

**REPORT OF THE  
EXPERT COMMITTEE**

**PERFORMANCE APPROACH  
TO COST REDUCTION IN  
BUILDING CONSTRUCTION**

**GOVERNMENT  
OF KERALA  
JANUARY 1974**

**PRINTED BY THE S. G. P. AT THE GOVERNMENT PRESS,  
TRIVANDRUM, 1974.**

## FOREWORD

There is a need in Kerala for a performance approach which will tailor housing closely to the needs of the people and be consistent with the level of economy and resource constraints. To this end the Government of Kerala in its order No. G. O. MS. 2/77 dated 16-2-1972 constituted an Expert Committee consisting of the following members:

Dr. Kirit S. Parikh,\* *Chairman,*  
Director, Programme Analysis Group,  
Department of Atomic Energy, Bombay.

Shri K. Madhavan,  
Director,  
Hydro Civil Designs, C. W. & P. C.,  
New Delhi.

Shri L. W. Baker,  
Architect,  
Nalanchira, Trivandrum.

Shri K. C. Alexander,\*\* *Member Secretary,*  
Structural Engineer, P. W.D.,  
Trivandrum.

## TERMS OF REFERENCE

The terms of reference of the Committee are as follows:

1. To examine and assess different methods of lowering the cost of construction of residential houses utilising to the maximum extent possible local materials and labour.
2. To consider to what extent the methods available for lowering cost of construction can be applied to Welfare Centres, Youth Hostels, Bus Transport Terminals, Rest Houses, Workshops for Industrial Estates etc.

---

\* At present Professor and Head, Planning Unit, Indian Statistical Institute, New Delhi.

\*\* At present Regional Engineer, Kerala State Housing Board, Cochin.

3. To examine the present organisation of the building industry in the State and suggest the necessary improvements (including training programmes, standardisation of materials and designs, provision of finance etc.) for making it capable of undertaking on a large scale the low cost construction methods suggested under 1 and 2 above.
4. To examine the National Building Code, the P. W. D. norms and the present governmental procedures and requirements in regard to building operations, in the light of the above, and suggest the changes needed in them in order to extend rapidly the use of cheaper methods of construction for achieving the larger objectives of development.
5. To examine and choose models of low cost housing available with a view to recommending the adoption of a large scale housing programme for the poorer sections of the people in the State.
6. To suggest any other means of promoting and encouraging the use of low cost methods of construction of building in the State.

The Committee started work together in April 1972. In addition to working and holding study sessions together in various parts of Kerala and other parts of India, they have interviewed architects and engineers, experts in many technical and manufacturing fields, and the lay public of Kerala's towns and rural areas. To all of these the Committee is grateful for the cooperation and help. They sent out questionnaires and tabulated and assessed results and they collected and studied the many previous reports and studies of others on Housing and Cost Reduction in construction, together with as much relevant printed materials and data (published in this country and in other parts of the world) that they collected.

The Report represents the result of all this study and we are presenting as much as we feel will be helpful to both

experts and laymen alike. Some illustrations and tables are appended to this report while others will follow with the final Report.

Some of the terms of reference have been touched on only lightly while other aspects which we feel to be currently relevant have been treated with some depth in this report.

The Committee want to express their appreciation of the services of its staff, Shri N. M. Sherafudeen and Shri M. Chandrasekhar.

## CONTENTS

	<i>Page No.</i>
Foreword ..	i - iii
Section I	
Approach to cost reduction ..	1
Section II	
Climate and materials ..	5
Section III	
Construction techniques ..	20
Section IV	
Planning and design ..	38
Section V	
Implementation and institutional changes ..	45
Section VI	
Summary and recommendations ..	49
Section VII	
Appendix ..	56

## SECTION I

### APPROACH TO COST REDUCTION

This report deals with cost reduction in construction in general in Kerala. Special emphasis is given to low cost housing, not only because of the current interest and effort in this area all over the State but also because of the importance of housing in improving the social well-being of the people.

Reducing the cost of construction is not merely a matter of planning and scientific design but a matter of looking at the institutional problems involved in methods of construction. A number of Committees (see list of references) in the past have looked at ways of effecting economies in construction and of reducing the cost of housing. Moreover, a number of National Research Laboratories have been working in this field for a long time and have brought forward many suggestions. Unfortunately, few of these suggestions have been implemented and the general impact on the cost of construction has been minimal. When these suggestions are not accepted by designers and builders, it may be due to mere laziness or tradition boundedness; or due to planned resistance from vested interests; or it may be that the suggestions made are illconceived or impracticable.

A large part of construction in the State is done under the supervision of the Public Works Department and similar public agencies. These agencies follow practices which provide no incentive for introducing change or innovations in existing practices. Moreover, a vicious circle exists in which over-designing allows for shoddy and inaccurate work by the craftsmen, together with opportunities for stealing materials, which in turn justifies over-designing. Such vicious circles must be broken and we intend to suggest ways for doing this. On the other hand the private construction industry, especially in housing, is geared to meet

the needs of those who can afford to pay and the designers and builders get paid on a percentage basis. Moreover, many rich clients *want* their houses to be ostentatious, for this gives them 'status'. Such ostentatious houses have increased the prices of housing beyond the reach of everyone else. Furthermore the "middle class" are prone to borrow in order to keep up with their wealthier neighbours.

### **Low-Cost for all not just for the Poor**

These prevailing tendencies towards waste of resources along with considerations of equity force us to state categorically that *the time has come for a strong campaign towards simple and comparatively less expensive building for All. We decry any move towards Low Cost Housing for "the Poor". Reform, rethinking, re-planning and re-designing must start at the top and spread through all strata of society.*

A beginning can be made towards simpler houses for all by a policy of the Government. While studying institutional housing we have noted that there exists a very unrealistic pattern of accommodation which is based entirely upon status and social position rather than on actual space and functional requirements. This almost invariably leads to a very obvious wastage. A comparatively elderly man at the peak of his profession, with his children grown up and already living and working elsewhere, is provided with a large area of unwanted floor space, while his younger assistant, usually with not only a number of growing children but often with aged parents or other dependents as well, has to live as best he can in one or two small rooms with inadequate cooking and sanitary facilities. Quite obviously this state of affairs can only be rectified by our ability to produce, inexpensively, sufficient accommodation for families which are not merely the size of those advertised on the Family Planning posters. We believe that by applying strictly the measures enlisted in this Report adequate accommodation can be provided for many.



When we say that construction as practised at present is wasteful, we imply that one could have built buildings with less material to serve adequately the purposes for which the building is built. However, a "Desirable Performance" is difficult to define. There is no definition of "The Desirable Level". Similarly it is difficult to define "The Minimum Standard" of acceptable performance. A large number of urban poor live in houses which by any standards are dismal and are far below anything that can be called adequate. Alongside these poor conditions we find the ostentatious buildings of the wealthy but there is not enough new construction for the middle sections of our society. A whole series of solutions in between the two extremes ought to be available but in fact is not. The fact that large masses of people live under extremely poor conditions may indicate the low priority that they themselves give to housing at their low level of incomes, or it may indicate that there is nothing better available to match their incomes and rent paying abilities.

This question of adequate performance cannot be separated from the question of cost of housing. Whether to have plastered walls, tiled floors and teakwood windows, or else an extra room with unplastered walls, clay tiled floor or brick jalties, would depend upon how much money one has.

In order that we may ascertain the real needs and preferences of people, opportunities should be provided to people to exercise these choices. We recommend that a set of houses be built in different towns, all costing the same amount of money, but providing different finishes and facilities.

### **Cost reduction is easy**

*It is our belief, that by a proper selection of known techniques and material and by a careful examination of each item of construction for its functional need, we can substantially reduce the cost of construction below current costs. This would make it possible to bring housing within reach of a much larger segment of the population.*

We intend to select only those techniques which do not require large additional investments; which do not require special or rare skills; and which do not require highly mechanised mass production.

Moreover, we intend to select materials which are locally made or locally available in abundance or which can be made by small scale manufacturing plants spread throughout the State and for which the process of manufacturing is labour-intensive, capital saving and fuel saving.

In this task we believe that ultimate cost to the State is of far greater importance than the apparent accounts cost of individual buildings. Our intention is to minimise costs in terms of material and resources rather than cost in terms of labour. In fact, we would concentrate on reduction of resources cost even though it may in some circumstances mean increased labour requirements.

In section II we intend to examine and make suggestions for what we consider appropriate materials, following in Section III an examination of the elements of construction with these appropriate materials and techniques for their economic usage. Section IV deals with planning and design and examines various suggested comparative type designs for low cost housing and other buildings. Section V deals with institutional problems for getting these suggestions implemented and Section VI summarises our recommendations. Section VII contains drawings, illustrations, tables, charts, calculations and data to supplement the written Report.

## SECTION II

### CLIMATE AND MATERIALS

We first deal with climatological considerations, for they influence our general approach to cost reductions.

Kerala has a warm humid climate and this table (below) gives the climatological data for Kerala.

#### TEMPERATURE (C)

	J	F	M	A	M	J	J	A	S	O	N	D
Monthly mean max.	32.0	33.0	34.0	33.8	32.4	29.9	28.6	29.0	29.6	30.5	32.1	32.4
Monthly mean min.	22.2	22.7	24.1	25.2	24.9	23.6	23.1	23.5	23.2	23.3	23.2	22.3
Monthly mean range	9.8	10.3	9.9	8.6	7.5	6.3	5.5	5.5	6.4	7.2	8.9	10.1

#### HUMIDITY %

Monthly mean max.	72	73	76	78	82	89	91	90	88	86	81	76
Monthly mean	62	57	61	69	73	82	83	82	79	79	71	64
Average	67	65	68	73	78	85	87	86	83	82	76	70

#### RAINFALL (mm.)

	J	F	M	A	M	J	J	A	S	O	N	D
Rainfall (mm.)	14.9	25.5	47.5	125.6	260.6	527.0	587.5	336.5	240.0	310.4	140.0	49.7

The generally critical period for special consideration of thermal design is in March and April when the maximum outdoor temperature is between 32° C and 34° C: The

## SECTION II

### CLIMATE AND MATERIALS

We first deal with climatological considerations, for they influence our general approach to cost reductions.

Kerala has a warm humid climate and this table (below) gives the climatological data for Kerala.

#### TEMPERATURE (C)

	J	F	M	A	M	J	J	A	S	O	N	D
Monthly mean max.	32.0	33.0	34.0	33.8	32.4	29.9	28.6	29.0	29.6	30.5	32.1	32.4
Monthly mean min.	22.2	22.7	24.1	25.2	24.9	23.6	23.1	23.5	23.2	23.3	23.2	22.3
Monthly mean range	9.8	10.3	9.9	8.6	7.5	6.3	5.5	5.5	6.4	7.2	8.9	10.1

#### HUMIDITY %

Monthly mean max.	72	73	76	78	82	89	91	90	88	86	81	76
Monthly mean	62	57	61	69	73	82	83	82	79	79	71	64
Average	67	65	68	73	78	85	87	86	83	82	76	70

#### RAINFALL (mm.)

	J	F	M	A	M	J	J	A	S	O	N	D
Rainfall (mm.)	14.9	25.5	47.5	125.6	260.6	527.0	587.5	336.5	240.0	310.4	140.0	49.7

The generally critical period for special consideration of thermal design is in March and April when the maximum outdoor temperature is between 32° C and 34° C: The

The comfort inside the house depends on this indoor temperature variation throughout the twenty-four hours and not merely on the maximum temperature during the day. Investigations on the thermal behaviour of building carried out in India, have been mostly for the hot dry climate of New Delhi (NBC-1961). These are not relevant for the warm humid climate of Kerala. Therefore we take the data from tests carried out in Durban, South Africa where climatic conditions are similar to those of Kerala. The figure 11.2 a (Below) shows a comparison of estimated indoor air temperature variations in an 11" cavity brick wall dwelling with a lined roof, and in a similar timber dwelling with insulated walls.

Figure 11.2 (a) Temperature (F)

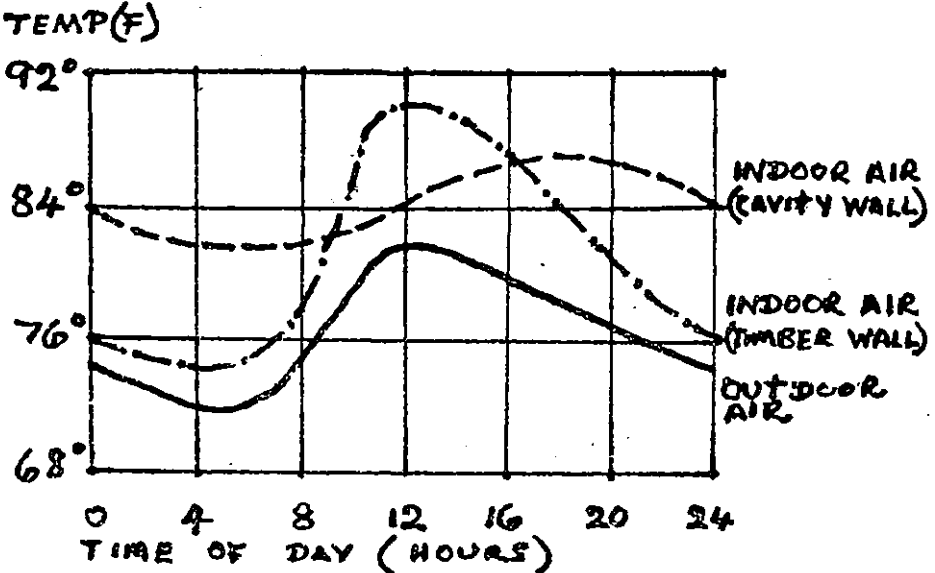


Figure II.2b. (Below ) shows the diurnal range of indoor air temperature.

Daily Indoor Temperature range (F)  
 Product of heat storing thermal capacity and resistance of external walls.  
 (relative units)

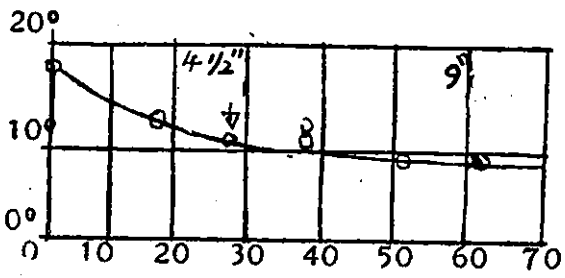
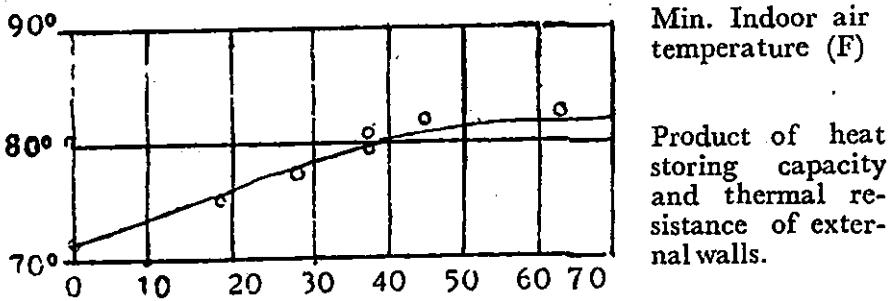


Figure II.2.c. (below) shows the diurnal range of minimum indoor air temperature.



These figures relate the performance of buildings of different construction types as a function of the product of the heat storage capacity and the thermal resistance which is seen to be an important parameter.

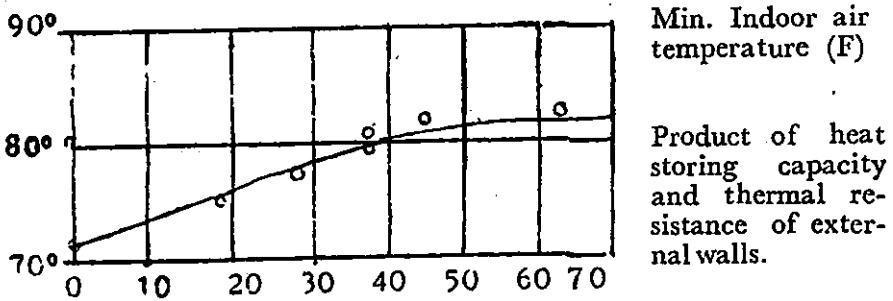
The minimum inside temperature (at night) where a 4½" brick wall is used is roughly 3° F less than the minimum temperature with a 9" brick wall. Moreover, the maximum temperature during the day time is no more than with 9" thick wall

For a light structure, the night temperatures, which are of great importance for comfortable sleep, are seen to be much less though there are slight increases in indoor day time temperatures. This is because of the heat storage capacity of thick walls which tends to even out large temperature fluctuations as they absorb heat during the day and emit heat during the night.

It is therefore clear to us that residential construction in Kerala should be as light (i. e. not heavy) as possible.

Equally important is the right choice of roof type for providing comfort. The radiant heat passing through a galvanised iron roof may be several times that passing through an East or West-facing 9" brick wall. Since heat transfer from ceiling to room air is mainly through radiant heat

Figure II.2.c. (below) shows the diurnal range of minimum indoor air temperature.



These figures relate the performance of buildings of different construction types as a function of the product of the heat storage capacity and the thermal resistance which is seen to be an important parameter.

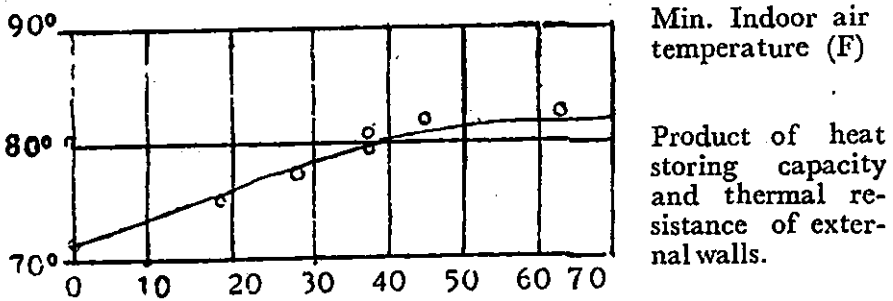
The minimum inside temperature (at night) where a  $4\frac{1}{2}$ " brick wall is used is roughly  $3^{\circ}\text{F}$  less than the minimum temperature with a 9" brick wall. Moreover, the maximum temperature during the day time is no more than with 9" thick wall

For a light structure, the night temperatures, which are of great importance for comfortable sleep, are seen to be much less though there are slight increases in indoor day time temperatures. This is because of the heat storage capacity of thick walls which tends to even out large temperature fluctuations as they absorb heat during the day and emit heat during the night.

It is therefore clear to us that residential construction in Kerala should be as light (i. e. not heavy) as possible.

Equally important is the right choice of roof type for providing comfort. The radiant heat passing through a galvanised iron roof may be several times that passing through an East or West-facing 9" brick wall. Since heat transfer from ceiling to room air is mainly through radiant heat

Figure II.2.c. (below) shows the diurnal range of minimum indoor air temperature.



These figures relate the performance of buildings of different construction types as a function of the product of the heat storage capacity and the thermal resistance which is seen to be an important parameter.

The minimum inside temperature (at night) where a 4½" brick wall is used is roughly 3° F less than the minimum temperature with a 9" brick wall. Moreover, the maximum temperature during the day time is no more than with 9" thick wall

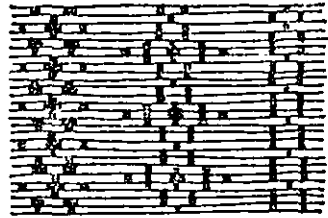
For a light structure, the night temperatures, which are of great importance for comfortable sleep, are seen to be much less though there are slight increases in indoor day time temperatures. This is because of the heat storage capacity of thick walls which tends to even out large temperature fluctuations as they absorb heat during the day and emit heat during the night.

It is therefore clear to us that residential construction in Kerala should be as light (i. e. not heavy) as possible.

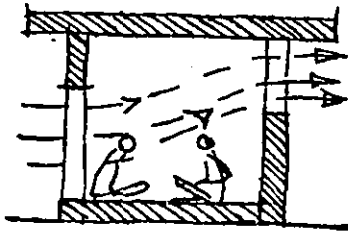
Equally important is the right choice of roof type for providing comfort. The radiant heat passing through a galvanised iron roof may be several times that passing through an East or West-facing 9" brick wall. Since heat transfer from ceiling to room air is mainly through radiant heat



excellent diffusion against light glare, maximum ventilation and an aesthetic quality which many find pleasing. It is undoubtedly cheaper than any other form of window opening, requires no special or costly materials and no special skills. Further more the design possibilities are almost limitless. therefore, must be encouraged.



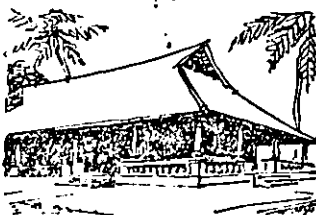
The extensive use of Jalis.



Cross ventilation is also necessary to encourage air flow through a room or building. Since hot air rises openings should always be provided high up on walls opposite the air intake wall. Again, we can find no cheaper method of doing this than by the use of jali walls.

Considering the high humidity in Kerala, it is difficult to see how dampness in buildings can make any substantial difference to people. Perhaps the best criteria for the effect of dampness in buildings in warm humid zones will be the prevention of *visible* dampness. Naturally the effect of dampness on structural strength has to be taken into full account.

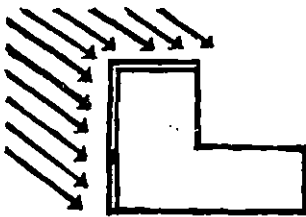
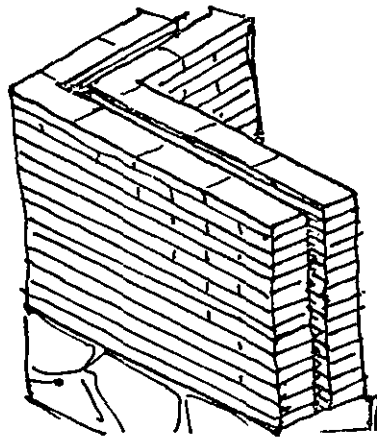
The best protection for walls from rains comes from the traditional provision of eaves with adequate overhang or from sunshades, chujjas etc.



There is an obvious case for the very substantial advantages derived from the verandahs surrounding our old buildings. It is equally obvious that these have been mainly abandoned for economic reasons.

The average burnt brick, laterite or granite stone walls bonded in good mortars are perfectly adequate without any external plastering to withstand all but exceptional weather conditions in Kerala. We are not suggesting that all plastering is unnecessary or should be done away with. But where there is the need to prevent excessive moisture penetration, (e. g. a wall facing driving rain) a good limesurkhi plaster is as good as, and cheaper than the usual cement plaster.

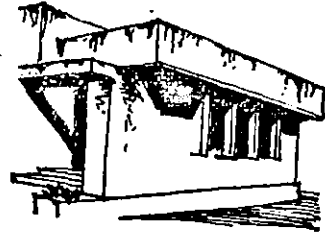
It must be noted here that plastering is not the only method of coping with this problem of excessive moisture penetration. A cavity wall consisting of two 4½" thick brick skins with a 2" cavity between them is both cheaper and more effective than a 9" solid brick wall with plaster. It has also the advantage of better insulation properties. But with either method



it is necessary to protect only those walls which are subject to exposure to these extreme weather conditions and for cost reduction it is important to prevent the repetition of these protective measures all round the house on walls which have no need for more than normal protection.

It is often stated to us that stains, mosses, lichens, and moulds will grow more readily on a bare brick wall than on a plastered surface, and that a plastered wall is more durable.

Observation of both types of wall at the end of the monsoon season will show that if there is any difference, it is the plaster (usually with colour) that has the shabbier appearance and has the more prominent discolouring.



Though external plaster on walls is in theory more durable, available evidence suggests that even without plaster durability of walls is satisfactory, provided the protecting overhang has been used.

*From these considerations we conclude that buildings should be light in weight and colour, should have adequate openings for ventilation which can be inexpensively provided with brick jalis and should have adequate overhangs or chujjas to protect walls.*

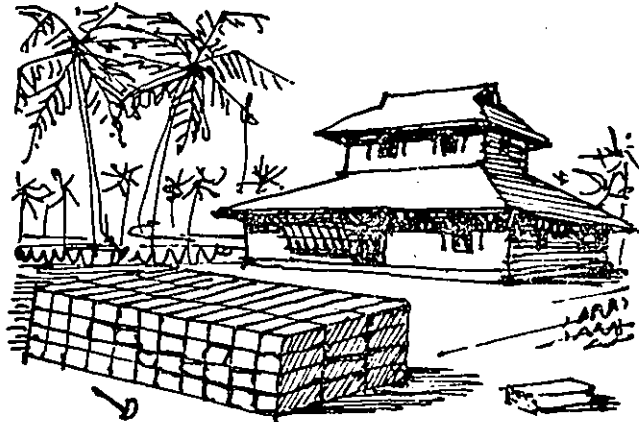
## MATERIALS

We now examine resource costs of different materials in order to establish a list of acceptable materials.

### Stone

Kerala has two main types of building stones, granite and laterite. Outcrops of granite and allied hard stones occur over many districts and there are almost limitless supplies for building stones and for the 'metal' required in concrete work.

Laterite also is widespread, and in well over half of Kerala is plentifully available as a building material.



All it requires for production is labour. Since it does not need any fuel, it is to be preferred even to bricks. Therefore, we recommend that wherever good quality laterite is available it should be used. Laterite of good uniform quality is not always available everywhere but there are vast supplies in many parts of Kerala, especially the northern half of the State.

### **Timber**

Although Kerala is well endowed with timber it can be expected to be scarcer as the pressure of population increases on land. Therefore, economy and discretion should be exercised in the use of timbers.

