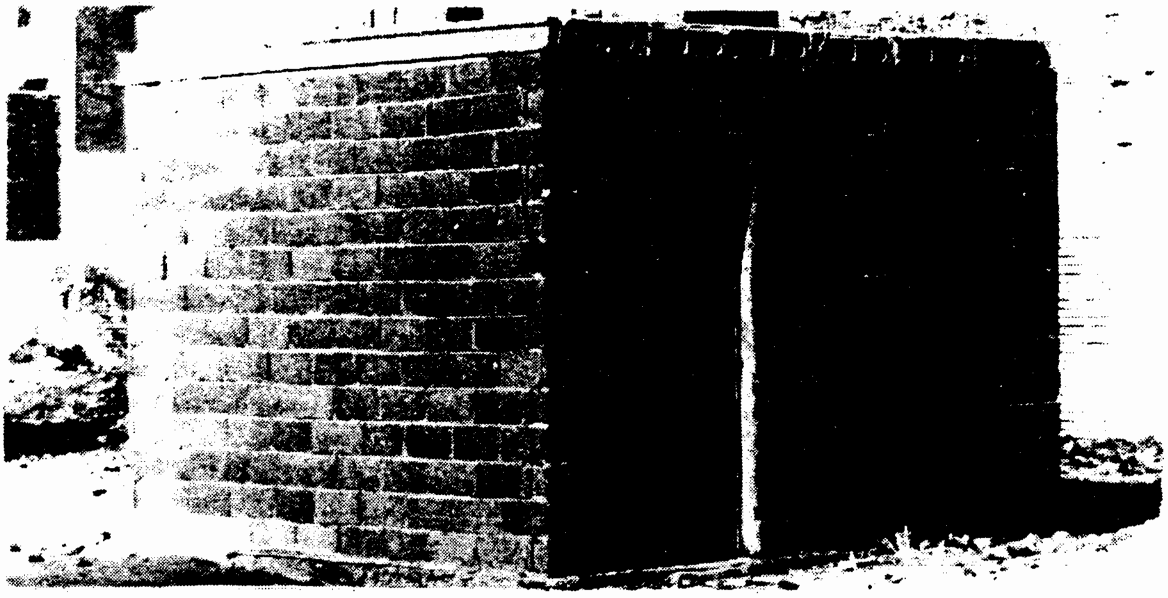
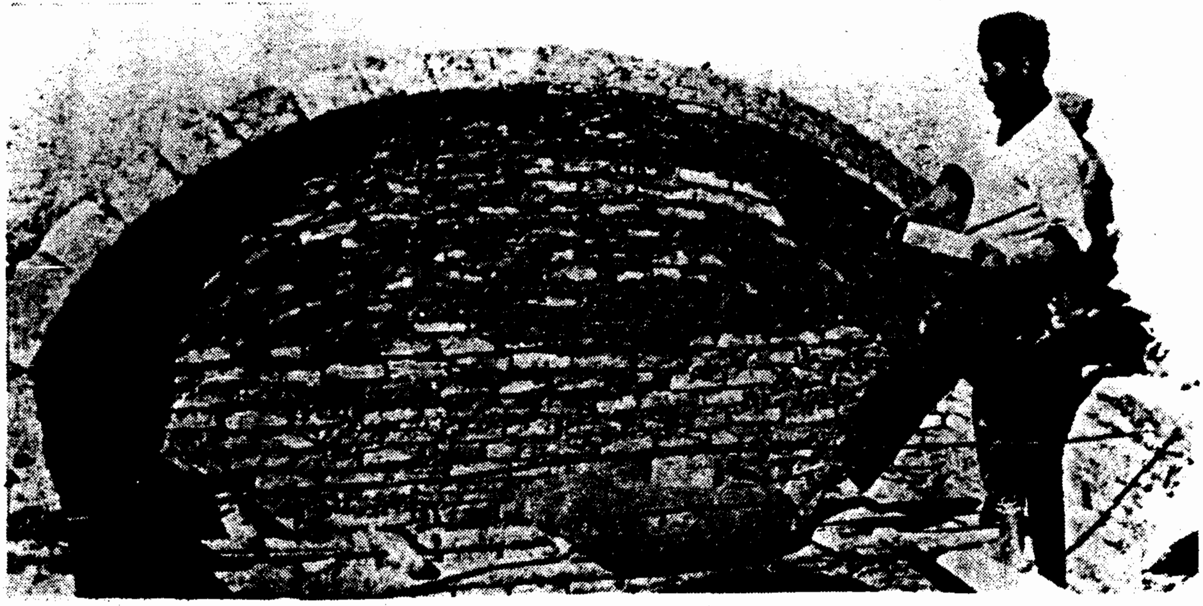


Fig. 919

Construction of the traditional Flat Roof becomes a problem when timber is expensive or unavailable



Reinforced concrete roofs are a solution, though very expensive.



Mud Brick Vault + Dome Construction can provide inexpensive roofing.

consists of heavy palm or imported wood beams. These components are also responsible for the costliness of these roofs. Over the beams is placed lathing of wood strips, palm stem barasti 'daams' or palm matting. The practice of incorporating layers of salt in conjunction with organic materials such as the palm wood or matting, as a deterant to insects has been noted in Iran. It is not known if this is common practice in Oman, but could be seen as a simple and inexpensive improvement. The bulk and weighty layer of clay, mud, gypsum, cement or mixture of these is placed over the lathing, often reinforced with mesh or palm matting. This layer is pressed or rammed to make a hard water repellant surface.

These roofs must have sufficient slope and be well guttered to ensure water runoff. After every period of rainfall roofs have to be checked and often repressed with a heavy roller. Because Oman is a country of little rainfall this type of flat roof is feasible, but sudden intense storms occasionally occur and cause some damage to flat roofs, particularly those badly designed for water runoff. These roofs can be improved without changing their basic design by introducing a water repellant surface or membrane. A hard surface layer such as cement of gypsum can be put over the mud or clay layer, but even minute cracks will let in water. Overlapping roofing felts held down by fine gravel, over existing mud surfaces are a better solution to the waterproofing problem.(see introductory photograph). Measures must be taken to ensure that felts are not ripped if roofs are used, for example for sleeping on or date drying.

Flat roofs described here, like the barasti pitched roofs provide shade from the sun and protection from the rain. Although they are heavier than pitched roofs, and require substantial supporting walls, flat roofs, because of the mud layer, provide a much higher degree of thermal insulation as well as providing a platform for summer use and a base for future building.

New Roofs

With increasing population and building activities, particularly in urban centres, the demand for certain indigenous building materials is exceeding the supply. Palm beams is a notabel example. In the past palm beams were used almost exclusively for most spanning problems in construction. More recently imported timber beams have been used as well. With recent large international increases in timber prices roofing costs have escalated.

New roofing solutions have been imported. Corregated iron has been used for roofing in some recent constructions. Although this material is water repellant and simple to install its use in the Oman condition is unwarranted. Without dwelling on its often unsightly appearance its principal drawback is its thermal properties. Metal roofs both reflect and absorb a certain quantity of the solar radiation which strikes them. The heat energy which is absorbed by the roof is immediately transferred into the interior and re-radiated into the building. Because these roofs provide no insulation temperatures inside buildings with such roofs are extreme (see Fig.921).

Reinforced concrete roof slabs or prefabricated concrete roofing units are another recently introduced solution. Like the indigenous mud-palm beam roofs, the concrete roofs are heavy, requiring substantial supporting walls, but also provide a flat usable platform for future building.

Reinforced concrete slabs are much thinner than the indigenous flat roof and have smaller insulation values, consequently much more heat is transferred through concrete roofs to overheat interior environments. The cement used in concrete as well as the steel needed for reinforcing is expensive making this a costly roofing solution, certainly out of the range of the average Omani.

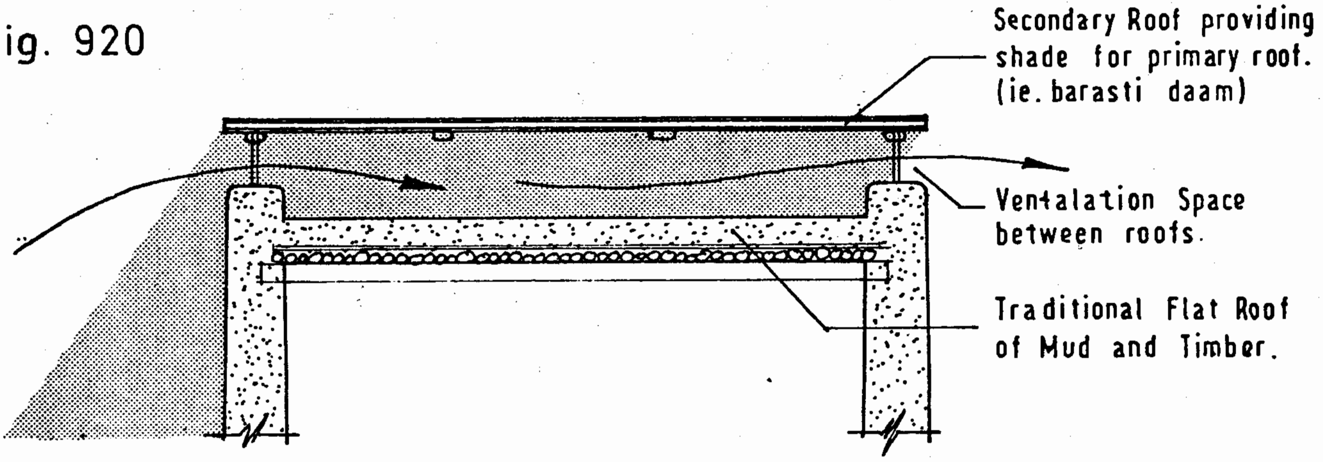
Since the palm beams necessary for constructing the traditional flat roof are less available than before and newly imported roofing materials present a number of problems, it may be advantageous to suggest other possible solutions.

If one looks to areas which have had similar problems to Oman's current one i.e. a need to provide inexpensive roofing materials, but finding a shortage of timber for spanning; the indigenous roofing solutions of both Egypt and Iran may provide answers. The three countries have similar geographical and climatic conditions and share the Islamic culture, and may offer more appropriate solutions than Europe can. In both Egypt and Iran the same material which is used for walls has been used for roofing, i.e. mud brick (adobe). If mud brick is used for roofing in the form of vaults and domes, then no other materials are needed for spanning between supporting walls. Sophisticated systems of construction for vault and dome building, have evolved in both Iran and Egypt, requiring no reinforcement or centering. The materials, tools and technology employed in these methods are minimal and available to any village builder. Mud brick vault and dome roofs have a good insulative value and are strong enough to support several floors of additional construction above. Material costs are minimal as mud brick is an inexpensive widely used material in most parts of Oman. This roofing method could prove to be of use in Oman and experiments towards this should be undertaken.

Research into new roofing solutions for the tropics has been undertaken recently by several different organizations. One of the problems dealt with, concerns the heat from solar radiation which is transferred through the roofing material into the interior of the dwelling. This heat can be abated by the use of materials with a high insulative value. Another solution to this problem is to protect the roof from receiving direct, any solar radiation. This can be done by constructing a light second roof above the principal roof with an air gap between. This secondary roof not only shades the primary roof but protects it from the direct force of rain.

Roofing costs will be somewhat greater since two roofs are needed instead of one, but by using an inexpensive indigenous material such as barasti for the secondary roof, these can be kept to a minimum. If a Barasti 'daam' supported by a framework above a traditional flat mud-palm roof is used (see Fig.920) the secondary roof can be rolled back in the winter when solar radiation is advantageous. During winter a portion of the solar radiation received by the roof is stored by the materials and re-radiated into the interior at night-time when air temperatures are cooler. Already platforms on roofs used for date drying approximate such a structure (Fig.409). They could be developed for the additional uses mentioned.

Fig. 920



Double Roofing System

9.3.2

HealthStandards for Dwellings

Climate and Hygiene

The modern home should not only provide protection from unfavourable atmospheric conditions, but also prevent the spread of contagious diseases and ensure physical and mental comfort, rest, or creative activity, and the maintenance of human health in the wider sense. Sanitary science as a whole, and the part applicable to housing in particular, must define optimum hygienic conditions for the home such that health of the population is maintained and their work output enhanced.

In defining the factors which produce a healthy environment within the dwelling, a variety of considerations must be made, including the physiological response of the individual to the house's interior micro climate as well as the physical design for problem areas of the house, such as water supply facilities, cooking areas and means of sewage disposal.

In most cases there exists indigenous features in the built environment for coping to some extent with each of the above problem areas. In some cases these indigenous forms may prove inadequate by accepted modern standards and in other cases they are quite adequate and even superior to newly introduced techniques. Particular problems exist where recent changes, (ie. migration producing population densities unexperienced before), over-tax indigenous sustems or present new problems with which indigenous systems can not cope.

In every case, although, it is advantageous to study the indigenous solution to each problem area because it will give an indication of the local inhabitants social and cultural bias, as well as useful technical information. A World Health Organisation publication states that "Mere technical improvement of the environment without public education in hygiene and sanitation, based on local customs, traditions and beliefs, has again and again proved futile". *

The improvement of the public health aspects of the built environment should be looked at in two ways; firstly the reinforcement of those indigenous features which play a positive role in the environment, and secondly public education to encourage the upgrading of areas which are unhealthy. Technical innovations should take into account exisitng social prejudices and should always be well within the economic means of the rural community.

When looking at the dwelling from the point of view of micro climatic standards it is found that the indigenous house usually responds to local environmental conditions in a way superior to newly introduced housing systems. Many examples of this are shown in the body of the report, Sections 3 to 8. It is therefore evident that certain features found in indigenous buildings should be encouraged in future building.

The micro climate of a dwelling is determined by the temperature of its walls and furnishings and by the temperature, moisture content, movement and exchange of air within it. Values for these factors must be selected to ensure maximum protection from severe exterior climates in order to promote the health of the occupants. Prolonged action of adverse climatic factors have a very important effect on the individuals health when viewed over his or her lifetime. Despite the considerable ability of the human body to adjust to the environment its powers of thermo-regulation can compensate for only a relatively small range of climatic conditions. There exists an optimum range of temperatures within which the human body operates efficiently and atmospheric conditions present the least demands. This is known

* W.H.O. Monograph no.39 - Geneva 1958

as the "Zone of Thermal Comfort". Prolonged conditioning of the human body to various meteoroligical conditions leads to certain changes in the thermo-regulation in the body and thus to differences in temperatures preferred by inhabitants of different climatic regions.

The Comfort Zone or the range of air temperatures within which most Omanis are likely to feel comfortable has been calculated to be between 21°C and 26°C.* These Comfort Zone temperature limits may vary somewhat from place to place within the country, because of regional climate variation. However these figures may be accepted as a guide.

It is not adequate to simply maintain average air temperatures inside the dwelling within the above mentioned comfort zone range at all times, as other factors come into play.

In hot seasons when temperatures are in excess of 35°C the difference in temperatures between outdoors and indoors should not exceed 8.5°C to 10°C, in order to avoid what is called "temperature shock". (Reference: Adolf (1952) Physiology of Man in the Desert and Aronin (1953) Climate and Architecture.)

