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Construction Methods for Low Cost Housing in India

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CONSTRUCTION METHODS FOR LOW COST HOUSING IN INDIA

by

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INTRODUCTION

Some new techniques for economy and speed of building construction which have been evolved through research and case studies are presented. Under-reamed pile foundations and Hyperbolic Paraboloid Shell foundations for black cotton and expansive soils of low bearing capacity have been recommended. Circular reinforced concrete column footings designed on the basis of theory of plates are preferred to square or rectangular ones. Brick cavity walls constructed with two leaves of brick on edge jointed together with ties at intervals, soil-cement blocks in place of bricks are recommended for low cost wall construction. Use of composite cement-lime mortars, replacement of cement with fly ash to the extent of 20% are also found to assist in economy. Reinforced concrete precast cored units for roofing and flooring, precast concrete channel units, cellular concrete units, composite floor and roof with precast reinforced concrete joists and brick in filling are recommended. UCOPAN systems of houses which have been evolved and constructed using prefabrication techniques in India are also presented.

ECONOMICAL TECHNIQUES FOR FOUNDATION

Under-reamed pile foundation

Soils like black cotton, expansive and filled up soils having low bearing capacities for foundations posed a major problem. Under-reamed piles are cast-in situ reinforced concrete piles bored into soils to a depth of 3 to 4 metres and a bulb is formed enlarging the base of the above-hole by under-reaming tool. To increase the bearing capacity of the pile additional bulbs may be provided (Figure 1).

The length of an under-reamed pile depends upon the depth of the stable zone. The spacing of the piles depends upon the plan of the structure, its loading and the safe bearing capacity of the piles.

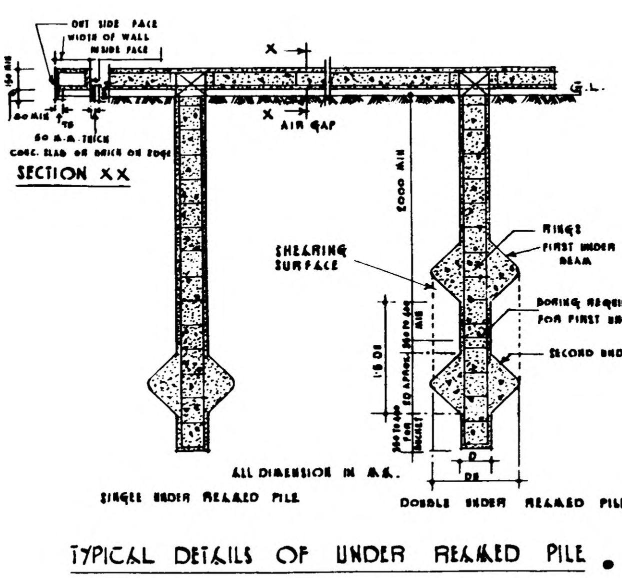

Fig. 1. Typical details of under-reamed pile

It may vary from 1.5m to 3.0m. A minimum pile diameter of 20cm should be used. The ratio of the diameter of the enlarged base to that of the stem of a pile may vary from 2 to 3. It is found that economy of the order of 20 to 30 percent can be effected by adoption of under-reamed pile foundations.

Hyperbolic Paraboloid Shell Foundations

In soils of low bearing capacity the versatile hyperbolic paraboloid shell can be used as foundations for columns with much advantage. The design of these footings assumes that the footings act as an inverted roof. The footing is formed by four rectangular hyperbolic paraboloids subjected to a uniform load (Figure 2). In India such footings with heavy cross ribs have been constructed near Calcutta and are now widely in use. These footings have been found to be about 10 per cent more economical than the conventional R. C. footings.

