Trapezopan, roofing/flooring schemes

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The paper describes a new precast reinforced concrete trapezopan roofing unit which has been successfully tried in prototype roofs. The scheme is about 20 percent cheaper than a conventional 100-mm thick reinforced concrete slab and provides substantial saving in the use of cement and steel. The method of production is such that, it avoids the use of large casting platforms and also minimises the amount of water required for curing. The size and weight of the unit make it easily handled by four workmen. The unit has been thoroughly tested for static loading, impact, and rain-penetration. Factors such as appearance and shape and form were given due consideration to assure acceptability.

The use of prefabrication in the building industry is a well proven technique for savings in time economy and maintaining quality in construction. However, the basic approach remaining constant, the method of prefabrication changes from time to time and place to place depending on factors like balance of labour with plant and machinery, materials to be used, and cost considerations. In developing countries human labour is available in plenty and it is still economical to engage in civil construction. This naturally, calls for labour oriented techniques and process for prefabrication. Moreover the size and weight of the units should be so developed as to avoid the use of sophisticated handling equipment. Several such components, techniques and systems have been developed in past at the Central Building Research Institute. The suitability of these has already been proved by their successful adoption in mass housing and school building projects in different parts of the country. The paper describes another roofing unit named 'Trapezopan' which has been recently developed for roofing and flooring schemes and is now ready for field application.

Trapezopan roof

Unit: The name of the unit has been derived from its geometry. The section of the unit is a trapezium in orthogonal directions, *Figs* 1 and 2. The unit measures 1450mm × 750mm × 100mm. Thickness of the flange is 35mm. Each edge of the unit carries one 10-mm diameter mild steel bar as reinforcement. The weight of the unit is 85 to 95kg enabling a gang of four to shift, lift and place it in position. Another size of the trapezopan unit is 2000mm × 900mm × 150mm having flange thickness 50mm can also be fabricated but it is required to be used with the help of a light hoist.

A completed roof consist of trapezopan units placed, on partially precast reinforced concrete joists. The haunches are filled up with insitu concrete after placing the required reinforcement, *Fig* 3. The units can be used for flat as well as sloping roofs. The partially precast joists used in this scheme is 120mm × 150mm. However, dimensions of joist shall be modified suitably if the span exceeds 3500mm.