In providing thermal comfort within dwellings, one must consider not only the optimum mean air temperature but also the horizontal differences in air temperature. Temperature pockets, layers or stratification within a room should be avoided. It is commonly accepted that horizontal differences in temperature should not exceed 1 - 2°C and that the difference between floor temperature and the temperature at a height of 1.5m from the floor should not exceed 3°C.

It must be remembered that vertical temperature differences within buildings depend, to a large extent, upon the nature of the heating or cooling source. Systems which rely on the heating or cooling of air by convection are particularly noted for this problem. The "Air Conditioner" or "Desert Cooler" often produces layers or pools of cool damp air in the lower portion of rooms while the upper reaches remain hot.

The effect of the body's loss of heat by radiation to the surroundings (ie. walls of a room) must be considered. The body is highly sensitive to small changes in environmental heat radiation. Health requirements are satisfied if the temperature of interior wall surfaces is not much lower than the air temperatures recommended for the "Comfort Zone". The difference should not exceed 3°C at the optimum indoor air temperature so that no sensation of cold is experienced.

On the other hand if air temperature falls far below comfort levels and wall temperatures are maintained within the comfort range the body will still feel comfortable because its radiant heat exchange with the surroundings will be maintained.

Thermal comfort conditions within dwellings can be maintained by two methods, convection (the heating or cooling of the air) or by radiation (the control of radiant heat transfer between surroundings and the person - thus control of wall surface temperatures.)

* Calculated with the aid of a formula derived by C T Mahoney - D.P.U. Climate Design Handbook - London.

There are fundamental differences between the physiological effects of heat exchange by convection and radiation. Convection heat acts mainly on the skin. Radiant heat not only acts on the body surface but also penetrates it and influences deeper lying tissues (Galanin 1956). This characteristic of radiant energy explains its marked biochemical effect. The maintenance of comfort conditions by keeping the heat radiation flow between the individual and his surroundings at an optimum level rather than the reliance on maintaining comfortable air temperatures will mean that the individual will require less energy to go about his daily activities. "Under conditions of radiant heating, 10 - 15% less energy is required for the performance of a given task than with convective heating (air conditioning).

Convection heating and cooling requires a source of external energy or fuel; some mechanical apparatus to convert this fuel energy into hot or cold air (this apparatus can be simple or as complex as an air central conditioning plant), and finally a method for distributing and circulating the conditioned air. Convective heating tends to be rather expensive initially in equipment costs and later in maintenance and requires a continuous energy supply.

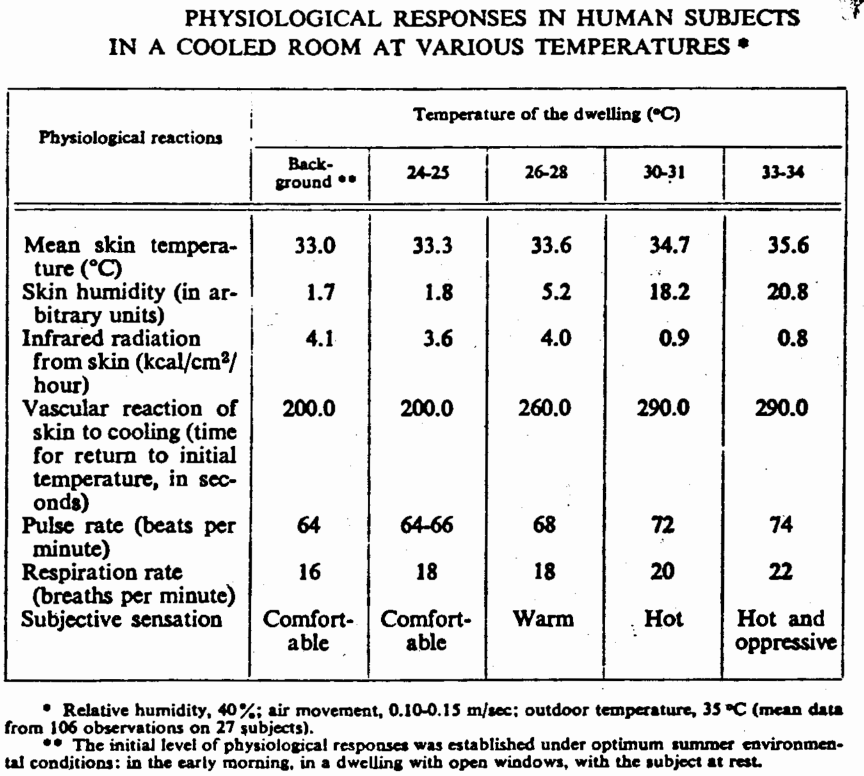
The concept of radiant heat however, has been employed in indigenous houses for centuries. Radiant heat energy is collected from the sun during the day or expelled to the dark sky at night. Its regulation is undertaken by thick mud or stone walls of the house which maintain interior walls at relatively constant temperature levels. Thermal comfort is attained by people within such buildings by the maintenance of optimum radiant heat flow from the body to the walls and surroundings.

Radiant heat can also be maintained by mechanical means such as radiant heating and cooling panels set into the walls, floor or roofs of dwellings. Wall surfaces maintained at optimum temperatures by either natural or mechanical means, not only receive and emit radiation from and to people within a dwelling but also heat or cool air which comes in contact with their surfaces. The high heat capacity of large areas of floors, ceilings, and walls of rooms heated by radiation guarantees rapid establishment of required air temperatures even after prolonged ventilation.

Experimentation in different parts of Oman has demonstrated the effectiveness the above mentioned temperature regulatory system. Where short comings are observed provisions are generally made to aid cooling by air movement or evaporative cooling, this depending on the local condition. Mechanical systems (either convectional or radiation) may be introduced when they are economically feasible and when they can suppliment and improve upon existing systems.

Over Heating in Dwellings

Prolonged residence in overheated buildings adversely affects a person's general condition because of extreme demands made upon his thermo-regulatory mechanism. Under the influence of high temperatures and or a high level of radiation the heat production and blood pressure fall, the respiration rate and blood circulation rate increases, there is an increase secretion of sweat, a marked change in general metabolism, and alterations in water and salt metabolism. Even though the thermo-regulatory mechanism is highly efficient it is unable to cope with excessive demands made upon it by these conditions. (Refer to Chart below. Physiological Responses in Humans to Various Temperatures - W.H.O. 1968.)



PHYSIOLOGICAL RESPONSES IN HUMAN SUBJECTS IN A COOLED ROOM AT VARIOUS TEMPERATURES *

Physiological reactions	Temperature of the dwelling (°C)				
	Background **	24-25	26-28	30-31	33-34
Mean skin temperature (°C)	33.0	33.3	33.6	34.7	35.6
Skin humidity (in arbitrary units)	1.7	1.8	5.2	18.2	20.8
Infrared radiation from skin (kcal/cm²/hour)	4.1	3.6	4.0	0.9	0.8
Vascular reaction of skin to cooling (time for return to initial temperature, in seconds)	200.0	200.0	260.0	290.0	290.0
Pulse rate (beats per minute)	64	64-66	68	72	74
Respiration rate (breaths per minute)	16	18	18	20	22
Subjective sensation	Comfortable	Comfortable	Warm	Hot	Hot and oppressive

* Relative humidity, 40%; air movement, 0.10-0.15 m/sec; outdoor temperature, 35 °C (mean data from 106 observations on 27 subjects).

** The initial level of physiological responses was established under optimum summer environmental conditions: in the early morning, in a dwelling with open windows, with the subject at rest.

Solar radiation entering a dwelling by way of windows or openings may be a cause of over heating. The combined use of different construction techniques can overcome this problem.

1. Planting of trees and shrubs, using irrigation if necessary, around built up areas, as well as the growth of greenery in window boxes and on balconies.
2. Orientation of building so that it presents least wall surface area to the sun and so that doors and windows face away from the mid-day sun.
3. The use of devices producing shade such as lattice work in windows (mushrageya - Egypt ref. Fig 372-379).
4. Use of light coloured wall surfaces so as to reflect as much radiation as possible.
5. Provision of ventilation, particularly at night.
6. Insulation of heat sources both within building (ie. kitchen) and outside of building (ie, thick heat retardant walls receiving solar radiation.)

The combined use of these techniques will lower room temperatures significantly.

Air Movement and Ventilation

Air movement has an influence on the body's heat loss/heat gain mechanism and therefore can be seen in its relationship to thermal comfort. The effect of air movement is most pronounced when considering heat lost by evaporation. Air movement has the effect of lowering the effective temperature, or the apparent temperature experienced by the skin's surface, by aiding evaporation. If air temperatures exceed comfort zone limits, thermal comfort can still be attained if air movement is induced, as shown in chart below.

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%

An unclothed person can sense air movement of only 0.05 m/sec. If temperatures are low, a too rapid indoor movement of air is felt as a draft.

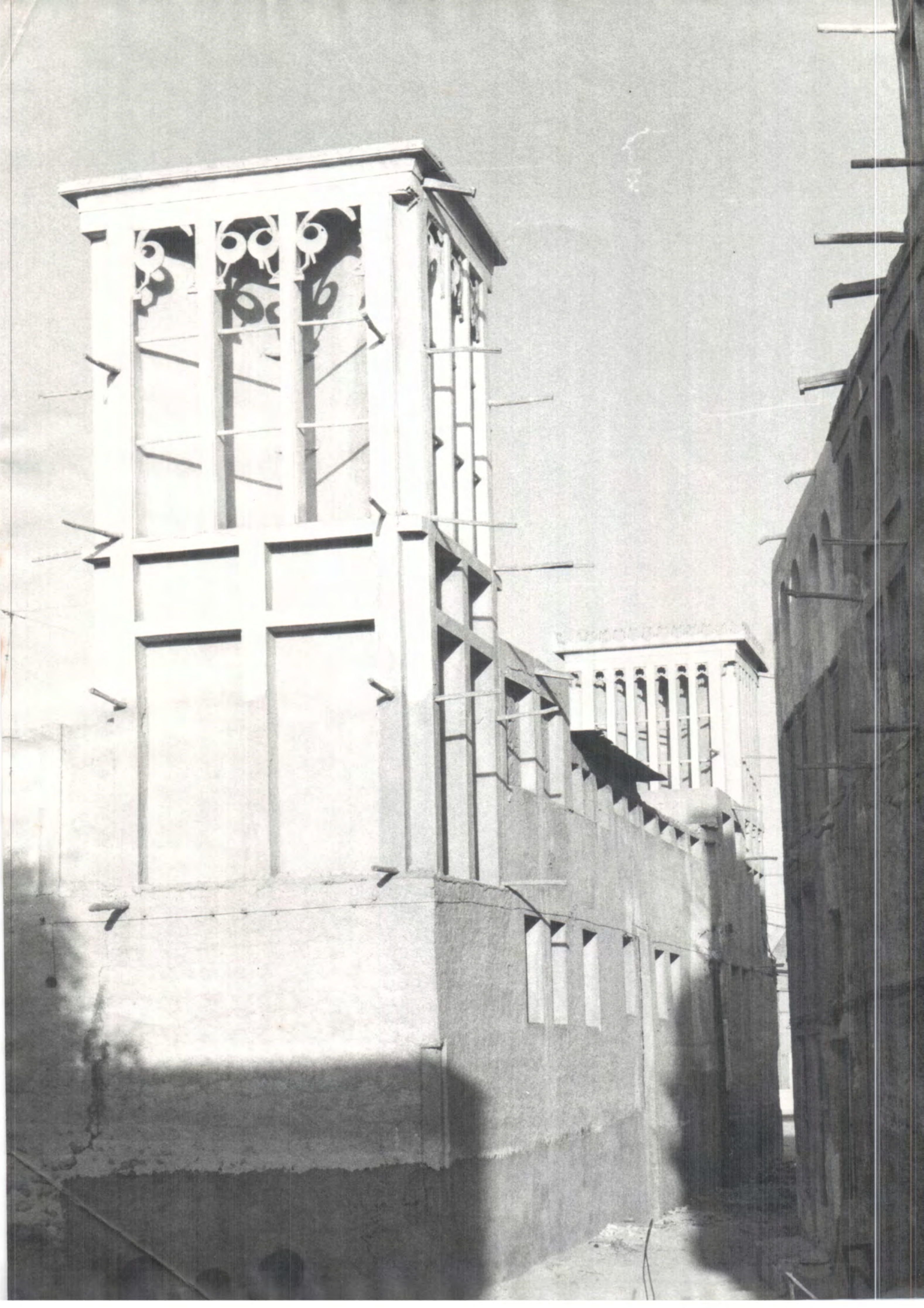
Provision for a constant supply of fresh air that is moving at an optimum velocity is, from the point of view of health, an important factor to be considered in the design of buildings.

Unpleasant sensations experienced by people remaining for a long time in a badly ventilated place are due chiefly to changes to the physical properties of the enclosed air that hinder heat loss, and to a deterioration in the composition of the atmosphere. In an inhabited room, the air becomes progressively contaminated by carbon dioxide, resulting from metabolic processes and by bacteria suspended in the exhausted air (ie. tuberculosis and diphtheria bacilli). In addition odour is given off by the surface of the skin. With the emanation of body heat, the indoor temperature tends to rise, and there is an increase in relative humidity due to moisture evaporated from the skin and exhausted from the lungs. For these reasons provisions must be made for an adequate rate of air renewal.

A person requires an optimum level of 113 m^3/ of fresh air per hour. In order that an allowable level of 0.05% of carbon dioxide is not exceeded three changes per hour are required for an air space of 30m^3 volume. Acceptable minimum levels of fresh air are although, in living rooms and bed rooms 25m^3/hour per person.

Carbon monoxide and sulphur dioxide are products of combustion, and present a toxidity problem in rooms containing cookers. The minimum amount of fresh air required therefore, by a person in a kitchen is 60m^3/per hour, but when a cooker is in use 150 to 300 m^3 of air should be extracted per hour.

It is recommended that heavily used rooms should always have provision for 'cross ventilation'. The purity of the indoor atmosphere can be increased by the isolation of the kitchen from the living quarters. Ventilation facilities should be provided for individual cooking or heating apparatus within the kitchen so as to provide an efficient extraction system for toxic fumes and odours. The wide spread use of the open courtyard for cooking in indigenous houses, is a simple solution to these problems.



9.3.2. (i)

Windcatchers

The windcatcher is a tower like device designed to funnel air from the unrestricted upper levels down into ground level rooms which might not otherwise have sufficient air movement to achieve a comfortable micro climate. Existing windcatchers in Oman are multi directional, so that air movement from any direction will be channelled into the house. (Fig 333-40).

In climatic conditions where temperature and humidity are both high, the air is heavily laden with water vapour and quickly becomes saturated so that very little evaporative cooling can take place on the skin's surface unless air next to the skin is continually replaced by air movement. This can sometimes only be achieved by the use of windcatchers.