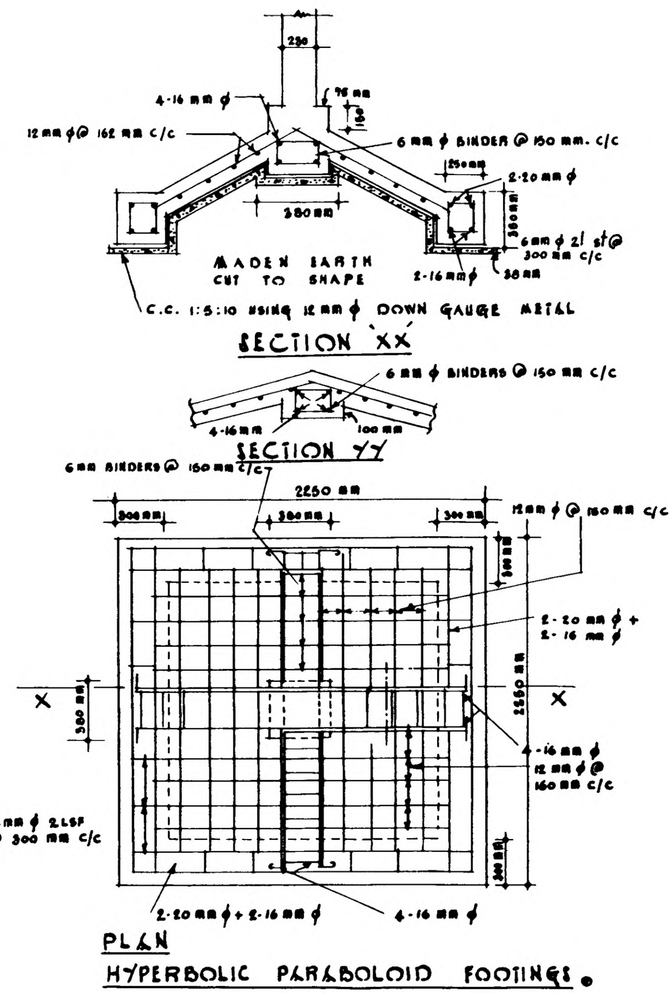

Fig. 2. Hyperbolic Paraboloid Footings

Reinforced Concrete Circular Column Footings

Conventional types of footings are either rectangular or square in plan and are designed for maximum bending moment providing reinforcements in both ways. Test results on square footings have shown that radial cracks develop in the footings at failure due to

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circumferential bending moment. Reinforced concrete circular footings designed on the basis of theory of plates are found to require only 50 per cent less steel when compared to the conventional ones. This method of design results in a saving of 7 to 8 percent in the cost of footings. Spirally reinforced circular footings have shown that circular footings compared satisfactorily with corresponding square slabs designed by the yield line method considering isotropic reinforcement.

MASONRY WALLS

Brick Cavity Walls

Cavity walls are constructed with two leaves of brick on edge with an air gap of 4 to 5 cm in between and joined together with ties of corrosion proof metal (Figure 3). This type of wall keeps the inside face wall dry, reduces the consumption of bricks and mortar without affecting the functional efficiency, economy in space through reduction of plinth area, reduces the total dead load to foundation and also allows for concealment of wiring, water supply pipes etc. This type of construction does not require any special masonry units and can be built with normal bricks. The strength of the bricks should not be less than 100 kg/cm^2 and the mortar to be used in the brick work should be either 1:3 cement, sand or 1:1:6 cement, lime, sand.

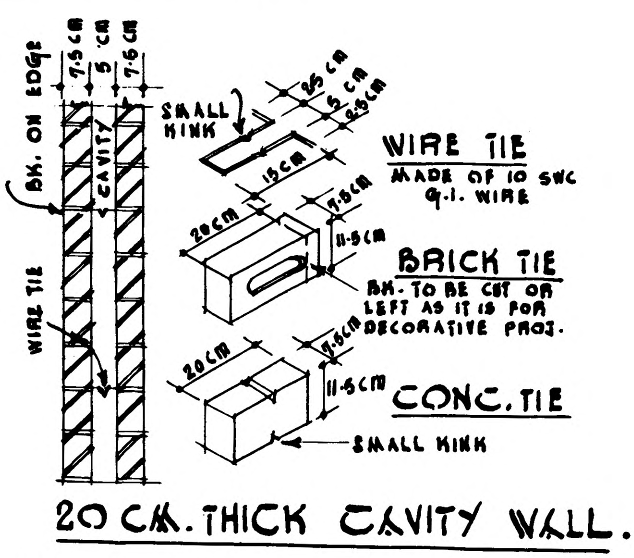


Fig. 3. Details of Cavity Wall

Thin cavity walls are limited to two storey buildings and must be supported laterally. This lateral support is derived from roof and floor. In multi-storey construction these walls can be provided as container walls. Cavity may be started in this wall either right above the concrete footing in foundation, or at floor level, depending upon the location of the floor level with respect to ground level (Figure 4). The cavity should be closed at the top of the wall and around openings like doors and windows in order to maintain consistency of temperature and prevent ingress of moisture.