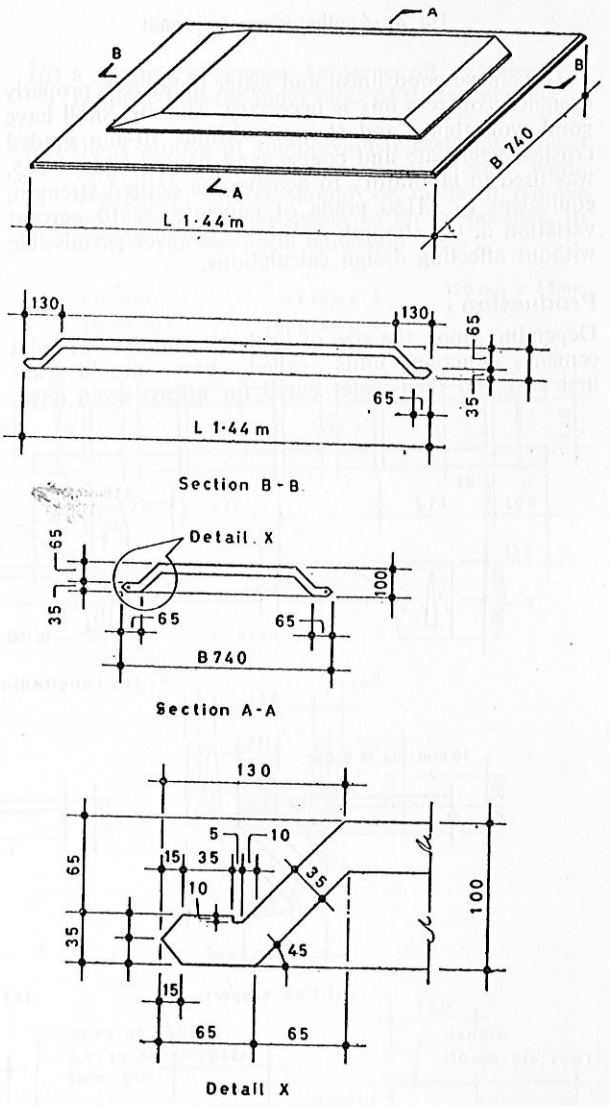

Fig 1 Elevation and cross-section of trapezopan unit

Design

Partially precast reinforced concrete joist for the trapezopan flooring/roofing scheme is designed as a simply supported T-beam slab, following latest IS:456-1978 code. The live loads considered in the design were recording to IS: 875-1970 for non-accessible roofs. To act as a T-beam slab it is necessary to achieve monolithicity between insitu haunch concrete, the flange of trapezopan and the partially precast joist. Therefore shear stirrups are provided in triangular form keeping 40 to 50mm exposed at the top, and the haunches in longitudinal direction are provided with one, 6-mm diameter mild steel bar throughout its length. Later on the load tests on the completed roof also revealed that the roof behaved as a T-beam roof.

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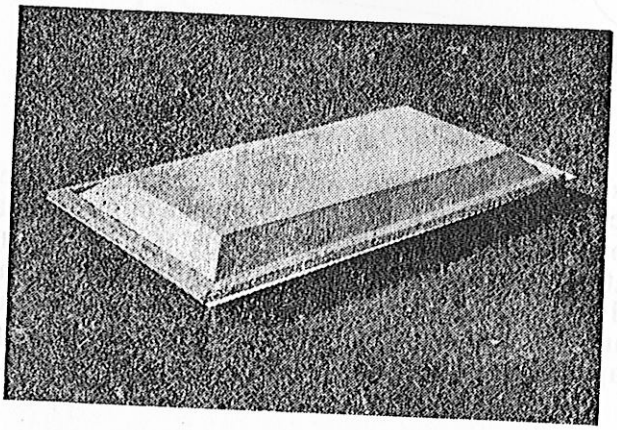


Fig 2 Another view of the unit

To achieve good finish and water tightness a properly designed concrete mix is necessary. The mix shall have good workability and strength. Minus 10-mm graded crushed aggregate and coarse sand having FM of 1.5, was used in laboratory to achieve the desired strength, equivalent to M150 grade of concrete. A 10 percent variation in the strength of mix is however permissible without affecting design calculations.

Production

Depending upon the size of project, a number of solid cement concrete units called base mould are first cast and then water cured for atleast seven days, *Fig* 4. The trapezopans are now cast on these base moulds. Further casting is carried out in vertical direction; *i.e.* one above another, thus avoiding the necessity of large casting platforms which otherwise account for appreciable share of cost in prefabricated systems. The number of units in one stack shall depend upon mason's height. However ten to fifteen units per stack can be comfortably cast. Waste newspaper is used as separating media between consecutive units. In this technique only the top unit is exposed to atmosphere which may be covered with wet gunny bags till the time next unit is going to be cast. The units lying below, thus need very little curing. Sprinkling of water on the edge of the units is sufficient for the required curing. Thus in this technique, the overall requirement of water is extremely low.

Mould

The mould for the unit consists of two timber frames upper and lower, *Figs* 5 and 6. The lower frame is a simple rectangular frame carrying a V-groove all along the inner face. The upper part is so made as to create the inclined surface of the trapezopan and also a V-shape groove at the junction of inclined surface and horizontal edge of unit. This groove acts as key between the haunch-filling and the unit itself and thus helps in attaining perfect bond between green and precast concrete. The rectangular frame is left with the unit for at least 6 to 8 hours, or preferably for one day, so that the edges of the unit do not crack or get damaged when the new unit is being cast above it. Whereas, the other part of the mould can be removed after one to two hours of casting depending upon climatic conditions. Therefore, the