At present, very little use is made of the so-called "country woods" as structural material. A table showing the qualities and uses of Kerala's timber is given in the Appendix. The main difficulty is that several of these timbers are very vulnerable to the ravages of white ants and borer insects. Otherwise, they have often many desirable qualities such as a wide range of colour and ease of workability. With appropriate treatment the disadvantages could be overcome without much difficulty. A very much greater use of these woods could be made if a public sector undertaking such as *ENCOS*,\* can start timber treatment plants. Moreover, to promote the use of such timber the undertaking should supply standard items made of such treated woods.

### **Lime**

Although lime-stone outcrops are rare in Kerala, shells are plentiful along the entire coast and in the beds of Kerala's extensive backwaters. Furthermore, the Minicoy and the Laccadive Islands have an abundant supply of shells.

---

\* *ENCOS* is an Engineers Co-operative Society.

Though many of these deposits are not adequate for a cement plant of economic size (1200 T/day) they can support many small or medium sized lime kilns. The economies of scale are not very dominant for the lime kilns and small scale production of lime can be economically undertaken. Small scale manufacture of lime shows very good potential for employment generation as well as for providing scope for economically exploiting small deposits of lime shells found all along the coast of Kerala. Many studies have shown the complete acceptability of cement-lime and lime-surkhi mortars and plasters.

The economic implications of using lime in preference to cement is clearly shown in Figure II. 4 which indicates the cost of replacing cement mortars by cement-lime and lime surkhi mortars. It is seen that the investment required for lime and surkhi together is very much less than for a cement plant. Moreover, Kerala is in a very fortunate position of not having to burn surkhi. The vast amount of broken waste tile and brick lying in and around the tile factories of Kerala, when properly ground, should give reactive surkhi of acceptable quality. Thus the use of lime reactive-surkhi mortar and plaster instead of cement mortar and plaster is very advantageous to Kerala.

COST COMPARISON OF EQUIVALENT MORTARS USING CEMENT,  
CEMENT AND LIME, AND LIME AND SURKHI

	1:6 Cement sand mor- tar	1:1:9 Ce- ment lime sand mortar	1:1.5 lime Surkhi sand mortar	
Item	Cost* of producing one million tonnes of cement per year	Cost of producing 1.33 million tonnes of lime(*) per year	Cost of producing 0.56 million tonnes of lime† per year	Cost of producing 1.20 million tonnes of surkhi(‡) per year
1. Fixed Invest- ment	Rs. 40-45 crores with (15%) foreign exchange	Rs. 40 lakhs	Rs. 18 lakhs	Rs. 8.2 crores to burn and Rs. 4.1 crores to grind
2. Fuel con- sumption				
a. Fuel oil	1,50,000 tonnes	1,40,000 tonnes	65,000 tonnes	
b. Coal (6000 BTU)		Or 3,30,000 tonnes	Or 1,50,000 tonnes	2,40,000 tonnes
c. Electricity	80 x 10 <sup>6</sup> Kwh			40 x 10 <sup>6</sup> Kwh for grinding

\* For a large scale modern plant.

(\*) For small scale sector operation.

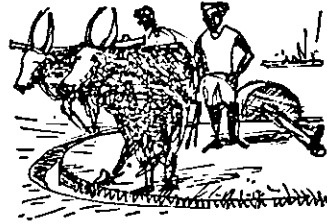
† When 1:2:9 cement : lime : sand mortar (by volume is used instead of 1:6 cement : sand mortar (by volume) 1.33 tonnes of lime is required to replace a tonne of cement.

‡ When 1:105 lime Surkhi sand by weight of (1:2:8 lime : surkhi : sand) mortar is used instead of 1:6 cement : sand mortar 0.60 tonnes of lime and 1.20 tonnes of surkhi is required to replace one tonne of cement.

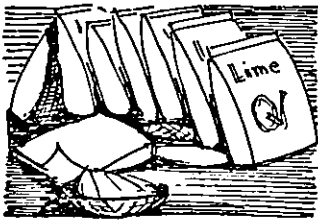
**Notes:**

(1) For equivalance of these mortars see I. S. Code 1439.

The unavailability of good quality lime and the cumbersome processes and inconveniences of using lime are given as reasons by many builders for not using lime. So if lime is to be made acceptable, these small scale units must be made to produce lime of assured quality.



For this purpose public sector organisation such as *ENCOS*, should be encouraged to go in for the manufacture of hydrated lime which is as convenient to use as cement now is. This should find acceptance on all counts by construction contractors. When packed properly in alkathene or similar bags it has the same keeping quality as cement.



We recommend that steps be taken to encourage the production and supply of quality lime and lime-surkhi mixes. Moreover, lime and lime-surkhi mortar should replace the use of cement mortar in masonry work including plaster.

## Earths and Clays

Kerala has abundant and wide-spread supplies of earths and clays suitable for the production of all products of the brick and tile industry.

Burnt clay bricks are widely available over many parts of Kerala. The bricks are produced in scattered small units. The hand moulded brick plants compared to mechanised brick plants not only require much less investment but also employ many more people. Various advantages are usually claimed for mechanised bricks, primarily its high strength and lower



consumption of mortar. Table below compares the economics of the production of mechanised bricks, hand moulded bricks and sand lime bricks.

Investment cost of production and labour required for alternative bricks and substitutes					
Material	Investment for a capacity of ten million bricks a year (Rs. in lakhs)				
		Foreign exchange (Rs. in lakhs)	Cost of production in Rs. per 1000 bricks	Total No. of persons employed	Remarks
1. Hand moulded bricks	3—4	0	35	300	Buildings up to 3 storeys
2. Machine moulded bricks	15	3	80	75	Buildings up to 5 storeys
3. Sand lime bricks	25	12	80	40	Fuel required is $\frac{1}{3}$ of that for clay bricks
4. Cellular concrete blocks	50	21	170*	60	Buildings up to 4 storeys No fuel

No agricultural land is required for 3 and 4

\* price per 2 cu. m. which is equivalent to 1000 bricks.

Source: Rao, A. V. R., Masonry Blocks for Building Construction, Journal of N. B. O., Vol. XVI, No. 2 October 1971.



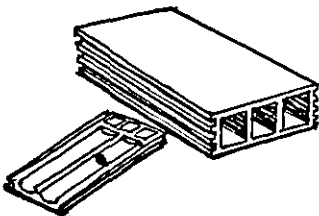
The extra strength of mechanised bricks is not required for buildings up to two storeys. Only when taller buildings are to be built with load bearing walls the higher strength bricks are useful.

However, even this required high strength can be obtained from country burnt bricks by introducing certain quality control measures.

The saving in cement in brick masonry work due to use of mechanised bricks is also very small and amounts to about 0.75 cft. of cement for 100 cft. of brick work. This is a small gain compared to the higher initial investment and lower employment potential of mechanised brick production. The advantages are not significant enough to make a case for the increased production capacity of mechanised bricks.

As a material for masonry, country burnt bricks provide a low cost, low investment and high employment generating material. The Government should therefore, encourage the small scale brick industry.

The use of the various other products of the tile industry of Kerala, tiles, hourdies, etc., should be maximised as large amounts of idle capacity exist and the marginal cost of production involves only fuel. It is also fortunate that use of these products results in the saving of cement and steel.



## SECTION III

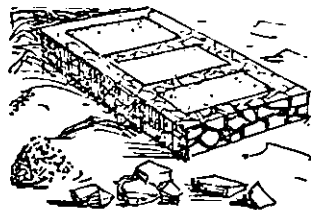
### CONSTRUCTION TECHNIQUES

Having established our choice of materials we can now proceed to building construction systems and techniques. Unfortunately, there are inevitable overlappings and cross references but we have attempted to deal with each system as we meet it when constructing a building.

#### Foundation and 'basements'

Throughout Kerala there is rarely anything used for the foundation-basement except granite. It is entirely satisfactory and there are few recommendations for change that can be made.

There is widespread belief that only concrete or stone is suitable for the construction of a foundation basement. We wish to point out that there are a few areas where the water table is low and brick or laterite is more easily and cheaply available than granite stone. Under these conditions brick or laterite are perfectly acceptable alternatives to stone.



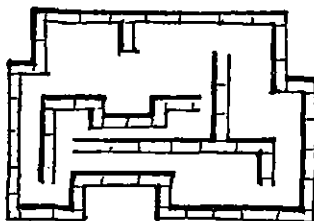
#### Superstructure—

##### Choice and structural design of walls

Except where very special conditions of structure or site warrant other forms of construction, load bearing masonry walls are the most economical in Kerala, for buildings up to three storeys. This is especially so if the latest trends in design based on strength and quality construction are adopted.

## Load bearing masonry walls

Load bearing masonry, in particular brick work, has been used for centuries. In the past, brick walls have been designed as isolated elements standing by themselves whereas these walls are, in fact, stiffened by cross walls and restrained by slabs, thus deriving additional strengths. Design of brick work which takes into account this strength is a relatively



recent practice. This had led to construction of many 4 to 5 storeyed buildings using 9" and 4½" load bearing brick walls in Europe.\* In fact even in Delhi three-storeyed buildings have been built using only load bearing walls of 9" thickness. It should, however be pointed out that for such multi-storeyed buildings the bricks required for the lower storeys must be of good quality.

The National Building Code has incorporated these latest trends of strength calculation for masonry. Kerala has taken the lead in setting up action committees to revise P. W. D. Codes in line with those of the National Building Code. Special and urgent attention should be given to adoption of the portions of the Code governing the strength of structures and quality of materials.

In the context of the freedom given by the Code which permits designs by rational analyses, full advantage should be taken of the potential of brick wall as a structural element.

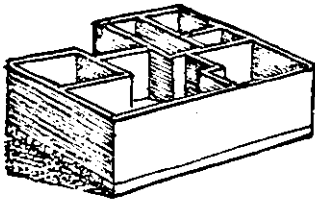
---

\* A typical example in U. K.. is the 5 -storeyed hostel in the University of Bangor, Wales, where external 11" cavity walls with internal load bearing 4½" brick walls have been used. Stress measurement on this building has demonstrated satisfactory structural behaviour of the walls.

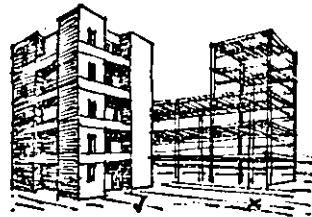
There are even examples, such as at Essex University, England, where 15 storey blocks have been built of load-bearing brickwork without frames.

*In single storied building with lateral support at top, 4½" brick walls in 1:6 (by volume) cement mortar or in (1:2:9) cement-lime-sand mortar or in 1:1:5 lime-surki-sand mortar (1:2:8 lime-surki-sand by weight) should provide sufficient strength as load bearing walls, even with use of country burnt bricks which have a compressive strength of 35 Kg./cm<sup>2</sup>. This is not to preclude the use of 9" or 11" cavity wall when other considerations such as moisture resistance on west facing walls require its use. When using a 4½" brick wall using country bricks, however, in walls with doors, extra area of walls may be provided by means of offsets etc.*

In buildings of more than two storeys, the thickness of brick walls should be calculated, in all cases taking into account the brick and mortar strengths and such stiffening effects due to cross walls etc. Such buildings can be provided with 4½" or 9" wall after checking the structural calculations.



Substantial economy can be achieved over framed structures by slender load bearing cross wall construction.



### **Reinforced concrete frame structures**

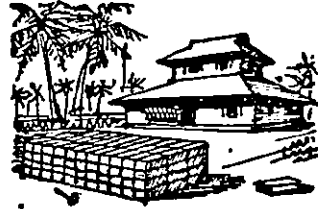
*Thus, we believe that there is no case for the use of reinforced concrete framed structures for normal buildings for three or four storeyed buildings in Kerala.*

We are well aware of the general scepticism towards the use of 4½" brick walls under any circumstances. *We are both satisfied and convinced that with proper design and selection of materials 4½" brick walls can be made to satisfy all the requirements of the National Building Code, as well as to meet the requirements of strength, durability, weather resistance*

*and climatic comfort generally expected by people. (For calculations for structural strength see appendix.)*

### **Laterite walls**

Laterite which is available over large parts of Kerala, is cheaper even than bricks. Unfortunately, however the strength of laterite is quite variable depending upon the state of weathering of the parent rock, and varies from 20 Kg./cm<sup>2</sup> to 200/Kg/cm<sup>2</sup>. Since its use will be widely disbursed because of local availability, simple index tests should be developed to ascertain the quality of laterite in the field. The National Building Code does not explicitly cover laterite masonry but the provision of the Code for rational design of masonry can be applied to laterite construction, taking also into account the relevant strength of the laterite units.



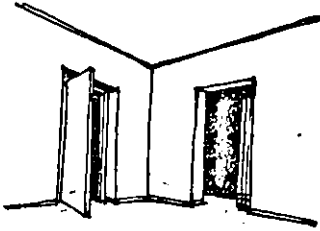
### **Sand-lime Bricks**

As pointed out earlier, very good sand-lime bricks are available in Kerala. These bricks also require less mortar than the country burnt bricks and have high strength. They should be used in areas to which they could be transported at reasonable cost such as Alleppey, Kayamkulam etc. These bricks are expensive compared to country burnt bricks. Since the plant is a public sector enterprise and since the production requires much less fuel these bricks should be locally used in public construction.

### **Doors and windows**

Doors and windows are among the costliest items in the construction of a building. This is because expensive materials and a lot of skilled labour are involved in their

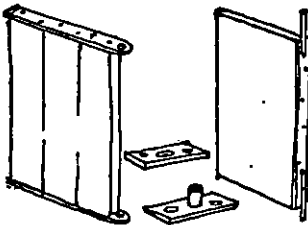
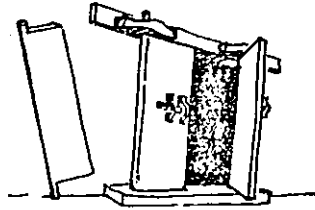
manufacture and there is the additional expenditure on items such as hinges, locks, bolts, sills, lintels, etc.



necessary, do not put it in. Considerable and immediate cost reduction is achieved.

Many doors need not be there at all. Often an opening in the wall is all that function and usage requires. Typical examples are the link between sitting and dining areas or between children's and parent's bed rooms. If a door is not

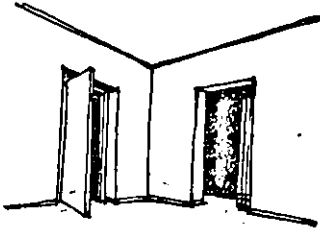
A doorway usually consists of a frame and a shutter or leaf. Again we can seriously consider whether any part of the normal door unit is necessary. The illustration shows that there is indeed an old Kerala traditional pattern which does away with part of the modern frame and which has a very simplified version of the shutter or leaf. In many parts of our



houses and insitutional buildings we do not require a tight fitting door and a simplified or contemporary version of the old traditional door can be used effectively with some cost reduction.

A window allows light and air to come into our room. It allows us to see outside. When closed it will keep out bad weather or give us privacy. But are all these functions necessary for every window in a house? If it is only ventilation and light that is needed, a brick jali is much cheaper

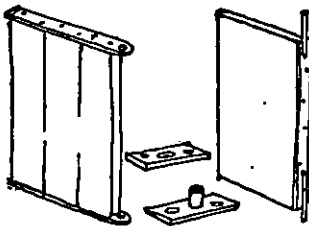
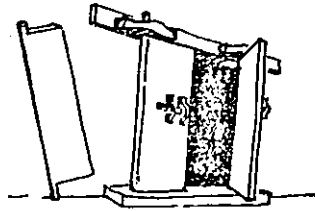
manufacture and there is the additional expenditure on items such as hinges, locks, bolts, sills, lintels, etc.



necessary, do not put it in. Considerable and immediate cost reduction is achieved.

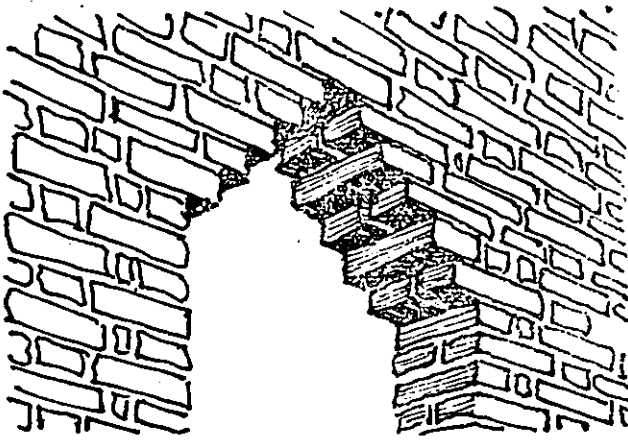
Many doors need not be there at all. Often an opening in the wall is all that function and usage requires. Typical examples are the link between sitting and dining areas or between children's and parent's bed rooms. If a door is not

A doorway usually consists of a frame and a shutter or leaf. Again we can seriously consider whether any part of the normal door unit is necessary. The illustration shows that there is indeed an old Kerala traditional pattern which does away with part of the modern frame and which has a very simplified version of the shutter or leaf. In many parts of our



houses and insititutional build-ings we do not require a tight fitting door and a simplified or contemporary version of the old traditional door can be used effectively with some cost reduction.

A window allows light and air to come into our room. It allows us to see outside. When closed it will keep out bad weather or give us privacy. But are all these functions necessary for every window in a house? If it is only ventilation and light that is needed, a brick jali is much cheaper

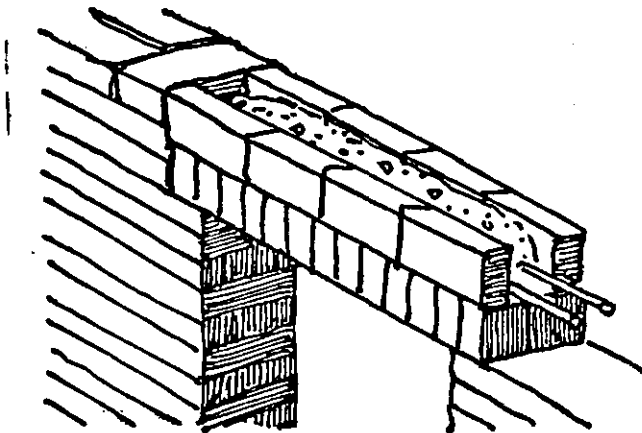


The very simplest and most economical spanning of an opening in a brick wall is to use the 'stepped arch' or 'corbelled arch' where the bricks on each course

are corbelled out a few inches beyond the course below, until the span is bridged.

The conventional design of lintels neglects the strength due to the composite action of the masonry above the lintel and studies by C. B. R. I. indicate that if due allowance is made for this the cost of lintels can be substantially reduced.

When the required lintel is placed above a door or window frame, the frame can act as a support for a permanent



brick shuttering whose cavity can contain necessary reinforcement. Such a cast-in-situ lintel provides greater composite action. It must also be remembered in the design of

lintels that they do not carry normally the load of the



entire walls, floors, roof etc., above the spanned opening but a mere triangular volume of brick work.

## Roofing Systems

The roof in Kerala should be light with good surface reflectivity, and above all leak-proof, to be climatically suitable. The commonly used durable roofs in Kerala are the Mangalore tile roof and reinforced concrete slabs, apart from the thatched



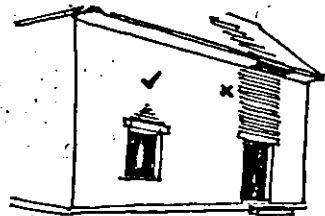
roofs used so widely

all over Kerala. In selecting an appropriate roofing system we should also include the attendant costs such as water proofing, if required. From these points of view, a sloping roof has the advantage that it does not require much water proofing.

A major consideration is the use of local materials such as Mangalore Tiles and hourdis.

## Mangalore Tiles

The Mangalore tile roof constitutes one of the most economical forms of roofing using local materials. Its absorption and transmission of solar heat is undoubtedly high but the heat is to a great extent dissipated by the inevitable air movement through the gaps between the tiles. For aesthetic reasons many people feel the need for a false ceiling under a Mangalore tile roof. In our opinion the false ceiling is quite unnecessary. When false ceilings are provided however, adequate cross ventilation in the air space between the roof and ceiling should be provided. The cost of a Mangalore

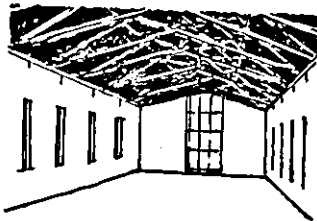
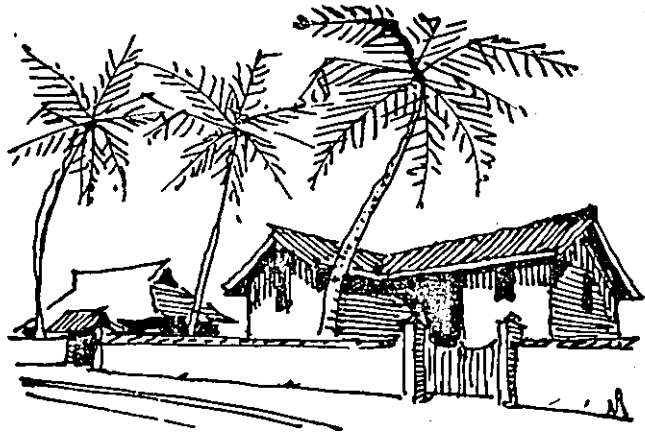


tile roof together with the false ceiling currently in use comes very near to the cost of reinforced concrete slabs. Since personal tastes, reflected in aesthetic considerations, make many people to want the false ceilings, there is scope for developing cheap

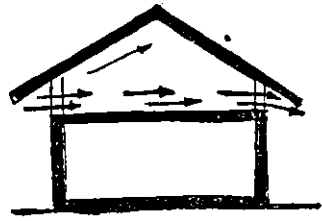
materials for false ceilings, using local resources such as coir, waste wood shavings, chips pulp etc.



convinced, however, that it is undoubtedly one of our most economical permanent roofs. It has proved itself capable of withstanding most of our adverse weather conditions. Some

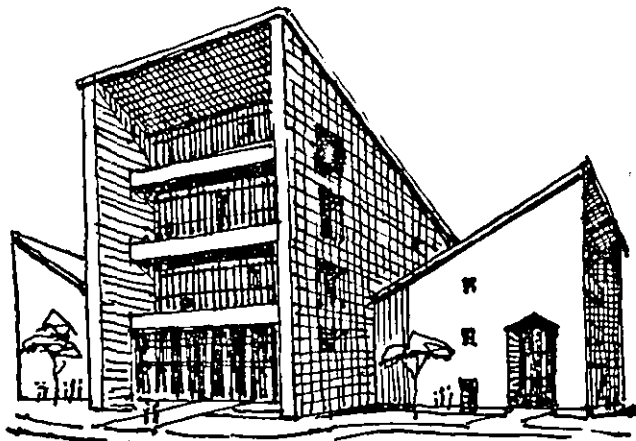


of its defects can be remedied (i. e. with white reflective surface) and the hitherto expensive, if beautiful, timber frame for the roof can easily be substituted by less expensive trusses using modern timber engineering techniques.



In the Appendix are given designs for such improved construction. The Mangalore tile roof, which some consider, old fashioned, can be incorporated in contemporary design.

We would again like to emphasise that various cheaper country timbers, especially after adequate treatment,



can be more widely used for the roof frames.

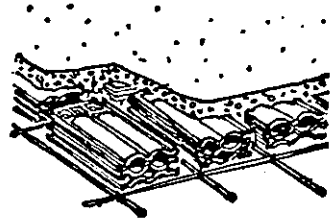
### **Reinforced Concrete Slab Roofs**

We are of the firm opinion that in both public and private constructions there is widespread wasteful and indiscriminate use of reinforced concrete slab roofs. In many instances where reinforced concrete slabs are used, a Mangalore tile roof would have been perfectly adequate from planning, structural and aesthetic angles. We strongly feel that the Mangalore tile roof should be used on a much wider scale than at present, especially by public agencies. However, for multi-storeyed buildings and for intermediate floors, other solutions have to be considered.

There are currently a number of systems being put forward, mainly by individuals and research organisations concerned with low cost construction for types of reinforced slab construction which are designed to cut down the quantities of cement concrete and steel used in the normal reinforced concrete slab. Some of these methods have already been quite extensively used by private builders and inspected by us, and several have also been tested at the Central Building Research Institute at Roorkee.

These are all essentially variations and local adaptations of filler slab or waffle slab construction used and accepted over many parts of India and indeed the world.

The basic idea of the waffle slab is to remove substantial portions of concrete below the neutral axis which does not contribute anything to the strength of the slab. This not only saves concrete, but, since this much dead weight does not have to be carried, the steel required is also reduced. The waffle slab requires intricate, and therefore costly, formwork. In a filler slab, this redundant concrete is replaced by some lighter material such as hourdis, bricks, tiles, coconut shells, etc. Though this increases the dead-weight slightly compared to the waffle slab, it requires only conventional shuttering. Besides the considerable saving of scarce commodities such as cement and steel, there are the further advantages of some of these systems viz., reduction in dead weight, increased insulation properties and a reduced heat storage capacity. However, the most important advantage for Kerala is that these systems, when commonly used, will give a tremendous boost to Kerala's tile industry. We, therefore, strongly urge that these systems be used in all places where a reinforced concrete slab is used at present and that the use of reinforced concrete slabs be restricted to exceptional situations.