Comparing 23cm solid wall in 1:6 cement sand mortar and 20cm cavity wall in 1:1:6 cement, lime, sand mortar, 20cm cavity wall offers savings of about 30 per cent in brick and 30 per cent in cement. The overall economy is 15 per cent.

Soil Cement Block Masonry

Most soils available are suitable for stabilization. Such soils generally require about 2 to 6 per cent of cement by weight of dry soil to provide the required strength in soil-cement blocks. For single-storeyed houses soil-cement blocks are made having a minimum crushing strength of 18 kg/cm^2 at the age of 28 days. Thermal insulation properties depend upon the type of soil used. Their moisture absorption is very much less than that of bricks. Blocks are manufactured to the standard modular size of 30 x 20 x

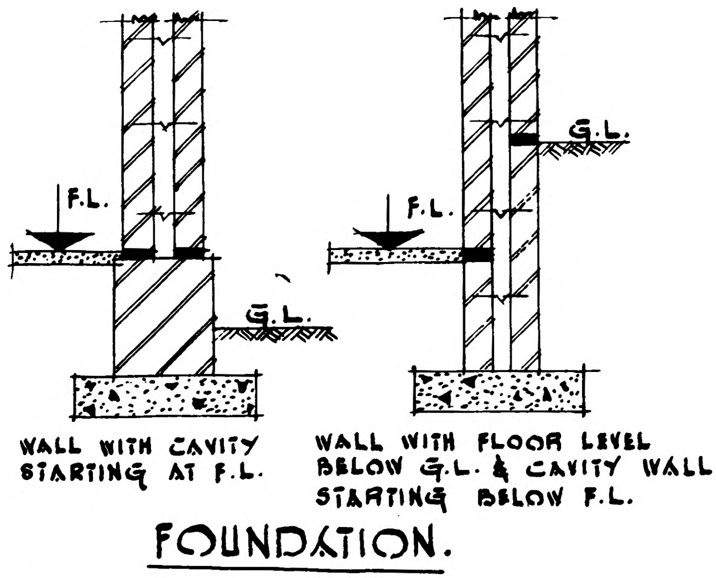


Fig. 4. Details of Foundation for Cavity Wall

10 cm; but their actual size is 29 x 19 x 9 cm making allowance for their mortar joints.

Soil cement block masonry is cheaper than brick masonry because only a small portion of cement need be used with the available soil and can be manufactured using simple moulds with unskilled labour at a much lesser cost than that involved for burnt clay country bricks. On account of their regular shape and their relatively large size soil-cement block masonry requires less mortar than brick masonry.

Use of Composite Cement-lime Mortars

Composite cement-lime-sand mortars are superior and more economical than cement-sand mortars for masonry work and plastering. Cement has quicker setting time and earlier development of strength whereas lime has better workability, plasticity, adherence to masonry, greater freedom from cracking, and resistance to water penetration. The use of such mortars are not popular in India since standard quality lime is not available in the market.

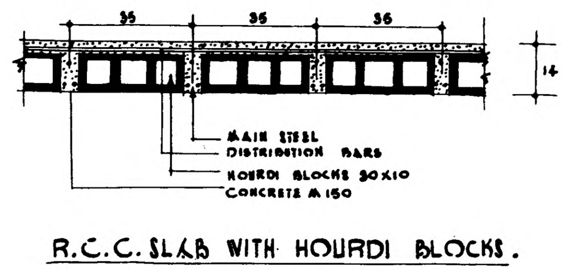
Replacement of Cement with Flyash to the extent of 20 percent

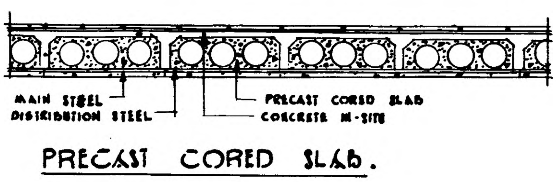
Experiments carried out by the Central Building Research Institute, Roorkee, and other research institutions have shown that flyash can be used as a replacement of cement up to 20 percent by weight in structural concrete and cement mortars and for making lime flyash mortars. This technique is at present widely in use in India. Replacement of cement with flyash improves workability without affecting the strength of concrete. It has also been established that addition of flyash does not increase the risk of corrosion in the reinforcement, and on the contrary improves the water tightness of concrete.

