# Appropriate Technology for Precast Flooring/Roofing Schemes

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In most developing countries, there is huge shortage of residential and other types of buildings due to post war backlog, large population growth and lack of resources. In India alone, the requirement of houses is estimated to be twenty million units. There is an urgent and compelling need to make a break in this field by introducing appropriate techniques of construction. Floors and roofs account for about twenty five percent of the overall cost of the building in India and introduction of appropriate techniques in this item will go a long way in reducing the total cost of construction. Keeping in view the above points, a number of partially precast flooring/roofing schemes have been developed at the Central Building Research Institute, India. Some of these schemes are discussed in this paper, along with the criteria considered for their development.

## Criteria For Developing Precast Schemes

In most developing countries, the housing problem is getting aggravated due to increase in population. Apart from houses, large number of schools, hospitals, offices and other buildings are also required to be constructed. Conventional construction techniques with their slow speed and high cost, cannot cope up with this large demand for buildings. The problem can be solved only by a rapid and economic method of construction, such as mass scale construction of buildings with precast components. However, many of the developing countries cannot afford the capital investment required for the heavy machinery and equipments needed for the production and handling of large precast components. In the developing countries where bricks and or stones are available at comparatively cheaper rates, concrete walls work out to be costlier. The experience of a prefabrication factory in public sector and a few private firms which have carried out large panel construction in the country shows that this technique of construction is costlier. Hence precast large panel construction is not suited to the country at the moment. However as floors and roofs of permanent buildings in urban areas are normally built with reinforced concrete, there is scope for their replacement with prefabricated schemes. In the traditional method of construction, there is delay in progress of work at each floor level due to the need of different trades coming in for fixing centering and shuttering, providing reinforcement and laying concrete. If the flooring/roofing components are precast and kept ready, they can be laid as soon as the walls or the building frames reach the floor/roof level, the construction above can proceed without delay. Considering the above mentioned points, a partially precast system of construction having walls built of bricks, stones or concrete blocks in the traditional way and floors/roofs built with precast components has been preferred. It results in a saving of about twenty percent in overall construction time.

Considering the equipments normally available at site for handling and erection of components, it was decided to keep the size and weight of the components small. The width has normally been kept around 30 cm, the length upto 420 cm and the weight upto 2000 N so that they can be erected manually or with light equipments, even in the case of multi storeyed buildings.

Fig. 1: Channel unit roof

One of the main criteria considered i the development of new techniques i the structural efficiency of the system In India, about sixty five percent o the cost of construction goes to ma terials. Hence the shapes of compo nents have been chosen to have max imum saving in materials withou loosing the structural efficiency. Fo example, concrete near or below th neutral axis which is not stressed t full extent has been taken away, re sulting in components having troug shaped, "L" – shaped or hollow cros section. By giving such shapes, th weight of components is reduced an their handling and erection becom easy. The reduction of self weight als results in saving in supporting struc tures like beams, walls and founda tions.

The precast components developed are suitable for residential and othe lightly loaded buildings having shor spans. For short spans, prestressed concrete does not work out to b economical. Hence, the component are normally cast with ordinary con

crete having cube strength 15 N/mm² and reinforced with mild steel or high strength deformed bars.

Labour intensive schemes are preferred in developing countries due to easy availability of labour and the social demand for providing more employment to them. This criteria has specially been considered while developing the precast schemes.

Considering the bottlenecks in transporting the units over longer distances and other factors, a system of casting the components at the site of construction or at a centralised location in case of small constructions spread over a number of sites, has been prefered to their factory production.

A number of flooring/roofing schemes have been developed at the Institute, considering the criteria discussed above. The salient features of some of the techniques are discussed below.

**Channel Unit Flooring/Roofing Scheme**

Channel units[1]) are precast reinforced concrete (R. C.) elements, trough shaped in section. The units are 30 to 60 cm wide, 10 to 15 cm deep with a flange thickness of 3 cm and are suitable for spans ranging from 250 to 420 cm. The longitudinal sides of the units are provided with corrugations on the outer face to ensure that the floor/roof acts as monolithic after the concrete grouted in the joints between the units attains strength. Normally no structural deck concrete is required. The floor finish or roof treatment is laid directly over the units. Channel unit scheme presents a ribbed ceiling.