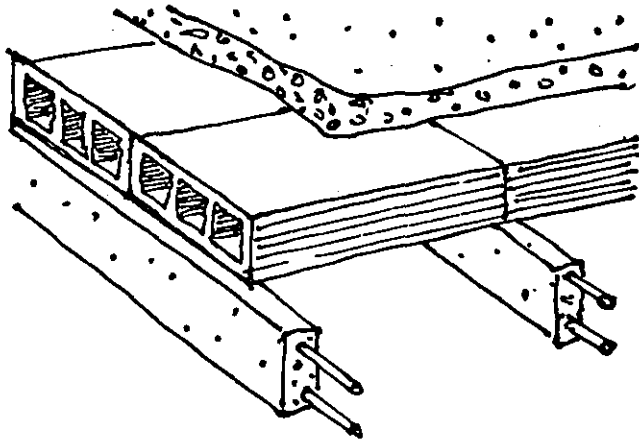


Several of these systems are already covered by the Building Codes of Western countries such as U. K., U.S.A., etc. There is, therefore, no reason why these systems, in view of the financial and valuable material saving, should not be adopted by Kerala.

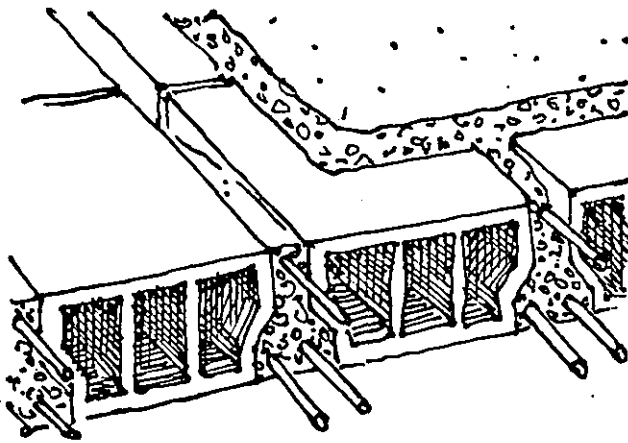
### **Hourdis or Precast Beams**

We had occasion to see a number of buildings put up by Shri E. P. Madhavan Nair at Ottappalam, using a variation

of the old Madras terrace roof where Hourdis were carried on timber beams. The variation used precast reinforced concrete beams to carry hourdis as a roofing system.



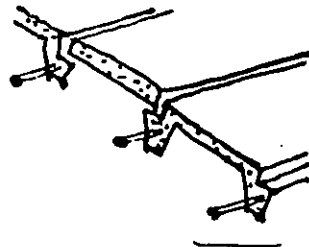
This eliminated shuttering. Since there is a free passage of air through the hourdis, it also provided excellent insulation.



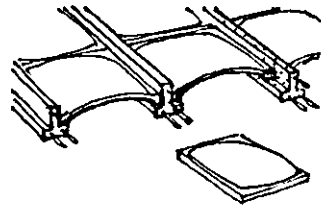
With specially shaped hourdis which are held in place by sides of the beam, rather than on top of them, a flat ceiling is obtained and the head room is increased.

### Precast Roofing Systems

There are other systems available which use precast concrete floor pans, doubly curved shell units, etc., which also have been tested and used at some places. Savings are effected as



shuttering is usually not required for these systems. However, these systems do not provide enough insulation and also pose the problems of handling comparatively large sized panels. Large scale introduction of such system seems to be difficult to us as the quality workmanship required in casting may be hard to achieve.



In addition, the precast system requires the laying of a layer of concrete on top to distribute the load and provide a leak proof surface. This to some extent reduces the overall savings in material affected. Moreover, use of precast elements does restrict to some extent, design flexibility.

**COST OF MATERIALS AND LABOUR REQUIREMENTS PER  
100 SQ. FT. OF VARIOUS ROOFING SYSTEMS**

	4" R. C. Slab							
	4" Filler slab							
	5" R. C. Slab							
	5" Filler slab							
	Hourdis on R. C. Beams							
	Tiles on timber							
	Tile on Tim-ber with ceiling							
	Shellcon							
Cement Concrete	100.00	60.00	125.10	66.00	25.00			
					33.00			
Steel	124.50	75.00	187.50	125.00	62.00			
Tiles or hourdis	0	20.00	0	30.00	100.00			
Shuttering etc.	60.00	60.00	60.00	60.00	3.00			
Labour	16.70	12.00	20.80	13.00	22.00			
<b>Total</b>	<b>301.20</b>	<b>227.00</b>	<b>393.45</b>	<b>294.00</b>	<b>245.00</b>	<b>167.00</b>	<b>267.00</b>	

*Note:* Cost of hourdis varies more than other items with big quality and transport differences

Although the traditional mangalore tile roof on timber frame is by far the cheapest System a majority of people want a ceiling as well.

The hourdis on R. C. beams require a layer of concrete over the top of the hourdis.

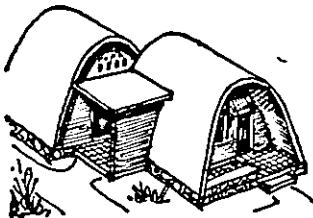
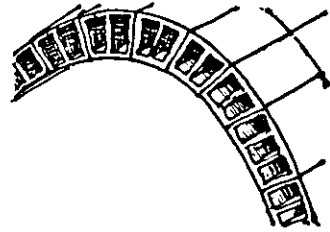
The traditional R.C. Slabs require insulation on top of the slab (cost not included here) while the filler tiles in the filler slabs provide sufficient insulation.

Cost and quality of timber and mangalore tiles vary considerably. Reject or 5th grade tiles only are required for filler slabs.

The table on page 33 compares the material and labour requirements of the different roofing systems. It is seen that the waffle slab with Mangalore tile fillers is the cheapest system and easiest to adopt. Typical calculations for this slab are given in the appendix.

### The Shellcon Shell

There is one further system which is of particular interest to Kerala, as it does not require any steel and very little cement or lime. This is known as the 'shellcon system' and consists of specially shaped hourdis which make a shell which is both wall and roof. As this is a system in which one cannot say when the wall ends and the roof begins,



comparison with other systems is difficult. However, in terms of fuel, the cost per sq. ft. of floor area for the shell is 2 Kg. of coal. This would certainly be less than the fuel consumed in the materials for walls and roof in other systems.

Though the shell form does have certain limitations in house planning this system has economic advantages and can be used.

### Flooring

The commonest form of flooring in Kerala is a smooth topped plaster finish over a base of cement concrete. For all except heavy duty floors, a layer of brick bats can be used instead of the usual layer of cement concrete. Inevitably every building operation leaves piles of broken bricks in its wake and this is an excellent use for these left overs. The plaster surface of almost pure cement over a cement plaster can be replaced by a lime, surkhi sand 1:2:4.5 mortar. This is easier to work and less liable to crack.

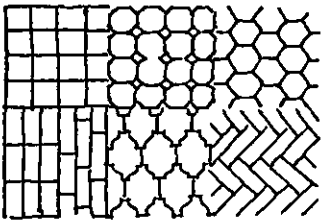


If a temporary shortage of lime or surkhi prevents the use of this alternative, a cement lime sand combination mortar can be used, thus at least reducing the amount of cement now used.

The next most used flooring surface is the same base and plaster finish with the addition of a red or black oxide to the final coating of cement. Unfortunately, pure red oxide is also now a very expensive item. If desired it can easily be added to the lime surkhi or other combination mortar finish. An alternative colouring matter is 'Kavi' or, if black is required the old traditional coconut shell charcoal powder.

### Burnt Clay Flooring Tiles

Another flooring system makes use of burnt clay flooring tiles. Unfortunately these have gone out of fashion but fashion can bring them in again and all people with rheumatic tendencies will welcome their return.



If only the manufacturers would give more interesting shapes the fashion could very easily gain popularity and this form of flooring is definitely within the "low cost" list for flooring.

For a variety of reasons many people want the terazzo (in Kerala called 'mosaic') floor. This can be laid as tiles and polished or can be laid in situ, but it is at least twice as costly as the floors previously described in this section. Several items in the "recipe" for mosaic work are costly and there are, within colour limitations, inexpensive alternatives.

We have seen one such example where costly white cement, costlier white marble powder, colours and oxides and colour stained chips have all been abandoned. In their place only two ingredients have been used; suitable self-coloured

brown chips and fawn coloured pozzalana cement. The result is both pleasing and efficient and its cost is exactly half the current price for mosaic work

Salt and lead glazes are inexpensive and could give an excellent finish to the burnt clay tile.

### **Plasters**

The table on page 37 indicates the ranges, mixes and uses of various mortars and plasters.

We can only insist that at present there is wide indiscriminate use of cement which is and will remain in short supply throughout the country. This report elsewhere also gives comparative costs of alternative materials such as lime and surkhi, lime of course coming from the same source as cement at much less cost.

*It is for these reasons that we would like to insist on the replacement of cement in all plasters and mortars by lime and surkhi mixtures.*

It must be mentioned that the objections concerning the 'handlability' of lime and surkhi can easily be remedied.

## RANGES, MIXES AND USES OF MORTARS AND PLASTERS

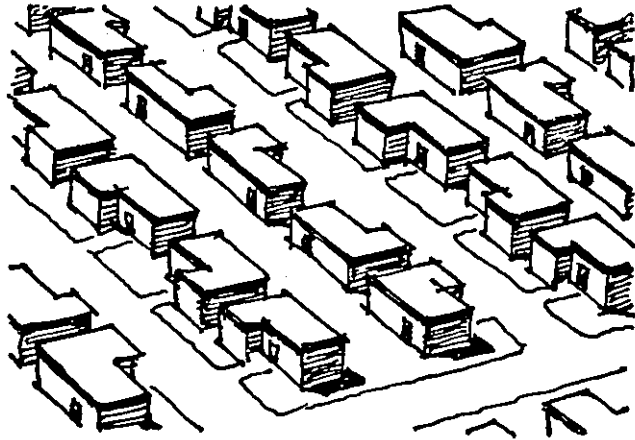
	Cement and Sand	Lime and Sand	Cement and Sand	Lime Surkhi & sand	Saving
Interior wall plaster cost (per 100 cu. ft.)	1:6 192/-	1:3 92/-	1:2:9 180/-	1:2:6 125/-	7%
Exterior wall plaster cost	1:5 225/-	.. ..	1:1:6 225/-	1:2:4½ 162/-	7%
Floor plaster cost	1:4 275/-	.. ..	1:1:6 225/-	1:2:4½ 162/-	5% 6%
Roof slab plaster cost	1:4 275/-	.. ..	1:1:6 225/-	1:2:6 125/-	4.5% 4.5%
Ceiling plaster cost	1:3 358/-	1½:1 217/-	1:1:4 325/-	1:1:4 178/-	5%
Interior 9" walls cost	1:8 150/-	1:4 75/-	1:3:12 150/-	1:2:8 100/-	6.6%
Exterior 9" walls cost	1:8 140/-	1:4 92/-	1:2:9 150/-	1:2:6 125/-	8%
Exterior 4 ½" walls cost	1:6 192/-	1:3 92/-	1:2:9 150/-	1:2:3½ 162/-	8.4%

## SECTION IV.

### PLANNING AND DESIGN

While accepting the need for practical type designs, we are opposed to the application of only one or two set type designs spread thickly over the entire State. Designs must vary for a number of reasons. There are varying patterns of living among our many communities which must be respected. There are a variety of geographical and climatological conditions which must be dealt with by differing design features. We do not need to point out the widely differing conditions in such places as Kuttanad, Kuttikanam, Kozhikode or Kumbanad. Similarly, we have stressed that inexpensive materials available locally in plenty should be made use of. Planning for the use of brick, granite or laterite superstructures, therefore, must result in different styles, construction methods and plans.

Furthermore some of our recommendations may be applicable in some areas but not in others. We have therefore, provided on page 39 an option table for the different design elements. Appropriate techniques and materials from this table need to be selected to design a comfortable efficient and appropriate building. Dull repetition of one or two designs only will mar the beauty of Kerala.

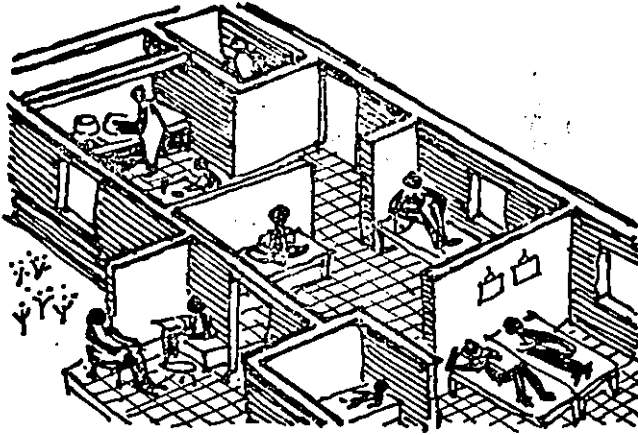


## Option Table

<i>Foundation and Basement</i>					
Granite in mud	Granite in mortar	Laterite	Brick over concrete	Granite over concrete	Under-reamed piles etc.
<i>Superstructure</i>					
Sundried or stabilised blocks	Hand moulded burnt bricks	Machine moulded burnt bricks	Laterite blocks	Random rubble granite	Sand lime bricks
<i>Mortar</i>					
Mud with Cement pointing	Lime surkhi	Lime Cement	Cement 1:10	Cement 1:8	Cemnet 1:6
<i>Wall plaster Finish</i>					
No Plaster	Lime or colour on brick	Lime surkhi plaster	Lime plaster	Lime Cement plaster	Cement plaster
<i>Door Frame and Window</i>					
No Frame	Treated country wood	Jack or Anjali wood	Re-inforced concrete	Metal	..
<i>Window Shutter</i>					
Brick Jali (no frame)	Single plank	Board & batten	Country wood panel	Jack or Anjali panel	Glass panel
<i>Inter Storey Floor Slab</i>					
Timber plank on joists	Filler Slab	Hourdis on R.C. beam	Timber on joist with ceiling	D. Funicul Shell on beams	R. Concrete slab
<i>Roofing</i>					
Ola on bamboo	Mangalore tile on timber	Filler slab	Mangalore tile on timber with ceiling	Hourdis on R.C. beams	R. Concrete Slab
<i>Flooring</i>					
Lime and surkhi over brickbats	Cement plaster over b. b.	Burnt clay tile over b. b.	Cement or tiles over concrete	Simplified grano	'Mosaic'

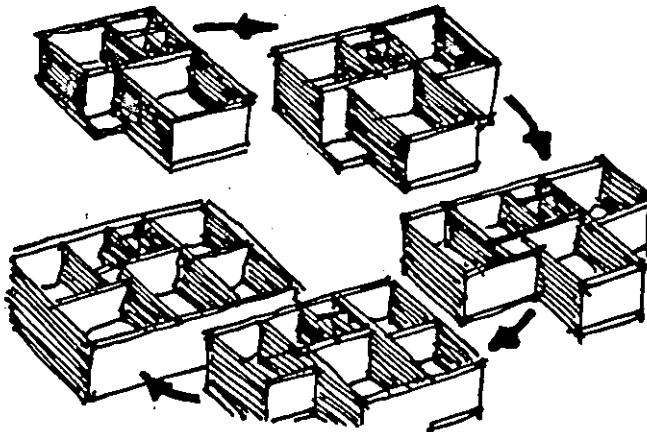
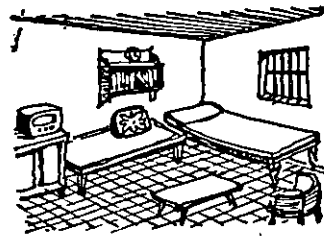
The columns on the left are the low-cost less expensive elements and those on the right are the usual higher cost elements.

The number of basic plan types are many. Some which we believe are suitable for use in Kerala have been isolated from the almost limitless number of possible house plan designs and are illustrated in the appendix.



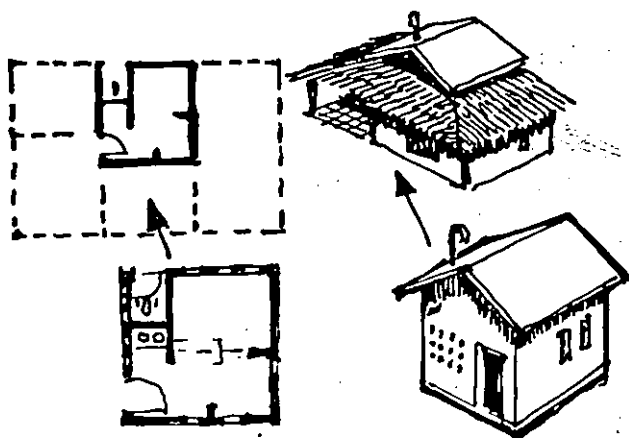
Although overall floor area often has to be limited, due to insufficient resources, there should be in each dwelling house well-defined living areas, which need

not necessarily be separate rooms with separate doors. They must, however, provide the privacy necessary for living. In essence these areas vary according to the time of day. There have to be areas to cope with the occupations of family life separated from other areas



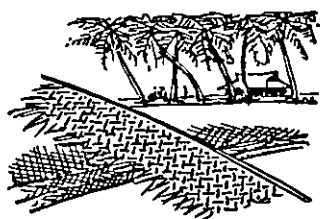
for coping with the social side of living. Often the same divided areas must be able to provide three distinct sleeping areas for parents and for children of both sexes

at night. However, when very small houses are built, planning should provide for future expansion. Expandible house plans are, therefore, included in our Type plans.



The expansions are inevitably eventually the concern and responsibility of individual owners. Government schemes may be expected to cope only with the basic first stage plan.

We wish to point out that Kerala does not have the same problems of housing that many other States have. Kerala is blessed with millions of coconut palms which yield an excellent roofing material 'ola' (cudjans) and which almost all, however poor or landless, can and do make use of. A very large percentage of existing housing is built of sundried mud bricks covered with bamboo and thatched palm leaves etc. Unfortunately, the only real problem (for the design of these traditional buildings is often good) is that the thatch only lasts for one year and then has to be replaced. We are including in our appendix of practical building suggestions simple methods of improving and expanding existing housing.



Though the mud wall and 'ola' roof house is not unsatisfactory, the lack of sanitary facilities is a great inconvenience



with limited resources. Provision of these facilities would improve the well-being of people much more than provision of new pucca

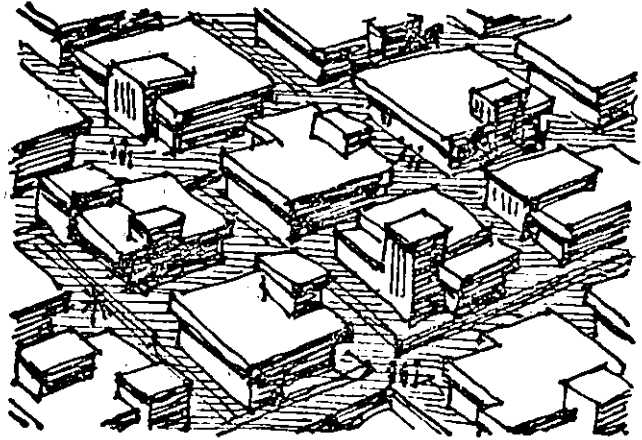
houses. A latrine with a china clay pan with a leach pit can be made without a roof or may be provided with a cheap 'ola' roof. All of this can be done within Rs. 300 per latrine.

Plans for institutional buildings such as schools and colleges, hospitals and dispensaries have special requirements for which simple functional practical plans are required. And again, we have illustrated only a few basic types upon which the option table can be applied to generate variety. A brief study of these plans and the option table should convince all that there is no excuse for monotonous repetition of buildings throughout the State.

Though we have given these designs it is clear to us that the mere study of type designs is not sufficient to cope with the building problems alone. Every building is inevitably related not only to people and their needs but to its position on the land and its relation to the other buildings in the same area or community. There has been an apparent tendency to regiment houses



in colonies and settlements and rehabilitation schemes with little regard for either aesthetics or for the economic design of services especially roads, water, sanitation, and electricity.



The chequer board pattern is still the favourite breaking up of land for colony development purposes and rarely is the lotus or necklace pattern made use of with its obvious service Economies.



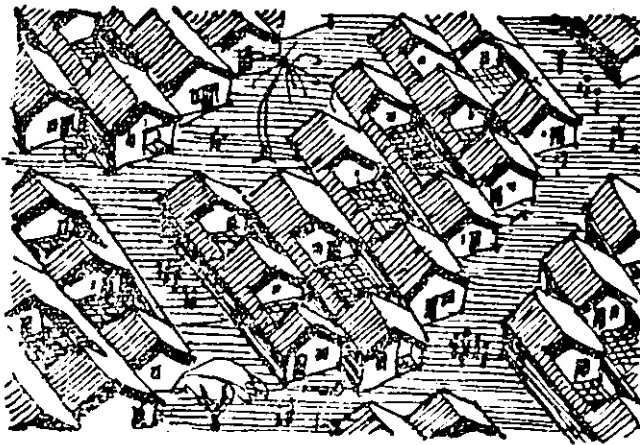
In this connection it should be pointed out, that some of the bye-laws related to the use of land and sites for building purposes are wasteful, especially for urban areas where land is expensive.

In many other parts of the world people have adapted themselves with satisfaction to types of accommodation



which save land or materials, e. g. flats, row houses with common walls, etc. These at present are always referred to as 'unsuitable' or 'undesirable' for Kerala. We are well aware

that traditionally the people of Kerala are deeply attached to their land, coconuts and patch of tapioca, or rice, however small. But with increased population and involvement in town occupations it is wasteful to carry essentially rural planning into the hearts of our growing cities. Appropriate planning can still



make provision for this world wide attachment to at least some small patch of Mother Earth. These are illustrated in our appendix together with a table of

typical bye-laws which are crippling and require changing.

## SECTION V

### IMPLEMENTATION AND INSTITUTIONAL CHANGES

The suggestions we have made will remain on paper unless certain specific actions are taken by the Government and Public Agencies. Some of our suggestions require basic changes in the institutional framework of the public agencies.

#### **Competition for Designs**

It has been pointed out by many in the past that there are no incentives to any designer working in a public organisation to exert himself to produce less expensive designs. In fact, not only does he not get rewarded for initiative and innovations but he often gets punished if something goes wrong. Unless some degree of competition with appropriate reward is introduced in the process of designing, the designs produced by public agencies will continue to be wasteful and excessive. *We suggest that competitive designs always be invited for all constructions exceeding, say, a lakh of rupees as well as for all designs which are to be repeated many times.* These competitive bids should be for design as well as for the execution of the work. The design organisation of the Public Works Department and other public agencies should be also asked to bid for these jobs. An adhoc committee can be set up to scrutinise these designs and tenders. We understand that such competitive designs are already being invited by some engineering departments in the State.

However, if the design organisation of the Public Works Department is to bid with confidence and with responsibility in any competitive environment it should also be the agent which prepares the cost estimates. In order to facilitate competitive bidding we suggest that the Public Works Department be reorganised into two wings, one a 'Planning, Design and Estimating' Wing and the other a

'Construction' Wing. Such organisations may take some time to bring about. Meanwhile to start with, for specific projects special groups could be nominated by the Chief Engineer consisting of the design team and the construction division and these groups can compete on the bid. Works for which the design Organisation bids and is successful should be executed by the Construction Wing directly. Those works for which designs prepared by other agencies are competitive should be executed under the supervision of Public Works Department after examining and approving the designs by the Design Wing.

*Suitable incentives in the form of appropriate prize money (for example an agreed percentage of money saved compared to the next lowest bidder), should be given to those who evolve competitive designs to encourage them for better performance without which the above system would be totally ineffective.*

Once such competitive designs are produced and the agency offering such designs entrusted with execution the scope for poor quality of workmanship is automatically reduced. Nevertheless, certain steps are necessary if the quality of work is to be improved. At present, the facilities for testing the quality of construction materials are not widely available in the State. The National Building Code requires appropriate testing of materials with specific frequencies. Unless testing facilities are available, these tests cannot be carried out. It is, therefore, recommended that in major towns of the State where a substantial amount of construction work is likely to take place, the Government should set up field laboratories and insist that testing of materials be carried out as per the National Building Code throughout the course of the work. Such laboratories need not necessarily be run by the Government. They may also be managed by other organisations such as Engineering Colleges or ENCOS. For this, testing fees should be charged and provision for such expenses should be made in the estimates.

Many of our recommendations require the use of materials and techniques of construction which are not currently in vogue. Unless adequate steps are taken to make these

materials available, some of our cost reducing recommendations cannot be followed.

Special steps are necessary for the supply of the following materials:

1. Lime;
2. Lime:surkhi mix;
3. Treated Country wood and products;
4. Concrete door and window frames;
5. Precast/prestressed concrete joists and roof components.

Unavailability of lime of assured quality has been advanced as the main reason for not using lime by many engineers. To improve the quality of lime produced by many small scale kiln operators the following steps may be taken:

(i) A public sector organisation—such as ENCOS—can start manufacture of lime and lime-surkhi in many small plants in the State. These plants, through competition, would prompt existing lime producers to improve the quality of their product;

(ii) In order that users can have confidence in the quality of lime supplied by private manufacturers who have improved the quality, the testing laboratories should offer periodically test certificates to the manufacturers. Thus the laboratories should have facilities to test lime and lime-surkhi;

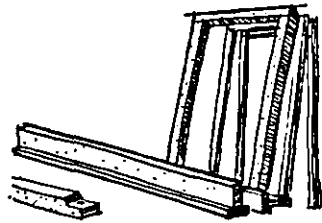
(iii) Many small scale manufacturers may need technical help to improve the quality of their product. Such consulting should be made available to them. KITCO, or Kerala State Productivity Council, could provide such technical help for the manufacture of lime and surkhi.



The quality of surkhi for lime:surkhi mortars, is crucially dependent on the fineness to which surkhi is ground. This requires the same kind of quality control and assurance steps as are required for lime.