NEW TECHNIQUES FOR ROOFING AND FLOORING

Reinforced Concrete Cored Units

Cored precast units can be used for flat roofs instead of the conventional solid slabs of 10 to 15 cm (Figure 5). The minimum thickness of the concrete in the units is maintained as 25 mm and concrete used is 1:2:4 mix with 10mm and down size aggregate. The design of units have been evolved by Central Building Research Institute, Roorkee, on the basis of actual loading tests. The cored units are cast either at site or manufactured in a factory. At the site the units can be cast in sufficient lengths and in widths of 30 cm or more. The units can have single core or more. The use of cored slabs provide considerable saving in time. In factories cored slabs can also be manufactured by extrusion process. Such slabs can also be of prestressed concrete.





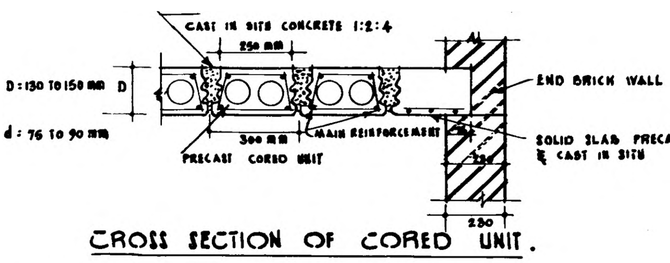


Fig. 5. Cross section of Cored Unit

Precast Concrete Channel Units

Reinforced concrete precast channel units are of trough type. The minimum thickness of concrete in the units is maintained as 25mm. The units are manufactured with 1:2:4 mix concrete with 10mm and down size aggregate. These units can be cast at site or in a factory same as cored units. The channel units can be of prestressed concrete. The channel units have been found to be 6 to 10 percent economical as compared with the solid reinforced concrete conventional slabs. The only disadvantage is that such roofing will not provide a flush ceiling.

Precast Cellular Concrete Units

Another method of providing precast roofing and flooring is by cellular concrete units placed on fully or partly precast beams. The supporting beams are designed according to the conventional design principles and partly precast. The recommended size for the cellular units is 1m x 0.5m x 0.1m which weighs approximately 55 kg and can be easily lifted and placed in position (Figure 6). The dimensions can vary depending upon the actual requirement. These units are precast with the help of simple rectangular frame work of timber and hollow spaces left by placing timber form work in position.

Use of composite floor and roof with precast Reinforced Concrete joists and brick in filling:

Composite construction of precast joists and ordinary bricks used as filling between the joists can be economically adopted for roofs and floors. Precast reinforced concrete joists are prepared and placed in position at intervals so that the space between two joists is exactly equal to the length of a brick. These joists can have projections of about 1 cm to 1 1/2 cm on either side to support the bricks placed between the joists, or can be made tapering so that the space on the top is equal to the length of a brick, and at the bottom about 1.5 cm to 2.5 cm less. The bricks can be chamfered and placed in between the joists in such a case. The spaces between the joists are filled up with bricks set up in cement mortar on all sides. A thin layer (4 cm) of cement concrete is laid on top with