Although multi directional windcatchers are auitable for the use on the North Coast of Oman, where the changing onshore and offshore breezes are beneficial, in other areas where there is a dominant wind direction, single direction windcatchers may be advantageous (such as those used at present in Cairo - malkaf).

Windcatchers provide an extremely simple method of directing air movement into an otherwise poorly ventilated room, and they can be closed down with planks or matting during cooler months when air movement is not required for cooling, enabling the occupant to control the micro climate of his dwelling. Cloth windcatchers in particular have the advantage that they can be taken down completely. (Section 3.3.2.D.)

Whilst the multi directional windcatchers of the Batinah Coast allow a well balanced air movement velocity into a room suitable for the climate of this area, a large proportion of the air channelled down the windcatcher returns immediately up the adjacent shaft, reducing velocity in the room, and likewise reducing the area that can be ventilated. Single shaft towers with separate outlets placed at a distance from the windcatch do sometimes allow air to circulate more efficiently through a larger room, since there is no immediate adjacent outlet, and in this case individual shafts could be placed slightly apart from each other, which whilst still being multi directional, will ventilate the room more effectively.

In some urban areas of Oman, particularly in Coastal areas, air movement is inhibited in settlements by the density of building. The adoption of windcatchers in these areas should be encouraged. In many cases they can be incorporated into existing town houses with little difficulty.

9.3.2. (ii)

Windows

Whilst in general the main functions of a window are firstly to permit light to penetrate the interior of a building in such quantity and distribution that a satisfactory interior illumination results, and secondly to provide a view of the exterior, in the case of Oman and hot countries in general, ventilation and the onctrol of glare that results from the brightness of the exterior light are both equally important functions. An additional function is to permit privacy while still permitting a view of the exterior.

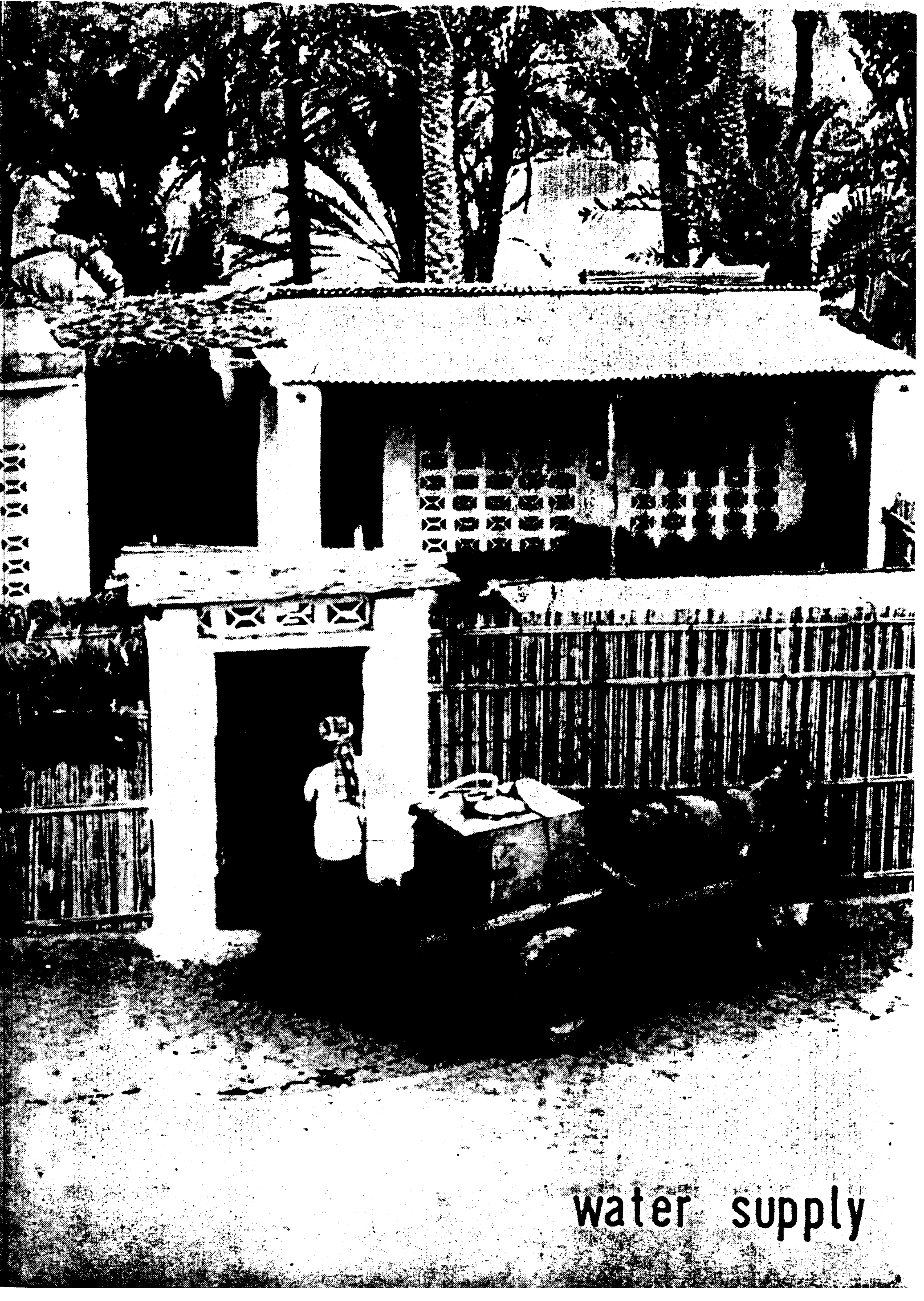
Windows in Oman fall into two types - those that are simple unprotected openings, as in the case of most Northern Upland mud brick house windows, where the control of light is provided by shutters; and secondly those openings or screen walls that in fact a latticed light baffle to the exterior.

The first category requires no elaboration being the basic form of window opening. The second category divides into two parts. In Muscat and Mutrah in particular, ordinary window openings are occasionally fitted with a lattice frame, constructed in a pattern that balances the areas of solid timber against the voids, so that the light that enters the room is reduced and equally that the impact of the exterior brightness is reduced. The contrast of the bright exterior surface against the apparant darkness of the interior also provides visual privacy for the occupant. A similar screen is also produced with the use of gypsum claustre work.

The second type is screens made up of stripped barasti stems, (Fig 372-9) which, as with the previous example, by merit of the balance between solids, being the stems, and voids, being the gaps between the stems, again controls the amount of light that enters the room, provides visual privacy for the occupant, and, as in the case for the wooden lattice, because of the relationship of dark and light areas, also causes the eye to focus upon the screen itself when the exterior is too bright, and allows the eye to focus beyond the screen when the exterior light intensity nears that of the interior. These factors all make for visual comfort. Although the former is a craft made article, the barasti screen, although a natural and largely spontaneous product, has an advantage, in that the stems have a circular section which allows the focus of the eye to move smoothly from dark to light areas, producing a harmonious effect to the viewer.

The barasti screens also have advantages in that they permit relatively unhindered passage to air movement into the building, a fact that is important in achieving or approaching comfort conditions in the climate of Oman.

Both types of screen could have a more widespread use than is at present the case, since they control the quality of light in conditions that make this necessary, and allow ventilation. Wooden screens should however be used with curved or circular sections to avoid an abrupt change from darkness to light. Circular elements in the screen thus cut down the contrast between the outside light and the solid dark areas of the screen itself.



water supply

9.3.2 (iii)

Water Supply, Storage and Washing Areas

Availability of water is a prime determining factor for settlement. Agriculture as well as humansrequires sufficient supplies of fresh water. Human requirements necessitate constant supplies of uncontaminated water while agriculture's requirements may be seasonal.

The subject of water is a basic one in Oman where sea-side towns such as Muscat and Salala receive on an average less than 100 mm's of rainfall per year. Inland areas get even less, and rainshowers are erratic and unpredictable. Most areas receive some rainfall in the winter months. Flash storms quickly fill the valleys (wadies) for a few days, but these soon dry up and are empty most of the year. In itself, this rainfall is not enough to support cultivation, and alternative sources of water must be found for irrigation.

On the otherhand efficient crops must be chosen to provide high food value for the amount of water they are given. The accompanying chart[1] gives a range of agricultural crops and shows their efficiency in terms of water required and the number of persons maintained. It can be seen that dates are by far the most efficient crop to grow in areas having little water. It is for this reason that much of the cultivated land in Oman is devoted to date production.

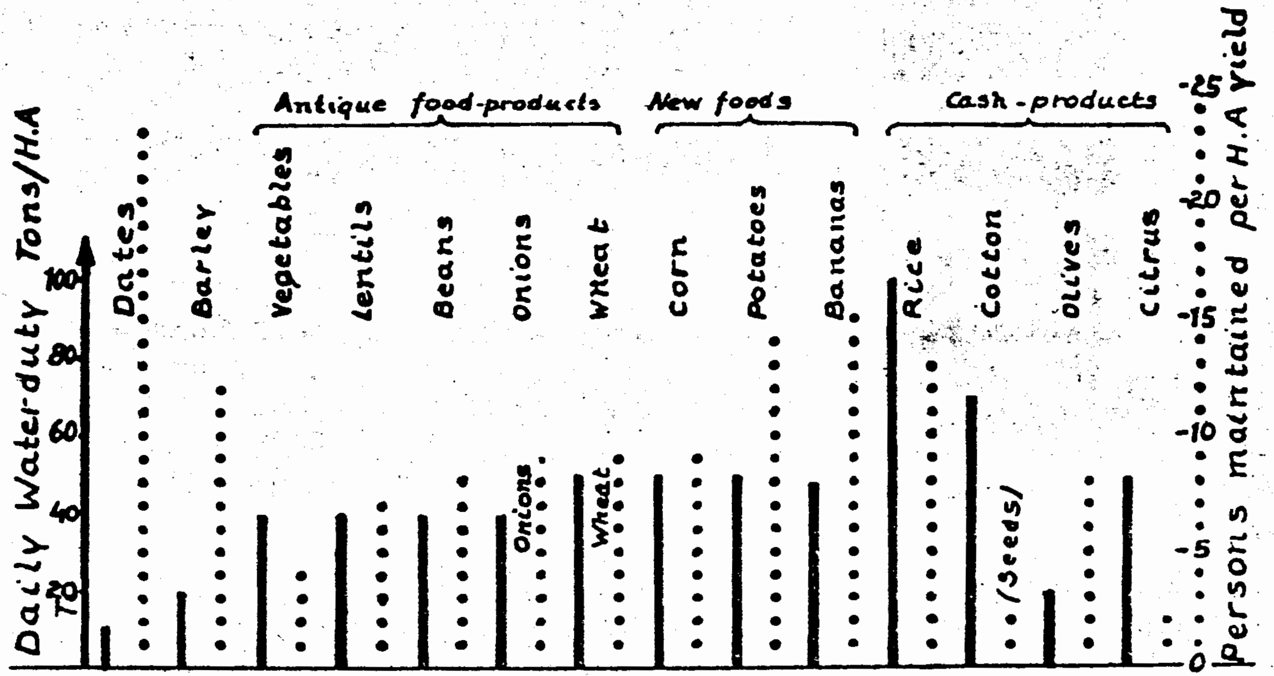


Figure 1. Number of people fed by, and water requirements of, selected agricultural products of the Nile valley

A number of solutions habe been employed in Oman to supply water for human use and agricultural irrigation. Reservoirs are employed to trop rainfall and the occasional seasonal flood waters. This form of water supply is unreliable because it depends on the erratic rainfall. Water retained in this manner lasts only a short while and can do little more than supplement other sources.

---

1. H Stam - New Sources of Energy. Volume 7 pp. 347. United Nations 1964.

Fig. 923
Stepped Well

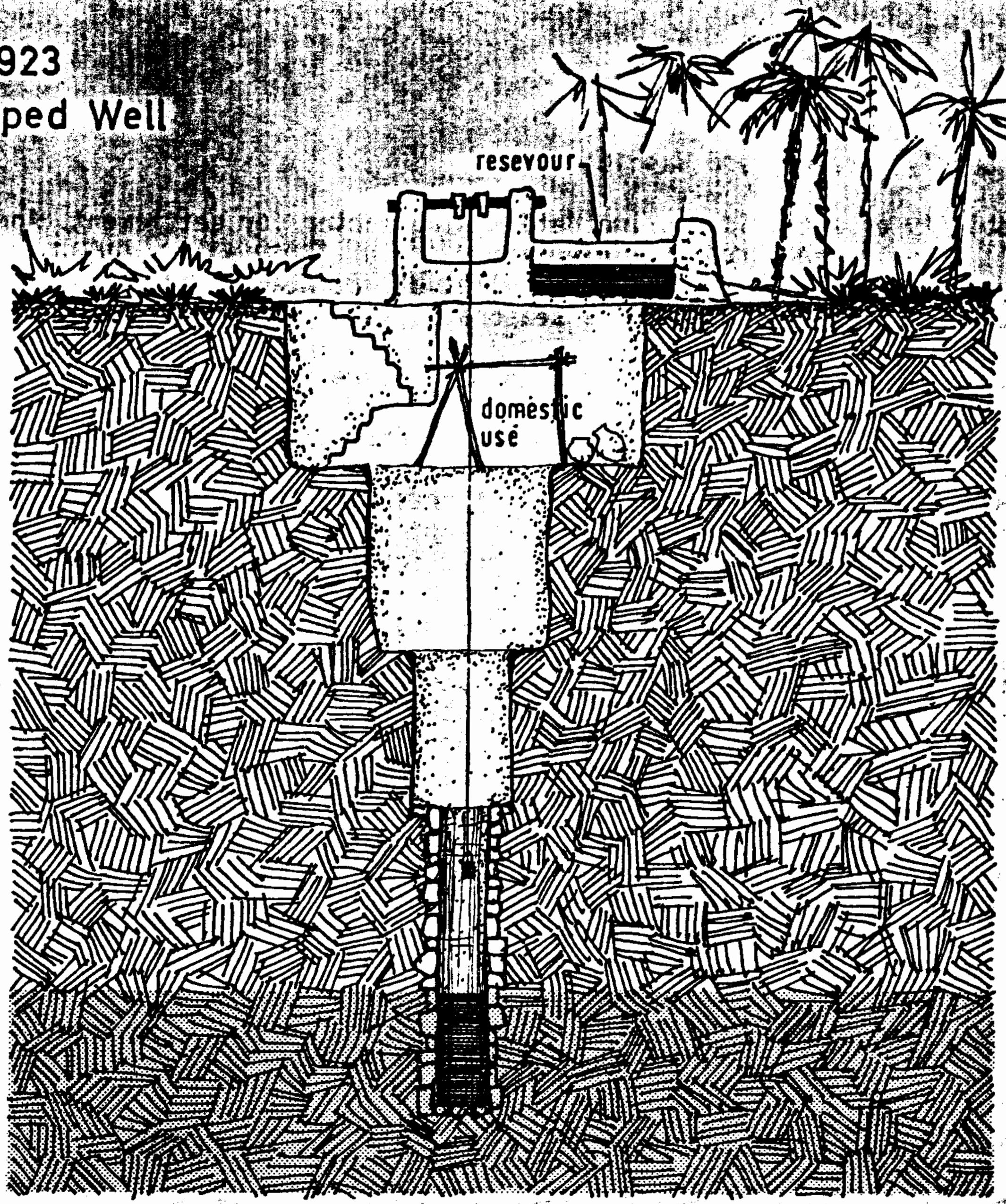
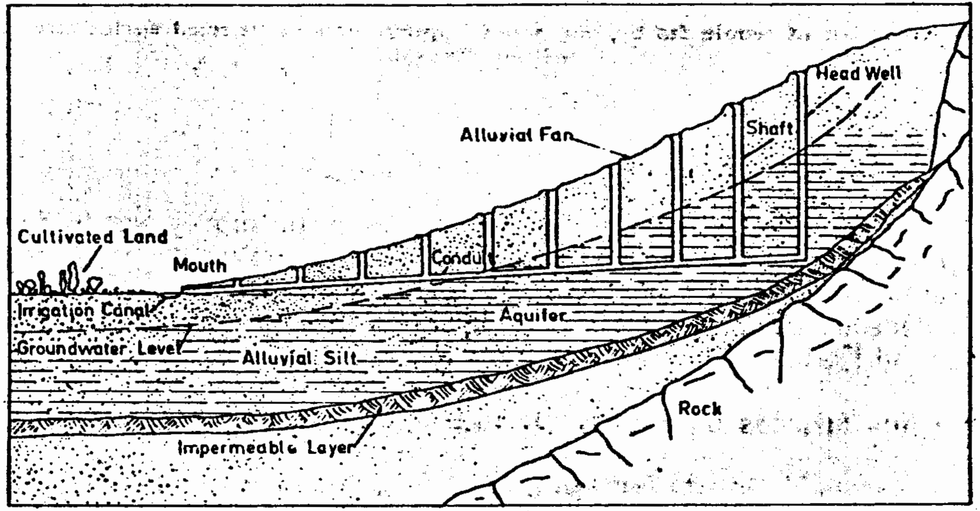


Fig. 924
Falaj - Water Supply System



section

Falaj - Irrigation system

Bathing Areas within house built over the Falaj.