The precast flooring/roofing scheme is designed considering various stages of loading and support conditions. In the first stage, the units are designed as simply supported elements for the self weight, the weight of concrete in the joints between the units and the live load during construction. In the final stage, the floor/roof is designed

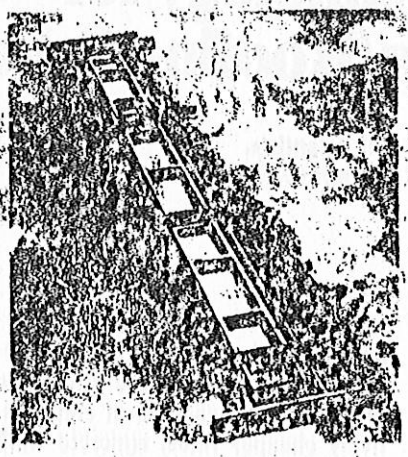

Fig. 2: Mould for chanal unit

as continuous spans for the loads coming after the insitu concrete has attained strength.

The units are cast manually in timber moulds on levelled platform. Concrete having a cube strength of 15 N/mm² is used. It is compacted using a plate vibrator. The units are demoulded about three hours after casting. They are cured for the first two days at the casting platform itself by covering them with wet gunny bags.

The units are then transported to the curing yard, stacked and cured by ponding water in the throughs. The units are water cured for two weeks and allowed to air dry for another two weeks. Once the superstructure has reached the floor/roof level, the precast units are lifted up manually or with the help of chain pulley blocks or light hoists and placed side by side across the span to be covered. After aligning and levelling the units, reinforcement for taking negative bending moments at supports are placed in the joints between the units. The joints are then filled up with concrete and cured properly.

The precast R. C. channel unit scheme has been used for the mass construction of floors and roofs of houses, schools, hospitals, factories etc. in the country. Compared to conventional insitu reinforced concrete slab, use of the channel unit scheme results in a saving of thirty five percent in concrete, eight percent in steel and twenty percent in cost in India at present.

**Cored Unit Flooring/Roofing Scheme**

Cored units[2]) are precast reinforced concrete units 30 cm wide, 13 cm thick and upto 420 cm in length, having two circular hollows of 9 cm diameter. They are cast manually in timber moulds. Galvanised iron pipes are used to form the hollows. The units are subjected to natural water curing. Lifting of the units is done manually or with the help of a light hoist developed at the Institute. The construction of floor/roof is done as in the case of channel unit scheme. The floor finish or the roof treatment is laid directly over the units. The cored unit scheme has been used in a large number of residential and office buildings including multistoreyed constructions in India. The scheme provides a flush ceiling. Concealed wiring can be done by taking the electrical conduits along the length of the cores. Compared to conventional insitu R. C. slab, the scheme results in a saving of twenty five percent in concrete, five percent in steel and about fifteen percent in overall cost.

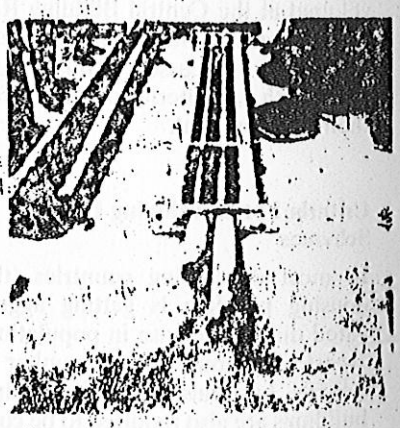

Fig. 3: Mould for cored unit

**Plank and Joist Flooring/Roofing Scheme**

It consists of precast R. C. planks 40 cm wide, 3.5 to 6 cm thick and 95 to 145 cm long supported on partially precast R. C. joists of size 15 x 15 cm spaced at 100 x 150 cm centre to centre. The scheme[3]) is suitable for floors and roofs of residential and other types of buildings having span upto 420 cm. The joists are designed

as Tee beams. The planks are provided with the designed reinforcement and are cast in simple timber moulds. As the maximum weight of the plank is only about 600 N, they can be easily handled manually. During the construction, the joists are first erected and propped at midspan. The planks are placed over the joists side by side. After placing reinforcement across the joists, concrete is filled over the joists and the haunches of the planks and finished level. After the insitu concrete has attained strength, the props are removed. No structural deck concrete is provided over the planks. The scheme provides a ribbed ceiling. The technique has been used extensively for the construction of residential, school and factory buildings including mass construction of houses for cyclone affected areas in the State of Andhra Pradesh in India. The scheme results in a saving of thirty percent in concrete, twenty percent in reinforcement and twenty five percent in overall cost, based on labour and material cost in 1979.