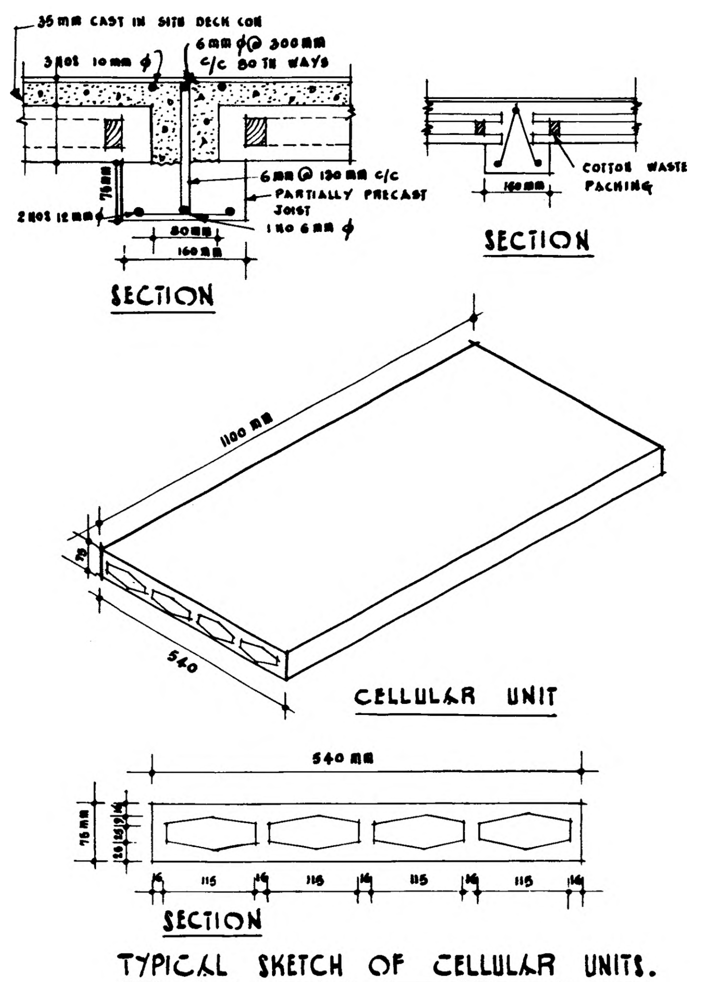


Fig. 6. Typical Sketch of Cellular Unit

nominal reinforcement to bind and unite the joists, and then plastered.

Prestressed concrete joists can also be used instead of reinforced concrete joists. Since the joists are light to be hoisted and placed, and the roof does not require any centering on shuttering, this type of roof gives about 20 percent saving in cost of construction. Hollow clay or cement blocks can be used in place of bricks, which will reduce the load on the roof and thereby the reinforcement in the bottoms can be reduced.

Precast Reinforced Concrete Sloping Roofs

This type of roof is particularly suitable for houses in areas which are subjected to heavy winds. Two economical types of precast sloping roofs are shown in Figure 7. The roof consists of precast reinforced concrete T-shaped joists with 36 cm wide flanges which overlap the adjacent area so that the ribs are only 30 cm apart. The joists are of similar section for all spans except that the depth varies for a set of spans.

The construction is very simple since the T-hoists can be made in simple wooden mould at this site. The ordinary T-joist sloping roof provides better thermal insulation than an ordinary tiled roof. But the hollow roof with cement-sand mortar ceiling tiles which can be provided at little extra cost possesses still better thermal insulation properties, and also has a plain ceiling.

UNIVERSAL CONCRETE PANEL SYSTEM (UCOPAN) OF CONSTRUCTION

The system essentially consists of precast reinforced concrete trough shaped panels called UCOPANS which are used for both walling and roofing. The roofing panels are 3.12m x 0.93m and the wall panels are 2.81m x 0.93m. All UCOPANS are 3.81cm thick and contain reinforcements. The close spacing of the reinforcements in the shape of a mesh ensures adequate protection against cracking due to temperature variations. The panels have ribs about 20 cm in depth all along the perimeter of panel which serve to provide the required stability and durability. In case of wall panels, these ribs of adjacent panels for vertical gaps which are filled with concrete and reinforcement, provide extra stability to structure. Roof panels also form horizontal gaps with the help of ribs and are filled with concrete and reinforcement (Figure 8).

The panels are cast horizontally in steel or wooden moulds. The panels are cast and well cured. The door, window and ventilator openings are formed in the wall panels by leaving gaps at suitable places while concreting. For handling the panels Dr. Zielinski has developed a three part simple hoist which has a lifting capacity of 500 kg to 1000 kg. This hoist can be fabricated easily using steel and timber sections.