9.3.2 (iii)

Water Supply, Storage and Washing Areas

Availability of water is a prime determining factor for settlement. Agriculture as well as humans requires sufficient supplies of fresh water. Human requirements necessitate constant supplies of uncontaminated water while agriculture's requirements may be seasonal.

The subject of water is a basic one in Oman where sea-side towns such as Muscat and Salala receive on an average less than 100 mm's of rainfall per year. Inland areas get even less, and rainshowers are erratic and unpredictable. Most areas receive some rainfall in the winter months. Flash storms quickly fill the valleys (wadies) for a few days, but these soon dry up and are empty most of the year. In itself, this rainfall is not enough to support cultivation, and alternative sources of water must be found for irrigation.

On the otherhand efficient crops must be chosen to provide high food value for the amount of water they are given. The accompanying chart[1] gives a range of agricultural crops and shows their efficiency in terms of water required and the number of persons maintained. It can be seen that dates are by far the most efficient crop to grow in areas having little water. It is for this reason that much of the cultivated land in Oman is devoted to date production.

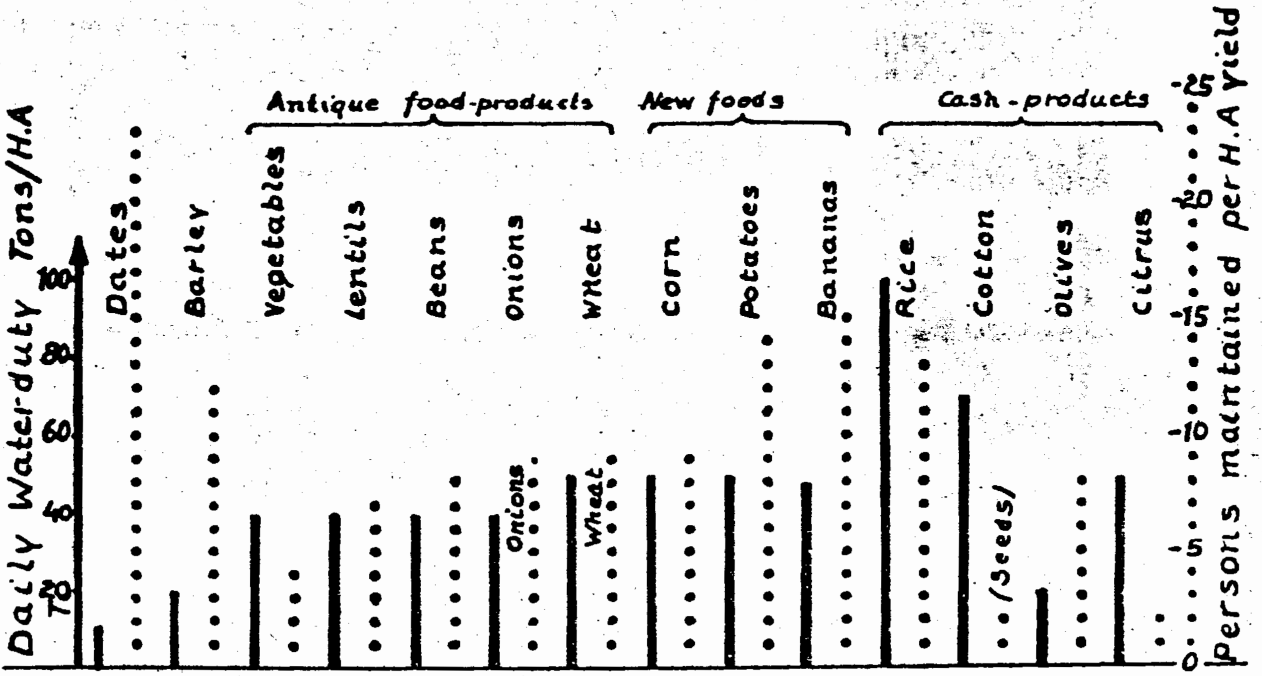


Figure 1. Number of people fed by, and water requirements of, selected agricultural products of the Nile valley

A number of solutions habe been employed in Oman to supply water for human use and agricultural irrigation. Reservoirs are employed to trop rainfall and the occasional seasonal flood waters. This form of water supply is unreliable because it depends on the erratic rainfall. Water retained in this manner lasts only a short while and can do little more than supplement other sources.

---

1. H Stam - New Sources of Energy. Volume 7 pp. 347. United Nations 1964.

Fig. 923
Stepped Well

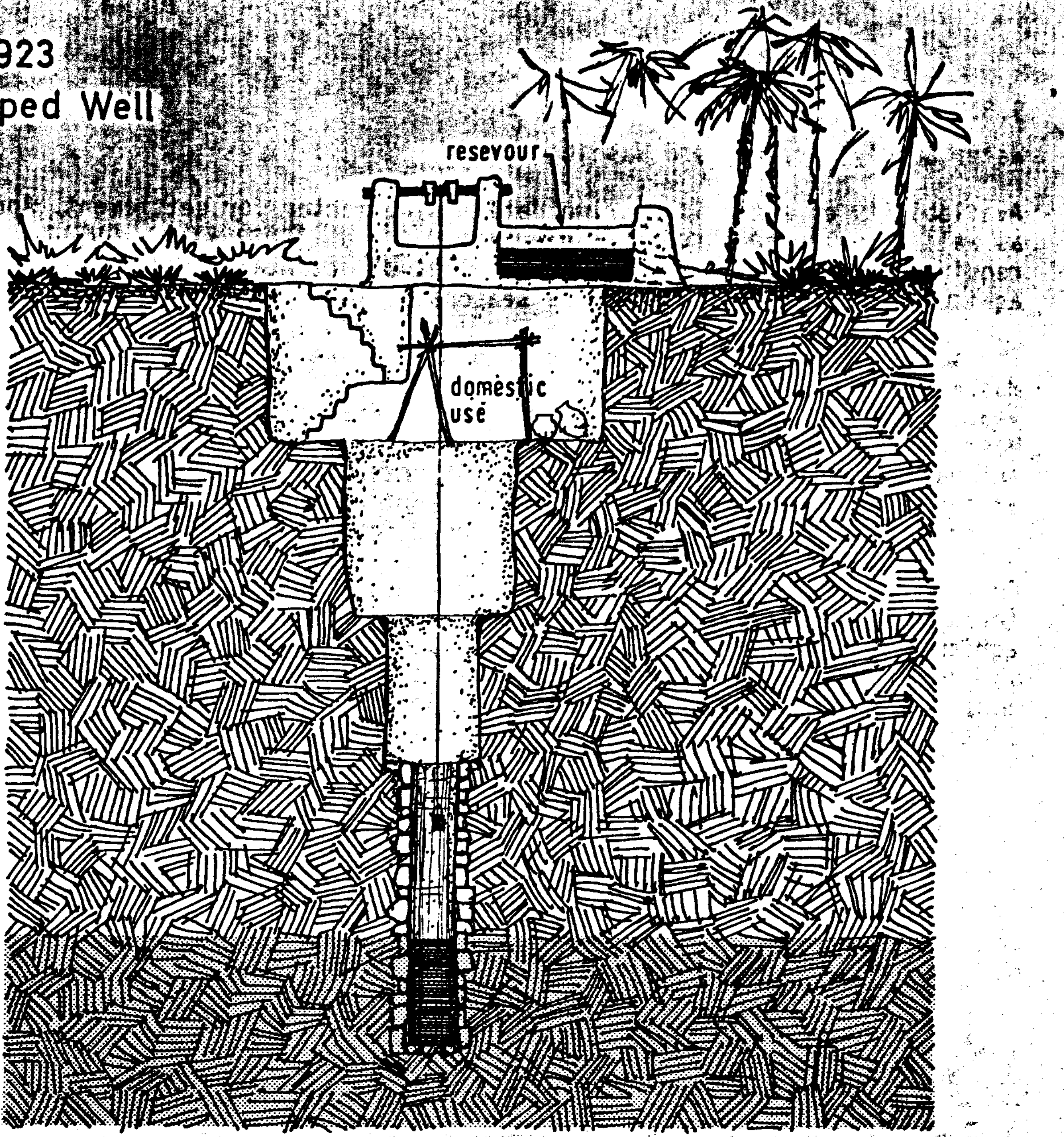
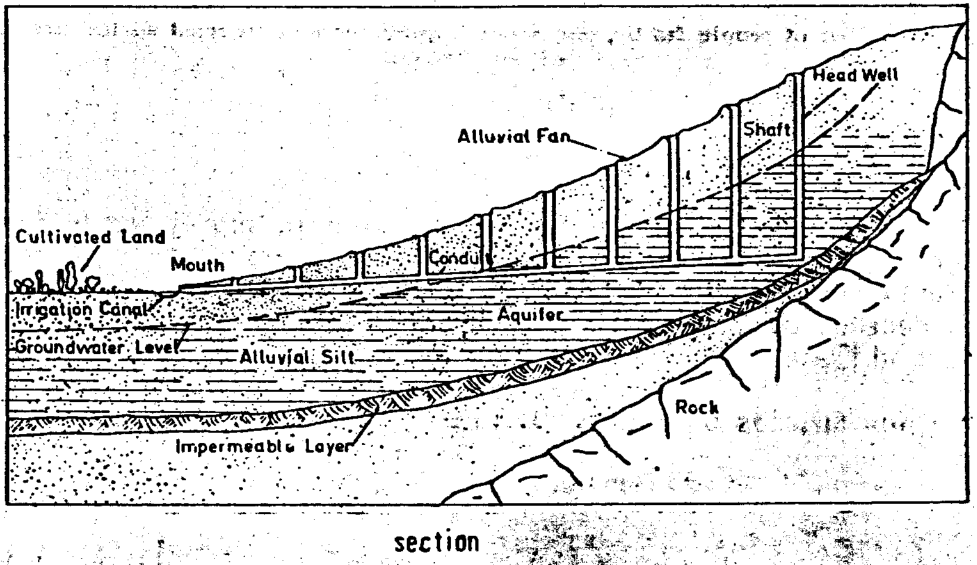


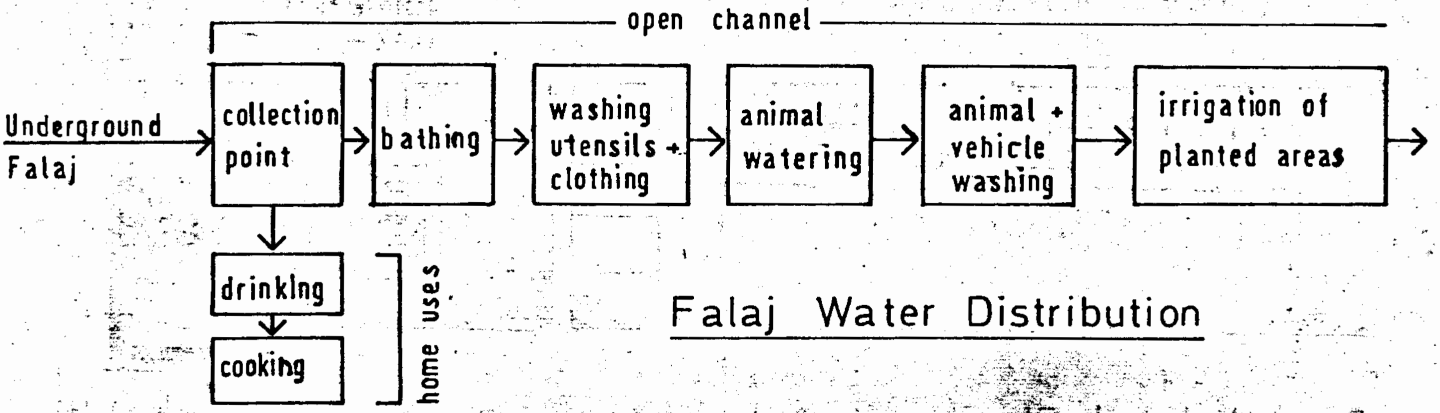
Fig. 924
Falaj - Water Supply System



Wells are reliable sources of clean cool water. The water table is in most places deep and a great deal of energy is needed to raise the water to the surface. In the past human and animal power was only able to irrigate a limited area of land. The digging of wells also presented a problem. This was overcome in Oman (see Fig.923) by a system of digging down in a stepped fashion, each step making the diameter of the pit smaller as the pit went deeper. In this way earth could be brought up out of the pit, in simple stages.

To avoid the need to expend energy in raising quantities of water to the surface for irrigation, a method invented centuries ago and widely used in the Middle East to bring water to the surface, is employed. It involves tapping the agufer or water table in high ground or hills and bringing the water down through tunnels to cultivated areas in the valleys or plains (see Fig.924).

In Oman this water distribution system is called the 'Falaj'. The actual distribution of Falaj water is organised in such a way as to minimize the chance of contamination. A definite linear ulitization pattern is held to as the water flows throughthe settlement, ensuring that human requirements for water are first met before water has a chance to be contaminated by washing or cattle watering. The observed flow pattern is as follows.