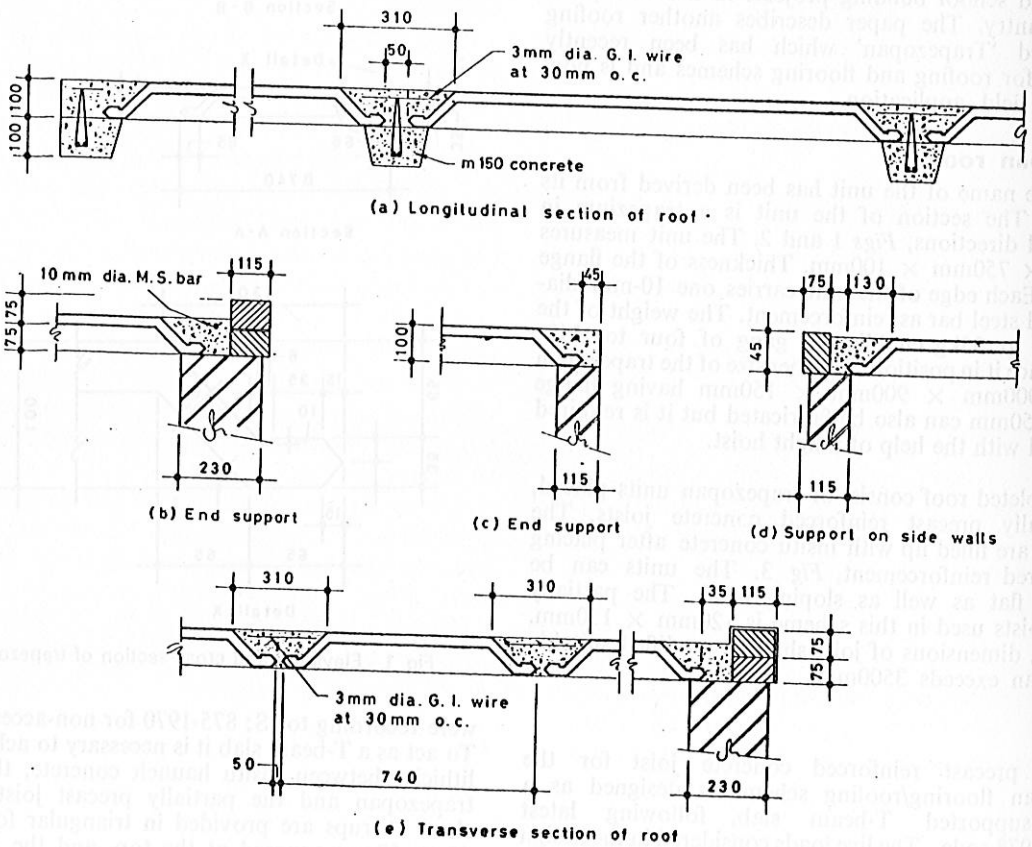


Fig 3 Jointing details

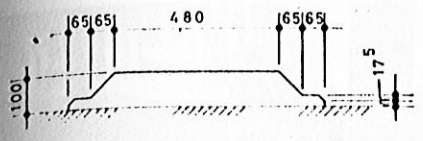
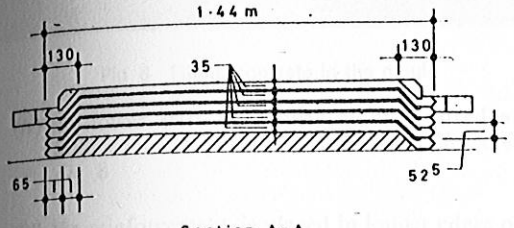
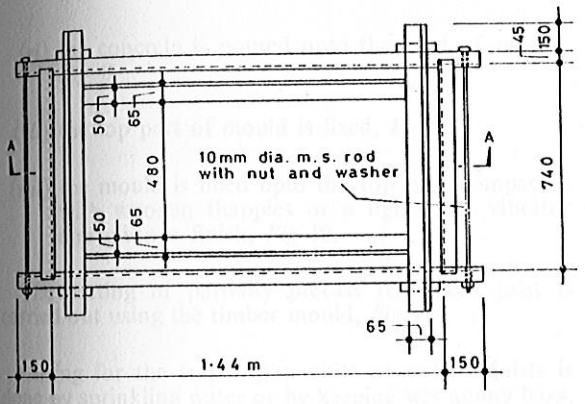


Fig 4 Concrete base mould

number of lower moulds shall be about 8 times more than that of the upper moulds. The mould for partially precast joist is quite simple and is shown in, *Fig* 7.



