



BUILDING RESEARCH NOTE

B.R.N. 85

DOUBLY CURVED TILE ROOF

Introduction

The cost of a roof usually amounts to 25 to 30 percent of the total cost of a building. A small saving in this item alone will appreciably reduce the total cost. Over the past few years considerable attention has been devoted to the development of cheaper roofs. Doubly curved tile roof is one such roof. The special features of this roof as against the conventional types are least form work, speed of construction, advantage of prefabrication, and saving in costly and scarce materials like cement and steel. The process has by now undergone several trials and has found adoption in many buildings. Simplicity of making tiles and construction of roof, apart from low cost, makes it adaptable in rural areas also.

Description of the roof

The roofing system is based on the use of simple roofing units comprising 70 cm square doubly curved tiles and partially precast R.C.C. joists. The method

of making tiles and joists and the construction of roof is so devised that it can be easily adopted by less skilled workers even at the village level.

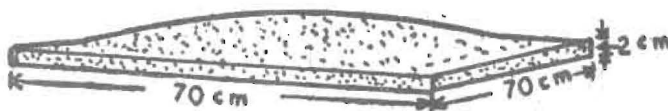
Design

(a) Tiles : The tiles are designed on the principle of simple shell with double curvature by taking the advantage of its property of resistance to static and shock loads. The smaller size of the shell units has helped in omitting the normally required R.C. edge beams in shells.

It has been found by experience that a tile size of about 70 cm × 70 cm × 2 cm thick (Fig. 1) is most convenient, both from the making and handling points of view.

(b) Partly Precast Joists : The P.P. Joists are designed for the following loading conditions :-

1. Live Load - 150 Kg/m².



Showing view of the Tile
Fig. 1

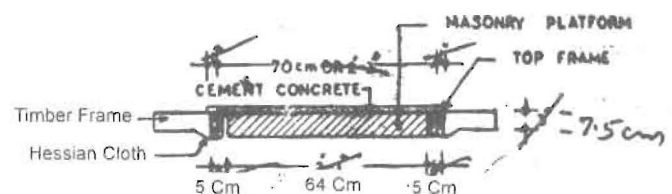


Fig. 2

2. Water proofing layer - 150 to 225 Kg/m² depending on the climatic conditions and treatment selected.
3. Weight of tiles, concrete in haunches and beams - 225 Kg/m²

The precast portion of the joist is usually kept 13 cm wide and 9 cm deep and reinforcement provided according to the designed requirement. To ensure good bond between precast and the cast in-situ concrete, stirrups are kept projecting by 5 cm above the precast portion. The haunches between the humps of the tiles are filled with cement concrete of

grade M15. Finally suitable water-proofing layer is provided.

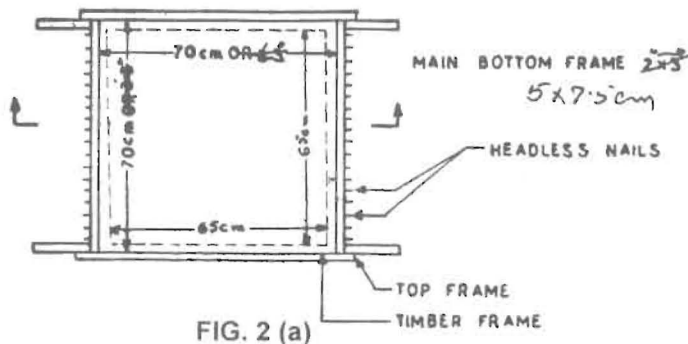
Process of Making

(a) Tiles : Make a masonry platform 64 cm x 64 cm x 7.5 cm, high of bricks laid flat and plaster it on top with a 1 : 4 cement sand mortar to make a smooth and level surface (Fig. 2).