Properly treated country wood is an excellent building material but at present it is not readily available. This is because other woods, though expensive, are available and present less risk where there is no understanding that treatment can increase durability. However, if these woods are made available, many people would use them after treatment for structural purposes and they would still be substantially cheaper. The Government should either itself set up plants, or see that others set up a number of treatment plants for country wood.

Scope exists for use of precast/prestressed reinforced concrete joists and roof components also for reinforced concrete door and window frames. Again, since these would be new products, encouragement may have to be provided to prospective manufacturers.



### **Training and Education**

Since low cost construction requires an attitude of mind and not merely the following up of 'cook book recipes', engineers, architects, designers, overseers and even craftsmen need to gain a fuller understanding of the philosophy of the State's need for low cost building. The customary education of all these groups involved in building sadly lacks 'education' that provides an awareness of social and economic context in which both architectural and structural designing should take place.

Young engineers and architects especially should be exposed to a course for a month or two. Besides social and economic context this course may also bring about an awareness of the potential of local materials.

Moreover, even for the adoption of techniques suggested here, the scepticism of the profession has to be dispelled. Even for this purpose a certain educational effort will be required. Such reorientation can best be given to senior level persons at a short term special course.

## SECTION VI.

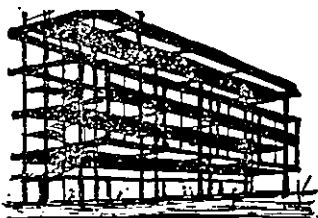
### SUMMARY AND RECOMMENDATIONS

#### Approach

Our recommendations are aimed at reducing the cost on all buildings. The goal should be low cost construction for India and low cost construction for all, not merely low cost construction of "The Poor".

The recommendations minimise the resource cost to the nation and not always necessarily the obvious financial cost involved. Our suggestions minimise the use of scarce

materials, especially of cement and steel, and promote the use of materials available locally and abundantly as well as materials which can be manufactured by small scale industry.



In particular we have tried to promote the use of all products of the burnt clay and tile industry, of laterite, of country wood, and of lime and surkhi. Some of these are, and others could and should, be manufactured all over Kerala.

We wish to emphasize here that the use of these materials

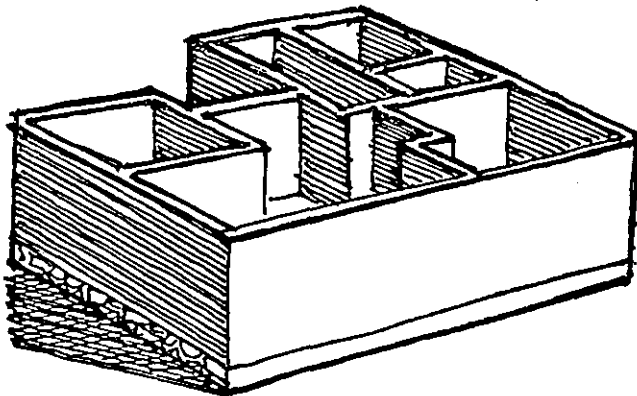


is not at the cost of either structural strength or functional adequacy, and that there is no conflict between use of local resources and cost reduction. Moreover, from what we have seen we feel that the use of these materials is aesthetically attractive.

### Techniques

A number of systems have been suggested which minimise the consumption of cement and steel. Some of them also make use of local materials. From these we have selected those that reduce costs. In particular we make the following specific recommendations:

- (a) For all masonry construction lime-surkhi mortar should be used.
- (b) There is rarely functional need for plastering walls, but where walls have to be plastered, lime-surkhi mortar should be used.
- (c) In the design of buildings, full use should be made for the strength of brick work considered as a three dimensional system, as permitted by the National Building Code.
- (d) 4½" Walls, when properly designed, meet the requirements of the National Building Code, especially for single storey buildings.



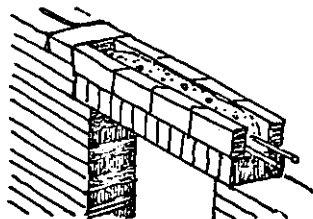
(e) Even with the proposed use of metric bricks, load bearing half brick walls will be possible, provided the number of folds and piers are adjusted



(f) Many windows in a house are seldom closed and these can profitably be replaced by brick jali walls.

(g) Windows which need to be closed can be designed to minimise the need for lintels.

(h) When required, lintel designs should be rationalised, as conventional lintels are over-designed.

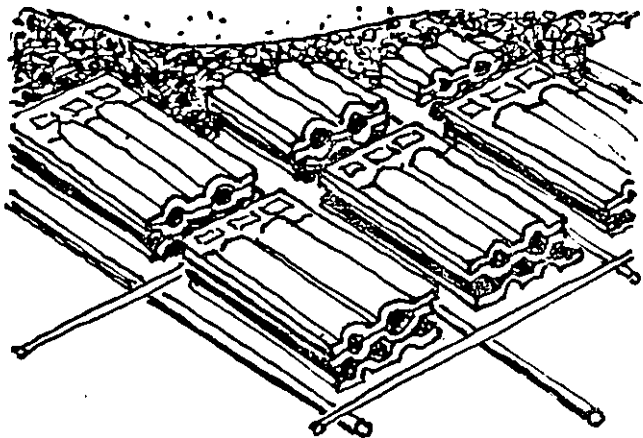


(i) Doors can often be frameless. Where frames are desired, the present concrete frame is cheaper than the normal timber frame.

(j) A number of country woods such as Mango, Maruthu, etc., after preservative treatment, can replace comparatively more expensive conventional timbers such as Anjali and Jack.

(k) The Mangalore tile roofs should be used wherever possible.

(l) Otherwise reinforced concrete filler slabs should be used. The fillers can be low quality Mangalore tiles, commonly used hourdis or special hourdis. The beams can be precast or cast in situ.



(m) The use of such systems should be made mandatory, especially for the public construction programme. The use of currently prevalent reinforced concrete slabs should be considered only under special circumstances.

(n) Except for heavy duty floors, the use of the concrete base can be replaced by a brick bat base paving. The usual surfacing of cement plaster should be replaced with lime-surkhi or lime cement combination plaster.

(o) The traditional use of burnt clay tile floors surface is still within low cost limits. Costs of terazzo (mosaic) flooring can be reduced by eliminating white cement, stains, oxides, marble powder etc., and by making use of grindable natural coloured stones with grey cement or brown pozzalana cement.

### **Experimental Housing**

In order to assess the real needs and preferences of people we recommend that sets of houses be built in different towns, all costing the same amount of money, but providing different finishes and facilities so that comparisons and choices can be made.

In site planning, buildings which require plumbing should be grouped together to minimise cost. Similarly proper planning can reduce substantially the cost of electrical services.

A number of satisfactory solutions are possible for houses of 25 sq. m. (about 250 sq. ft.) for the low income group using the above recommendations. The cost per sq. ft. can be reduced to Rs. 7 to Rs. 10. For all houses, including the smallest one of 150 sq. ft., provision of a separate latrine can greatly improve its livability. Latrines with enclosures, china clay commode with a water seal, and a leach pit can be provided for less than Rs. 300.

For low cost houses of areas of 500 sq. ft. and above, many possibilities exist. The type designs given are not the only possible ones but are illustrative of what can be achieved using our recommendations.

### **National Building Code**

The provisions of the National Building Code for structural strength and safety permit rational design procedures.

If full advantage is taken of the various provisions, great reduction in costs is possible. All the suggestions we have made are consistent with the National Building Code.

A few sections of the Code which deal with planning considerations (such as minimum ceiling heights, size of room, ventilation required etc.) are not relevant to the particular conditions of Kerala and are unnecessarily restrictive.

### **Implementation**

Cost reduction calls for efficient designs as well as efficient execution of works. To promote this the following are required:

(a) We recommend that competitive designs always be invited for all constructions exceeding a lakh of rupees as well as for all designs which are to be repeated many times.

(b) Suitable incentives such as prize money should be given to those who evolve competitive designs to encourage them for better performance.

(c) We recommend that in major cities of the State where substantial amounts of construction work are likely to take place, the Government should set up field laboratories and insist that testing of materials be carried out as per the National Building Code throughout the course of the work.

### **Supply of Materials**

Special steps are necessary for the supply of certain materials. For this we suggest the following:

(a) A public sector organisation—such as *ENCOS*—can start manufacture of lime and lime-surkhi in many small plants in the State. These plants through competition would prompt existing producers to improve the quality of their product.

(b) In order that users can have confidence in the quality of lime supplied by private manufacturers who have improved the quality, the testing laboratories should offer periodically

test certificates to the manufacturers. Thus the laboratories should have facilities to test lime and lime-surkhi.

(c) Many small scale manufacturers may need technical help to improve the quality of their product. Such consulting services should be made available to them. *KITCO* or Kerala State Productivity Council should provide such technical help for the manufacture of lime and surkhi.

(d) The Government should either set up plants for treatment of country woods and products and for the supply of precast and prestressed concrete products, or they may encourage others to do so.

### **Training and Education**

Training and education are essential if cost reduction practices are to become a way of life and not be a one-shot affair.

(a) Training courses of four to eight weeks' duration for young engineers to impart to them awareness of economic and social context of their work and of the potential for local materials should be conducted.

(b) Short term special courses for senior level persons will help in promoting the acceptance of the ideas in this Report.

## COST REDUCTION POSSIBILITIES

Main building cost items	% of total building cost	% range of saving possible on each item	% range of overall saving on total cost
Foundations and basement etc.	10%	0 to 5%	0 to 0.50%
Superstructure (walls & frames)	17%	20% to 33%	3.4% to 5.6%
Doors and windows	17%	10% to 45%	1.7% to 7.53%
Plaster and Finishes	8%	30% to 85%	2.4% to 6.8%
Flooring	5%	10% to 40%	0.5% to 2.0%
Roofing	26%	10% to 30%	2.6% to 7.8%
Plumbing, sanitation and electrification	17%	0 to 10%	0. to 1.7%
Total	100%	..	10.6% to 32.05%

## SECTION VII.

### APPENDIX

This Appendix contains an assortment of information together with illustrations, tables and charts etc. For convenience when reading the Report, some of this information has already been included in the text of the Report.

1. Option table
2. Average percentage share of different items of cost in the construction of a building
3. Minimum core house 144 sq. ft. in area
4. House of 250 sq. ft. area
5. Row house of 250 sq. ft. area
6. Three room house of 500 sq. ft. area
7. Three room house of 500 sq. ft. area with a courtyard
8. Two storey house of 500 sq. ft. area
9. House of 750 sq. ft. area
10. Two storey house of 750 sq. ft. area
11. House of 1000 sq. ft. area with courtyard
12. School classroom
13. Tourist accommodation
14. Doors and windows
15. Latrines, bathrooms and septic tanks
16. General information concerning waste and avoidance of waste.
17. Calculations.

**Option Table**

Every building is built up of many different parts. Very often each item can be made of different materials, or of different qualities of the same material. One quality or style may be needed in one part of the building and another quality or style in another. Obviously these fluctuations in quality and type will mean corresponding fluctuations in price, and exactly the same plan, say, of a building 250 ft. square in plinth area, can bring from one man a quotation of estimated cost at Rs. 1250.00 and from another man an estimate of Rs. 7500.00. In order to cope with this problem we have here an Option Table.

*Foundation and Basement*

Granite in mud	Granite in mortar	Laterite	Brick over concrete	Granite over concrete	Under-reamed piles etc.
----------------	-------------------	----------	---------------------	-----------------------	-------------------------

*Superstructure*

Sundried or stabilised blocks	Hand moulded burnt bricks	Machine moulded burnt bricks	Laterite blocks	Random rubble granite	Sand lime bricks
-------------------------------	---------------------------	------------------------------	-----------------	-----------------------	------------------

*Mortar*

Mud with cement pointing	Lime Surkhi	Lime Cement	Cement 1:10	Cement 1:8	Cement 1:6
--------------------------	-------------	-------------	-------------	------------	------------

*Wall Plaster Finish*

No plaster	Lime wash or colour on brick	Lime surkhi plaster	Lime plaster	Lime Cement plaster	Cement plaster
------------	------------------------------	---------------------	--------------	---------------------	----------------

*Door Frame and Window*

No Frame	Treated country wood	Jack or Anjali wood	Re-inforced concrete	Metal	..
----------	----------------------	---------------------	----------------------	-------	----

*Window Shutter*

Brick Jali (no frame)	Single plank	Board & batten	Country wood panel	Jack or Anjali panel	Glass panel
-----------------------	--------------	----------------	--------------------	----------------------	-------------

*Inter Storey Floor Slab*

Timber plank on joists	Filler Slab	Hourdis on R.C. beam	Timber on joist with ceiling	D. Funicular shell on beams	R. Concrete slab
------------------------	-------------	----------------------	------------------------------	-----------------------------	------------------

*Roofing*

Ola on bamboo	Mangalore tile on timber	Filler slab	Mangalore tile on timber with ceiling	Hourdis on R. C. beams	R. concrete Slab
---------------	--------------------------	-------------	---------------------------------------	------------------------	------------------

*Flooring*

Lime and surkhi over brickbats	Cement plaster over b.b.	Burnt clay tile over b. b.	Cement or tiles over concrete	Simplified grano	'Mosaic'
--------------------------------	--------------------------	----------------------------	-------------------------------	------------------	----------

The columns on the left are the low cost less expensive elements and those on the right are the usual higher cost elements



AN AVERAGE PERCENTAGE SHARE OF DIFFERENT ITEMS  
OF COST IN THE CONSTRUCTION OF A HOUSE.

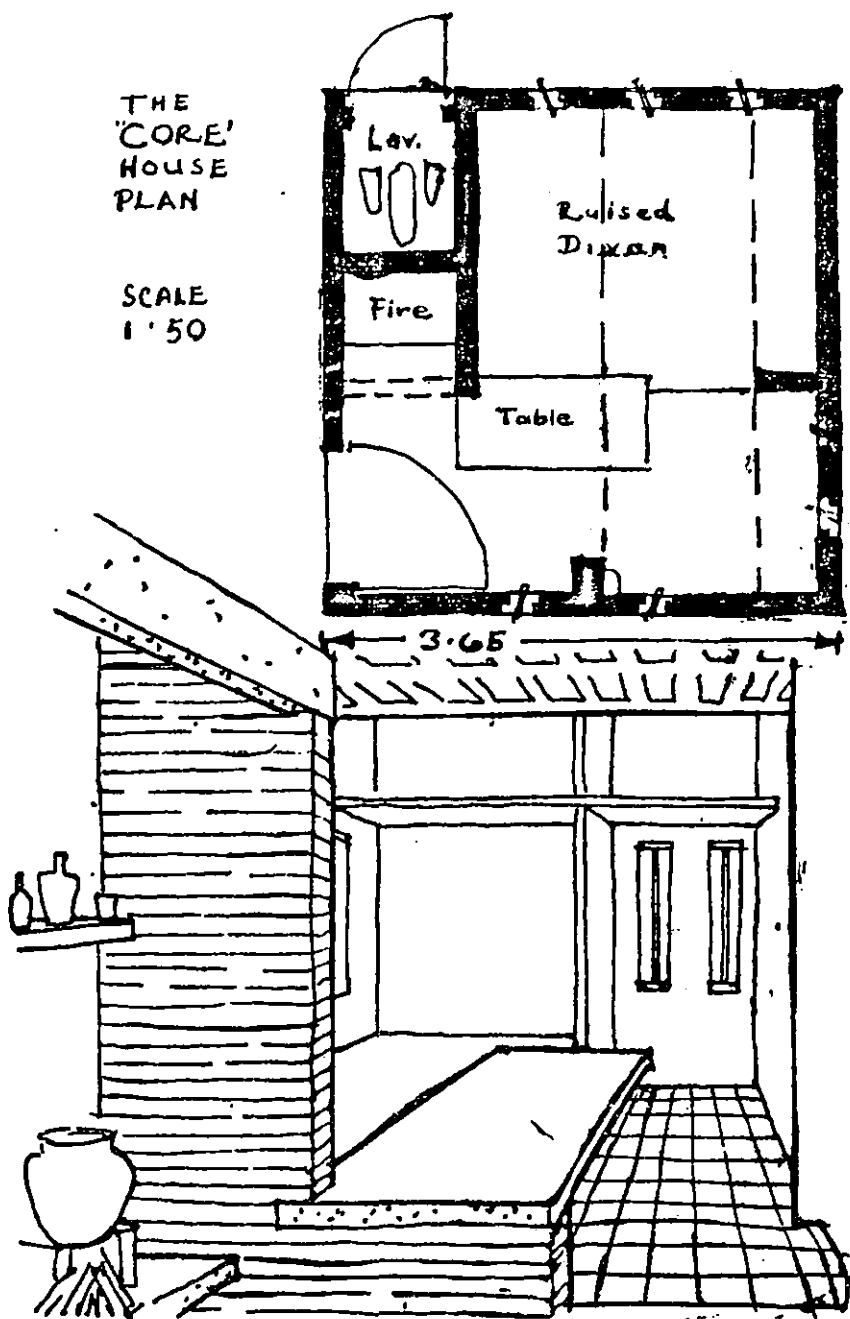
1.	Stone blocks	3.47
2.	Stone broken chips	3.12
3.	Burnt bricks	7.41
4.	Sand	2.30
5.	Cement	11.48
6.	Lime	2.00
7.	Timber	6.11
8.	Tiles	3.05
9.	A. C. or G. I. Sheets	2.34
10.	Iron and Steel	4.69
11.	Doors and windows	5.52
12.	Paints and varnish etc.	0.51
13.	Sanitary fittings	5.76
14.	Electrical fittings	2.90
15.	Plumbing and water supply	5.42
16.	Other materials	13.11
17.	Labour, skilled	6.66
18.	Labour, unskilled	5.86
19.	Supplied from home	3.08
20.	Municipal fees and taxes	0.68
21.	Supervision and charges	4.53

### **Minimum Core House**

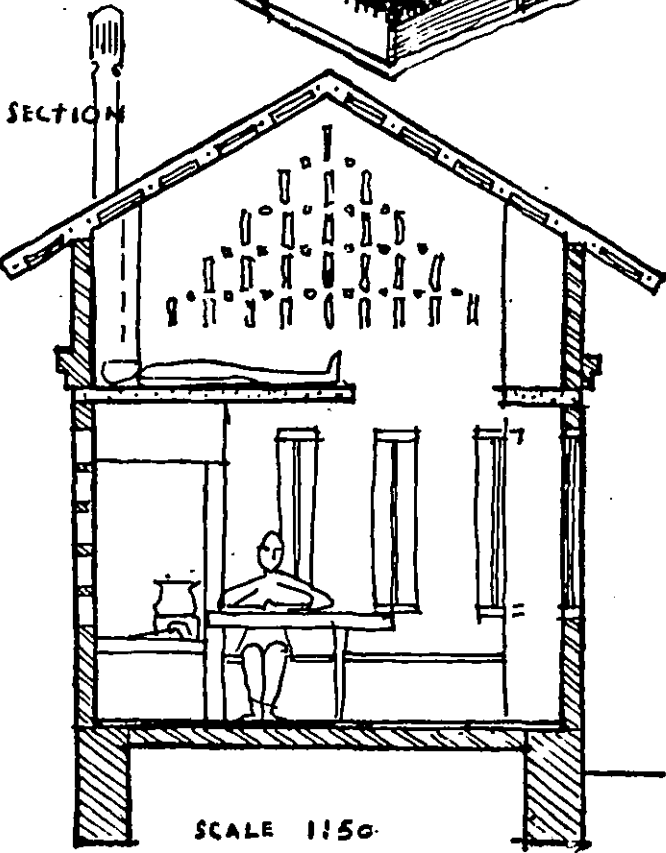
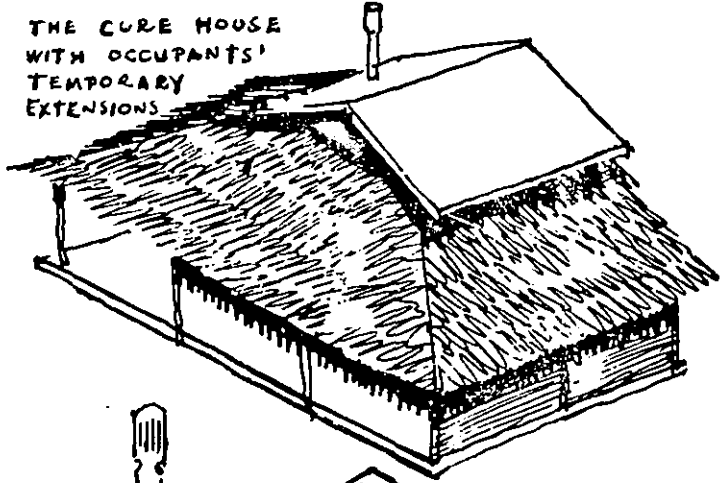
Any organisation or Government is eventually faced with the choice between quality and quantity. If a lakh of rupees is available for building new houses for a slum clearance scheme should we build one hundred houses each costing only one thousand rupees, or should we build only ten first class houses each costing ten thousand rupees. We believe that any new housing scheme must provide each house with a lavatory of its own (communal lavatories rarely work) and with a cooking place where smoke will not be a problem or fill the entire house. Living, and especially sleeping areas must be at least partly separated from each other. Many interested people have decided that a family can, with difficulty, incorporate these requirements into a house with a plinth area of 250 square feet. Even if we can build for as little as five rupees a square feet, this still means a cost of Rs. 1250.00. Sometimes even this money is not available. Can anything cheaper be done? We have therefore, considered for certain exceptional cases, the possibility of providing a solid permanent core, or nucleus, of a house and around this the inmates can add their own rooms and living spaces, perhaps at first with only temporary materials such as mud and ola thatch, and later with more permanent materials. This drawing shows that such a small minimum core could be built within a square of 144 square feet. The core has a minimum size lavatory. It has a small fireplace with a chimney. It has a table and a raised diwan or ready-built solid bed, and it has a large shelf, six feet wide and ten feet six inches long which can be used as another sleeping area or for storage purposes. This could be built for Rs. 750 to Rs. 1,000.

THE  
'CORE'  
HOUSE  
PLAN

SCALE  
1:50



THE CURE HOUSE  
WITH OCCUPANTS'  
TEMPORARY  
EXTENSIONS

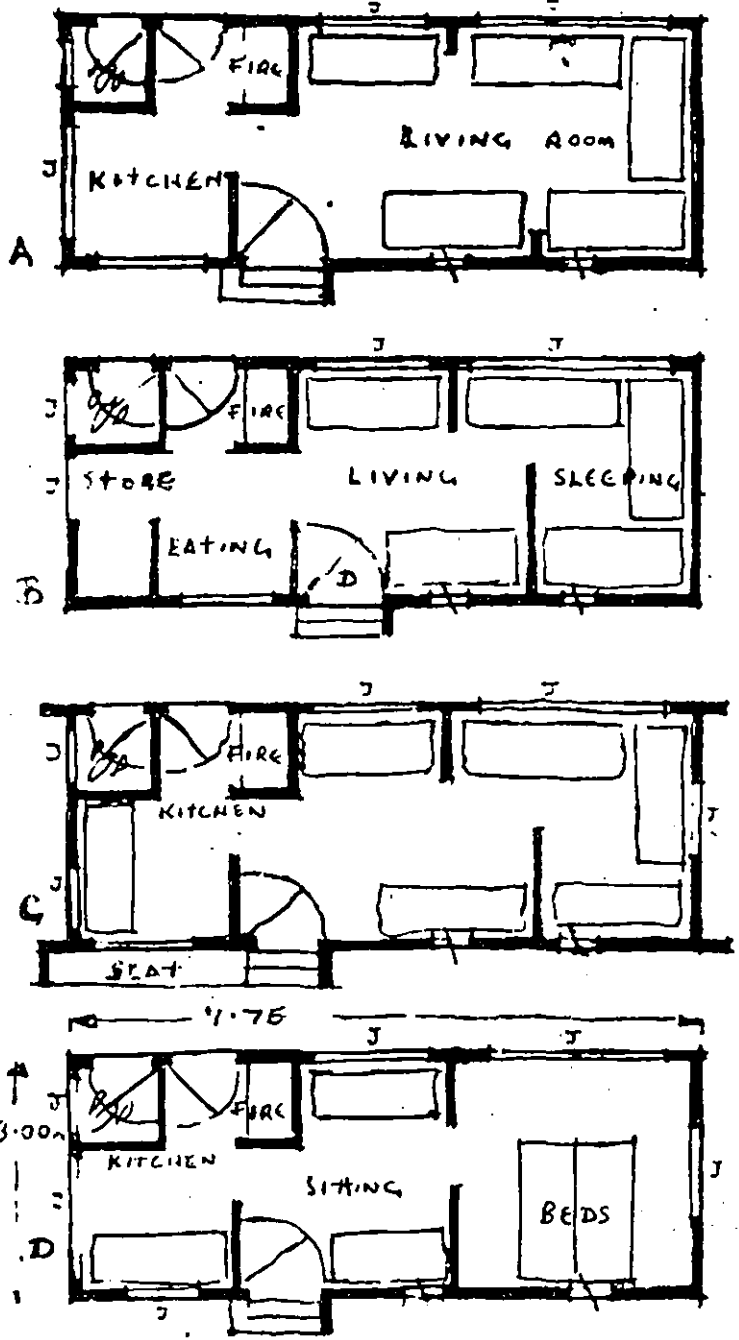


**31912/MC-5**

**House of 250 Sq. Ft.**

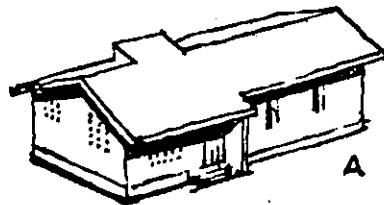
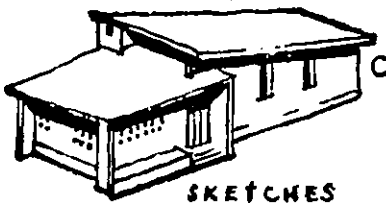
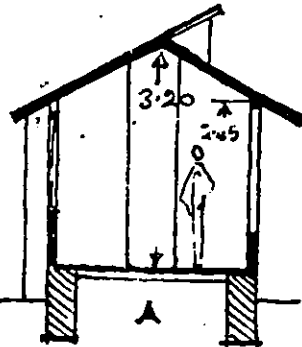
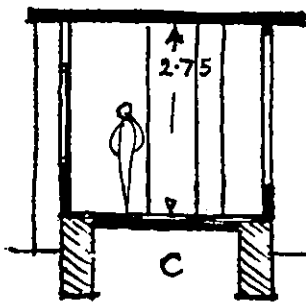
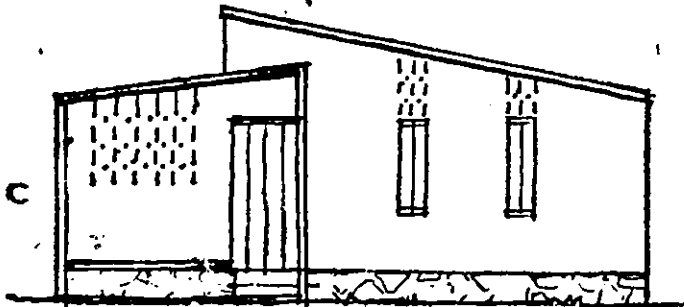
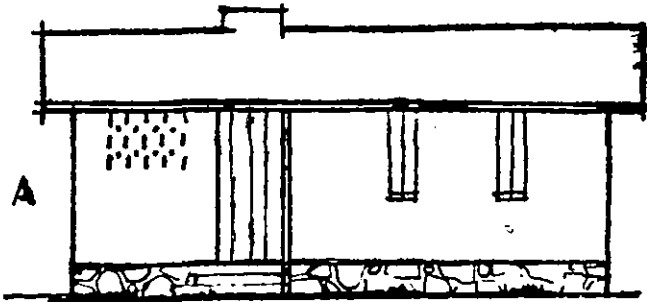
250 square feet is a very small area. After the area taken up by walls is removed you will get a room less than 210 feet square or 12 ft. x 18 ft., 21 ft. x 10 ft., or 24 ft. x 9 ft. You must think more in terms of the inside of a small railway compartment than of a house. In this drawing we suggest that for ventilation and efficient division of space into the necessary living and sleeping areas, the long narrow building is better, and we show four (of many) ways of dividing up such a space. To each plan the option table can be applied and the variety of houses that result are many. We show only two sections, two elevations, and sketches of two different types that can be built from such plans.