Falaj Water Distribution

It can be seen that drinking water is always taken from the Falaj, at the point that it emerges from the ground, to ensure that it is as clean as possible. Water is often collected from this point and deposited in pots at points further along the Falaj, for public drinking. In Al Hamrah in the Northern Uplands the most sophisticated Falaj system was noted. Here houses fronting onto the Falaj had bathing rooms built over the Falaj so that washing could be done privately. Systems have also been long established to control the flow of water into private plots in conjunction with a tax levied on the volume of water used. Income from water taxes went to support schools and other public facilities.

Improvements upon the traditional Falaj system are suggested in Fig.925. A sand filter is introduced along with a disinfectant tank to ensure that drinking water always meets safety standards. Improvements are suggested for the design of public bathing facilities.

In town centres it is not possible for everyone to have direct access to either the Falaj or wells. In the absence of piped running water, drinking water is distributed by tanker. (see introductory photograph). Vehicles, engine or animal powered, can collect fresh water from wells or from the head of the Falaj and distribute it throughout the community.

The indigenous domestic water storage vessel in hot countries is the unglazed ceramic jar. These jars take various shapes in different countries but

Fig. 925

Falaj - Irrigation system

Bathing Areas within house built over the Falaj.

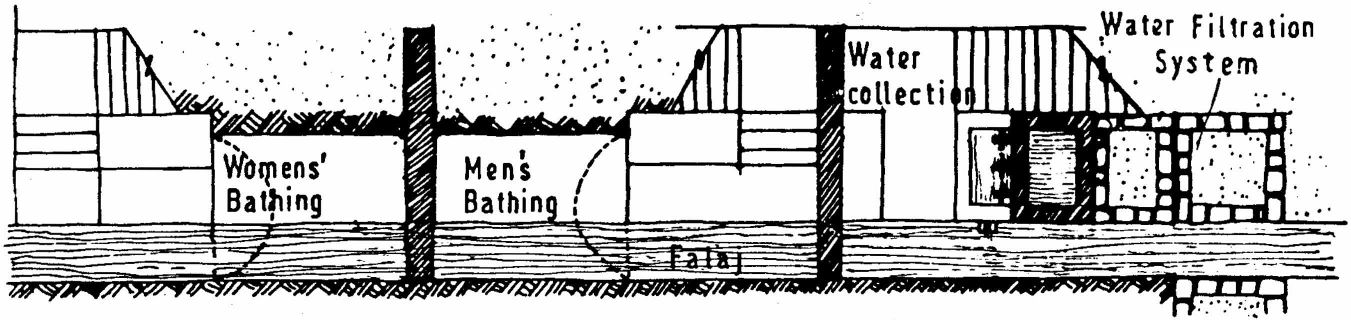
Fig. 925

Falaj - Irrigation system

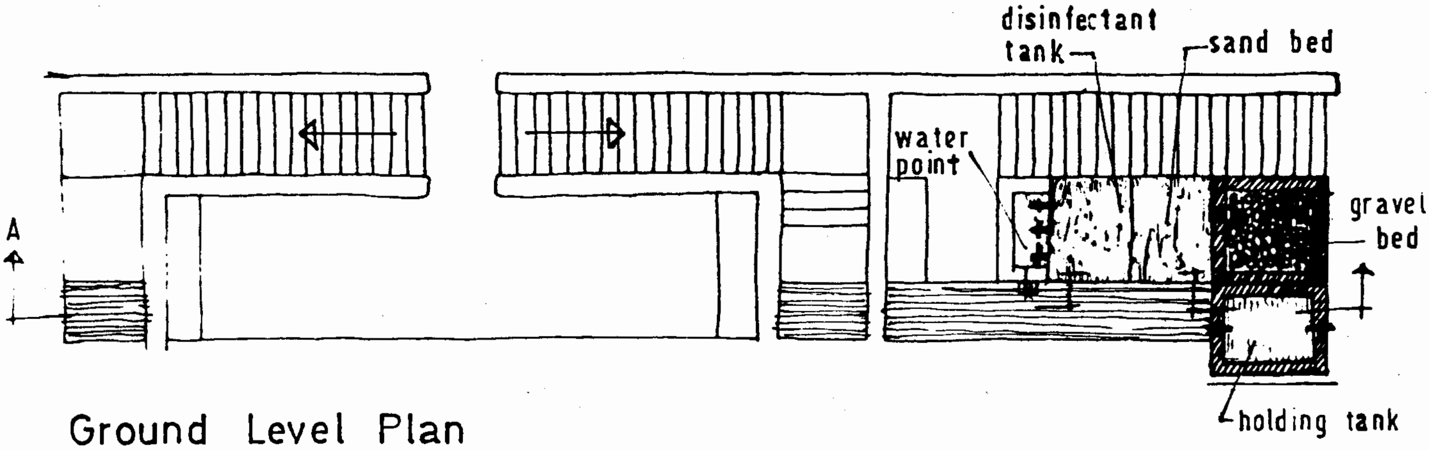
Bathing Areas within house built over the Falaj.

Fig. 926

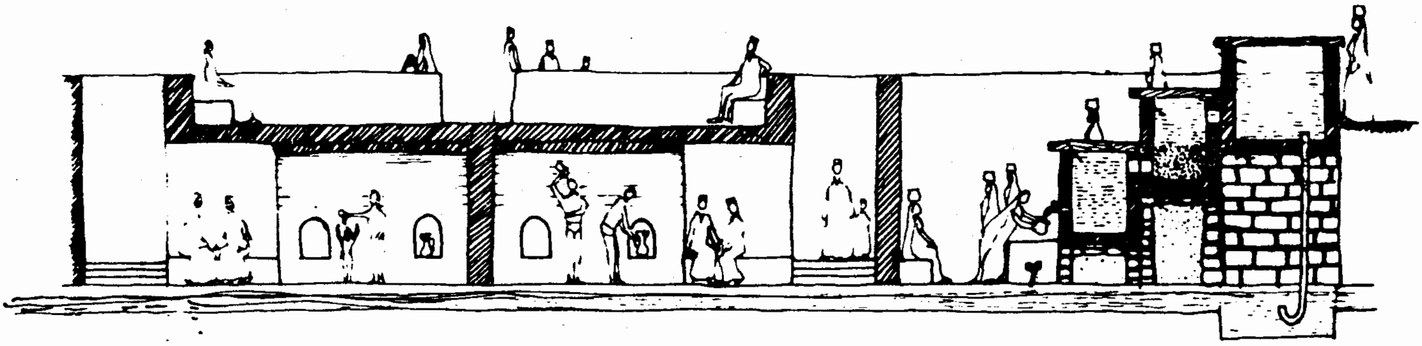
Falaj - Water Purification + Bathing Area Improvements



Falaj Level Plan



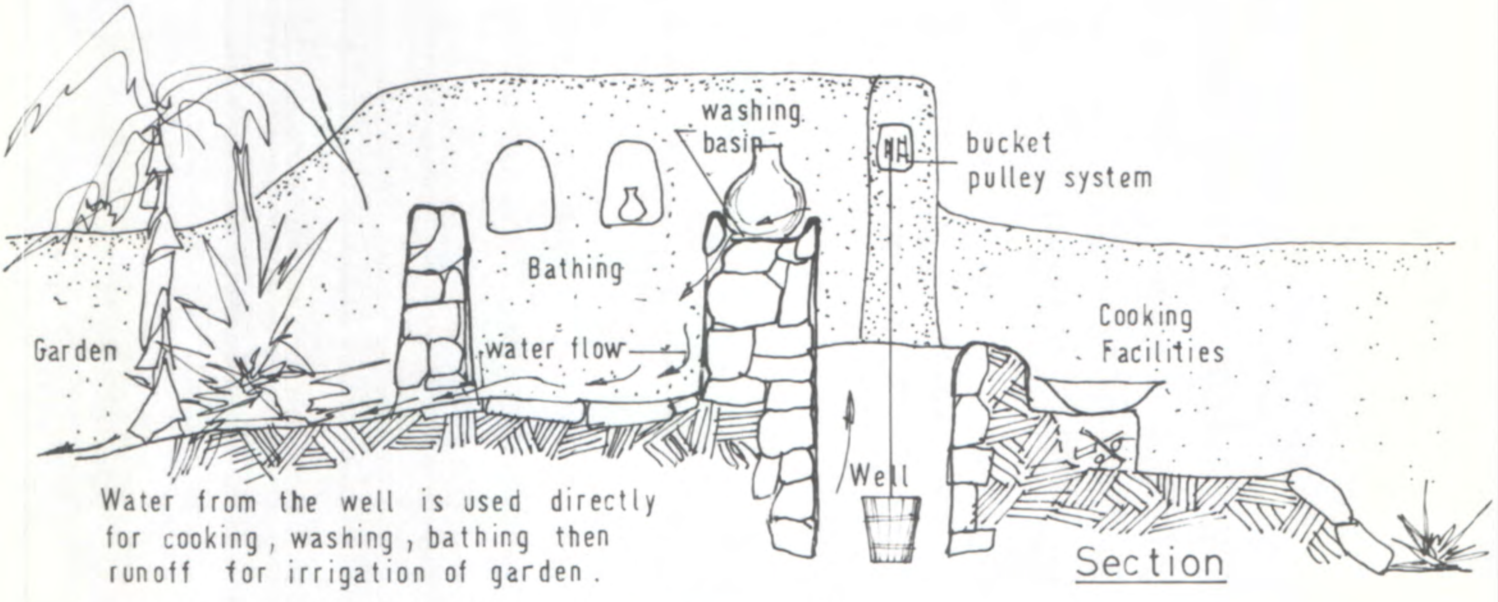
Ground Level Plan



Falaj Section A-A

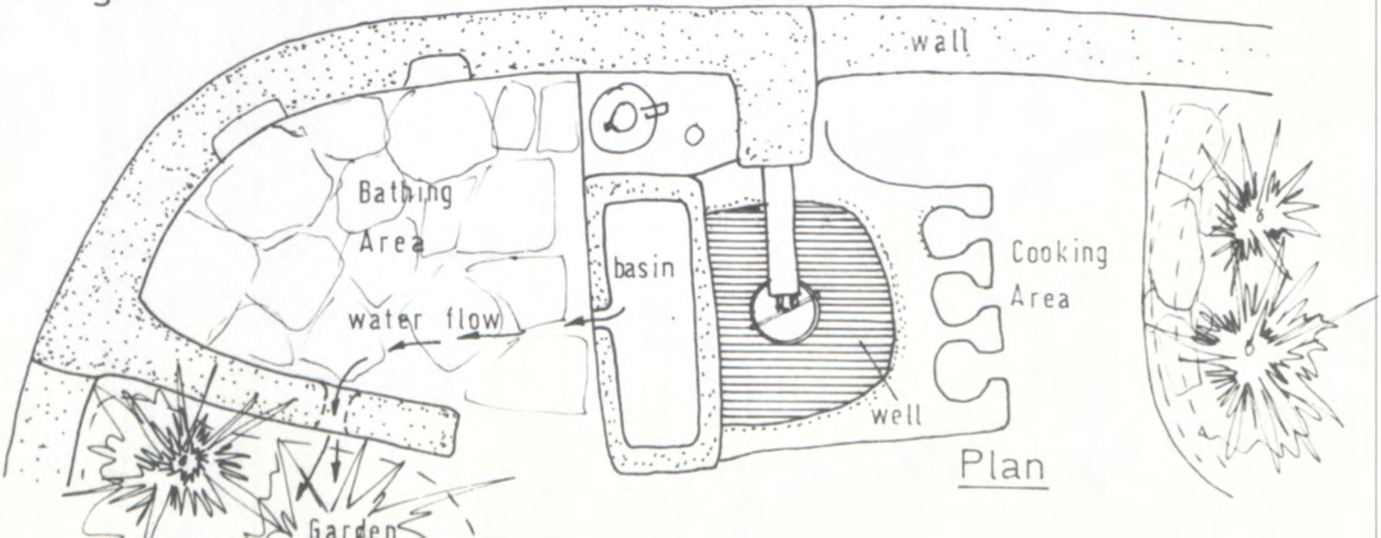
Fig. 927 Washing Facilities

Washing Area designed by Professor Hassan Fathy



Water from the well is used directly for cooking, washing, bathing then runoff for irrigation of garden.

Washing Area for Nizwa Summer House



functions similarly. Water placed inside seeps through the porous pot to the outside surface. Evaporation of water from the pot's surface causes cooling of the pot and its contents. The degree of cooling is dependant on the percentage of humidity in the atmosphere and on air movement over its surface. See Fig. for an example of the use of these pots in a cooling system in Muscat. Large quantities of water can be stored coolly in cisterns or reservoirs underground. A gravity system for running water for bathing etc. can be introduced by placing storage tanks on the roof of the house directly above the area where water is needed. Water can either be carried up by hand or pumped to the roof, but the container must be sheltered, from the sun, if cool water is required.

Washing areas within the home should be designed so as to conserve as much water as possible. Indigenous examples of demestic washing facilities show the concern that was taken to cut down wastage. In the example Fig.927 an integrated washing, bathing, well and cooking area is illustrated. Water runoff from washing is channelled to the bathing area and finally is used to irrigate a fruit tree.

An example of a well designed washing area based on physiological proportions is illustrated in Fig.928. The designer Professor Hassan Fathy, studied the way women go about washing clothes in order to minimalize the energy and effort expelled during the process.

These two examples illustrate how washing areas can be designed that harmonise with traditional ways of washing and yet are acceptable in health terms while being inexpensive enough and simple enough to construct for the average Omani.

9.3.2 (iv)

Public Health: Sewage Disposal

The problem of sewage disposal along with plans for the provision of an adequate supply of safe drinking water are big issues in the study of environmental sanitation. The inadequate and insanitary disposal of infected human waste leads to the contamination of the ground and sources of water supplies, as well as increasing problems with insects and rodents. Diseases spread by insanitary sewage disposal systems include cholera, typhoid and paratyphoid fevers, dysentry, infant diarrhoea, hookworm, ascariasis, bilharzia and other parasitic infections. Man in the reservoir of most of the diseases that destroy or incapacitate him. The technical objective of sanitary excreta disposal is therefore to isolate human waste so that the infectious agents in them cannot possibly get to a new host.

A World Health Organisation publication states that, "Mere technical improvement of the environment without public education in hygiene and sanitation, based on local customs, traditions, and beliefs, has again and again proved futile." [1] An understanding of indigenous methods of waste disposal and their shortcomings is important.

The Islamic culture itself places great importance on sanitation and personal hygiene. Locally used systems of sewage disposal, especially in rural areas, may have in the past been quite adequate. Populations of low density can exist healthily by disposing of wastes in a natural way away from inhabited areas. It is a wide spread practice of inhabitants of coastal areas to deficate on the tidal flats where the salt water tides will cleanse the beach twice daily.