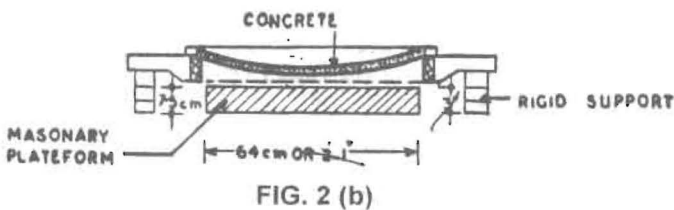
Make a square wooden frame of hard wood with four piece 6 cm x 5 cm in cross section (Fig. 3) Clear inner dimensions of this frame should be 65 cm x 65 cm. On the outer sides of this frame fix 2 mm thick and 5 cm long or similar size headless nails. Mount hessian cloth on this frame in such a manner that it is held taut by the nails. Put this frame on the masonry platform. It should just fit on this platform and the hessian cloth should remain tightly stretched. Now place another square wooden frame 70 cm x 70 cm x 2 cm clear inner dimensions on the first frame to hold the concrete and to serve as a gauge, (figures 3a and 2a).

Pour M15 cement concrete (stone chips 6 mm size) on this form work to a depth of 2 cm and lift the entire form work with concrete resting on hessian cloth and place it away from the platform on four rigid supports (Fig 2b). The hessian cloth will then sag under the weight of concrete and will form into a doubly curved tile. In fair weather the concrete should be sufficiently set to allow its removal from the form after 24 hours. Remove the tile and place it on edge into water stored in a tank, abutting against a side, for curing. The tank should be 3 m x 3 m x 80 cm deep and large enough to hold all the tiles made in 14 days.

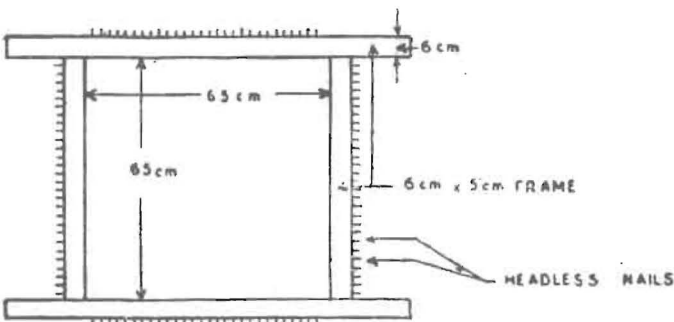
Cast about eight to ten tiles first by the above method.



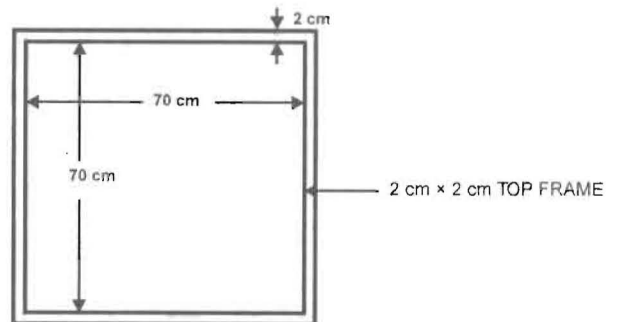
SHOWING MOULD WITH HESSIAN CLOTH PLACED ON RIGID PLATFORM



SHOWING MOULD WITH CONCRETE AND PLACED ON RIGID SUPPORT



SHOWING THE MOULD WITH CLOTH
FIG. 3



SHOWING TOP FRAME FOR GAUGING CONCRETE
FIG. 3 (a)

For subsequent tiles, lay these on level ground. Fill the hollow space between the tile and ground with earth or sand to provide uniform support. These tiles will now serve as base moulds for casting more tiles. Spread polythene sheet or oiled paper 80 cm × 80 cm on each of these tiles. This provides a smooth surface for the tile to be moulded and concrete will not stick to the base tile.