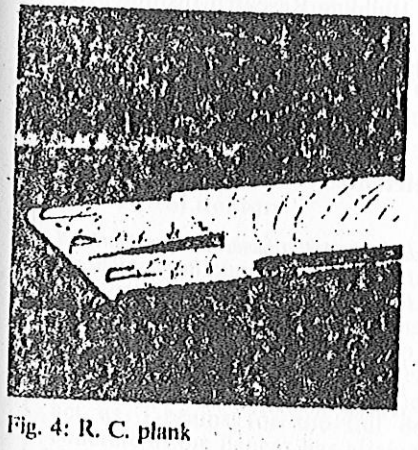

Fig. 4: R. C. plank

**Brick Panel Flooring/Roofing Scheme**

It consists of precast reinforced brick panels[4]) 56 cm wide, 7.5 cm thick and 104 to 120 cm long, placed over precast R. C. joists 10 x 13 cm in section and upto 420 cm long, spaced at 110 to 125 cm c/c. 3.5 cm thick structural deck concrete with nominal reinforcement is provided over the panels. The brick panels are cast manually in timber forms on levelled ground. Bricks are arranged in the form with the joints in the adjacent rows of bricks staggered. The joints are either filled with cement : sand motar 1 : 4 or concrete having a cube strength of 15 N/mm². The panels are reinforced with two 6 mm diameter mild steel bars. The bricks used shall have a minimum crushing strength of 7 N/mm², if 1 : 4 cement : sand mortar is used for filling the joints in the panels. In case the joints are filled with concrete, bricks having a crushing strength as low as 3.5 N/mm² can be used. The brick panels are cured by sprinkling water for two weeks and then allowed to air dry for another two weeks before using them in any construction. As the weight of the panels is only 750 to 900 N, they can be easily handled manually. After erecting, the joists are levelled and propped at middle third points. The brick panels are then lifted and placed over them (Fig. 2) with 1 : 4 cement : sand mortar between joists and panels. 6 mm diameter mild steel bars one on each panel both ways are provided over the panels and deck concrete is laid over them. The props are removed after the deck concrete has attained strength. The joists act as Tee beams with the deck concrete acting as flange. The technique has been developed by rationalising the reinforced brick slab construction, prevelant in northern India. Compared to traditional reinforced brick slab construction, the technique results in a saving of thirty percent in the consumption of bricks and motar and twenty five percent in steel, besides saving about thirty percent in overall cost. The technique is ideally suited for the construction of semi-permanent and permanent buildings in rural and semi-urban areas. So far about 5000 houses have been built in different parts of India using this technique.

**Waffle Unit Flooring/Roofing Scheme**

This scheme[5]) is suitable for two way spanning floors and roofs of buildings having spans of 900 cm or more. The waffle units are nominally reinforced open box type units, square or rectangular in plan, having lateral dimensions upto 120 cm. The depth of the unit will vary according to the design loads and spans. The units are cast manually and cured by ponding water in them. Partial shuttering is required for the construction. The units are assembled in a grid pattern

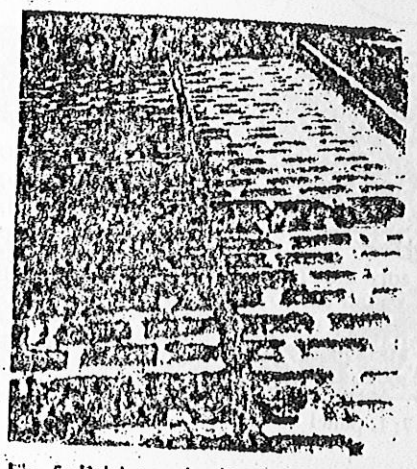

Fig. 5: Brick panels placed over joists

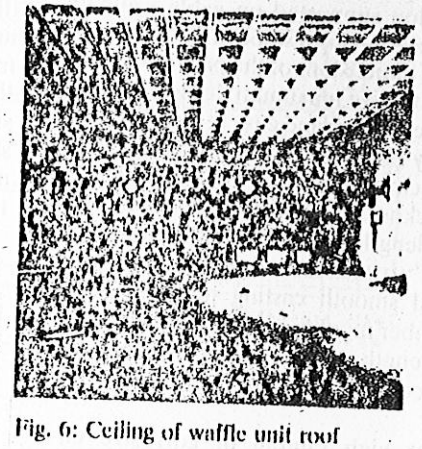

Fig. 6: Ceiling of waffle unit roof

over the shuttering leaving a gap between the units. Designed reinforcement for the grid beams are provided in the gaps at right angles to each other and they are filled up with concrete. The precast units are shaped in such a way that after the insitu concrete laid in the joints attains strength, the floor/roof acts monolithically. The shuttering is removed after the concrete has gained sufficient strength. No structural deck concrete is provided over the units. The scheme has been used in the construction of roof of a number of halls and auditoriums and presents aesthetically pleasing ceiling. Compared