These traditional practices break down and become health risks when rural population densities increase such as in urban areas. It is common practice in long established town houses to incorporate a latrine into the basic plan (Fig.407). Usually the latrine is located on the first floor and a room is located directly beneath it to collect sewage wastes. This lower room has no opening and is never emptied, and often constitutes a health risk. If walls are made of mud brick there is a danger of liquid waste seepage through them. Seepage through the ground contaminates the surrounding soil, and smell is often a problem. In areas such as Salala, where limestone bedrock is found close to the surface, water forn bacteria is carried over large areas, because there is chance for it to filter down into the soil.

In coastal towns the practice of deficating on the beach front is still common. Such intensive use does present a health risk since the beach is sometimes used for bathing as well. This problem has been greatly agricated in Mutrah in the Capital Region where a corniche has recently been built along the beach front cutting it off from the inhabited town area. Residents who are without other sanitary facilities are forced to use a small area where the tides still flow under the new road.

Due consideration for an indigenous system of dealing with one problem, in this case sewage disposal, would minimalize the possibility of aggrivating it by changes made to solve other problems.

The realm of public health, particularly sewage disposal, is an area where action must take place in a co-ordinated planned way. Municipalities or even small communities must develop solutions appropriate to their local conditions. A range of technical solutions to sewage problems are available, the choice depending upon factors such as population density and settlement pattern, physical terrain, slope of land, type of soils, economic feasibility and cultural implications.

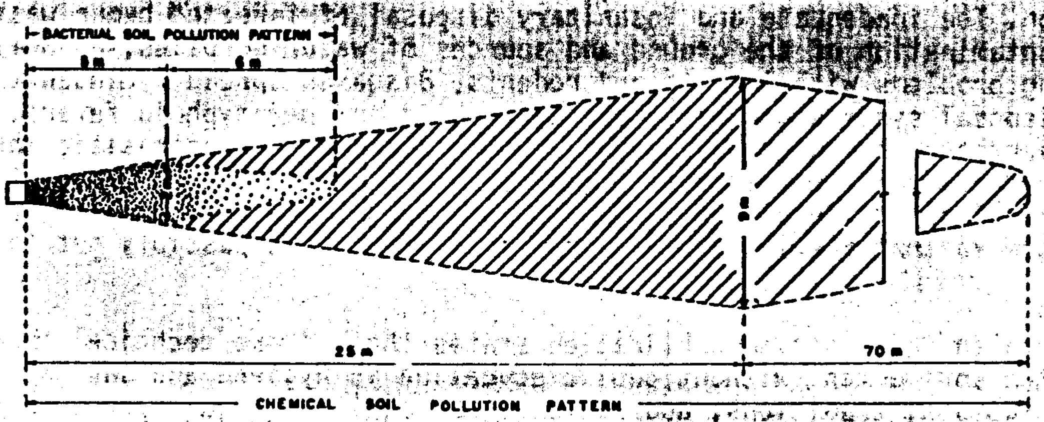
---

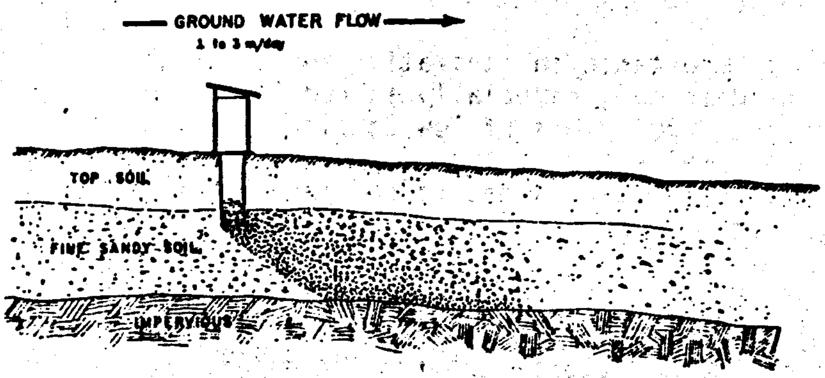
1. pp. 17. Excreta Disposal for Rural Areas and Small Communities. W.H.O. 1958

Fig. 934

Pit Privy Sewage Disposal System

BACTERIAL AND CHEMICAL SOIL POLLUTION PATTERNS AND MAXIMUM MIGRATIONS*





The source of contamination in these studies was human excreta placed in a hole which penetrated the ground-water table. Samples positive for coliform organisms were picked up quite soon between 4 m and 6 m (13 ft and 19 ft) from the source of contamination. The area of contamination widened out to a width of approximately 2 m (7 ft) at a point about 5 m (16 ft) from the privy and tapered off at about 11 m (36 ft). Contamination did not move "upstream" or against the direction of flow of the ground water. After a few months the soil around the privy became clogged, and positive samples could be picked up at only 2 m to 3 m (7 ft to 10 ft) from the pit. In other words, the area of soil contamination had shrunk.

The chemical pollution pattern is similar in shape to that of bacterial pollution but extends to much greater distances.

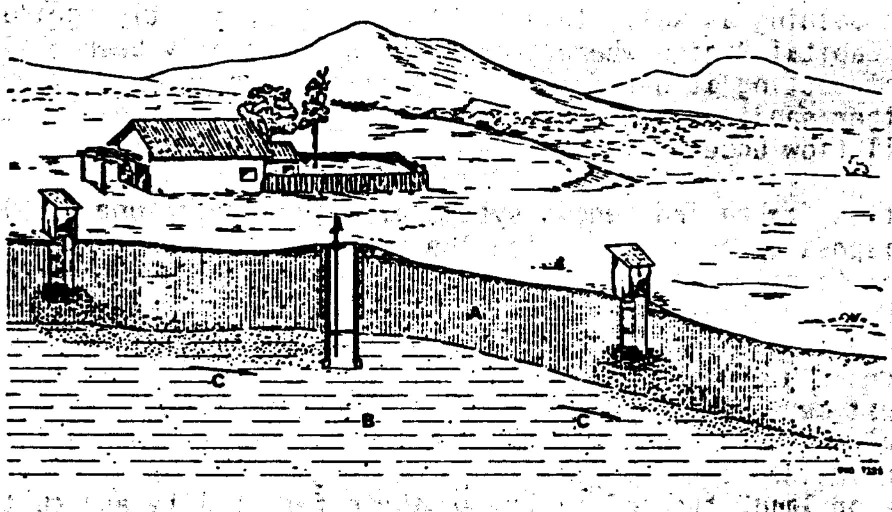
From the point of view of sanitation, the interest is in the maximum migrations and the fact that the direction of migration is always that of the flow of ground water. In locating wells, it must be remembered that the water within the circle of influence of the well flows towards the well. No part of the area of chemical or bacterial contamination may be within reach of the circle of influence of the well.

---

* Based on data from Caldwell & Parr [4, 5] and Dyer, Bhaskaran & Sekar.[10, 11]

THE PRIVY METHOD OF EXCRETA DISPOSAL

MOVEMENT OF POLLUTION IN UNDERGROUND WATER



A = Top soil B = Water-bearing formation C = Direction of ground-water flow

Sewage disposal can be solved within the individual house, using pit privies, septic tanks, cesspools etc. or on a community level, necessitating a water born or collection system and a disposal plant. In general the individual house can cope with its own sewage problem if settlement patterns show wide spacing, but in dense urban situations it is advantageous to solve the problem on a community level.

a) Individual Dwelling - Low Density Settlement

A number of sewage disposal solutions which pertain to single houses will be discussed here.

Pit Privy: The pit privy (Fig934) represents the lowest (construction) cost solution to sanitary waste disposal. The pit privy is a dry disposal system and the sanitary fixture (squatting plate) must be directly over the pit. If located and built properly there will be no soil polution or surface or ground water contamination, flies and rodent problems minimul, no handling of material and negligible odour. On the otherhand, to ensure that privies do not contaminate wells they must be placed at least 15 meters away to prevent bacterialogical infection and 25 meters or more away to prevent chemical polution. Privies should be sited at least 6 meters away from dwellings. The pit privy is unsuitable in areas with bedrock close to the ground (such as Salala) because bacteria can be carried great distances by water trapped above the bedrock. In densely settled areas the distance requirements for privies can not be met and this solution is unsuitable.

Compost Privy: Night soil has been used as fertilizer by many different cultures. The danger of contamination by bacteria and parasites of crops, particularly vegetables grown close to the ground, is now known. Investigations show on the otherhand that if the human waste is retained and decomposed for a period of time, the heat generated in the decomposition or composting process will kill dangerous bacteria. Organic kitchen wastes can be disposed of along with human wastes in this manner.

Waste must be kept several months to ensure that pathogenic organisms die off. For this reason two identical privies are required so that wastes in one can be left to decompose without additional bacteria. The composting cycle between the two pits should be 9 to 10 months. After this period, compost can be removed from the privy and used as fertilizer on the fields.

Night soil which is periodically collected by the municipality in Salala has been used as fertilizer. It was declared free of dangerous organisms by the British Royal Engineers based in Salala.

Compost Privy

DOUBLE-VAULT LATRINE

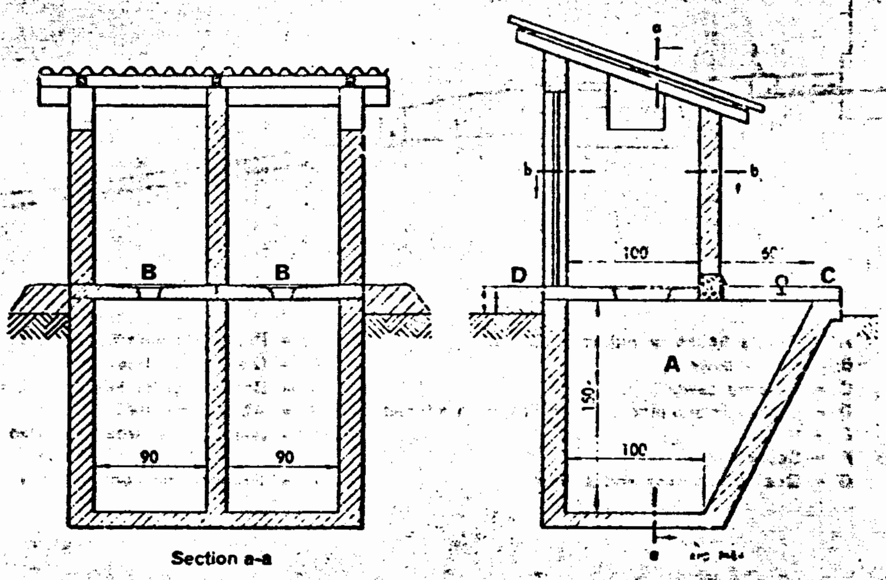
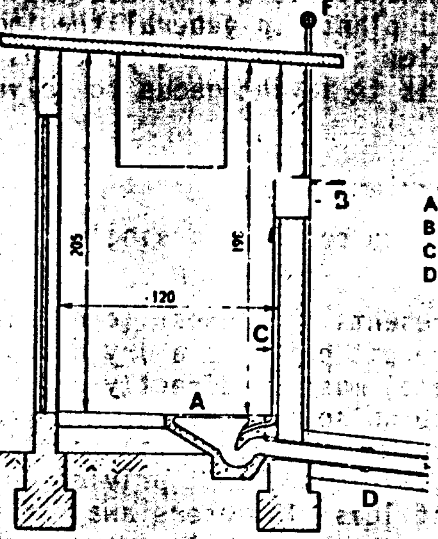


Fig. 935

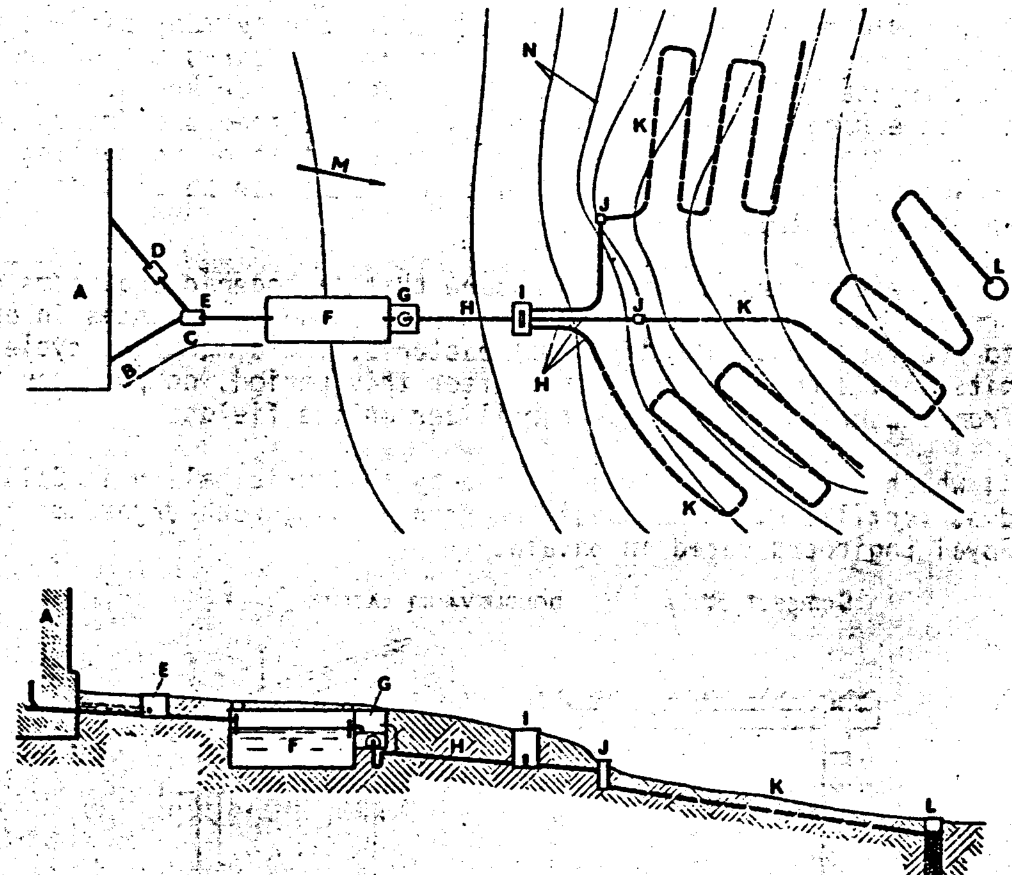
Fig. 936

WATER-SEAL LATRINE



A = Water-seal bowl with S trap
B = Water tank, filled by hand and provided with plug cock and overflow pipe
C = Water pipe leading from tank to bowl for flushing purposes
D = Drain pipe embedded in concrete leading to seepage pit

