Prefabrication Building Methodologies for Low Cost Housing

Shri P K Adlakha, Fellow
Shri H C Puri, Member

This paper aims to popularise the promotion of prefabrication building methodologies for low cost housing by highlighting the different prefabrication techniques, and the economical advantages achieved by its adoption.

Keywords: Prefabrication; Precast RCC ‘kular’; Precast joist

INTRODUCTION

In a building the foundation, walls, doors and windows, floor and roof are the most important components. These components can be analysed individually based on the needs. This will improve the speed of construction and reduce the construction cost.

Foundations

Various type of foundations normally adopted are:

(i) Open foundations.
(ii) Rib foundations.
(iii) Columns and footings.
(iv) RCC raft foundation.

Conventional methods using in-situ techniques are found to be economical and more practical for low cost housing of slums which generally consists of low rise structures. In seismic regions, special attention is required to make the foundations continuous using horizontal reinforcement. Prefabrication is not recommended for foundations in normal situations.

Walls

In the construction of walls, rammed earth, normal bricks, soil cement blocks, hollow clay blocks, dense concrete blocks, small, medium and room size panels etc of different sizes are used. However, bricks continue to be the backbone of the building industry. In actual construction, the number of the bricks or blocks that are broken into different sizes to fit into position at site is very large. As a result of this, there is wastage of material and the quality of construction also suffers.

Increasing the size of wall blocks will prove economical due to greater speed and less mortar consumption, which can be achieved by producing low density bigger size wall blocks and advantages of industrial wastes like blast furnace slag and fly ash can be made.

Several prefabrication techniques have been developed and executed for walls but these medium and large panel techniques have not proved economical for low rise buildings as compared to traditional brick work.

Floor and Roof

Structural floors/roofs account for substantial cost of a building in normal situation. Therefore, any savings achieved in floor/roof considerably reduce the cost of buildings. Traditional cast-in-situ concrete roof involve the use of temporary shuttering which adds to the cost of construction and time. Use of standardised and optimised roofing components where shuttering is avoided prove to be economical, fast and better in quality.

Some of the prefabricated roofing/flooring components found suitable in many low-cost housing projects are:

(i) Precast RC planks.
(ii) Precast hollow concrete panels.
(iii) Precast RB panels.
(iv) Precast RB curved panels.
(v) Precast concrete/ferrocement panels.
(vi) Precast RC channel units.

PREFABRICATION AS APPLIED TO LOW COST HOUSING

In India, adoption of prefabrication building techniques have many merits in the context of availability of materials, labour and technical skills. Advantages of prefabrication are:

(1) In prefabricated construction, as the components are readymade, self supporting, shuttering and scaffolding is eliminated with a saving in shuttering cost.

(2) In traditional construction, the repetitive use of shuttering is limited, as it gets damaged due to frequent cutting, nailing etc. On the other hand, the mould for the precast components can be used for large number of repetitions thereby reducing, the cost of the mould per unit.

(3) In prefabricated housing system, there is saving of time as the elements can be casted before hand during the course of foundations being laid and even after
laying slab, the finishes and services can be done below the slab immediately. While in the conventional in-situ RCC slabs, due to props and shuttering, the work cannot be done, till they are removed. Saving of time means saving of money.

(4) In prefabricated construction, there is better quality control, shape and size of precast elements. Therefore, in structural design, full advantage of properties of cement and steel can be exploited. There is disciplined use of scarce materials like cement, steel and timber.

(5) In precast construction, similar type of components are produced repeatedly, resulting in increased productivity and economy in cost too.

(6) In precast construction, the construction is not affected due to weather, rain, wind etc.

(7) In prefabricated construction, the work at site is reduced to minimum and therefore, work is qualitatively better, more reliable and clean.

(8) Because of faster completion and reduction in time period of construction the houses can be occupied earlier, which means early return of the investment.

LIMITATIONS OF PREFABRICATIONS

(1) As the precast elements have to behave monolithic on erections, extra reinforcement may be necessary in some cases.

(2) Extra reinforcement is required to take care of handling and erection stresses.

(3) Temporary props may be required in some cases, before the in-situ concrete joints achieve strength.

(4) The cracks may develop at the joints between the precast and in-situ concrete due to shrinkage and temperature stresses. To overcome them, extra steel is required across the joint.

(5) As there are chances of leakage/seepage through the joints between the precast components, extra care is required to make them leak proof.

CRITERIA FOR SELECTION OF PREFAB IN INDIA

In India, the technology adopted for housing components should be of the order that, the production and erection technology be adjusted to suit the level of skills and handling facilities available under metropolitan, urban and rural conditions. In other words, the structural systems and components selected should ensure minimum material utilization with maximum structural advantage. However, the component and systems so designed are to be manufactured and erected by manual means in villages, semi-mechanical techniques in towns and more or less fully mechanical operations in the metropolitan cities.