Section A-A



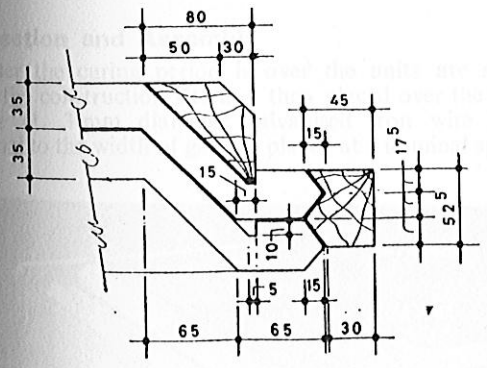


Fig 5 Details of timber mould for trapezopan

Casting

Sequence of casting operations is as shown in *Figs* 8, 9 and 10. One gang consisting of one mason and four mazdoors is required on three locations/stacks. The step by step operation is as given below:

(*i*) the mould should be cleaned with the help of a wire brush

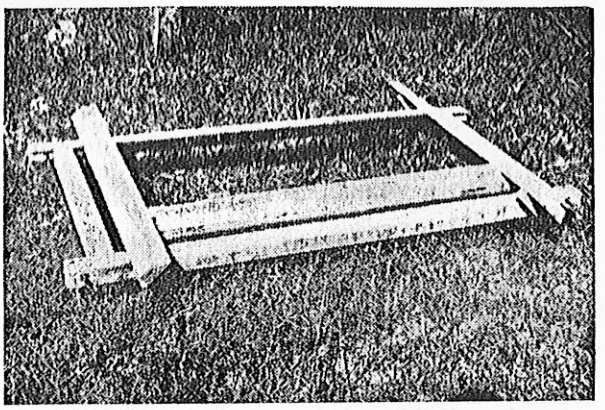
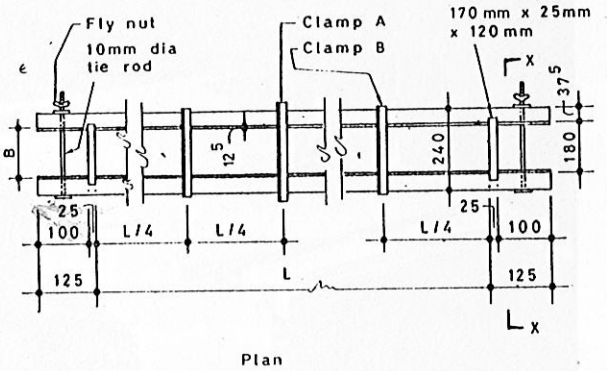


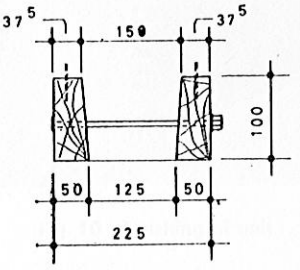
Fig 6 Timber mould

(*ii*) a mixture of grease, kerosene oil or burnt oil is applied on the inner faces of timber moulds

(*iii*) the V-groove of the previously cast unit is filled with dry sand and then covered with waste newspaper; efforts should be made to remove wrinkles in the newspaper as far as possible, to achieve smooth finish underside