Place a wooden frame 70 cm × 70 cm inner dimensions and 4 cm (Fig. 4), around the tile on the ground. Pour M15 cement concrete on the polythene sheet to a thickness of 2 cm. To ensure that the thickness of cement concrete is 2 cm throughout, use the wooden template shown in Fig. 4 and 4(a) By moving this template across the tile all excess concrete can be removed and all the thinner patches will come to light. Remove this wooden frame about ten minutes after the tile is finished. After 24 hours, put the tile in to the tank of water for curing. 14 days curing under water is required.

Stack the tiles on edge in a shed for at least 14 days for drying.

It has been observed that one mason with two helpers is able to cast 30 to 35 tiles per day.

(b) Partially Precast Joist: It is rectangular shaped 13 cm wide 9 cm deep with stirrups projecting upward. Mould is made from seasoned good quality timber or M.S. channels can be used as mould. To avoid bulging of joist during casting, clamps of angle iron

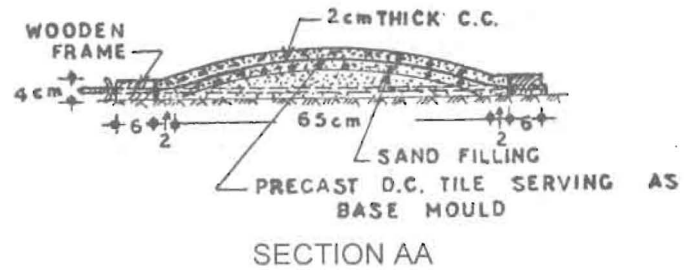
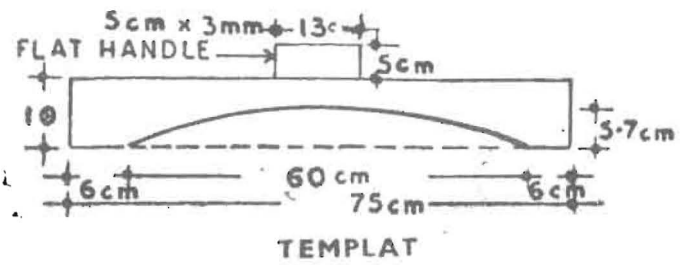
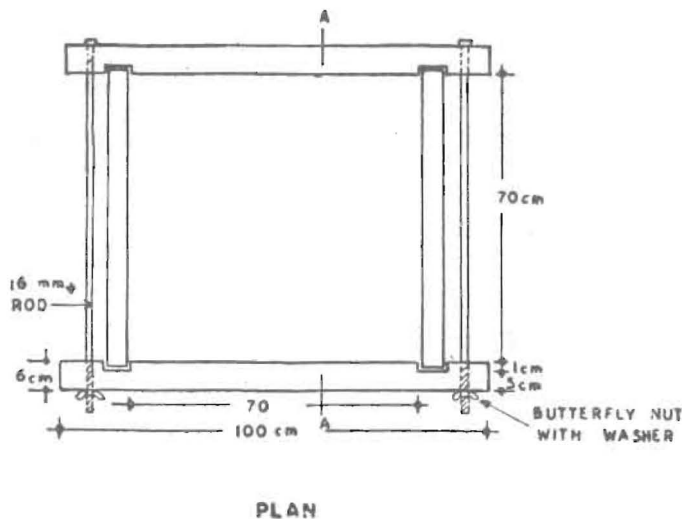


FIG. 4



Fig. 4 (a) : Tiles placed in position

wooden members. A 25 cm layer of M15 grade is laid in the mould before placing reinforcement. Mould can be removed after two hours, depending on the water cement ratio and climatic condition. Joists should be cured for 14 days and dried for another 14 days before using.