In urban areas, the concentration of construction activity does not justify prefabrication. The answer is hybrid construction combining standardised mass-manufactured roofing and other components (at site) with in-situ brick walls or other masonry structures. A wide variety of roofing methods to suit these requirements have been developed and used on mass scale in many housing projects such as funicular shell, cored slabs, RCC channel units, precast cellular units, precast RC planks and joists, prefab brick panels and joists, RCC joists and hollow concrete blocks, precast RCC ‘Kular’ slab.

TECHNIQUES

Precast RC Plank Roofing System

This system consist of precast RC planks supported over partially precast joist. The completely finished slab can be used as intermediate floor for living also. The total thickness of slab is 6 cm. The scheme is ideally suited for spans upto 4.2 m, but can be used for large spans, by providing secondary beams. RC planks are made with thickness partly varying between 3 cm and 6 cm. There are haunches in the plank which are tapered. When the plank is put in between the joists, the space above 3 cm thickness is filled with in-situ concrete to get tee-beam effect of the joists. A 3 cm wide tapered concrete filling is also provided for strengthening the haunch portion during handling and erection. The planks have 3 numbers 6 mm dia MS main reinforcement and 6 mm dia @ 20 cm centre to centre cross bars. Concrete used is of grade M-15. The planks are made in module width of 30 cm with maximum length of 150 cm and the maximum weight of the dry panel is 50 kg (Figure 1).

Precast joist is rectangular in shape, 15 cm wide and the precast portion is 15 cm deep (Figure 2). The above portion is casted while laying in-situ concrete over planks. The stirrups remain projected out of the precast joist. Thus, the total depth of the joist becomes 21 cm. The joist is designed as composite Tee-beam with 6 cm thick flange comprising of 3 cm precast and 3 cm in-situ concrete (Figure 3). This section of the joist can be adopted upto a span of 400 cm. For longer spans, the depth of the joist should be more and lifting would require simple chain pulley block.

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In residential buildings, balcony projections can be provided along the partially precast joists, designed with an overhang carrying super imposed loads for balcony as specified in IS : 875-1964, in addition to the self load and the load due to balcony railings. The main reinforcement of the overhang provided at the top in the in-situ concrete attains sufficient strength. The savings achieved in practical implementations compared with conventional RCC slab is about 25%.

Prefabricated Brick Panel Roofing System

The prefabricated brick panel roofing system consists of:

(a) Prefab Brick Panel

Brick panel is made of first class bricks reinforced with two MS bars of 6 mm dia and joints filled with either 1:3 cement sand mortar or M-15 concrete. Panels can be made in any size but generally width is 53 cm and the length between 90 cm to 120 cm, depending upon the requirement. The gap between the two panels is about 2 cms and can be increased to 5 cms depending upon the need. A panel of 90 cm length requires 16 bricks and a panel of 120 cm require 19 bricks (Figure 4).

(b) Partially Precast Joist

It is a rectangular shaped joist 13 cm wide and 10 cm to 12.5 cm deep with stirrups projecting out so that the overall depth of joist with in-situ concrete becomes 21 cm to 23.5 cm, it is designed as composite Tee-beam with 3.5 cm thick flange.

STRUCTURAL DESIGN

The prefab brick panel for roof as well as for floor of residential buildings has two numbers 6 mm dia MS bars as reinforcement upto a span of 120 cms.

The partially precast RC joist, is designed as simply supported Tee-beam with 3.5 cm thick flange. The reinforcement in joist is provided as per design requirements depending upon the spacing and span of the joist.

An overall economy of 25% has been achieved in actual practice compared to cast-in-situ RCC slab.

Precast Curved Brick Arch Panel Roofing

This roofing is same as RB panel roofing except that the panels do not have any reinforcement. A panel while casting is given a rise in the centre and thus an arching action is created. An overall economy of 30% has been achieved in single storeyed building and 20% in two or three storeyed buildings (Figures 5 and 6).

Precast RC Channel Roofing

Precast channels are trough shaped with the outer sides corrugated and grooved at the ends to provide shear key action and to transfer moments between adjacent units. Nominal width of units are 300 mm or 600 mm with overall depths of 130 mm to 200 mm (Figure 7). The lengths of the units are adjusted to suit the span. The flange thickness is
The width of a panel is 300 mm and depth may vary from 100 mm to 150 mm as per the span, the length of the panel being adjusted to suit the span. The outer sides are corrugated to provide transfer of shear between adjacent units. The ‘kulars’ are placed inverted so as to create a hollow during precasting (Figure 8). Extra reinforcement is provided at top also to take care of handling stresses during lifting and placement. There is saving of about 30% in cost of concrete and an overall saving of about 23%.