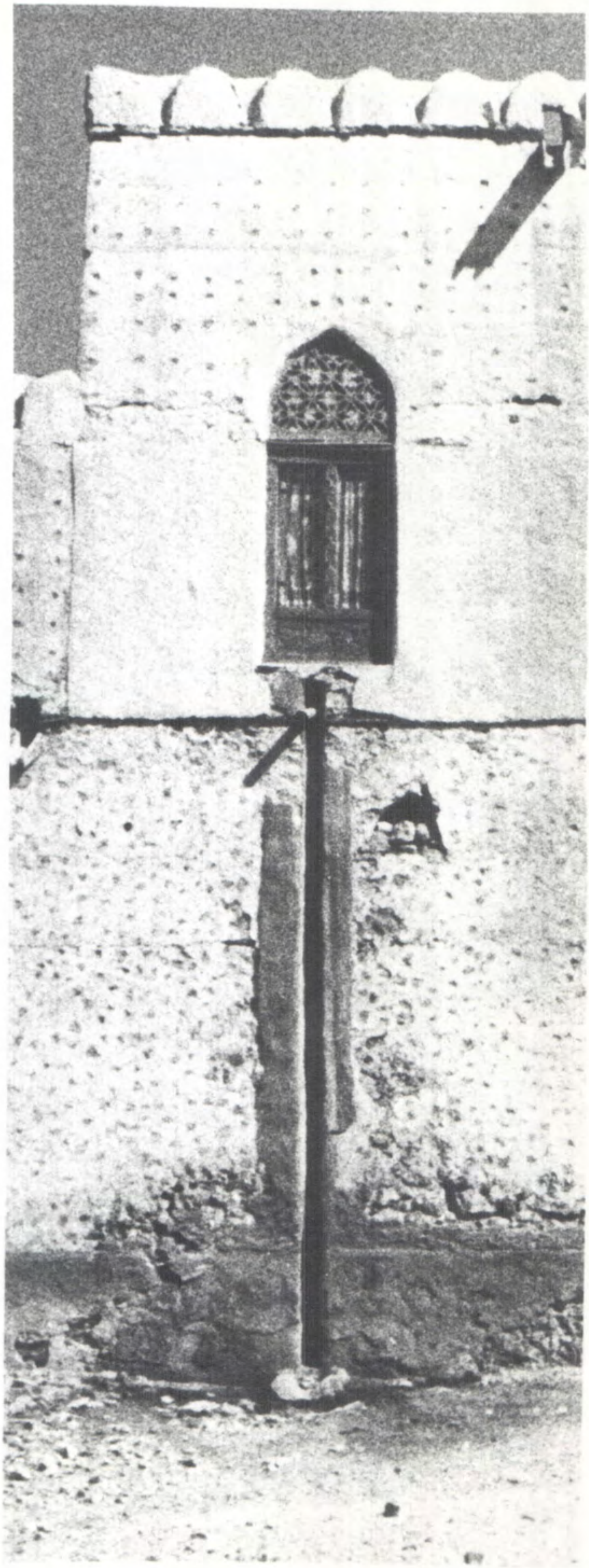
TYPICAL LAYOUT OF SEPTIC-TANK SYSTEM



A = Private house or public institution
B = House sewer
C = Building sewer
D = Grease interceptor on pipe line from kitchen
E = Manhole
F = Septic tank
G = Dosing chamber and siphon
H = Pipes laid with tight joints
I = Distribution box
J = Drop-boxes or terracotta L's
K = Absorption tile lines
L = Seepage pit, when required
M = Slope of ground surface
N = Topographic contour lines

Fig. 937

In densly settled areas waste water disposal and drainage should be dealt with on a community level.



Septic Tank: The septic tank is a water-carried system for the disposal of excreta. A water seal latrine (Fig.936) is used in conjunction with this disposal system so that the latrine itself can be located within or directly adjacent to the dwelling. Although only small quantities of water are necessary for its operation this can be a serious disadvantage in areas with water shortages. Drinking water standards are not necessary for the carrier water. The fact that there is a carrier medium for the waste means that the disposal area need not be directly adjacent to the house, giving this system a measure of flexibility. One septic tank and disposal system can serve several houses or a small community. The disposal system incorporates a septic tank where sewage is retained for 1 to 3 days during which time solids settle out, and undergo bacterialogical decomposition and a secondary disposal bed into which the effluent flows to undergo a further decomposition process involving oxidation. Liquid waste is filtered through the disposal beds into the soil after decomposition at which time the effluent is no longer dangerous.

Sludge must be removed from the septic tank periodically (1 to 4 years) and the system requires a degree of continuous inspection and maintenance. A principal drawback with this system is the fact that disposal beds occupy large areas of ground.

b) Community Sewage Disposal - Towns - Urban Areas

The water born system of sewage disposal offers one solution to the problem in crowded town cnetres or urban areas. These areas already have defined settlement and street patterns. The organised efficient sewer system plan that the sanitary engineer might design, can not be simply laid over existing settlement plans. New flexible plumbing systems (using easily workable P.V.C. piping) could offer a solution. Costs may be quite high because sewer piping would have to follow existing streets rather than be laid in straight lines. Water borne systems are also dependant on gravity to ensure flow. This also adds maintenance problems; systems with bends and turns require more inspection facilities.

Sewage can be carried to a disposal plant which can deal with all of the town's wastes. The design of the disposal plant depends on the quantity of waste and the local physical and environmental factors.

Dealing with a communities sewage in a uniform way ensures that safety standards are always maintained if the desposal plant is run efficiently. If everyone had his own sanitary disposal system, checks must be kept on them all.

Communities need not resort to the water 'carrier' system of sewage disposal. Salala for example is an urban area, though not densely clustered, which has introduced pumping trucks to collect sewage wastes from individual dwellings (Fig.815), since it is not safe for individual houses to dispose of their own wastes. Instead a house's sewage is retained in tanks and collected periodically (approx. every 6 months) by tanker trucks and then desposed of.

These are two options i.e. a water borne system and tanker truck collection which are available for urban areas where individual disposal is not possible or safe. Technical data for the design of sewage disposal systems can be obtained from:

World Health Organisation publication.
Excreta Disposal for Rural Areas and Small Communities.
E.G. Wagner and J.N. Lanois 1958. Geneva

Fig. 929 Cooking Areas

Raised platforms are often used for storing food. The introduction of insect and rodent guards would be an improvement.

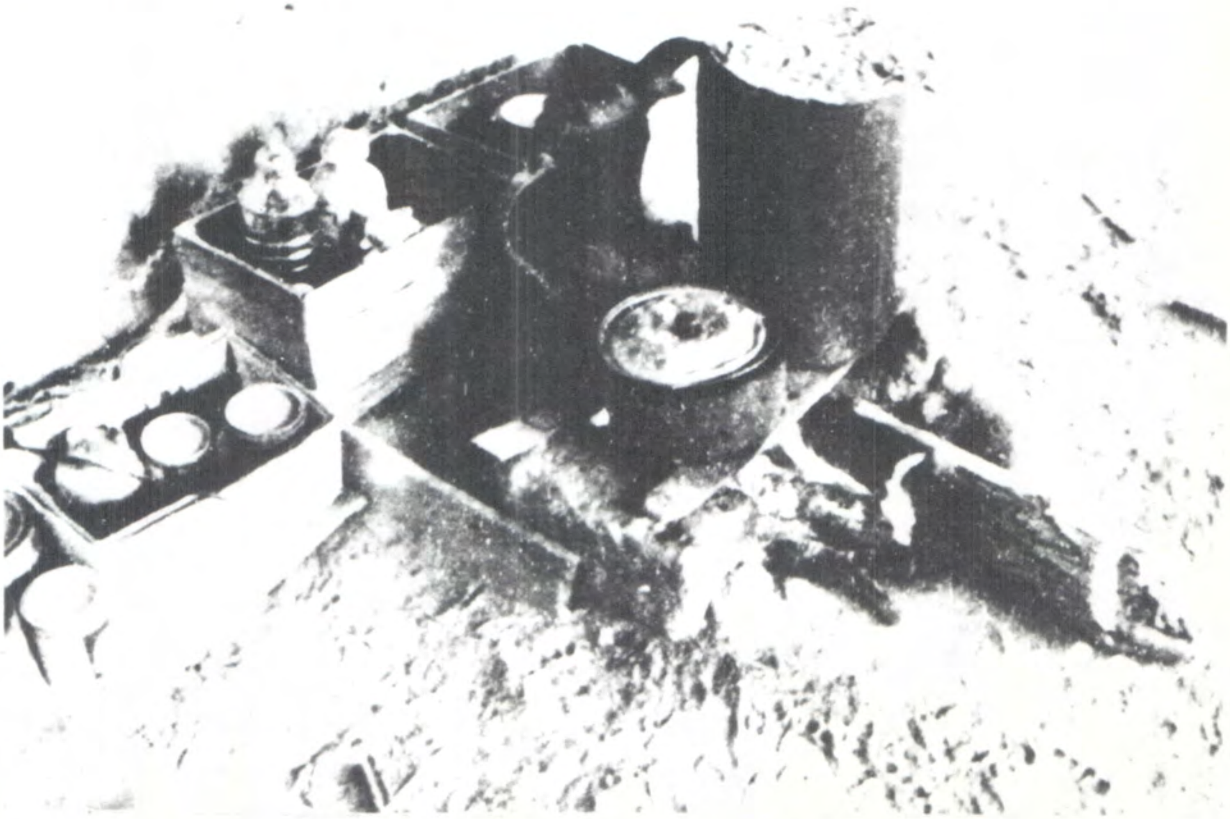


Fig. 930 Typical facilities for cooking in existing rural houses.

9.3.2 (vi)

Cooking Areas

Cooking is an activity requiring special attention when considering the design of houses. Open fires are still often used, these presenting a considerable fire risk in badly designed kitchens. The functions of the cooling area include food storage, fuel storage as well as food preparation and cooking.

Food must be stored in such a way as it is protected from insects and rodents. Some foods, particularly grains must be stored in a dry place, while perishable foods should be kept cool and covered. A high platform (Fig.929) is often used to keep food out of reach of pests. These platforms could easily be improved by installing insect and rodent guards to the supporting posts.

Drying racks are found on the roofs of many Omani houses for the drying of dates. As dates are still an important food source for many Omanis new houses in rural areas should allow access to roofs. Perishable foods are most often eaten quickly because cool storage facilities are not available to most rural Omanis. Evaporative cooling could be utilized simply and inexpensively to provide some degree of cooling for foods. A system used in India employing two ceramic pots, one large and unglazed and a smaller glazed one which is inserted inside the first. Food is put inside the central glazed pot and covered. Water is poured into the cavity between the two pots, moistening the porous outer unglazed pot. Water evaporates from the outer surface of the unglazed pot causing the whole unit to cool (see Fig.931). Since the pottery industry thrives in the interior of Oman, these coolers could be easily manufactured on a local basis.

Fuel storage is a problem if bulky dry kindling is used and by its very nature presents a fire risk. Liquid fuels are sometimes used in rural areas and being more compact, finding space for storage becomes less of a problem. Fuel storage facilities should be kept well away from open fires and be protected from stray sparks or hot ash. Dry fuels can be kept in a bin made of fire proof materials i.e. mud or concrete block. Combustible liquid fuels should be stored away from inhabited areas.

Food preparation is an activity that is generally carried on in a squatting position. Though food's contact with the ground should be discouraged, preparation surfaces and cooking facilities should be located so that cooking habits need not be significantly damaged. Washable surfaces of fired and glazed tiles could be introduced and produced locally.

In rural areas the only cooking fuels which are readily available are solid ones such as dried palm and scraps of wood. Open fires or braziers are often used for cooking. These systems are inefficient in heat output and quantities of fuel consumed. Smoke is a problem and the need to contain sparks must be considered. Without adopting liquid fuel stoves improved cooking arrangements can be designed making use of solid fuels. Professor Hassan Fathy has designed such a stove minimizing fuel consumption while making efficient use of heat generated (Fig.932). A similar cooking system can be borrowed from India. An improved smokeless cooker (chulna) is shown in Fig.933. Both these cooking stoves can be made using simple materials such as mud at very low cost.

Kitchen areas must be designed carefully to ensure firstly that they do not present a fire hazzard and that health requirements are met. In Omani houses cooking is often done in the open courtyard thus minimizing fire risks and ensuring adequate ventilation. Idealy kitchens should be located away from the living area of the house, especially when combustible barasti is the main building material. If physical isolation is not possible, walls dividing the kitchen from the rest of the house should be fire proof i.e. mud brick or concrete. Similarly roofs of kitchens and those roofs immediately surrounding, should not be of barasti because of the problem of sparks igniting them. Chimneys should be used with cookers to ensure that smoke and toxic gas does not stay within the house.

Kitchens should be well ventilated for health reasons. The burning of fuels causes the build up of toxic carbon monoxide, sulfur dioxide and carbon dioxide. Frequent air changes are necessary.

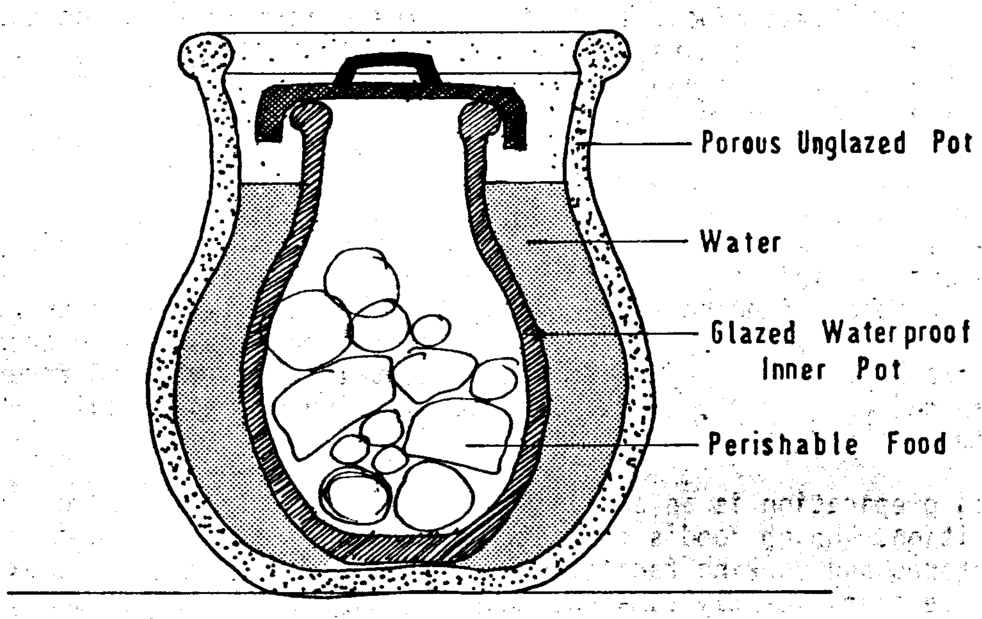
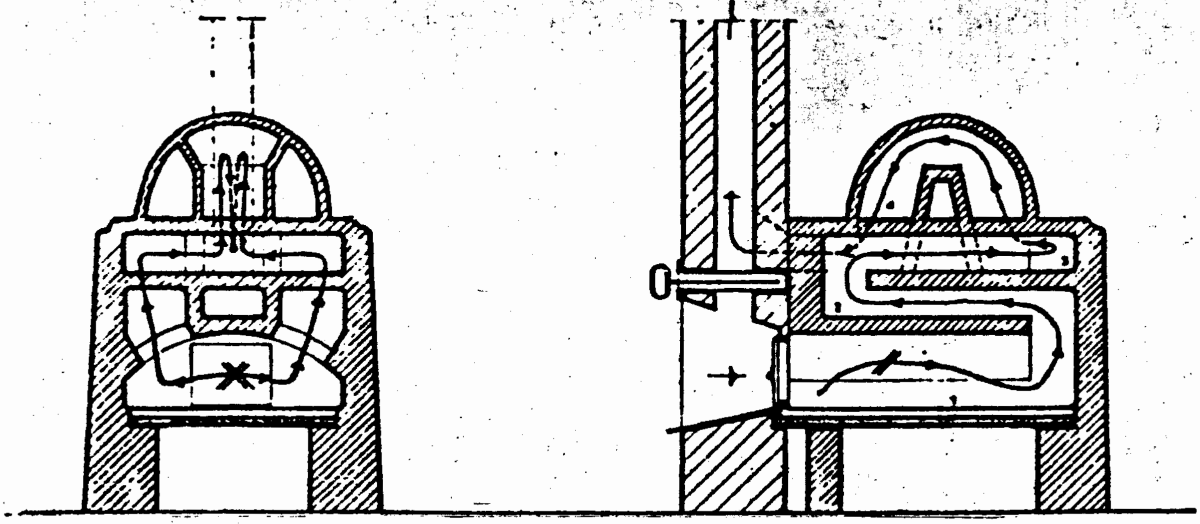