Plan



Section X-X

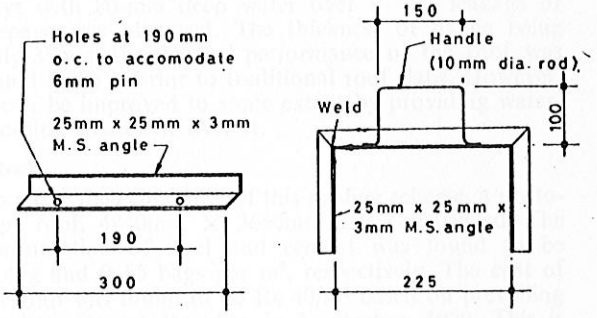


Fig 7 Mould for partially precast joist

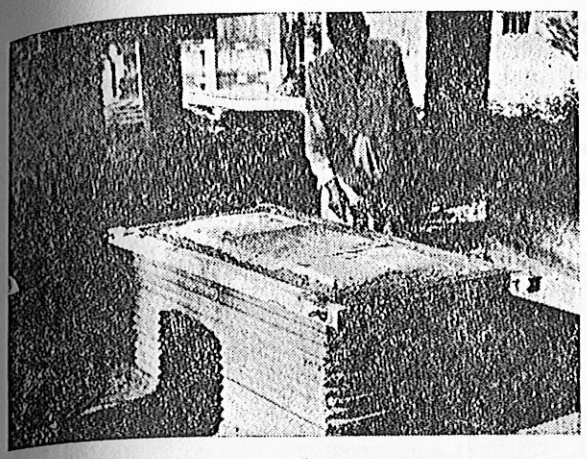


Fig 8 Filling concrete in the mould

(*iv*) the lower part of timber mould is fixed and a little concrete placed in the space thus created, *Fig* 8

(*v*) the reinforcement is placed in longer edges of the unit

(*vi*) the concrete is poured upto the level of mould, *Fig* 8

(*vii*) the top part of mould is fixed, *Fig* 9

(*viii*) the mould is filled upto the top and compacted with wooden thappies or a light plate vibrator and given a finish, *Fig* 10.

The casting of partially precast reinforced joist is carried out using the timber mould, *Fig* 7.

Curing for the trapezopan units as well as joists is done by sprinkling water or by keeping wet gunny bags, for a period of 14 days.

Erection and Assembly

After the curing period is over the units are shifted to the construction site and then placed over the joists, *Fig* 11. 3-mm diameter galvanised iron wire pieces equal to the width of gap are placed at a nominal spacing

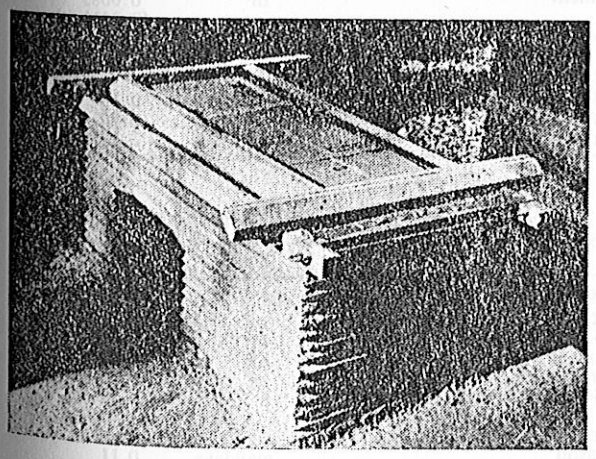


Fig 9 Upper portion of mould filled

at 300mm centres in both directions. This is done to prevent separation cracks which might occur at a later date due to temperature variations or due to improper bond between new and old concrete and to help in the transfer of shear from unit to unit. The haunches are thereafter filled with insitu concrete and cured the normal manner. Temporary props below the roofiing units are provided during these operations.

Load test

During the load test on trapezopan unit alone, no distress was observed even at a loading intensity of 1200kg/m², *Fig* 12. To find out the suitability of trapezopan units for roofs, a prototype roof measuring 3750 mm × 3000 mm was constructed at the Institute, *Fig* 13. The roof was then tested against static, impact, and punching loads in accordance with the relevant IS codes and ACI provisions. The roof withstood all