(c) Construction of roof : Lay the P.P. Joists on a slope of 1 in 48. To achieve this slope keep the supporting walls at different levels. Distance between the joists, centre to centre, should be 76 cm. Provide two wooden props at middle third points along the length under the p.p. joist before placing the D.C. tiles. Spread some mortar 1:3 on the edges of the p.p. joists before placing the D.C. tiles. This provides

uniform support and bond with the tiles. After placing the tiles in position (Fig. 4 b and 6 a), fill up the haunches with M20 cement concrete, leaving a small

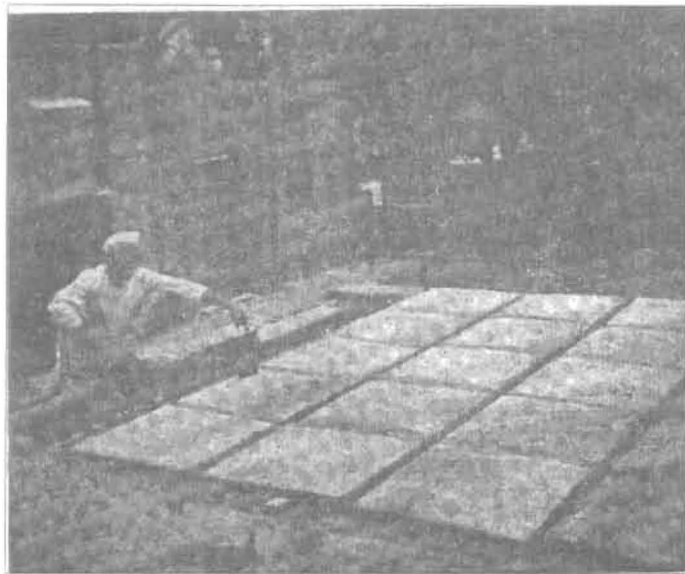


Fig. 4(b)

Use of wooden template to ensure thickness

ridge uncovered. Diameter of these exposed patches should not be more than 15 cm. For bigger spans or special situations, provision of a cast in-situ primary R.C.C. beam may become necessary. Beams may also be placed in level, if desired and the slope required may be provided in the waterproofing material, however laying beams to slope above is more advantageous and economical.

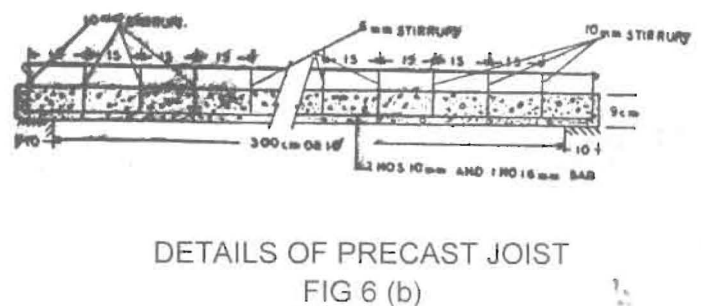
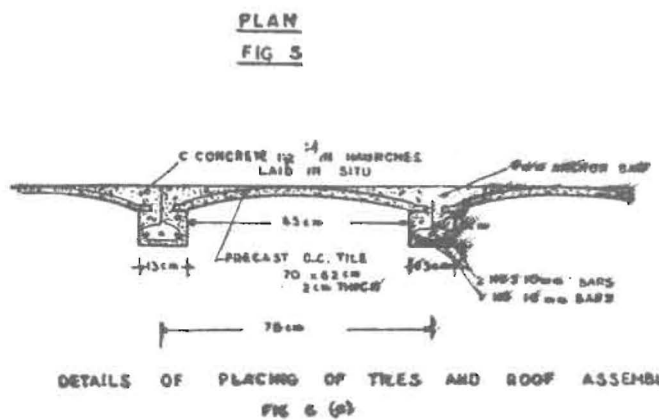
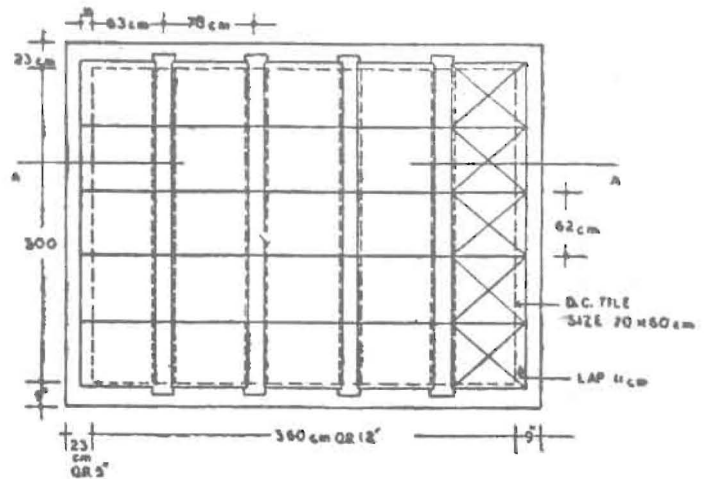
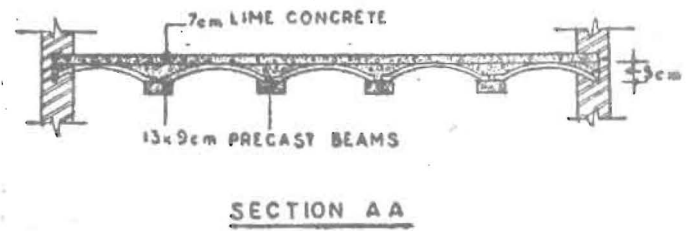
Water Proofing and Insulating treatments