HOUSE OF 250 SQ. FT.  
ALTERNATIVE PLANS SCALE 1:100



SOME ELEVATIONS AND SECTIONS OF THE 250 sq. FT HOUSE

SCALE 1:100



SKETCHES



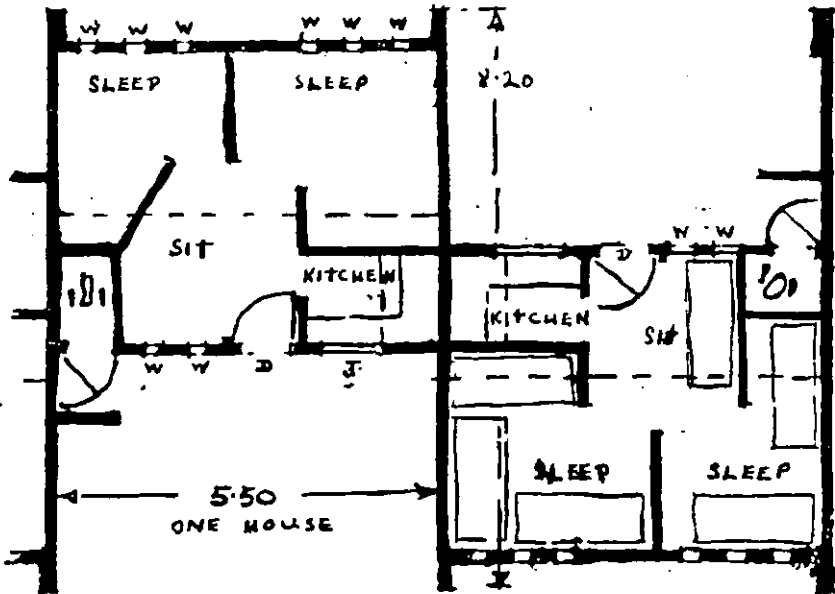
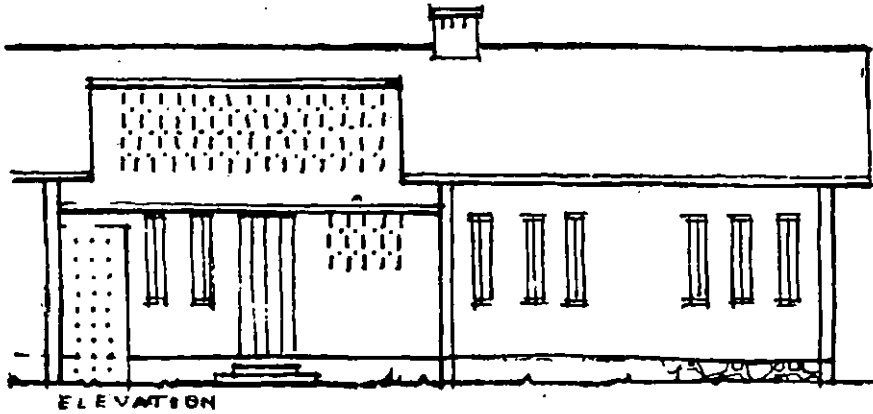
### **250 Sq. Ft. Row Houses**

In the text of the Report we have mentioned the objections that many Kerala people have to joining houses together for purposes of economy etc. These objections are understandable in rural surroundings where each farmer wants to be in the middle of his plot of land, but individual houses with a space all round them are very wasteful in urban settings, and usually, even in expensive colonies, the result of isolated buildings is a miserable unusable strip of land only a few feet wide all round each house and privacy is impossible.

This plan, therefore, is to demonstrate one of many ways of coping with this problem, and while saving both land and materials, privacy for each house is considerable. The only common walls are at the back of the fireplace and in the lavatory. The planning gives every house its own private garden or courtyard.

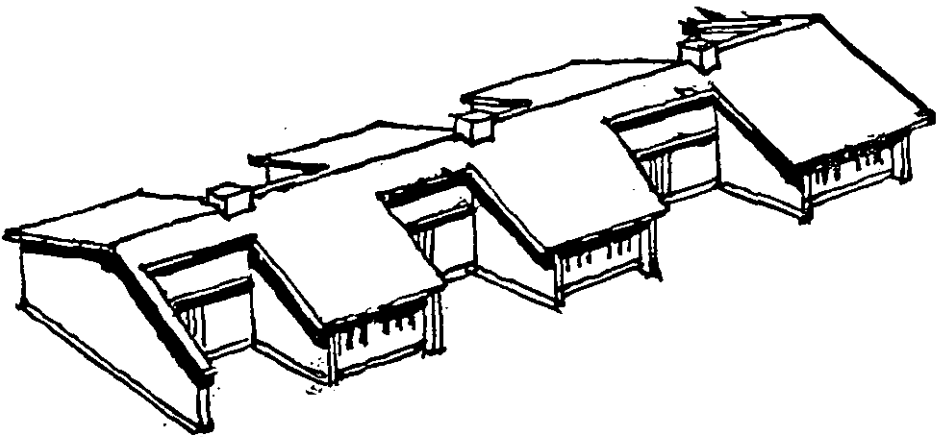
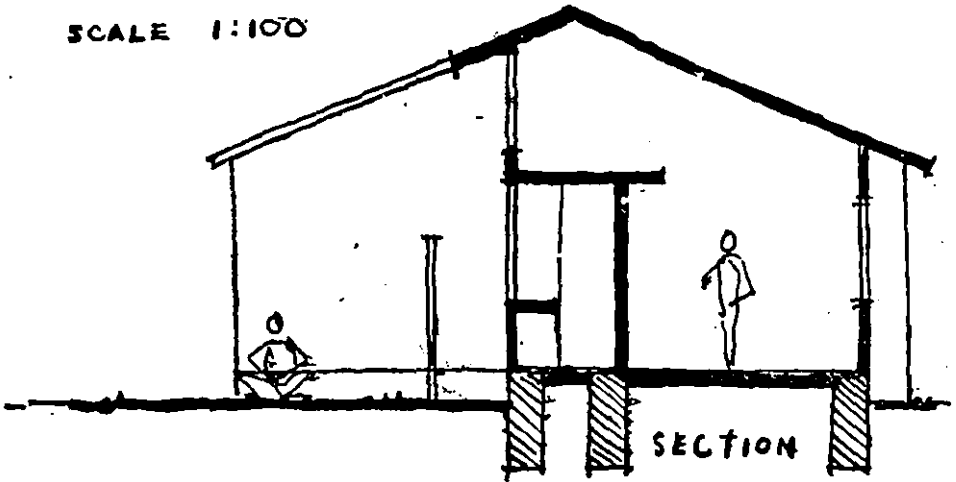
250 SQ FT ROW HOUSES

SCALE 1:100



SECTION AND SKETCH OF 250X50 SQ. FT.  
ROW HOUSES.

SCALE 1:100

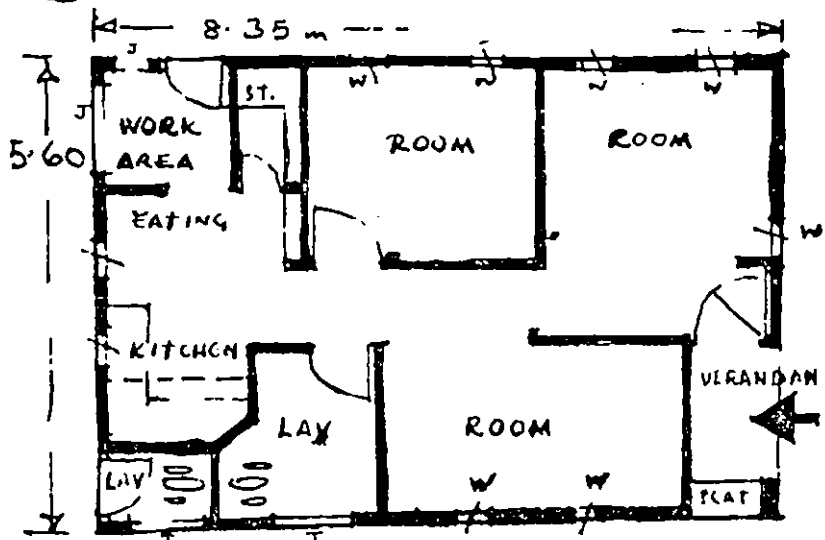
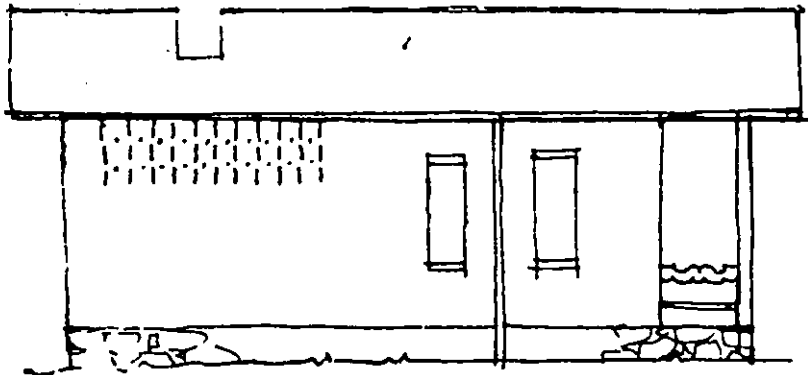
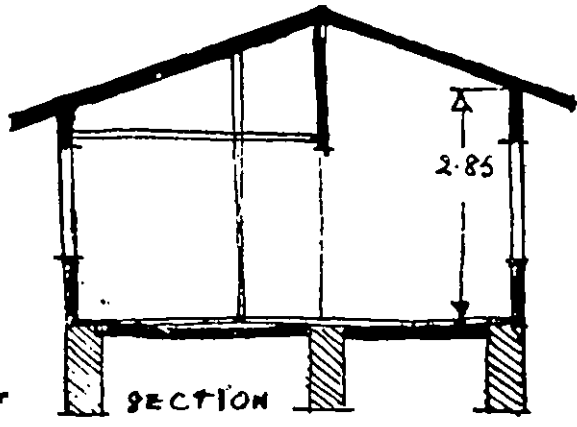


**500 Sq. Ft. House 3 Rooms**

Even an area of 500 square feet is still remarkably small when laid out full size on the ground—about 21 ft. square, or a rectangle or, say, 27'-6" x 18'-9" as in this simple plan. Again, the basic necessities take up much of the floor area and this is one of many such plans which includes all the normal requirements for a very small family house. These rooms do not conform to the National Building Code requirements but are much larger than many to be found in the majority of our country houses. Code requirements can be satisfied by leaving out actual doors and having a living area with divided living spaces.

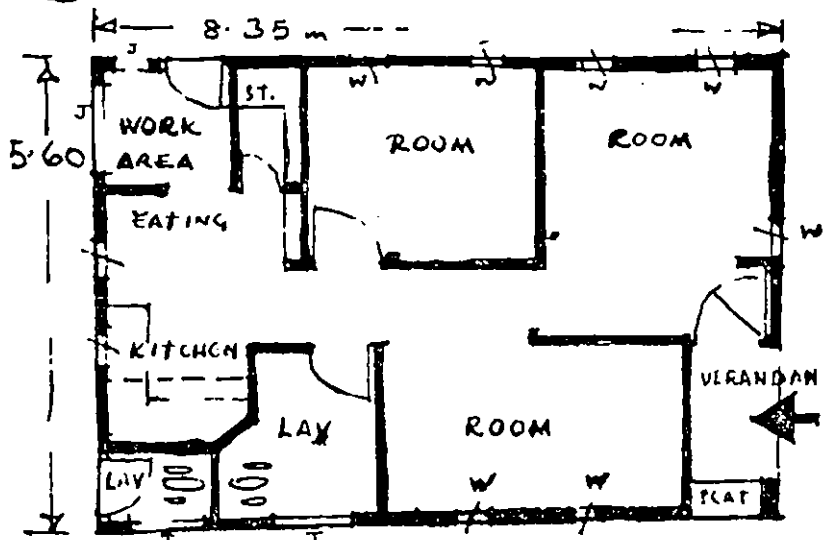
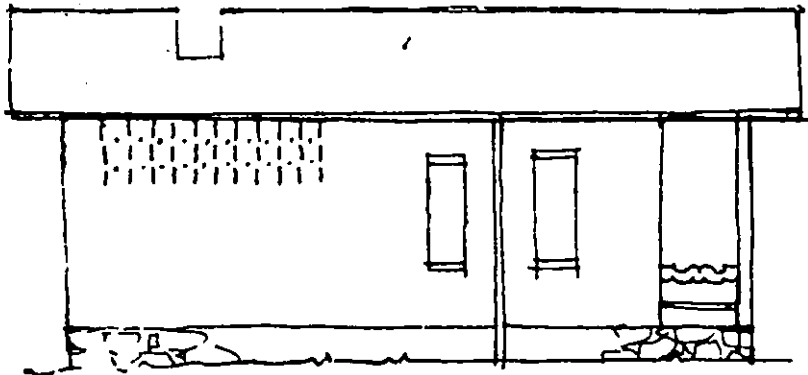
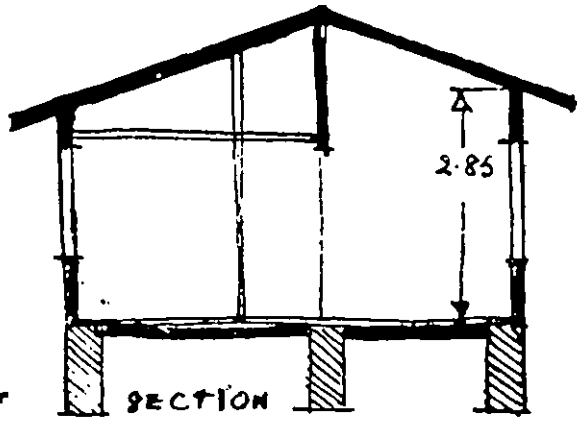
HOUSE OF  
500 SQ. FT.  
WITH  
3 ROOMS

SCALE  
1 : 100



HOUSE OF  
500 SQ. FT.  
WITH  
3 ROOMS

SCALE  
1 : 100

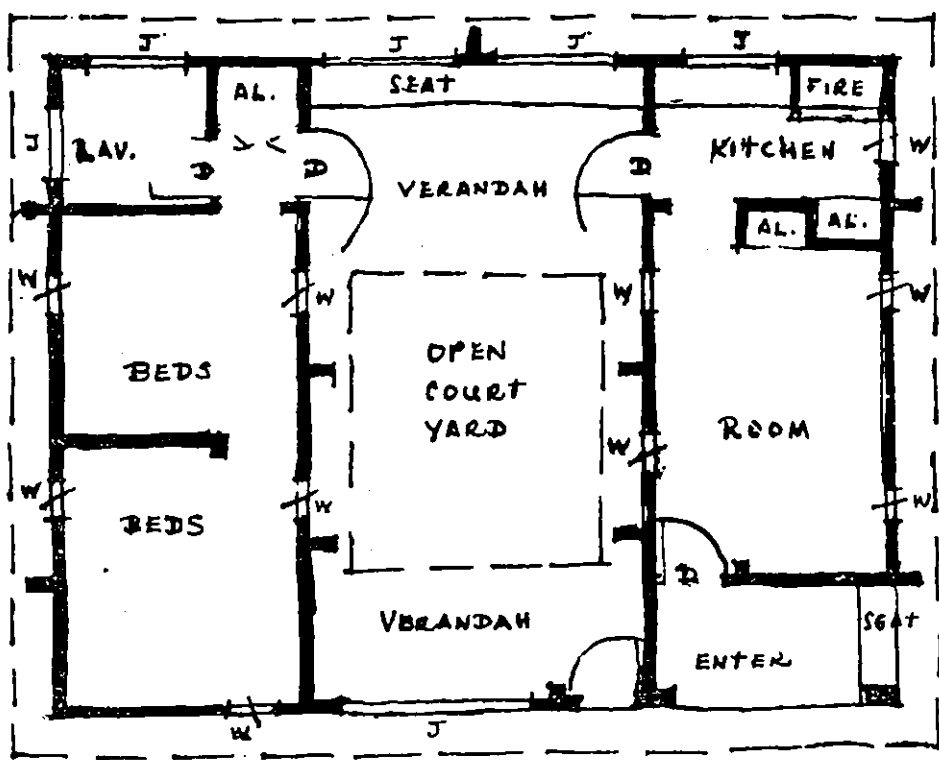
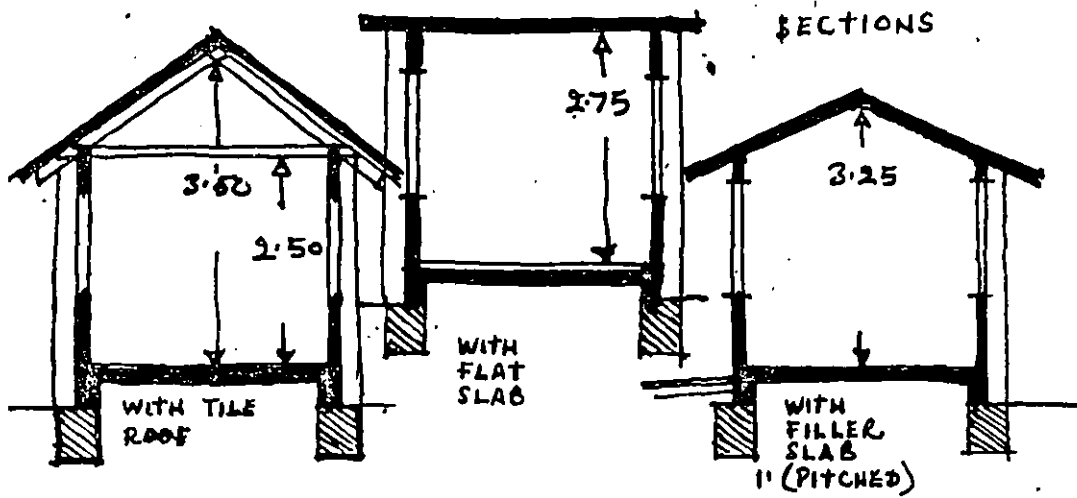


### **500 Sq. Ft. House with a Courtyard**

As we continue to point out, even an area double that which is considered to be a minimum area for a family house is still pitifully small. By dividing the plan into two sections and separating them with a courtyard or anganam, living area is greatly increased while building costs are only slightly more. The little bird's eye view sketches show this principle and the lower sketches show how the courtyard walls joining the two wings together can be extended either into verandahs or even later on into rooms. This plan should be compared with the previous plan. Again, this is only one of many possibilities for giving small buildings more living space so that for three hundred days of the year the family has almost twice as much living space as the small compact plan provides.

HOUSE OF 500 SQ. FT WITH A COURTYARD 1:100 SCALE

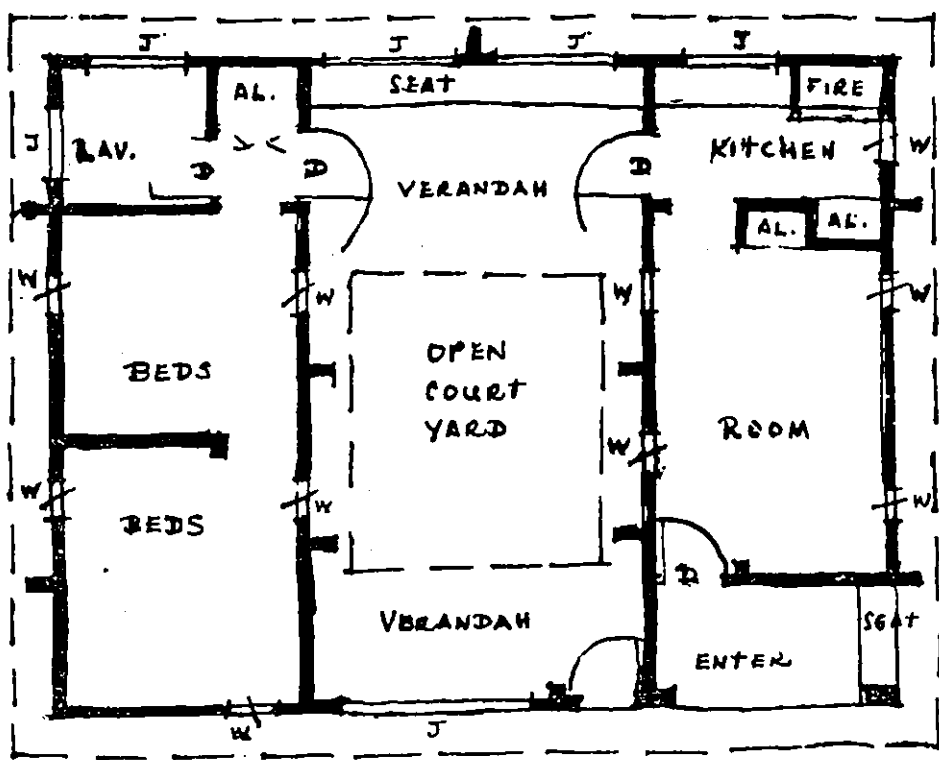
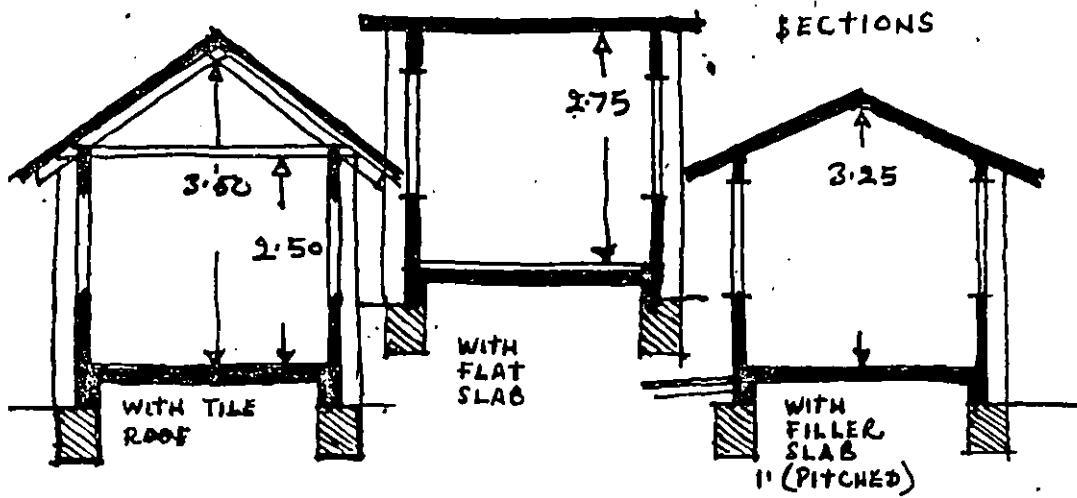
SECTIONS