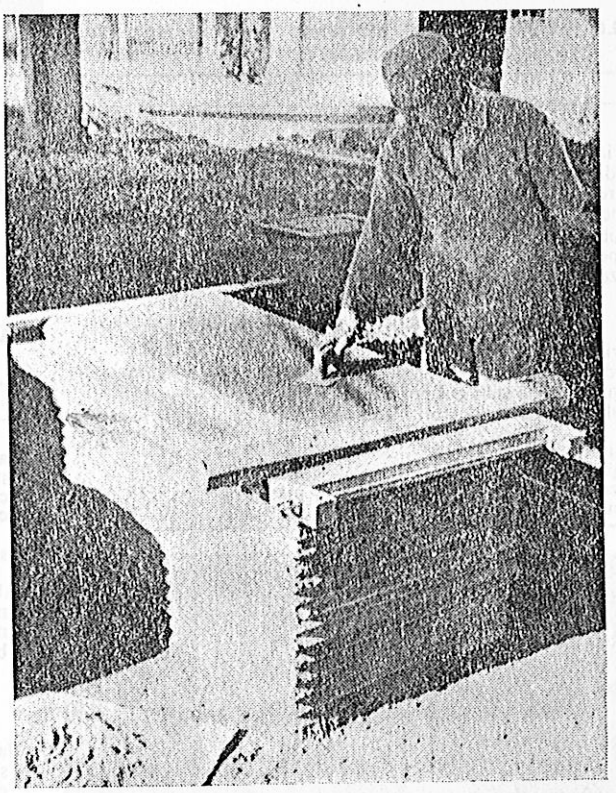


Fig 10 Finishing of unit

the tests requirements without showing any distress. To observe watertightness the roof was left for five days with 80-mm deep water over it. No leakage or seepage was observed. The thickness of flange being only 35mm, the thermal performance of the roof was found to be inferior to traditional roof slabs. However, it can be improved to some extent by providing waterproofing treatment over it.

Cost

To study the economics of this roofing scheme, a prototype roof, 4840mm × 3640mm was constructed. The consumption of steel and cement was found to be 3.4kg and 0.85 bags per m², respectively. The cost of the roof was found to be Rs 40/m² based on prevailing market rates at Roorkee in November, 1979. This is about 20 percent cheaper than reinforced concrete slab and 10 percent cheaper than asbestos cement sheet

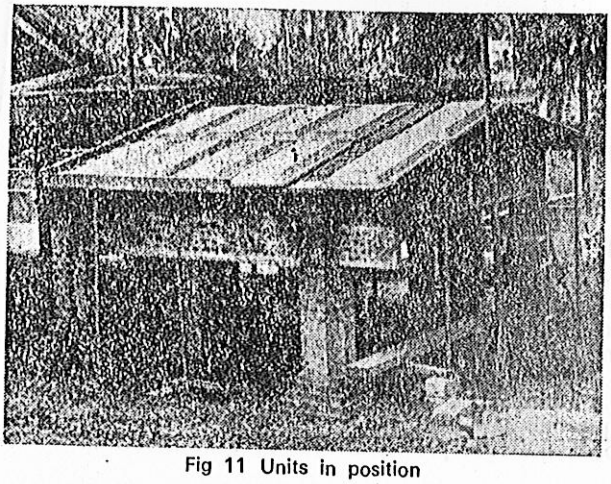


Fig 11 Units in position

TABLE 1 Labour and materials requirement for moulds.

	Unit	*Quantity*
Trapezopan unit		
Material		
deodar/teakwood	m^3	0.047
tie rods, nuts, washers etc LS	kg	0.5
cement concrete in Base mould	L.S.	
Labour		
carpenter	Man days	1.0
mazdoor	Man days	1.0
Reinforced precast joist		
Material		
deodar/teakwood	m^3	0.04
10 mm ϕ bolts with nut nos 2 and washers nos 3 mild steel clamps	kg	0.2
	kg	1.0
Labour		
carpenter	mandays	0.75
mazdoor	mandays	0.75
fitter	mandays	0.25