Fig. 931

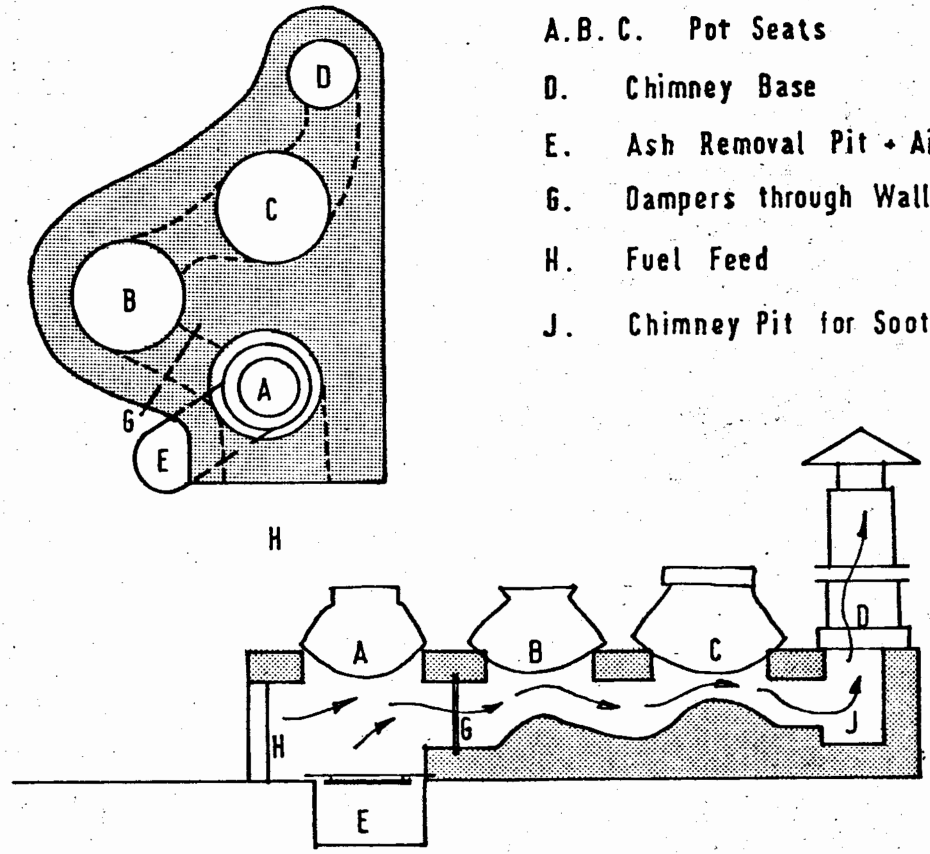
Food Storage Cooling Unit (Indian Origin)

Cool temperatures are maintained by evaporative cooling on the damp exterior surface of the outer pot.
Most effective in a dry atmosphere.

Fig. 932



Stove unit — Designed by Professor Hassan Fathy.



A.B.C. Pot Seats

D. Chimney Base

E. Ash Removal Pit + Air Vent

G. Dampers through Wall

H. Fuel Feed

J. Chimney Pit for Soot Accumulation

Fig. 933 Indian Chulna — Cooker burning dry fuels

Constructed of mud clay or similar material.

In Conclusion

To the best of our knowledge this is the first time a study of this kind has been attempted on a national scale. We had the opportunity to carry out this research while fulfilling the basic brief between us and the Government. Inevitably the research is not as thorough as it could have been if it had from the outset been planned to specifically be a regional study of the Indigenous Built Environment of Oman.

Nevertheless we believe the present study makes a clear case for the potentials of this Indigenous Built Environment with regard to Oman's modern building programmes. Here we would like to conclude the study by making the following points.

1. This study is particularly relevant for a programme aimed at the lower-income brackets - the majority of Omani's - as prevalent in the shanties of the rapidly urbanising areas of the capital region and Salala and in the rural communities as a whole.

2. It also has relevance for the preservation of the cultural heritage of Oman in the form of particular buildings and environments and for a tourist industry that does not violate and distort Oman's uniqueness in the wake of its financial advantages. These two areas though important, are not our primary concern here.

3. Mud-brick, palm frond stems (Barasti) and limestone used in the ways that we researched in Oman with improvements that can be suggested should be used extensively in developing the built environment.

4. For the shanties of the urban areas, drawing from the experience of other developing countries the following can be suggested:

   i) Locating housing sites close to the major sources of employment or serviced by a cheap, reliable public transport system to work areas.

   ii) Security of tenure so that the owner has confidence to invest on his plot.

   iii) Basic water supply,waste disposal services - a site and services scheme for example.

   iv) Provision of building tools and cheap building materials.

   v) Technical training, advice and assistance in building.

The aim should be to promote a self-help housing activity with the provision of community services and income-generating activities. More detailed suggestions need to be based on a thorough study of this particular area in Oman. Some of our research in the Capital Region and Salala as well as the proposals for a pilot project (in "Proposals on the Built Environment" and outlined below) would be relevant.

5. A research and development establishment for the built environment should be set up. This would work on improving indigenous materials and

technologies, the design of spaces, particularly health-risk areas (kitchens, lavatories, water-collection points etc), and the economics and organisation of building based on indigenous methods. It would study and apply available published information on cheap materials, technologies and organisation of building. A great deal of such useful information exists which we have as yet not fully researched. It would carry out further field studys of the indigenous built environment in Oman. All the above would be an on-going process, serving and learning from building projects in the country. It could be part of the Ministry of Development, Rural Affairs and Municipalities Department and in the rural areas work through the local municipalities.

6. Some experimental dwelling units, testing in practice and demonstrating the potential of local building methods should be built.

7. On the basis of this work a pilot project for developing the built environment in one village should be attempted. This should focus around the building of the village centre and could include such public amenities as the market place, cafe, mosque, public water-collection and washing (Falaj outlets). It could also include housing units demonstrating the improved use of local materials and technologies and design for the improvement of health risk areas. This pilot project should be treated as much as an educational as a building programme. The aim should be to educate the local people on hygiene matters and to teach them building skills. This could be done by:-

    i) Close and early consultation with the villagers on the aims of the project.

    ii) The involvement of local people and builders in the building process.

    iii) A training programme integrated into the building, teaching building skills.

    iv) Health education using the design and building of health risk spaces as part of the education. (Such a pilot project is discussed in more detail in Proposals - On the Built Environment).

8. On the experience gained from the above, a regional building programme can be put into effect.

9. Rural building programmes along the above lines would achieve the following:-

    i) Necessary public amenity buildings would be built inexpensive enough to be constructed in a maximum number of rural locations.

    ii) Government investment on the project would go into the local community, enriching it and generating employment.

    iii) A core of competent local builders will be trained who could be of direct use to the community or to the government if further government building is implemented in the rural areas.

    iv) General building skills and health education would be disseminated in the rural community helping the people to improve, use and maintain their built environment satisfactorily and in a self-sufficient way.

YARSLEY TESTING LABORATORIES

A Division of Yarsley Research Laboratories Limited
Registered in England No. 534313. Registered Office: Stoke Poges Bucks SL2 4QD
OFFICIAL APPROVAL NOS. D.Q.A.B. 29107. A.R.B. A1/4621/55

The Street, Ashtead, Surrey Telephone: Ashtead 76391/6
Telegrams: Yarsleys Ashtead

Third World Research Group
Architectural Association
34 Bedford Square
London WC1

OUR REF

YOUR REF

DATE 4th April 1974.

REPORT NO. U.60313/1.

THE THERMAL CONDUCTIVITY OF PALM FROND PANELS

Samples of palm frond panels have been tested for thermal conductivity to BS 874 with the following results:-

Reference	Moisture content % W/W	Temperature, °C			Thermal conductivity W/mK		Thermal conductance W/m²K
		Cold face	Hot face	Mean			
Single layers	24	25	35	30	(i) 0.062) (ii) 0.068)	0.065	2.0
Double layers	21	25	35	30	(i) 0.065) (ii) 0.065)	0.065	1.2

Specimens approximately 0.3 m x 0.3 m were tested in accordance with BS 874: 1973 Appendix C. The single specimens were approximately 33 mm thick and the double specimens 55 mm thick. All specimens were conditioned at 95% rh 35°C to constant weight before test and the moisture content determined after test by drying to constant weight at 105°C.

Notes:

1. Samples were submitted on 11th March 1974
2. The work was covered by Mr. Norton's verbal request of 11th March.

REPORTED BY..........................
p.p. M.M. RILEY
Head of Electrical & Thermal Testing Department

DISTRIBUTION:

Mr. J. Norton
File
Records
MFT.

AUTHORISED BY..........................
J.A. MEAD
General Manager

Directors: W.E. Duckworth, M.A., Ph.D., F.I.M., F.I.S., F.Inst.P., W. Flavell, B.Sc., A.R.I.C., F.P.I.

BIBLIOGRAPHY.

GENERAL.

Abrams, C. "Housing in the Modern World." Faber. 1969.

"The Language of Cities - A Glossary of Terms." New York. Viking Press. 1971.

Cambridge Conference Report on Development. U.K. 1965.

Cresswell, K.A.C. "Early Muslim Architecture." Oxford. Clarendon Press. 1932.

Dunkerly, H. Oxford Conference on "Exploding Cities." 1974.

Fathy, H. "Architecture for the Poor." University of Chicago Press. 1973..

Hodder, B.W. "Economic Development in the Tropics." University Paperbacks. Methuen. 1973.

Hodes, A.D. "The Modular Housing Industry"-Financial Analysts Journal. May - June 1970.

Middle East Economic Digest. July 1973.

Oliver, P. "Shelter in Society" London. Barrie and Rockecliff. 1969.

"Shelter in Africa." Barrie and Jenkins. 1971.

Pope, U and Ackerman. "A Survey of Persian Art" M.I.T. Press.

Rappaport, A. "House, Form and Culture." Prentice Hall Inc. 1969.

Robinson, R. "Developing the Third World." - The Experience of the Sixties." Cambridge University Press. 1971.

Statistical and Economic Review. "Indutrialisation in West Africa." No.23.

Turner, J. and Fichter, R. (Editors.) "Freedom to Build." Collier Macmillan. 1972.

Wulff, H.E. "The Traditional Crafts of Persia." M.I.T. Press. 1967.

Third World Research Group* "Two Egyptian Villages - Gourna and Tod." Egypt. 1973. (unpublished)

Whitehead Consulting Group. "Economic Survey of Oman-1972." Muscat. Oman.

BIBLIOGRAPHY. (Cont.)

CLIMATE.

Colloquium on Building Climatology. Pre-prints. Stockholm. 1972.

Development Planning Unit. "Climate Design Manual". University College London.

Dunham, D. "The Courtyard as a Temperature Regulator." New Scientest. Sept.8th. 1960.

Geiger, R. "Climate near the Ground." Harvard Press. Mass. 1965.

Givoni, B. "Man, Climate and Architecture." Elsevier Ltd. 1969.

Koenigsberger, Ingersoll, Mayhew, Szokolay, "Manual of Tropical Housing and Building." Part 1. Climatic Design. Longmans. 1974.

Meteorological Office. "Airflow over the Western Indian Ocean." H.M.S.O. London.

"Tables of Temperature, Humidity and Precipitation for the World - Asia." H.M.S.O. 1966.

Olgay, V. "Design With Climate." Princeton. University Press. New Jersey. 1963.

Rusin, and Flit. "Man Versus Climate." Peace Publishers. Moscow.

Sutton, "Micro-meteorology" McGraw Hill. 1953.

Third World Research Group.* "Climatic Studies of Traditional Building." Egypt. Architectural Association. London.1973. (unpublished)

United Nations. "New Sources of Energy." 1964.

"Design of Low Cost Housing." Vol. 1. "Climate and House Design." 1971.

Van Straaten,J.F. "Thermal Performance of Buildings." Elsevier.1967.

TECHNICAL.

Cartwright and Findlay. "Decay of Timber and its Preservation." HMSO London. 1958.

Debes. C. "Technical Properties of Mud-Brick." Cairo University. 1954. (unpublished thesis.)

Desh,H.E. "Timber, Its Structures and Properties." Macmillan. 1968.

BIBLIOGRAPHY.(Cont.)

TECHNICAL.(Cont.)

Fox, "Geology and Mineral Resources of Dhufar Province" Published by Government of Oman. 1947.

Goromosov, "The Physiological Basis of Health Standards for Dwellings." Public Health Papers. WHO Geneva. 1968.

Harris, W.V. "Termites and their Recognition and Control." Tropical Agricultural Series. Longmans. 1961.

Sliwa and Fairweather. "A.J. Metric Handbook." Architectural Press. 1969.

Spurling, "Protecting Building Against Termites." Overseas Division. B.R.S. Garston, 1967.

Third World Research Group.* "Mud-Brick and Vault and Dome Technology." Architectural Association. London. 1973.(unpublished.)

United Nations. " The Use of Bamboo and Reeds in Building Construction." U.N. Dept. of Economic and Social Affairs. 1972.

"Soil Cement - Its Use in Building." 1964.

Wagner and Lanoix. "Excreta Disposal for Rural Areas and Small Communities." WHO Geneva. 1958,

"Water Supply for Rural Areas and Small Communities." WHO Geneva. 1959.

Halcrow Consulting Group. "Land and Water Resources Survey - Dhofar. Inception Report." Dhofar Development Authority. Oman. 1973.

---

* Reconstituted as Development Workshop.

INSTITUITIONS.

The following instituitions assisted in the preparation of the study:

Architectural Association. London.U.K.

Development Planing Unit. University College. London. U.K.

Materials Testing Laboratory. University College London. U.K.

Yarsley Testing Laboratories. Leatherhead. U.K.

School of Oriental and African Studies. London. U.K.

Soil Mechanics Dept. Cairo University. Cairo. Egypt.