HOUSE OF 500 SQ. FT WITH A COURTYARD 1:100 SCALE

SECTIONS

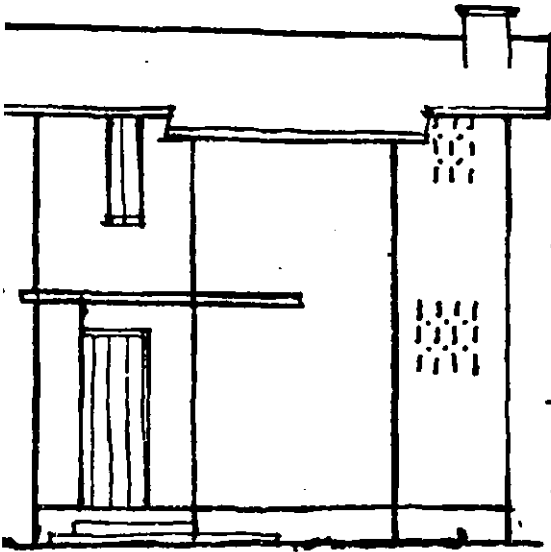


3|912|MC-6

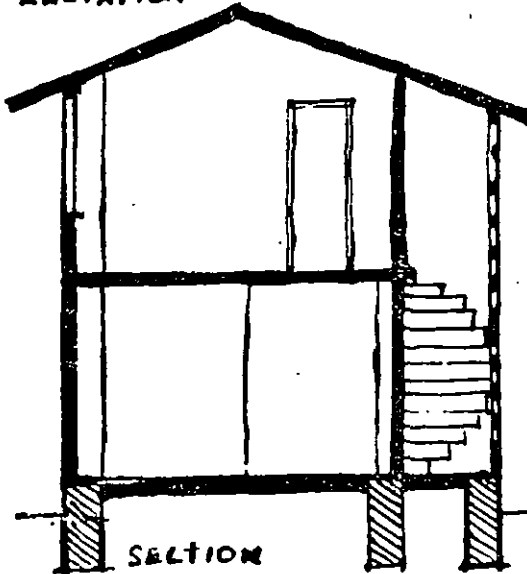
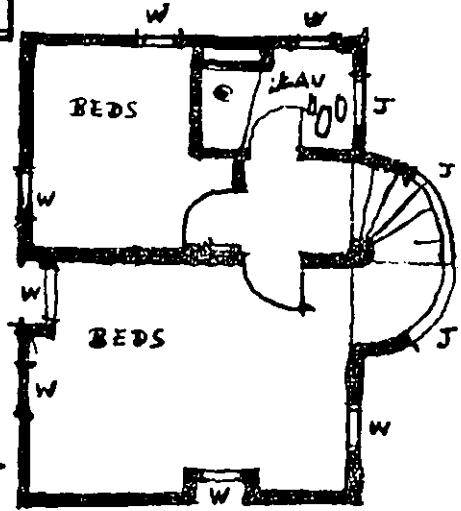
3|912|MC-6

2 STOREY 500 SQ. FT. HOUSE

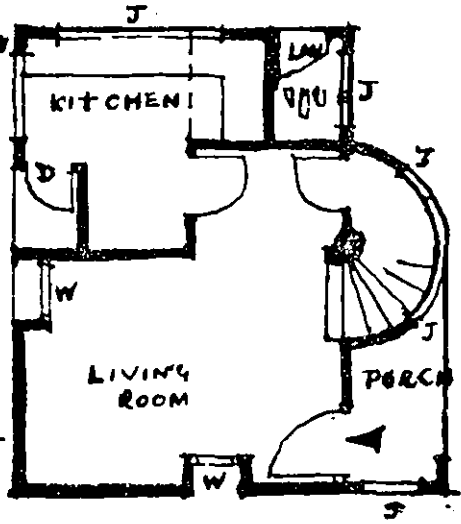
SCALE 1:100



ELEVATION



SECTION

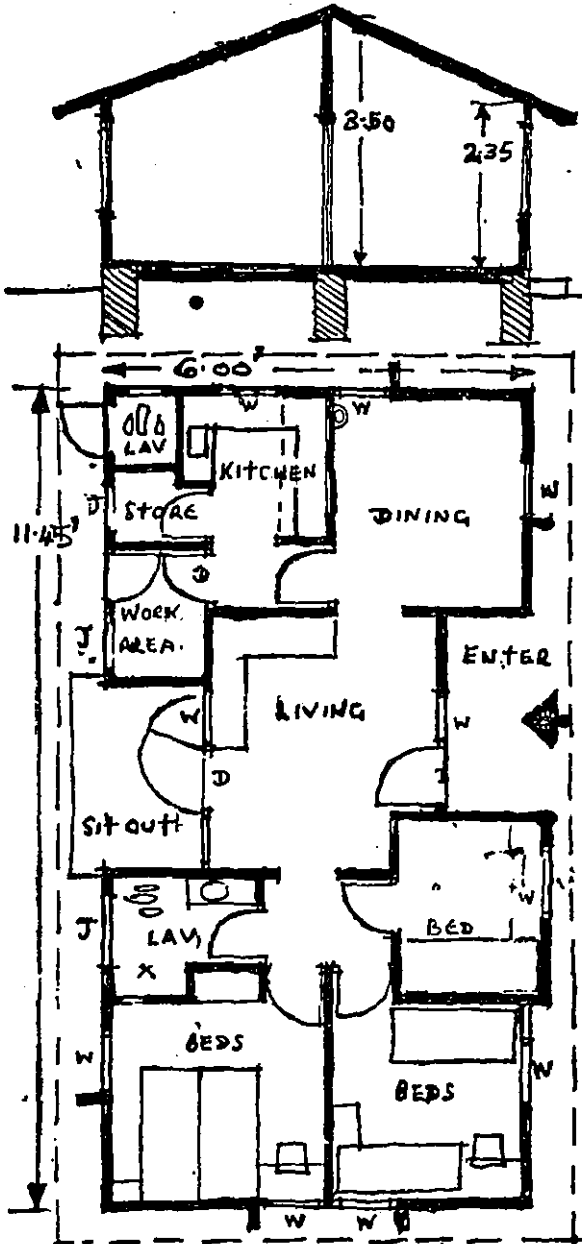


**A House 750 sq. ft. in area**

The 750 sq. ft. house is large enough to provide most of the accommodation required by a family. Obviously such plans are almost limitless, so we illustrate here one which shows that such a plan can contain both a sitting and a dining room and three separate bed rooms. Although many people would prefer bigger rooms, we have seen that people who are likely to use this size house often have a number of various dependents who cannot happily sleep in the same room as others, so separate rooms, however small, are of more use to the family.

HOUSE OF 750 SQ. FT

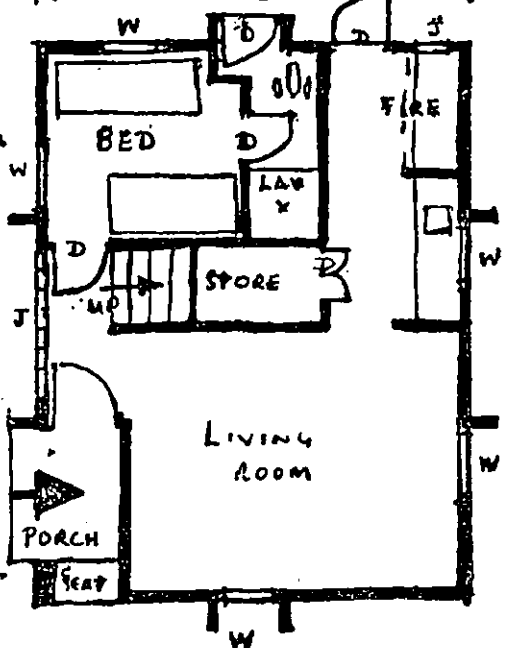
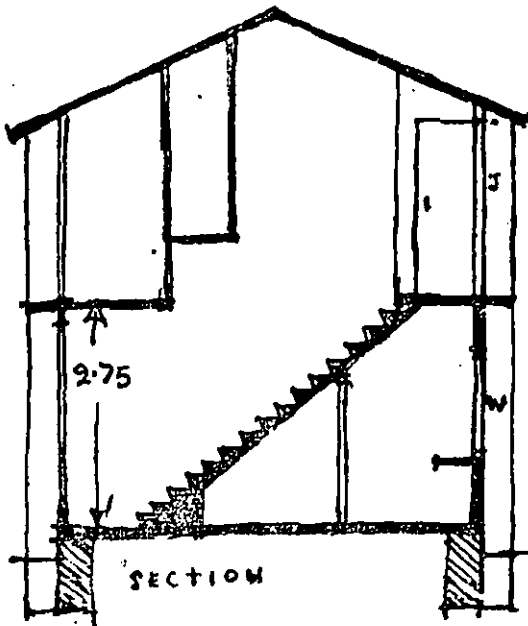
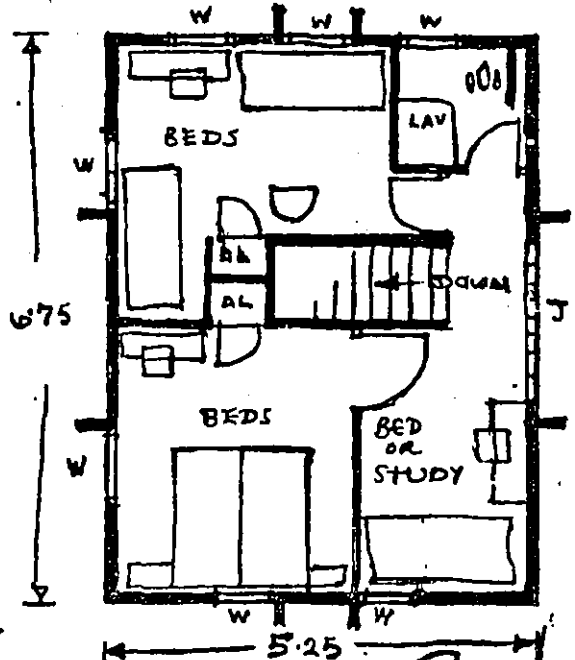
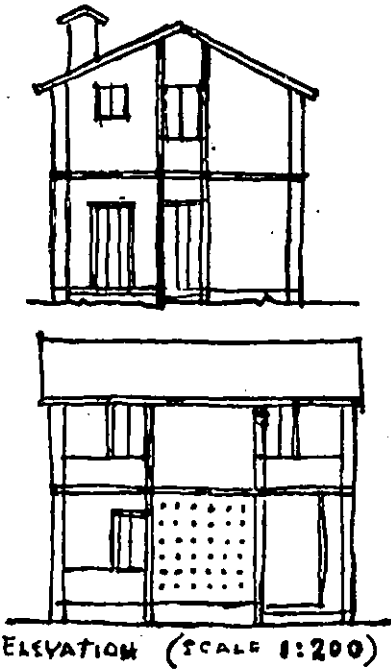
SCALE 1:100



**A Two Storey 750 sq. ft. House**

Although a staircase uses up valuable room, there is obviously a need for a two storey house where land must be conserved for other purposes than building. Again we illustrate a house which has one larger room for living on the ground floor, together with one small room which can be used as a bed room for an elderly person or as a study or guest room. Upstairs the object has been to provide three sleeping rooms to cope with adults, girls and boys separately.

TWO STOREY HOUSE OF 750 SQ.FT (TOTAL AREA OF BOTH FLOORS)  
SCALE 1:100



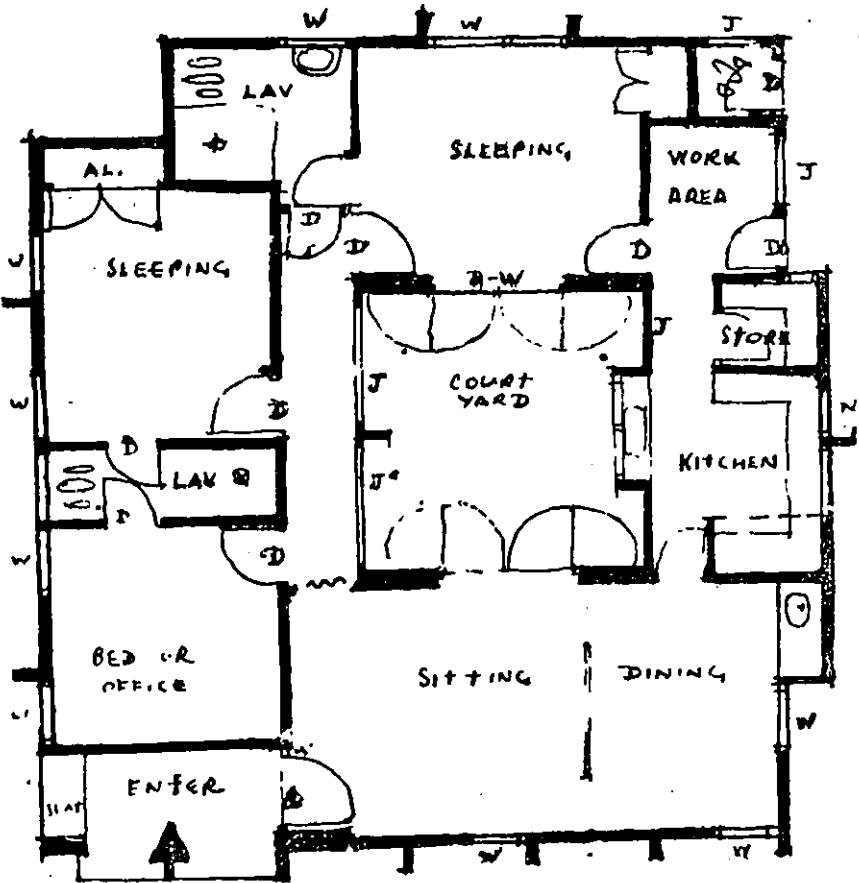
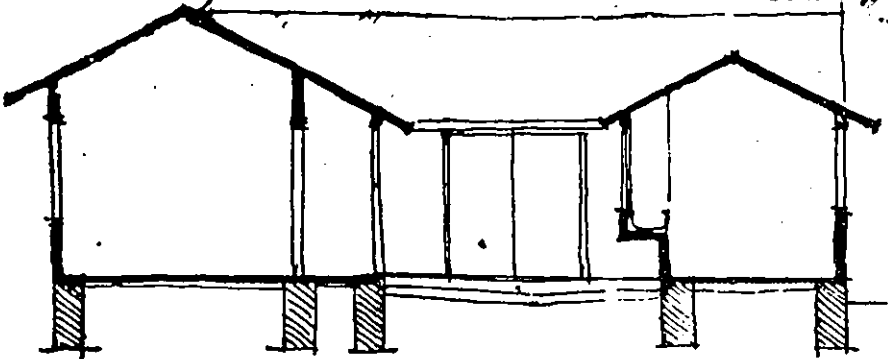


**House of 1000 sq. ft. area, with Courtyard**

The number of plans which can be designed for one thousand square feet plinth area are almost numberless.

We are illustrating one which gives even more living space by having a courtyard or anganam in the middle. This also aids cross ventilation which is one of the problems of the larger house. The application of the option table, and the variation of room shapes and sizes, positions of doors and windows and cupboards, and use of various elevation treatments, roof construction, etc., will give almost endless designs from such a basic design.

HOUSE OF 1000 SQ FT WITH A COURTYARD 1:100 SCALE



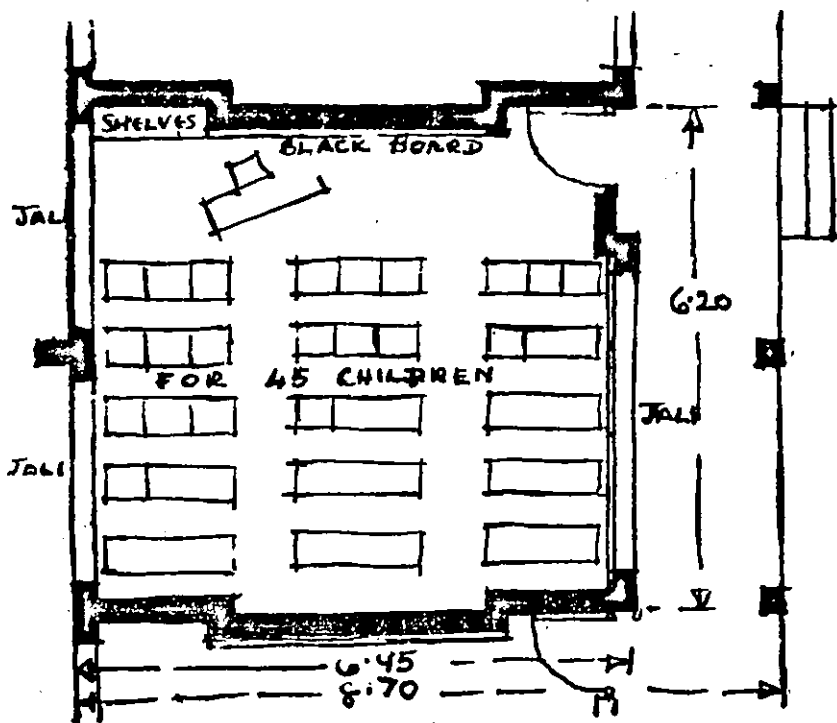
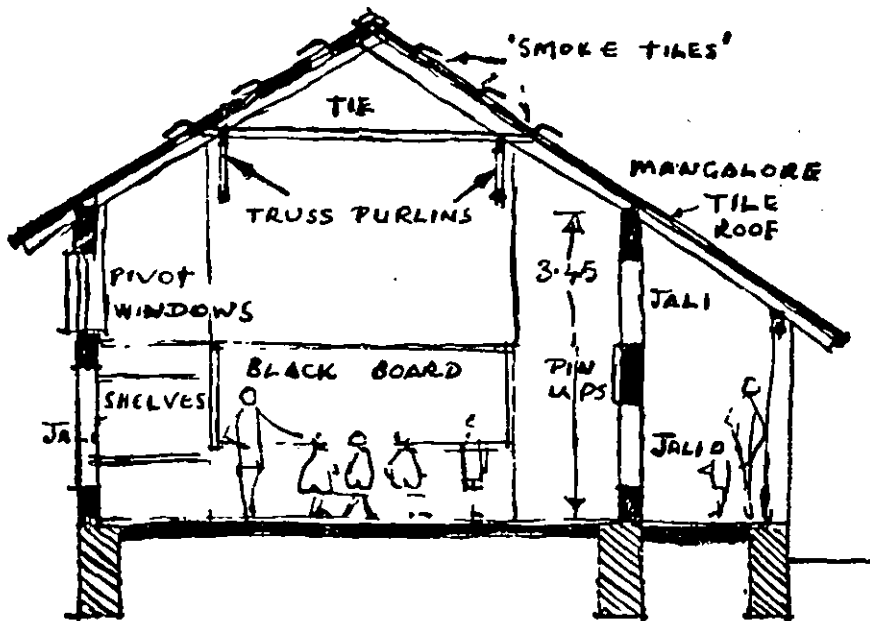
## **Class Room**

When designing schools we have to cope with a number of problems which are extra to those of house design. First of all our classes are large and each room has to be big enough to hold at least 45 children. The second problem is that children can be thoughtless, irresponsible and destructive, so buildings must be capable of standing up to hard wear and tear. Plaster gets knocked off, door and window shutters get broken off their hinges. Any loose fitting quickly disappears altogether. Good diffused lighting and plenty of cross ventilation is needed but this in turn produces the further problem of how to cope with extraneous disturbing noises and sights. Much dissatisfaction is now expressed about our education and teaching methods and in many countries there is a tendency to experiment with multipurpose rooms where freer teaching methods can be used and where children can indulge in a mixture of activities under one roof. However, there seems little or no movement towards such ideas here in Kerala so we are confining ourselves to the design of the usual almost square room surrounded by four walls.

Again our option table must be applied and there is scope for considerable economy in construction. In this, one of several possible plans, a bare nine inch brick wall is used throughout, but long stretches of wall are avoided and the resulting recesses made use of while extra strength is given to the whole structure. The usual problem wall is the one between the class room and the approach corridor or verandah. Ventilation is necessary but classes are disturbed

CLASS ROOM

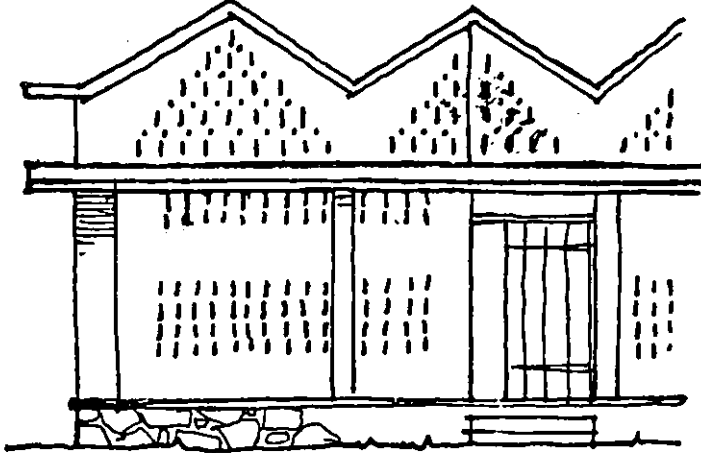
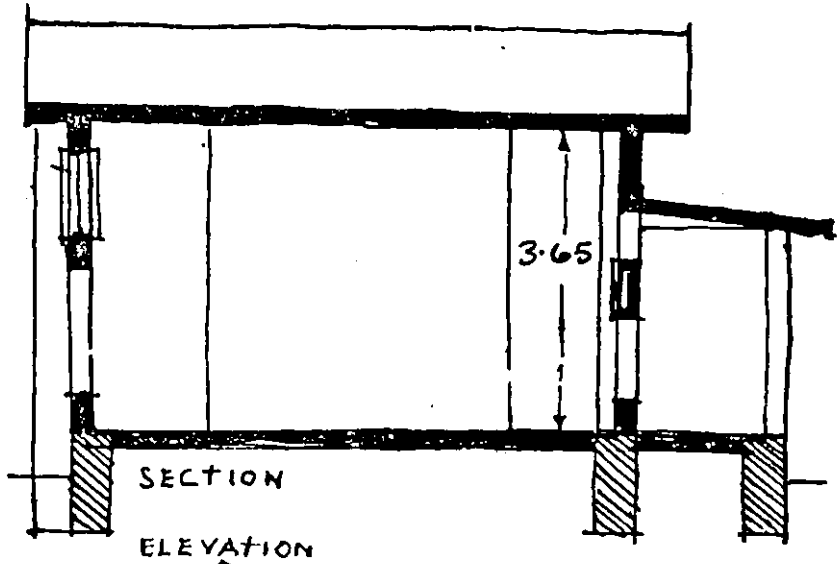
SCALE 1:100



by people using the corridor. To avoid this, a special jali is used so that there is light and air but there is no direct view out from the class room.

Above seated head height there is a strip of solid wall for hanging up drawings, charts, etc. On the opposite outside wall there is a similar problem of disturbance, so again up to door top height the diagonal jali pattern is used with windows above. There is no reason why the simplified frameless window should not be used in class rooms and the possibility of damage is much less. If the roof is to be made with Mangalore tiles, simple truss-purlins simplify roof spanning problems, and if a filler slab is considered more durable and suitable, a folded plate design avoids the need for heavy expensive R. C. beams.

CLASS ROOM SCALE 1:100  
ALTERNATIVE SECTION USING FILLER SLAB



SECTION AND SKETCH OF 250 SQ. FT  
ROW HOUSES  
SCALE 1:100

## **Tourist Accommodation**

There are many opinions about the type, quality and design of buildings which could be provided for tourists. As an example of what could be done at low cost we are illustrating here some possible cottages to meet various tourist needs at such a beauty spot as Ponnammudi, only two or three hours run above Trivandrum.

The octagonal cottage has one bed-sitting room with a view over the plains below. Table-desks are built in, and there is plenty of built in almira space. There is a small entrance room and a bath room.

There is a square stone cottage with two rooms. One is the ordinary bed-sitting room. The other can be fitted with built in divans so that it can either be used as a sitting room, or be used as a bed room. The two rooms together with an entrance room and bath rooms form a suitable cottage for family tourist use.

There is a larger cottage for the use of students or other groups of tourists. This has a large common room with a sunken sitting area round a fire place and there are built in seats and tables, all with beautiful views through the windows.

Then there is a dormitory-like room fitted with built in bunks and lockers. A small entrance room, lavatories and a place where students can brew their own coffee etc., completes an attractive but simple building made almost entirely from the local stone.

Very often tourists cannot afford tourist hotel food prices. We have included, therefore, a simple canteen building in which a warden can live and serve simple meals to visitors occupying the cottages.

## **Tourist Accommodation**

There are many opinions about the type, quality and design of buildings which could be provided for tourists. As an example of what could be done at low cost we are illustrating here some possible cottages to meet various tourist needs at such a beauty spot as Ponnammudi, only two or three hours run above Trivandrum.

The octagonal cottage has one bed-sitting room with a view over the plains below. Table-desks are built in, and there is plenty of built in almira space. There is a small entrance room and a bath room.

There is a square stone cottage with two rooms. One is the ordinary bed-sitting room. The other can be fitted with built in divans so that it can either be used as a sitting room, or be used as a bed room. The two rooms together with an entrance room and bath rooms form a suitable cottage for family tourist use.

There is a larger cottage for the use of students or other groups of tourists. This has a large common room with a sunken sitting area round a fire place and there are built in seats and tables, all with beautiful views through the windows.

Then there is a dormitory-like room fitted with built in bunks and lockers. A small entrance room, lavatories and a place where students can brew their own coffee etc., completes an attractive but simple building made almost entirely from the local stone.

Very often tourists cannot afford tourist hotel food prices. We have included, therefore, a simple canteen building in which a warden can live and serve simple meals to visitors occupying the cottages.