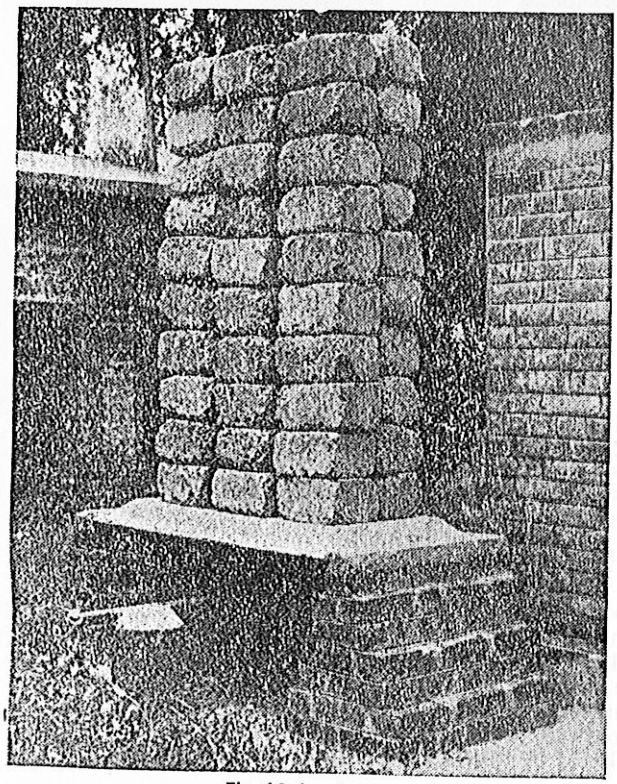


Fig 12 Load test

roofing. Besides saving in scarce materials, the scheme takes much less time than any other roofing scheme. Labour and material constants for construction of trapezopan roof are presented in *Tables* 1, 2 and 3.

Conclusion

The newly developed prefabricated reinforced concrete trapezopan unit is suitable for both roofs and floors.

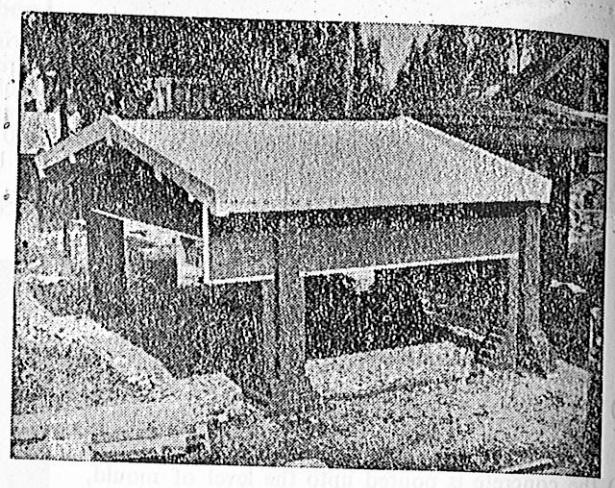


Fig 13 View of completed prototype

TABLE 2 Material quantities for trapezopan and joist production

	Unit	*Quantity*
Trapezopan unit		
Material		
stone grit 10-mm maximum size	m^3	0.0385
coarse sand	m^3	0.0193
cement	m^3	0.0096 (0.264 bag)
steel	kg	0.64
Labour		
mason	mandays	0.125
mazdoor	mandays	0.25
barmender	mandays	0.025
Precast reinforced concrete joist		
Material		
stone grit 100-m maximum size	m^3	0.0334
coarse sand	m^3	0.017
cement	m^3	0.0085 (0.243 bag)
Steel (upto 4.0. m span)	kg	10.644
Labour		
mason	mandays	0.10
mazdoor	mandays	0.20
barbender	mandays	0.125

TABLE 3 Labour and materials for roof

	Unit	*Quantity*
Material		
stone grit 10-mm down graded	m^3	0.0234
coarse sand	m^3	0.0120
cement	m^3	0.006
3-mm diameter G.I. wire	kg	0.09
750-mm diameter ballies	metre	0.30
Labour per m^3		
mason	mandays	0.11
carpenter	mandays	0.003
mazdoor	mandays	0.25

The method of vertical casting employed for the production of these units avoids using large area of casting platform. The trapezopan unit itself acts as mould for subsequent casting of units. The casting operations are simple and minimise the use of skilled labour. The performance of roof consisting of trapezopan was found to be very good. Besides appreciable saving in materials and shuttering cost the resulting roof is aesthetically pleasing. The scheme is therefore recommended for low- and middle-income housing schemes.

Acknowledgement

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