The wall panels are placed side by side on a cement concrete foundation 20 cm thick and 45.7 cm deep. The foundation contains a continuous reinforcement at the base which projects at intervals into the gap between two wall panels. This gap between the panels is filled in with cement and mortar, thus firmly anchoring the wall panels with the foundation. The roof panels are also in turn hooked with the wall panels. Waterproofing consists of a 3.81 cm thick lean concrete screed covered with bitumen tar and sand. As the panels have been made smooth, the ceiling and walls do not need any plastering. The structure is strong and rigid in spite of its very thin walls of 3.81 cm thickness. This space of about 16.5 cm up to the edge of the ribs can be filled in with insulating material so as to have a flush face. Suitability of this system for multi-storeyed construction is to be analysed. Viewing in the context of the rising costs of urbanization, the UCOPAN system offers a low cost solution to reduce housing costs even though this type of house does not provide required thermal comforts unless properly insulated.

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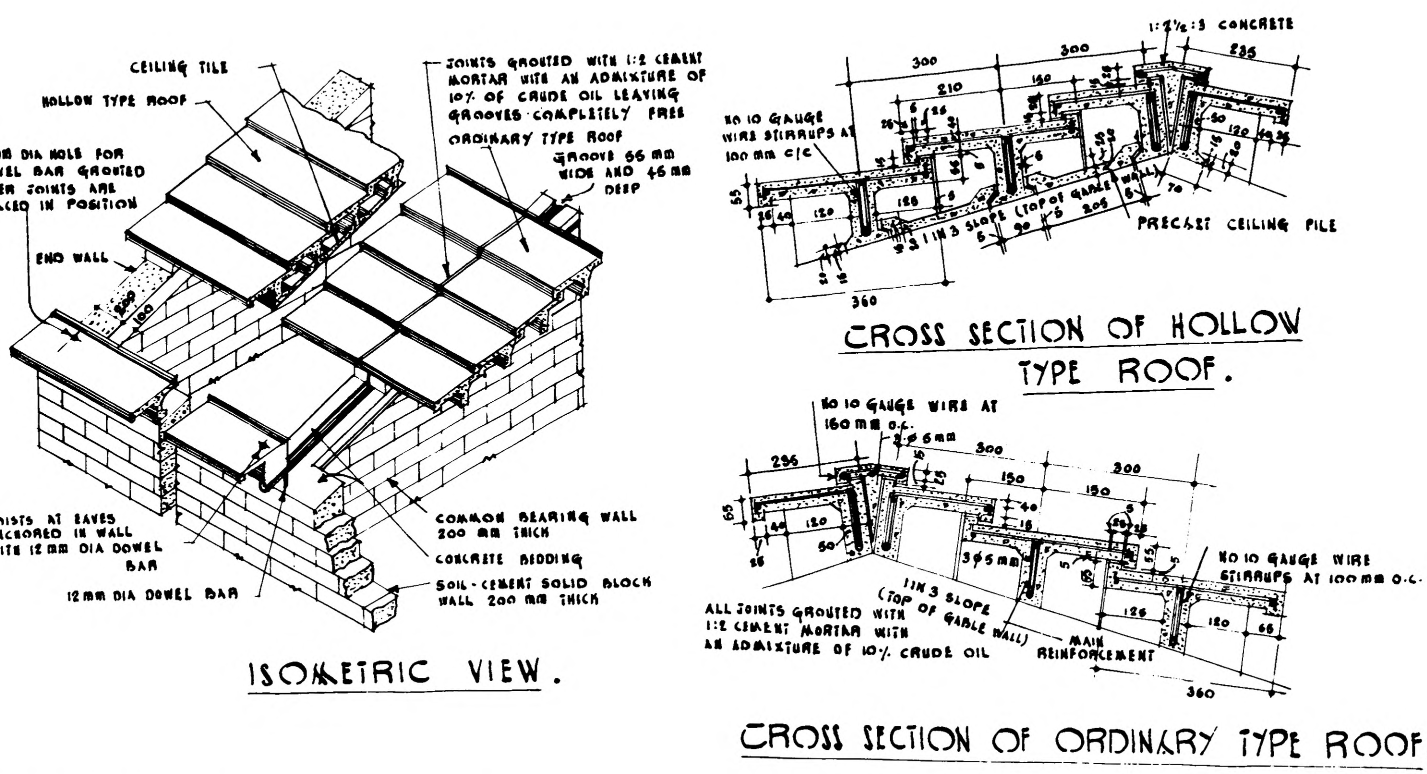