## **Tourist Accommodation**

There are many opinions about the type, quality and design of buildings which could be provided for tourists. As an example of what could be done at low cost we are illustrating here some possible cottages to meet various tourist needs at such a beauty spot as Ponnammudi, only two or three hours run above Trivandrum.

The octagonal cottage has one bed-sitting room with a view over the plains below. Table-desks are built in, and there is plenty of built in almira space. There is a small entrance room and a bath room.

There is a square stone cottage with two rooms. One is the ordinary bed-sitting room. The other can be fitted with built in divans so that it can either be used as a sitting room, or be used as a bed room. The two rooms together with an entrance room and bath rooms form a suitable cottage for family tourist use.

There is a larger cottage for the use of students or other groups of tourists. This has a large common room with a sunken sitting area round a fire place and there are built in seats and tables, all with beautiful views through the windows.

Then there is a dormitory-like room fitted with built in bunks and lockers. A small entrance room, lavatories and a place where students can brew their own coffee etc., completes an attractive but simple building made almost entirely from the local stone.

Very often tourists cannot afford tourist hotel food prices. We have included, therefore, a simple canteen building in which a warden can live and serve simple meals to visitors occupying the cottages.

## **Tourist Accommodation**

There are many opinions about the type, quality and design of buildings which could be provided for tourists. As an example of what could be done at low cost we are illustrating here some possible cottages to meet various tourist needs at such a beauty spot as Ponnammudi, only two or three hours run above Trivandrum.

The octagonal cottage has one bed-sitting room with a view over the plains below. Table-desks are built in, and there is plenty of built in almira space. There is a small entrance room and a bath room.

There is a square stone cottage with two rooms. One is the ordinary bed-sitting room. The other can be fitted with built in divans so that it can either be used as a sitting room, or be used as a bed room. The two rooms together with an entrance room and bath rooms form a suitable cottage for family tourist use.

There is a larger cottage for the use of students or other groups of tourists. This has a large common room with a sunken sitting area round a fire place and there are built in seats and tables, all with beautiful views through the windows.

Then there is a dormitory-like room fitted with built in bunks and lockers. A small entrance room, lavatories and a place where students can brew their own coffee etc., completes an attractive but simple building made almost entirely from the local stone.

Very often tourists cannot afford tourist hotel food prices. We have included, therefore, a simple canteen building in which a warden can live and serve simple meals to visitors occupying the cottages.

## **Tourist Accommodation**

There are many opinions about the type, quality and design of buildings which could be provided for tourists. As an example of what could be done at low cost we are illustrating here some possible cottages to meet various tourist needs at such a beauty spot as Ponnammudi, only two or three hours run above Trivandrum.

The octagonal cottage has one bed-sitting room with a view over the plains below. Table-desks are built in, and there is plenty of built in almira space. There is a small entrance room and a bath room.

There is a square stone cottage with two rooms. One is the ordinary bed-sitting room. The other can be fitted with built in divans so that it can either be used as a sitting room, or be used as a bed room. The two rooms together with an entrance room and bath rooms form a suitable cottage for family tourist use.

There is a larger cottage for the use of students or other groups of tourists. This has a large common room with a sunken sitting area round a fire place and there are built in seats and tables, all with beautiful views through the windows.

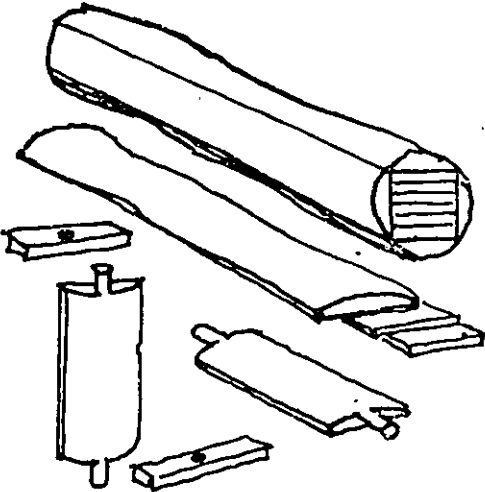
Then there is a dormitory-like room fitted with built in bunks and lockers. A small entrance room, lavatories and a place where students can brew their own coffee etc., completes an attractive but simple building made almost entirely from the local stone.

Very often tourists cannot afford tourist hotel food prices. We have included, therefore, a simple canteen building in which a warden can live and serve simple meals to visitors occupying the cottages.

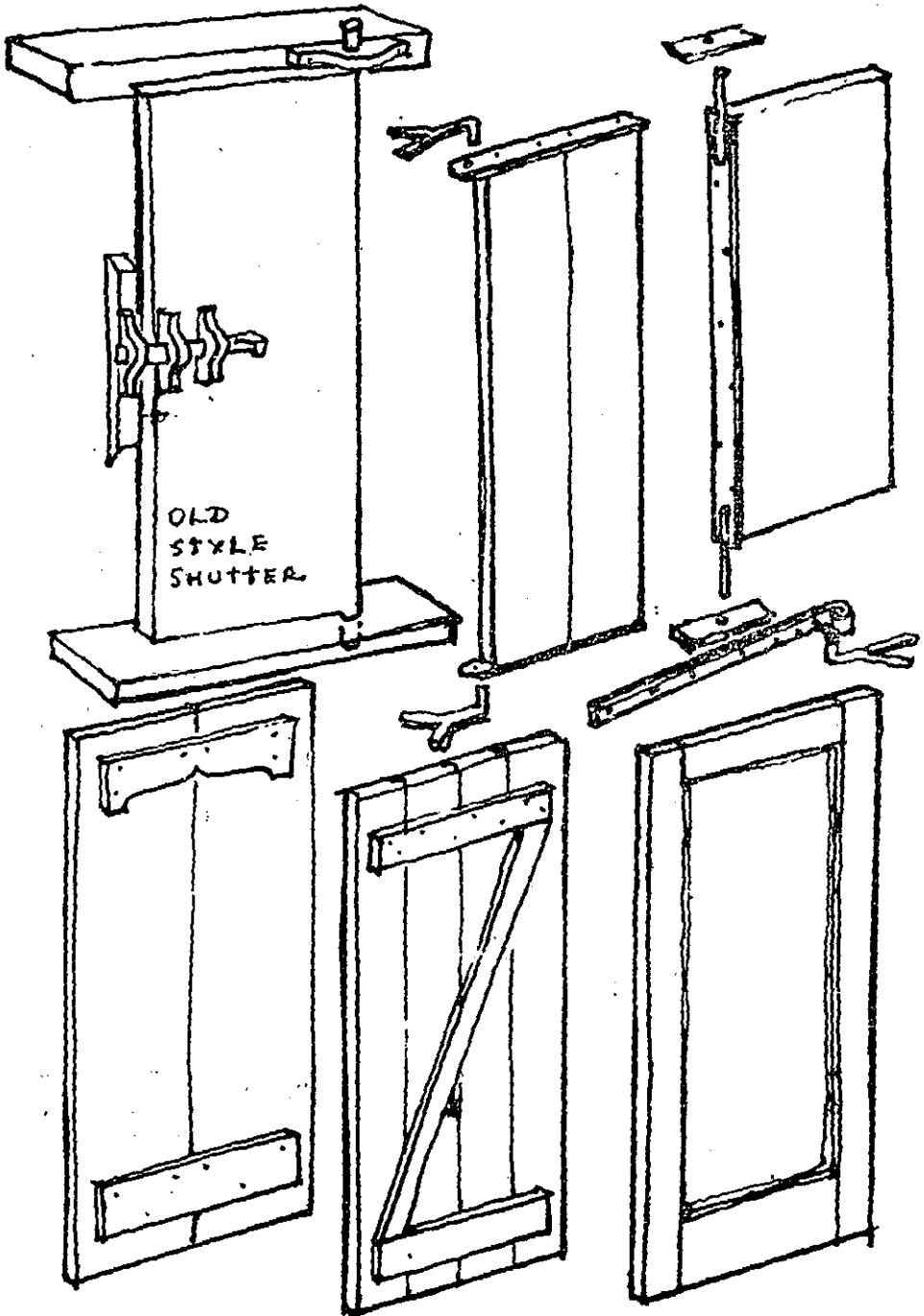
3|912|MC—a

## Windows and Doors

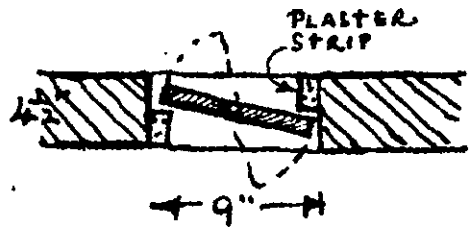
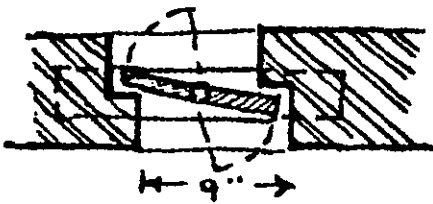
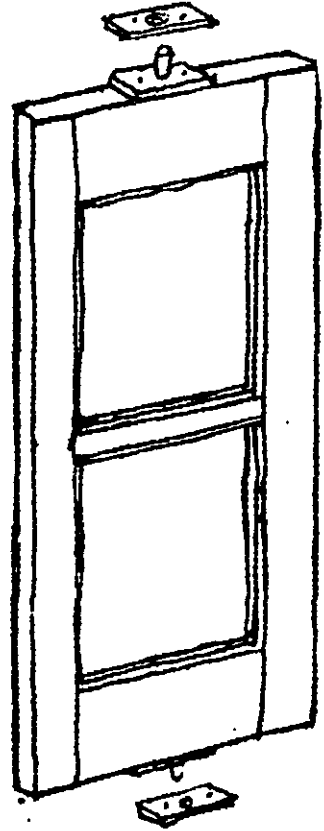
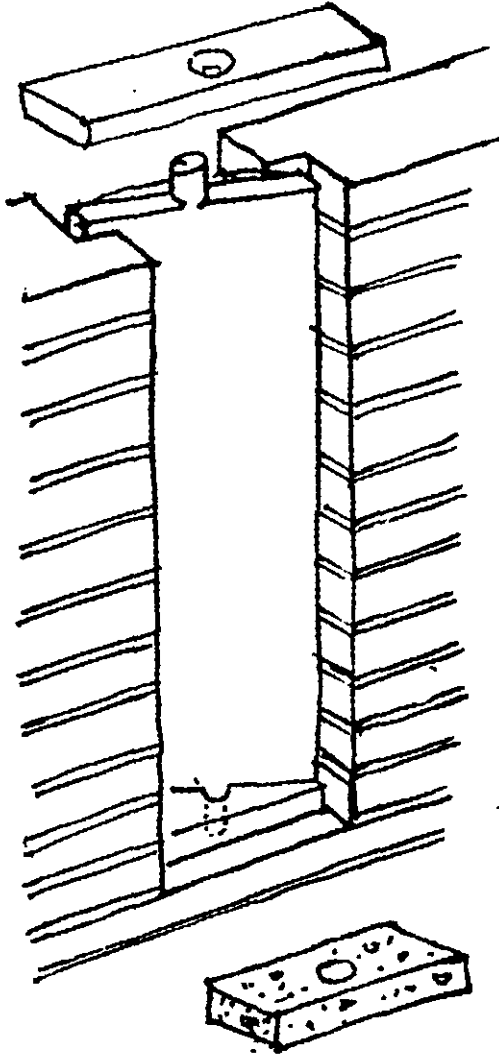
These drawings show the possibilities for using doors and windows which are mainly frameless. These can well be made of the outer waste wood from a log of timber when it is being sawn up.



FRAMELESS DOORS



FRAMELESS WINDOWS



## **Rural, or Bore Hole Latrines and Septic Tanks**

Outside our larger city areas sanitation is a problem.

We are therefore illustrating two types of waste disposal units, the bore hole and the septic tank.

The bore hole, as it's name implies, is a simple hole dug out of the ground. It should be as deep as possible (not less than six feet or two meters) and the deeper it is the better it is. It can be as small in diameter as is possible to make it. For practical reasons of digging and working at excavation the usual diameter of the hole is about three feet or one meter. If the top few feet are through loose soil, then a ring of masonry or brick work is necessary to prevent the sides at the top falling in. But lower down, usually no lining is necessary. The top should be covered with small reinforced concrete slabs (the reinforcement can be of bamboo, not steel). The latrine shed can be built immediately above the hole, with a suitable slab containing a water-seal latrine pan and trap. However, for purposes of eventual cleaning out, or if the contents are to be used for manure, it is more convenient to build the latrine shed a few feet away from the bore hole and the pan be connected to the hole with two or three earthenware pipes, as shown in the drawings.

A practice recommended, but not often much used for practical reasons is to have two bore holes to one latrine shed.

The pan is connected to a system of pipes laid in a Y shape. While one hole is being filled, the other hole can be emptied and the contents used as manure.



# BORE HOLE OR RURAL LATRINE

SCALE 1:50

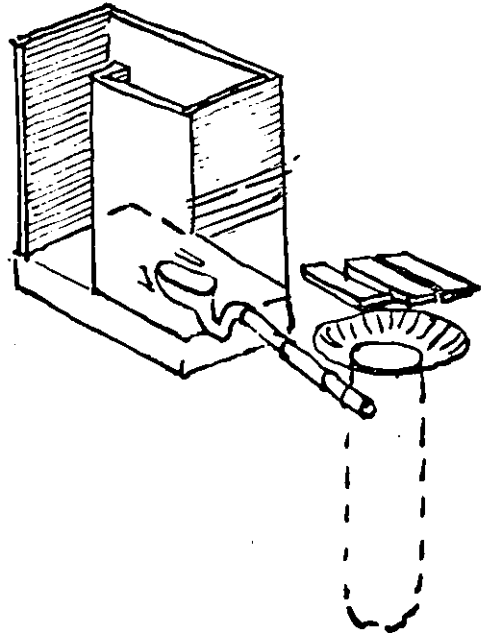
PRECAST SLAB COVERS  
THE BORE HOLE  
(REINFORCEMENT CAN BE BAMBOO)

ANY TYPE  
OF  
SUPER-  
STRUCTURE

BRICK  
LINING  
AT TOP  
IF THE  
SOIL IS  
LOOSE

BORE HOLE  
AS DEEP AS  
POSSIBLE

SECTION



The septic tank is similar to any other recommended septic tank with one or two alterations. The tank is made very long and narrow instead of the usual square or almost square plan. This allows a cheaper form of covering to be made of a number of small narrow pre-cast concrete slabs which can be reinforced with bamboo instead of steel. When cleaning out of the tank has to be done, it is easier to lift off these smaller slabs than the usual large solid slab. A manhole is more costly and is not always where one needs to clean out or excavate.

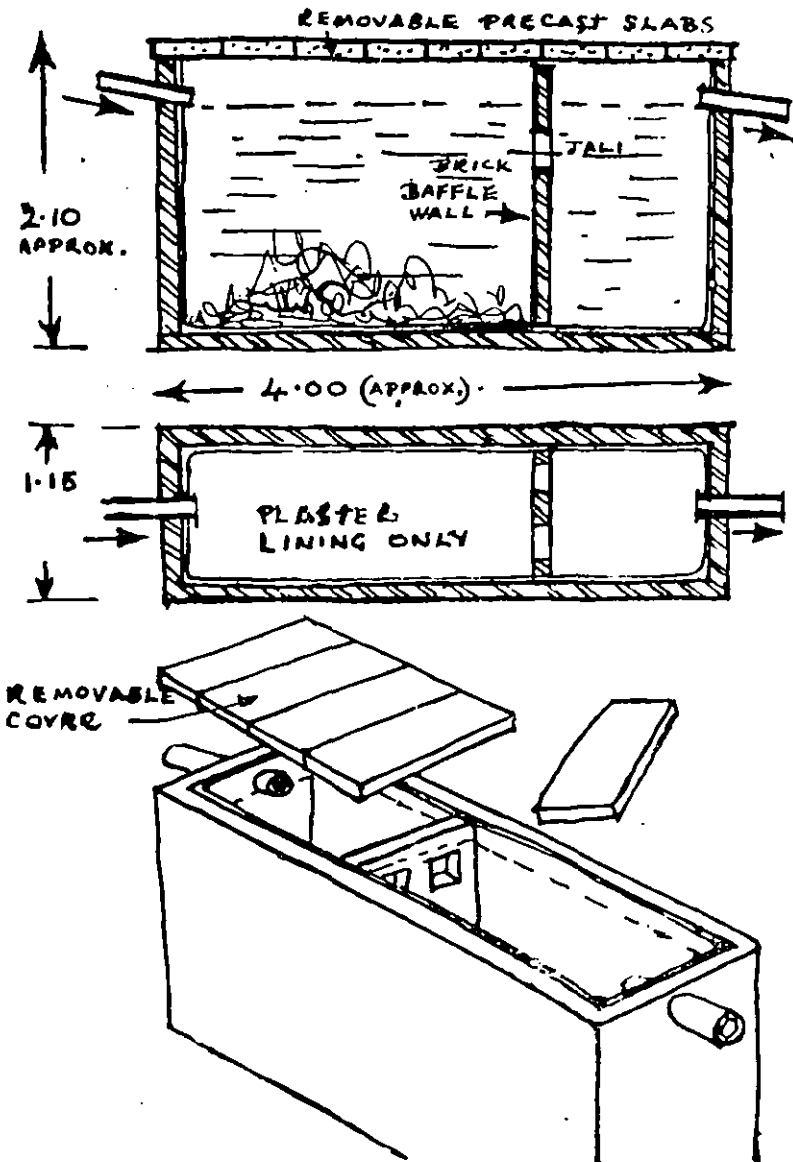
The depth of the tank should be not less than four and a half feet but can be deeper. Again-the deeper the better. A septic tank must be plastered inside and be water-proof. The baffle wall can be built in afterwards and be an unplastered brick jali wall.

Usually the entry pipe ends in a T pipe, but this is often the cause of obstruction and blockage. An ordinary straight entrance pipe is perfectly satisfactory.

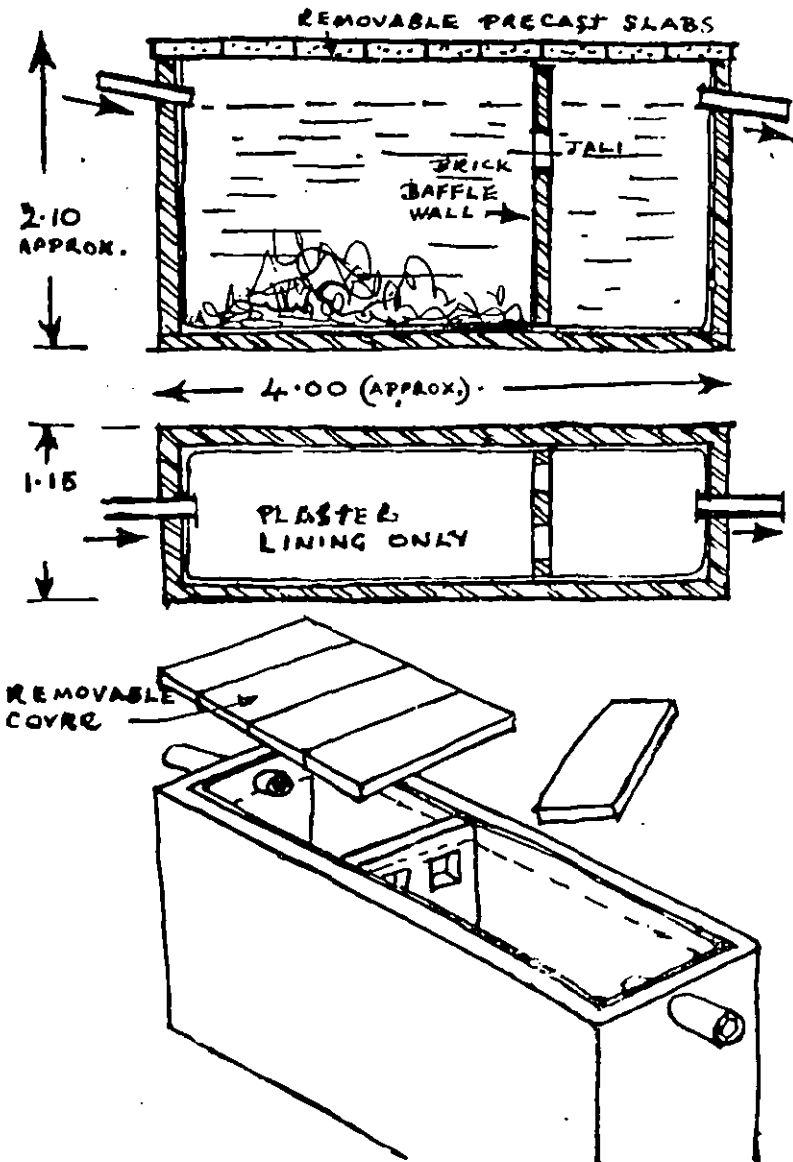
Some form of gas outlet pipe should be used.

There are many types of latrine shed, or the tank can be connected to bathrooms within the house by means of pipes.

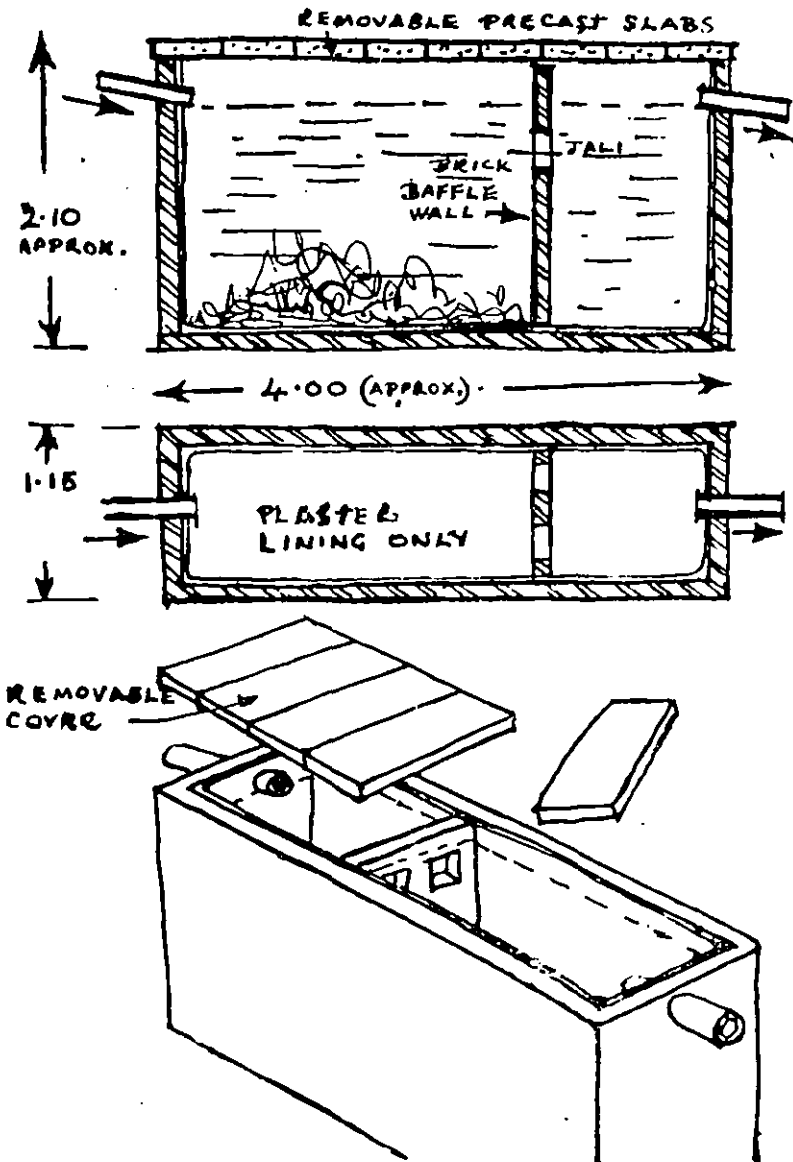
SIMPLEST TYPE OF SEPTIC TANK  
SCALE 1:50



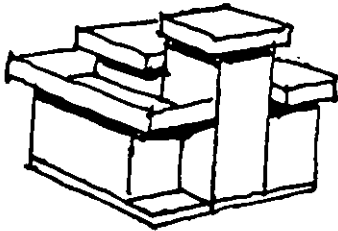
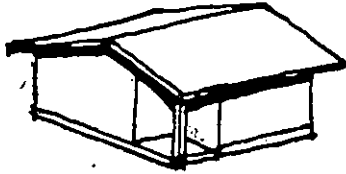
SIMPLEST TYPE OF SEPTIC TANK  
SCALE 1:50



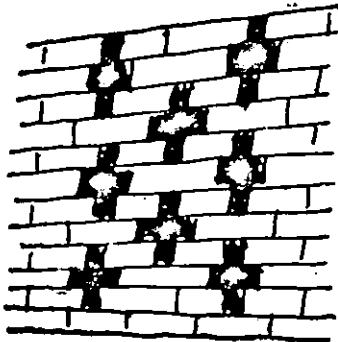
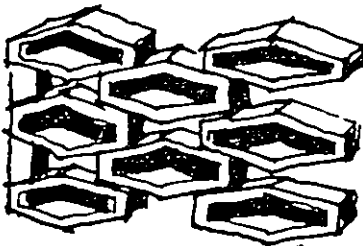
SIMPLEST TYPE OF SEPTIC TANK  
SCALE 1:50



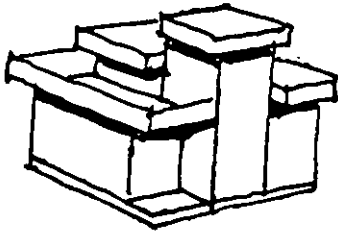
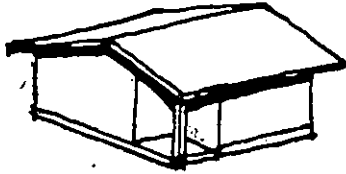
Many houses indulge in multi level roofing. This very often increases the total roof slab area by 25% and is therefore very wasteful of precious materials such as steel and cement.