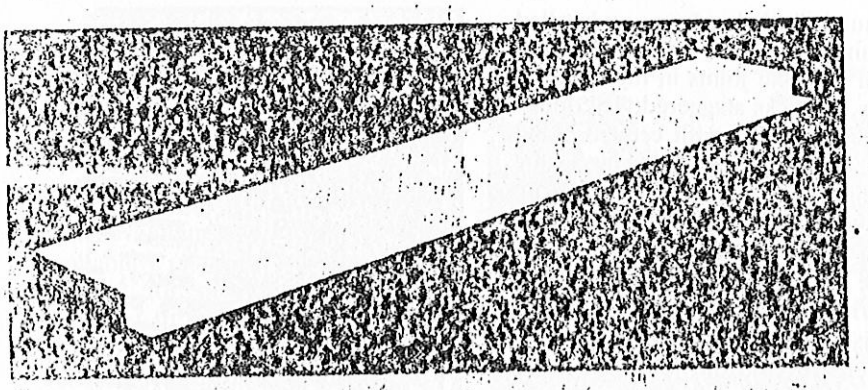

Fig. 7: L-panel

to insitu Tee beam and slab construction, waffle unit scheme results in a saving of fifteen percent in concrete, ten percent in steel and about fifteen percent in overall cost.

### L-pan Roofing Scheme

It is a sloped roofing scheme[6]) consisting of R. C. components of "L" section supported on gable walls or trusses having a slope of 1 : 4 to 1 : 3. The dimensions of the panels are chosen to give maximum design efficiency, economy and ease in handling and vary from 30 to 90 cm in width, 8 to 15 cm in depth of rib, 3 to 4 cm in thickness of flange and upto 400 cm in length. The panels are cast manually in an inverted position on a level and smooth casting platform using timber moulds. Concrete having cube strength 15 N/mm² is normally used.

For high rainfall or corrosive environment, richer concrete has to be used, besides taking other precautions. The fully cured panels are lifted and placed manually or using light hoists. The panels are laid side by side, with an overlap of 8 to 15 cm. At the ridge and joints between two bays, insitu concrete is provided with reinforcement. A demonstration house was put up with L-pan roof in connection with the International Seminar on Low Cost Housing held at Madras in 1977. A large number of schools and residential buildings with L-pan roofs are under construction in various parts of the country at present. The scheme is comparable in cost with asbestos cement sheet roof and provides a sound and aesthetically pleasing roof. Compared to insitu R. C. slab roof, it results in a saving of twenty five percent in cement, thirty percent in steel and thirty percent in overall cost. In case of temporary constructions, the panels can be reused.

### Conclusion

The precast flooring/roofing schemes discussed in this paper do not require any sophisticated machinery, equipments or large capital investment for their adoption. As the techniques are simple, they can be picked up within a short period by the type of labour available in the developing countries.

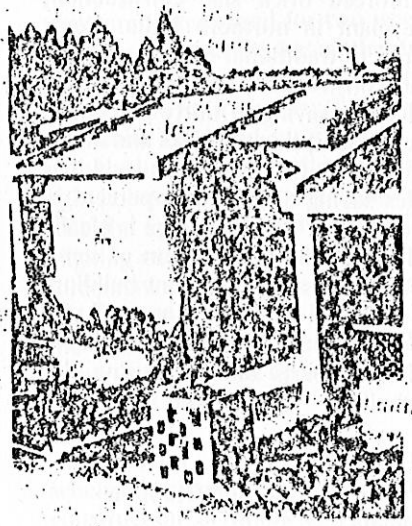

Fig. 8: A demonstration house with L-panels

The tests carried out on the precast units and the floor/roof assemblies have proved their structural adequacy and functional efficiency and the large scale constructions done so far have proved their adoptability and practicability. The adoption of these schemes will result in the saving of scarce materials like cement and steel and in the cost of construction. It will avoid the use of centering and shuttering completely or to a great extent and reduce the construction time.

Hence, they are ideally suited to the developing countries which are facing the problem of providing more and more houses and other buildings within the limited resources of materials and finance.

### Acknowledgement

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