**Precast Concrete Panels Roofing**

The system comprise of precast panels 600 mm × 600 mm and only 30 mm thick (Figure 9). The reinforcement consists of 2 mm dia MS wire or equivalent welded mesh. The panels are 30 mm to 35 mm. Where balcony is provided, the units are projected out as cantilever by providing necessary reinforcement for cantilever moment. A saving of 14% has been achieved in actual implementation in various projects.

**Precast Hollow Slabs Roofing**

Precast hollow slabs are panels in which voids are created by earthen ‘kulars’ without decreasing the stiffness or strength. These hollow slabs are lighter than solid slabs and thus save the cost of concrete, steel and the cost of walling and foundations too due to less weight.
placed over fully precast RCC beams of 75 mm width and 125 mm to 150 mm depth depending on the span. The ends of panels are tapered so as to form a V-groove when placed over beams. This groove is filled with cement mortar. The beams are designed as simple supported.

After placement of panels and filling of the V-grooves a screeding concrete 25 mm thick with chicken mesh reinforcement is laid. This screeding concrete act as floor finish and as earthquake strengthening measure. The panels can also be casted in ferrocement by using cement mortar 1:2 and fine 6 mm down grit and chicken mesh reinforcement in two layers. A saving of about 25% has been achieved in actual practice over conventional system.

SEISMIC STRENGTHENING ARRANGEMENTS OF PRECAST ROOFING SYSTEMS

IS-4326; 1993 has given recommendations regarding strengthening measures for precast roofing techniques. The code recommends that for building category A, B and C based on seismic co-efficient, a tie beam is to be provided all round the floor or roof to bind together all the precast components to make it a diaphragm. The beams shall be to the full width of supporting wall less the bearing of precast components. The depth of the beam shall be equal to the depth of the precast components plus the thickness of structural deck concrete, whenever used over the components. Tie beams shall be provided on all longitudinal and cross walls.

In category D, structural deck concrete of 35 mm thickness reinforced with 6 mm dia bars, 150 mm both ways and anchored into tie beams shall be provided. For economy, the deck concrete itself can serve as floor finish.

OTHER USES OF PREFABRICATION

The use of prefabrication for other materials can be made like lintels, sun shades, cupboard shelves, kitchen working slab and shelves, precast ferrocement tanks, precast staircase steps, precast ferrocement drains (Figures 10 and 11).

(a) Thin Precast RCC Lintel

Normally lintels are designed on the assumption that the load from a triangular portion of the masonary above, acts on the lintel. Bending moment, will be \( W \times L / 8 \) where \( W \) is the load on the lintel and \( L \) is the span assumed for the design purpose. By this method, a thickness of 15 cm is required.

Thin precast RCC lintels are designed taking into account the composite action of the lintel with the brick work. Design chart prepared for thin precast RCC lintels in the brick walls of normal residential building is applicable only when the load on the lintel is uniformly distributed. The brick work over the lintel is done in a mortar not leaner than 1:6. The thickness of the lintel is kept equal to the thickness of brick itself having a bearing of 230 mm on either supports.

Use of precast lintels speeds up the construction of walls besides eliminating shuttering and centreing. Adoption of thin lintels results in upto 50% saving in materials and overall cost of lintels.

(b) Doors and Windows

Innumerable types and sizes of doors and windows used in single and similar buildings. This involves the use of additional skilled labour on site and off site and also wastage of expensive materials like timber, glass etc. Economy can be achieved by:

(i) standardising and optimising dimensions;
(ii) evolving restricted number of doors and window sizes; and
(iii) use of precast door and window frames.

for example:
- bed room, kitchen, entrance, living room, balcony doors 900 mm width and 2000 mm height; and
- windows of 400 mm, 800 mm, 1200 mm, width and of 400 mm, 800 mm, 1200 mm or 1600 mm heights.
CONCLUSION

Mass housing targets can be achieved by replacing the conventional methods of planning and executing building operation based on special and individual needs and accepting common denominator based on surveys, population needs and rational use of materials and resources.

No single approach and solution is available which can satisfy the community at large. However, what is ideal and desirable is to have a system which can provide choice for people and also appropriate techniques to meet the situation. The essence lies in the system approach in building methodology and not necessarily particular construction type or design. Adoption of any alternative technology on large scale needs a guaranteed market to function and this cannot be established unless the product is effective and economical. Partial prefabrication is an approach towards the above operation under controlled conditions.

The methodology for low cost housing has to be of intermediate type — less sophisticated involving less capital investment.

REFERENCES

1. 'Study on Low Cost Incremental Housing Scheme for UP State.' BMPTC, Adlakha and Associates.

2. 'Standards and Specifications for Cost Effective Innovative Building Materials and Techniques.' BMPTC.


4. 'Workshop on Capacity Building for Project Managers of Building Centres.' organised by HSMI, April 20-May 2, 1988.


6. P K Adlakha. 'New Economical Construction Techniques for Walls and Roofing.' Seminar on Intraction on New Materials and Technologies in Built Environment, Delhi, October 14-17, 1993.