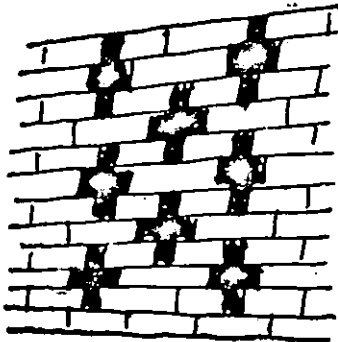
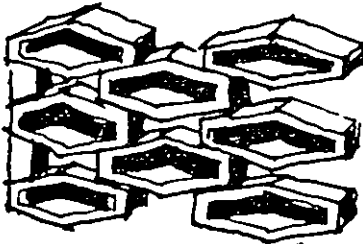
The Jali is an essentially Indian feature and the current fashion makes use of small precast cement jali blocks. These are very much more costly than the ordinary burnt brick which can serve exactly the same purposes.



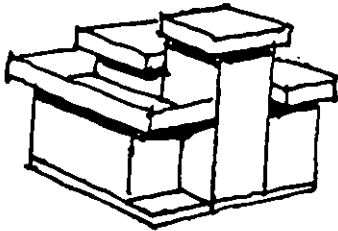
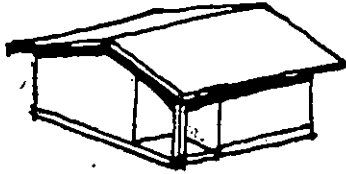
Many houses indulge in multi level roofing. This very often increases the total roof slab area by 25% and is therefore very wasteful of precious materials such as steel and cement.



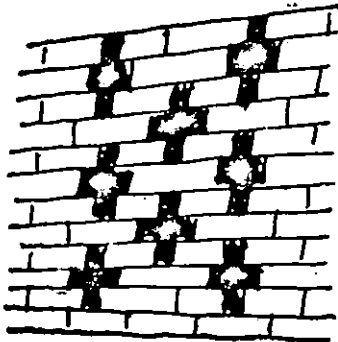
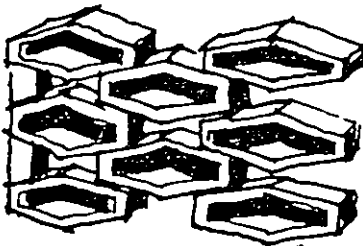
The Jali is an essentially Indian feature and the current fashion makes use of small precast cement jali blocks. These are very much more costly than the ordinary burnt brick which can serve exactly the same purposes.



Many houses indulge in multi level roofing. This very often increases the total roof slab area by 25% and is therefore very wasteful of precious materials such as steel and cement.



The Jali is an essentially Indian feature and the current fashion makes use of small precast cement jali blocks. These are very much more costly than the ordinary burnt brick which can serve exactly the same purposes.





## CALCULATIONS

### Calculations for structural Strength of walls

Check a  $4\frac{1}{2}$  inch (11.5 cm.) thick wall, 9 feet long in Variation II of Basic plan for 250 sft.

Roof Slab, filler type with M. P. tiles and slopping; Height of wall 9'-0"

Effective height— $9 \times 0.75 = 6.75$  feet = 2.05 m.

Load from roof:

Dead load = 200 Kg./m<sup>2</sup> (Say)

Live load = 75 "

Total = 275 Kg/m<sup>2</sup>.

Span of slab = 9' = 2.70 m; Eaves projection = 0.5 m.

Load on wall/m =  $275 \left( \frac{2.70}{2} + 0.5 \right) = 506$  kg.

Stress on masonry =  $\frac{506}{11.5 \times 100} = 0.44$  Kg/cm<sup>2</sup>

Stress due to self wt. =  $2.7 \times 2000 = 5400$  Kg/m<sup>2</sup>  
= 0.54 Kg/cm<sup>2</sup>

Total stress on masonry =  $0.44 + 0.54$   
= 0.98 Kg./cm<sup>2</sup>

$\frac{L}{t} = \frac{205}{11.5} = 18$ ; For this value of  $\frac{L}{t}$

Safe stress factor as per National Building Code = 0.50.

Safe stress on Brick masonry using bricks of strength 35 Kg/cm<sup>2</sup> and 1: 6 cement mortar is given in N. B. C. as 3.5 Kg/cm<sup>2</sup>.

Safe stress on the  $4\frac{1}{2}$  " wall =  $3.5 \times 0.5 = 1.75$  Kg/cm<sup>2</sup>.  
Since this is more than actual stress, the wall is safe without any openings.

Check for stress—at level of opening at 4'—6" height.

$$\text{Stress with 50\% opening} = \left( 0.44 + \frac{1.35 \times 2000}{10000} \right)^2$$

$$= 1.42 \text{ Kg/cm}^2.$$

Since this is less than 1.75 Kg/cm<sup>2</sup> permissible masonry is safe.

Check for Earthquake force

Earthquake load with a coefficient of 0.05 is given by  
 $0.05 \times 2000 \times 0.11 = 11 \text{ Kg./m}^2$

$$\text{B. M.} = \frac{11 \times 2.7^2}{8} = 10 \text{ Kg m}$$

$$\text{Stress} = \frac{10 \times 100 \times 6}{100 \times 11.5^2} = 0.45 \text{ Kg/cm}^2$$

$$\text{Total stress} = 1.42 + 0.45 = 1.87 \text{ Kg/cm}^2$$

$$\text{Permissible stress} = 1.33 \times 1.75 = 2.32 \text{ Kg/cm}^2$$

Hence safe.

### **Design calculations for typical R. C. Solid slab, filler slab and precast R. C. beams supporting Hourdis.**

#### **A. Sloping roof.**

(i) R. C. Solid slab.—Assume a thickness of 10 cm.

$$\text{Dead load} = 240 \text{ Kg/cm}^2$$

$$\text{Finish} = 30 \text{ ,,}$$

$$\text{Total} = \frac{\quad}{\quad} = 270 \text{ Kg/m}^2$$

$$\text{Live load} = 75 \text{ Kg/m}^2$$

Using load factor method of design

$$\begin{aligned}\text{Design load} &= 270 \times 1.5 + 75 \times 2.2 \\ &= 570 \text{ Kg/m}^2\end{aligned}$$

For a span of 2.7 m (say)

$$\text{B. M.} = \frac{570 \times 2.7^2}{8} = 520 \text{ Kgm.}$$

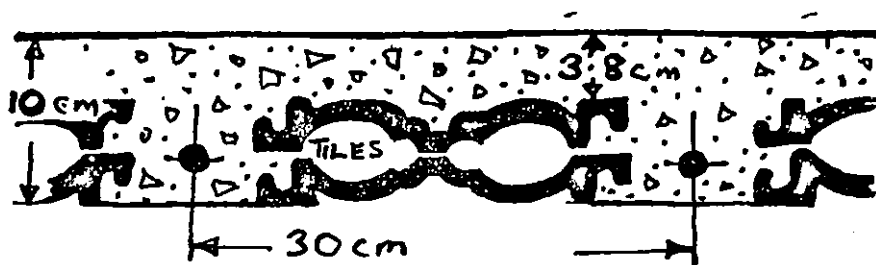
$$\text{effective depth} = 10 - 2 = 8 \text{ cm.}$$

$$\text{Steel required} = \frac{520 \times 100}{0.8 \times 8 \times 2600} = 3.1 \text{ cm}^2.$$

Use 8 mm. rods at 16 cm. c/c

For distribution use 6 mm. rods at 18 cm. c/c.

(ii) **Filler slab with 2 M. P. tiles**



Taking a a panel of 30 cm x 45 cm.

$$\text{Weight of 2 tiles} = 5 \text{ Kg. (say)}$$

$$\text{Weight of concrete} =$$

$$\begin{aligned}2400 (0.10 \times 0.30 \times 0.45 - 0.23 \times 0.04 \times 0.062) \\ = 18.7 \text{ Kg.}\end{aligned}$$

$$\text{Total dead load} = 23.7 \text{ Kg.}$$

$$\text{Dead load/m}^2 = \frac{23.7}{0.3 \times 0.45} = 175 \text{ kg.}$$

$$\text{Finish} = 30 \text{ kg.}$$

$$\text{Total} = \frac{205 \text{ Kg/m}^2}{}$$

$$\text{Live load} = 75 \text{ Kg/m}^2$$

$$\begin{aligned} \text{Design load} &= 205 \times 1.5 + 75 \times 2.2 \\ &= 473 \text{ Kg/m}^2 \end{aligned}$$

Use one 10 mm. rod in each rib as main reinforcement.

### Distribution steel required

$$\begin{aligned} \text{gross concrete area} &= 10 \times 45 - 6.2 \times 40 \\ &= 200 \text{ cm}^2 \end{aligned}$$

$$\text{area of rods required} = \frac{0.15 \times 200}{100} = 0.3 \text{ cm}^2$$

$$\text{use one 8 mm. rod with } a = 0.5 \text{ cm}^2$$

(actually one 6 mm. bar ( $a = 0.28 \text{ cm}^2$ ) is nearly sufficient).

using load factor method and yield-line analysis; depth of neutral axis is given by

$$0.785 \times 2600 = 30 \times a \times 0.55 \times 150$$

$$a = \frac{0.785 \times 2600}{30 \times 0.55 \times 150} = 0.82 \text{ cm.}$$

$$\begin{aligned} \text{Moment of resistance} &= 0.785 \times 2600 (8 - 0.41) \\ &= 15200 \text{ Kg/cm} \end{aligned}$$

$$M_x = \frac{15200}{0.3} = 51000 \text{ Kg/cm.}$$

$$M_y = \frac{0.50 \times 2600 \times 7.6}{0.45} = 22000 \text{ Kg/cm.}$$

$$\frac{M_y}{M_x} = \frac{22}{51} = 0.43$$

$$\text{and } \frac{L_x}{L_y} = 0.66 \text{ (assuming aspect ratio of 1:1.5).}$$

$$M_x = \frac{w L x^2}{24} \left( \sqrt{3 + 0.43 \times (0.66^2)} - 0.66 \sqrt{0.43} \right)^2$$

$$= \frac{w L x^2}{13}$$

$$\text{permissible } w = \frac{M_x \times 13}{L x^2} = \frac{510 \times 13}{2.7^2} = 900 \text{ kg./m}^2$$

$$\text{Actual Load} = 473 \text{ Kg/cm}^2 \quad \text{Hence safe.}$$

## B. FLAT ROOF

### (i) R. C. Solid slab

Dead load	= 240 Kg./ m <sup>2</sup>
lime terracing	= 150 „ (say)
Finish	= 35 „ (say)
Total	= 425 „
Live load	= 150 Kg./m <sup>2</sup>
Design load	= 425 x 1.5 + 150 x 2.2
	= 970 Kg/m <sup>2</sup>

using same aspect ratio and ratio of moment,

$$\begin{aligned} \text{B. M.} &= \frac{WL^3}{13} \\ &= \frac{970 \times 2.7^3}{13} = 540 \text{ Kg m.} \end{aligned}$$

$$\text{Main steel required} = \frac{540 \times 100}{2600 \times 7.6} = 2.74 \text{ cm}^2$$

use 8 mm. rods @ 18 cm c/c

$$M_y = 0.43 \times 540 = 230 \text{ kgm.}$$

$$\text{distribution steel required} = \frac{230 \times 100}{2600 \times 6.8} = 1.3 \text{ cm}^2$$

$$\text{Minimum steel} = 0.15\% = 1.5 \text{ cm}^2$$

Provide 6 mm. rods @ 18 cm. c/c.

### (ii) Filler slab

$$\text{Self weight} = 175 \text{ Kg/m}^2$$

$$\text{Lime terracing} = 150 \text{ ,,}$$

$$\begin{aligned} \text{Finish} &= 35 \text{ ,,} \\ \text{Total D.L.} &= 360 \text{ Kg./m}^2 \end{aligned}$$

$$\text{Live load} = 150 \text{ Kg/m}^2$$

$$\begin{aligned} \text{Design load} &= 360 \times 1.5 + 150 \times 2.2 \\ &= 870 \text{ Kg/m}^2 \end{aligned}$$

This is less than the permissible load of 900 Kg/m<sup>2</sup> obtained by earlier calculation . Hence safe.

**C. Precast beam and Hourdis; Spacing of beams 60 cm.**

$$\text{D. L. due to Hourdis} = 60 \text{ Kg/m.}$$

$$\begin{aligned} \text{Do. due to concrete topping} &= 0.038 \times 2400 \times 0.6 \\ &= 55 \text{ Kg/m.} \end{aligned}$$

$$(10 \text{ cm} \times 15 \text{ cm.}) \text{ self wt of beam} = 36 \text{ Kg/m}$$

$$\begin{aligned} \text{Finish} &= 35 \times 0.6 &= 21 \text{ Kg/m.} \\ \text{Total} &&= 172 \text{ Kg/m.} \end{aligned}$$

$$\text{Live load} = 75 \times 0.6 + 45 \text{ Kg.}$$

$$\begin{aligned} \text{Design load} &= 1.5 \times 172 = 45 \times 2.2 \\ &= 357 \text{ Kg/m} \end{aligned}$$

$$\begin{aligned} \text{Steel required} &= \frac{357 \times 2.7^2 \times 100}{8 \times 2600 \times 9.38} \\ &= 1.34 \text{ cm}^2 \end{aligned}$$

Provide 2 nos. 12 mm. rods

$$\text{Shear stress} = \frac{357 \times 1.35}{10 \times 0.87 \times 12} = 4.6 \text{ Kg} < 5 \text{ Kg}$$

Provide nominal stirrups 6 mm. at 15 cm, c/c.

**Yield line analysis for a slab 3m x 4.5 m**

$$L = 4.5 \text{ m}$$

$$B = 3 \text{ m.}$$

$$x = \frac{L}{B} = \frac{4.5}{3} = 1.5$$

$$u = \frac{M_1}{m} = 0.5 \text{ assumed}$$

$M_1$  and  $m$  are moments of resistance in the two  $\perp$  directions

$$\tan Q = \sqrt{3u - \frac{u^2}{x^2}} - \frac{u}{x}$$

$$= \sqrt{3 \times 0.5 - \frac{0.5^2}{1.5^2}} - \frac{0.5}{1.5}$$

$$\tan Q = 0.85$$

$$Q = 42.7^\circ$$

$$m = \frac{WB^2}{24} \left( \frac{3x - \tan Q}{x + \frac{u}{\tan Q}} \right)$$

$$= \frac{WB^2}{24} \left( \frac{3 \times 1.5 - 0.85}{1.5 + \frac{0.5}{0.85}} \right)$$

$$= \frac{WB^2}{13.7}$$

**Filler Slab with Mangalore Tiles 100 mm thick sloping roof**

Self weight	183 kg/m <sup>2</sup>
Finishes	<u>40 kg/m<sup>2</sup></u>
Total DL	223 kg/m <sup>2</sup>
LL	75 kg/m <sup>2</sup>
Ultimate Load	= 1.5 × 223 + 2.2 × 75
	= 335 + 165
	= 500 kg/m <sup>2</sup>
Ultimate	$\frac{WB^2}{13.7}$



$$\begin{aligned} \text{Moment} &= \frac{500 \times 3^2}{13.7} \\ &= 328 \text{ kg m} \end{aligned}$$

$$\text{Effective Depth} = 8 \text{ cm.}$$

Assume stress block  $0.43 d = 3.44 \text{ cm.}$

$$\text{Lever arm} = 8 - \frac{3.44}{2} = 6.28 \text{ cm}$$

$$\text{Steel} = \frac{328 \times 100}{6.28 \times 2400} = 2.18 \text{ cm}^2$$

Steel provided

$$10 \text{ mm } 300 \text{ c/c} = \frac{0.785}{0.3} = 2.62 \text{ cm}^2$$

$$\begin{aligned} \text{Stress Block} &= \frac{2.62 \times 2400}{0.55 \times 150 \times 100} \\ &= 0.76 \text{ cm} < 3.44 \text{ cm} \end{aligned}$$

$$\text{For an area } 45 \text{ cm} \times 30 \text{ cm} = 0.45 \times 0.3 = 0.135 \text{ m}^2$$

$$\begin{aligned} \text{Concrete} &= 0.45 \times 0.3 \times 0.1 - 0.4 \times 0.23 \times 0.05 \\ &= 0.0135 - 0.0046 \\ &= 0.0089 \text{ m}^3 \end{aligned}$$

$$\text{Tiles} \quad 2 \text{ Nos.}$$

Steel	10 mm	0.45 m	0.282 kg.
	8 mm.	0.3 m.	0.12 kg.
	Total		0.402 kg.

### For Sloping Roof with no eaves

projected area  $21 \text{ m}^2$

10% extra added for slope.

$$\text{Concrete} = \frac{21}{0.135} \times 0.0089 \times 1.1 = 1.52 \text{ m}^3$$

$$\text{Tiles} = \frac{21}{0.135} \times 2 \times 1.1 = 342 \text{ Nos.}$$

$$\text{Steel} = \frac{21}{0.135} \times 0.402 \times 1.1 = 69 \text{ kg.}$$

### For Sloping Roof with eaves

Projected area 34 m<sup>2</sup>

10% extra added for slope

$$\text{Concrete} = 2.46 \text{ m}^3$$

$$\text{Tiles} = 554 \text{ Nos.}$$

$$\text{Steel} = 111 \text{ Kg.}$$

### Filler Slab with Mangalore Tiles 125 mm. thick Flat Roof

$$\text{Self weight} = \frac{5}{4} \times 183 = 228 \text{ kg/m}^2$$

$$48 \text{ kg/m}^2$$

$$\text{Total DL} = 276 \text{ kg./m}^2$$

$$\text{LL} = 150 \text{ kg/m}^2$$

$$\begin{aligned} \text{Ultimate Load} &= 1.5 \times 276 + 2.2 \times 150 \\ &= 414 + 330 \\ &= 744 \text{ kg/m}^2 \end{aligned}$$

$$\begin{aligned} \text{Ultimate Moment} &= \frac{WB^2}{13.7} \\ &= \frac{744 \times 3^2}{13.7} \\ &= 487 \text{ kg m} \end{aligned}$$

Effective Depth 10.5 cm

Assumed stress block  $0.43 d = 4.5$  cm.

$$\text{Lever arm} = 10.5 - \frac{4.5}{2} = 8.25 \text{ cm.}$$

$$\text{Steel} = \frac{487 \times 100}{8.25 \times 2400} + 2.46 \text{ cm}^2$$

Steel provided

$$10 \text{ mm } 300 \text{ C/c} = \frac{0.785}{3} = 2.62 \text{ cm}^2$$

$$\begin{aligned} \text{Stress Block} &= \frac{2.62 \times 2400}{0.55 \times 150 \times 100} \\ &= 0.76 \text{ cm.} < 4.5 \text{ cm.} \end{aligned}$$

For an area  $45 \text{ cm} \times 30 \text{ cm} = 0.45 \times 0.3 = 0.135 \text{ m}^2$

$$\begin{aligned} \text{Concrete} &= 0.45 \times 0.3 \times 0.125 - 0.4 \times 0.23 \times 0.075 \\ &= 0.0169 - 0.0069 \\ &= 0.01 \text{ m}^3 \end{aligned}$$

Tiles 3 Nos.

Steel	10 mm	0.45m	0.282 kg.
	8 mm.	0.3 m.	0.12 kg.
		Total	0.402 kg.

For a flat roof with no eaves Area  $21 \text{ m}^2$

$$\text{Concrete} = \frac{2.1}{0.135} \times 0.1 = 1.56 \text{ m}^3$$

$$\text{Tiles} = \frac{21}{0.135} \times 3 = 464 \text{ Nos.}$$

$$\text{Steel} = \frac{21}{0.135} \times 0.402 = 64 \text{ kg.}$$

**Precast RC Beams with Hourdis on top Flat Roof**

Dead Load for 60 cm x 1 m area

$$\begin{aligned} \text{Concrete flooring 38 mm thick} &= 2.4 \times 0.6 \times 1 \times 0.038 \times 1000 \\ &= 54.5 \text{ kg.} \end{aligned}$$

$$\begin{aligned} \text{Beam 10 cm x 15 cm} &= 2.4 \times 0.10 \times 0.15 \times 1 \times 1000 \\ &= 36 \text{ kg.} \end{aligned}$$

$$\begin{aligned} \text{Hourdis 11 cm. x 60 cm (assuming 50\% Vad area)} & \\ &= 0.5 \times 2.0 \times 0.11 \times 0.6 \times 1 \times 1000 \\ &= 66 \text{ kg.} \end{aligned}$$

$$\begin{aligned} \text{Total} &= 54.5 + 36 + 66 \\ &= 156.5 \text{ kg.} \end{aligned}$$

$$\text{Add for finishes 40 x 0.6} = 24 \text{ kg.}$$

$$\text{Total DL} = 181 \text{ kg/m}$$

$$\text{LL 75 x 0.6} = 45 \text{ kg/m}$$

$$\begin{aligned} \text{Ultimate Load} &= 1.5 \times 181 + 2.2 \times 45 \\ &= 272 + 99 \\ &= 371 \text{ kg./m} \end{aligned}$$

$$\begin{aligned} \text{Ultimate Moment} &= \frac{WB^2}{8} \\ &= \frac{371 \times 3^2}{8} \\ &= 417 \text{ kg. m.} \end{aligned}$$

$$\text{Effective Depth for beam} = 13 \text{ cm.}$$

$$\text{Assume stress block } 0.43 \text{ d} = 5.6 \text{ cm.}$$

$$\text{Lever arm} = 13 - \frac{5.6}{2} = 10.2 \text{ cm.}$$

$$\text{Steel} = \frac{417 \times 100}{10.2 \times 2400} = 1.7 \text{ cm.}^2$$

2 bars 10mm 1.57 cm<sup>2</sup>

$$\begin{aligned} \text{Stress Block} &= \frac{1.57 \times 2400}{0.35 \times 150 \times 10} \\ &= 4.56 \text{ cm} < 5.6 \text{ cm.} \end{aligned}$$

$$\text{Lever arm} = 13 - \frac{4.56}{2} = 11.72 \text{ cm.}$$

$$\text{Steel} = \frac{417 \times 100}{11.72 \times 2400} = 1.48 \text{ cm}^2$$

For an area 0.6 m x 0.3 m = 0.18 m<sup>2</sup> < 1.57 cm<sup>2</sup> provided.

$$\begin{aligned} \text{Concrete} &= 0.6 \times 0.3 \times 0.038 + 0.1 \times 0.15 \times 0.3 \\ &= 0.00684 + 0.0045 \\ &= 0.01134 \text{ m}^3 \end{aligned}$$

Hourdie 1 No. 600 x 300 x 110

Steel 10 mm 2. x 0.3m. 0.375 kg.

6 mm (1x 0.3 m.) 1 x 0.3m. 0.068 kg.

Stirrup 4 mm 2x 0.34 m 0.068 kg.

Chicken mesh 4 mm. 1.2m  $\frac{0.120 \text{ kg.}}{0.631 \text{ kg.}}$

For a flat roof with no eaves Area 21 m<sup>2</sup>

$$\text{Concrete} = \frac{21}{0.18} \times 0.01134 = 1.32 \text{ m}^3$$

$$\text{Hourdie} = \frac{21}{0.18} \times 1 = 117 \text{ Nos.}$$

Steel	$= \frac{21}{0.18} \times 0.631$	$= 74 \text{ kg.}$
<i>R. C. Slab</i>	100 mm. thick	Flat Roof
Self weight	$= 240 \text{ kg/m}^2$	
Finishes	$= 40 \text{ kg/m}^2$	
Total DL	$\frac{280 \text{ kg/m}^2}{\text{---}}$	
LL	$150 \text{ kg/m}^2$	
Ultimate Load	$= 1.5 \times 280 + 2.2 \times 150$	
	$= 420 + 330$	
	$= 750 \text{ kg/m}^2$	
Ultimate Moment	$\frac{WB^2}{13.7}$	
	$= \frac{750 \times 3^2}{13.7}$	
	$= 492 \text{ kg m}^2$	
Effective Depth	$= 8 \text{ cm.}$	
Assume stress block	$0.43 d = 3.44 \text{ cm.}$	
Lever arm	$= 8 - \frac{3.44}{2} = 6.28 \text{ cm.}$	
Steel	$= \frac{492 \times 100}{6.28 \times 2400} = 3.26 \text{ cm}^2$	
8 mm bars	150 C/C	$3.33 \text{ cm}^2$
Stress Block	$\frac{3.33 \times 2400}{0.55 \times 150 \times 100}$	
6 mm	300 C/C	$= 0.97 \text{ cm} < 3.44 \text{ cm.}$

For a flat roof with no eaves      Area      21 m<sup>2</sup>

Concrete                      =21 x 0.1=2.1 m<sup>3</sup>

Steel 8 mm                       $\frac{7}{0.15} \times 3=140$  m      56 kg.

6 mm                               $\frac{3}{0.3} \times 7=70$  m       $\frac{16 \text{ kg.}}{72 \text{ kg.}}$

---

For a flat roof with no eaves      Area    21 m<sup>2</sup>

Concrete                      =21 x 0.1=2.1 m<sup>3</sup>

Steel 8 mm                       $\frac{7}{0.15} \times 3=140$  m    56 kg.

6 mm                               $\frac{3}{0.3} \times 7=70$  m     $\frac{16 \text{ kg.}}{72 \text{ kg.}}$