The usual waterproofing-cum-insulating treatment of either lime concrete or mud phuska and clay tiles can be provided over the roof in the conventional manner.

Typical Plan

A detailed plan and section for roofing a room 3.60 m × 3.00 m is given in Figures 5, 6(a) and 6(b). The design is based on the loadings given earlier. Lime concrete terracing, weighing 150 Kg/m² has been assumed as water-proofing and insulating treatment. The size of the tile has been taken as 70 cm × 62 cm to suit this particular span. Similar adjustment in the

size can be made according to the size of the room to be roofed.



Materials and Labour Required

(i) For casting one tile 70 cm × 70 cm

Materials :

Stone grit or crushed stone 6mm	0.0085 m ³
Local Sand	0.0043 m ³
Cement	0.00213 m ³

Labour :

Mason	0.04 man day
Beldar	0.08 man day

(ii) For casting one p.p. joist (3.30 meters long) :

Materials :

Crushed stone 10 mm graded	0.0340 m ³
Coarse sand	0.017 m ³
Cement	0.0085 m ³
M.S. Round Bars (6, 10 & 16 mm dia)	13.6 Kg

Labour :

Mason	0.10 man day
Beldar	0.20 man day
Black Smith	0.25 man day

(iii) For the assembly of roof, putting one p.p. joist in position, D.C. tiles over it on either side, and concreting the haunch formed by two tiles.

Materials for haunch filling : (Average thickness 6 cm of concrete)

Crushed stone 10 mm graded	0.142 m ³
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Sand Local	0.071 m ³
Cement	1 bag

Labour :

Mason	0.5 man day
Beldar	1.0 man day

NOTE The above analysis is based on the following assumptions.

1. A minimum of 200 D.C. tiles and 20 p.p. joists are cast.
2. A minimum of 4 p.p. joists are laid at a time as the hoisting and placing of a beam can be carried out by 3 to 4 persons only.

Precautions in the Construction of the Roof

1. The p.p. joists must be propped at the middle third points till the concrete in the haunches has set and has attained sufficient strength. This usually requires 7 to 10 days.
2. The supports should preferably be removed only after the water proofing treatment has been done.
3. Labourers should not walk on the D.C. tiles. Proper cat-walks should be arranged for placing D.C. tiles and laying in-situ concrete.
4. The thickness of tiles should be uniform throughout, and should not be less than 2 cm anywhere.
5. The minimum bearing of the tiles on beams should be 2.5 cm and on walls 5 to 7 cm.

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