Fig. 7. Details of Sloping roof with pre-cast reinforced concrete T-joists

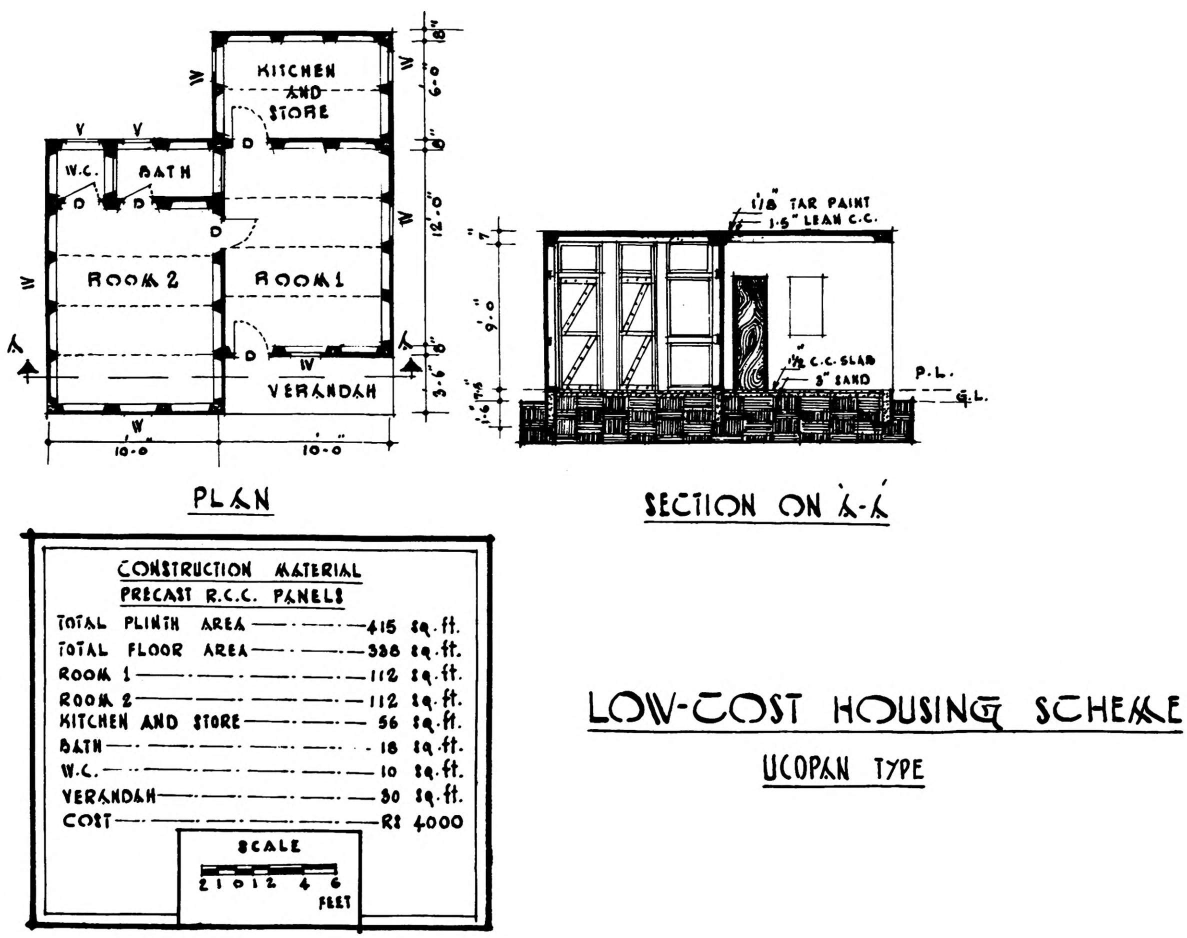

Fig. 8. Details of UCOPAN House