LOW COST HOUSING

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Abstract:
This paper aims to point out the various aspects of prefabricated building methodologies for low cost housing by highlighting the different prefabrication techniques, and the economical advantages achieved by its adoption. In a building the foundation, walls, doors and windows, floors and roofs are the most important components, which can be analyzed individually based on the needs thus, improving the speed of construction and reducing the construction cost. The major current methods of construction systems considered here are namely, structural block walls, mortar less block walls, prefabricated roofing components like precast RC planks, precast hollow concrete panels, precast concrete/Ferro cement panels are considered.

Keywords: Prefabrication; Precast RCC 'kular', precast joist, Ferro cement products

Introduction

Affordable housing is a term used to describe dwelling units whose total housing cost are deemed "Affordable" to a group of people within a specified income range. (www.wikipedia.com)

In India, the technology to be adopted for housing components should be such that the production and erection technology be adjusted to suite the level of skills and handling facilities available under metropolitan, urban and rural conditions.(P.K.Adlakha and H.C.Puri, 2003)

Logical approach for optimizing housing solutions:

There should be a logical approach for providing appropriate technology based on the availability of options, considering its technical and economical analysis.

1. There should be optimal space in the design considering efficiency of space, minimum circulation space.
2. Economy should be considered in design of individual buildings, layouts, clusters etc.
3. While preparing the specifications it should be kept in mind that, cost effective construction systems are adopted.
4. Energy efficiency has gained considerable importance due to energy crisis especially in developing countries. Orientation, built–form, openings & materials play a vital role besides landscaping / outdoor environment.
5. To develop an effective mechanism for providing appropriate technology based shelter particularly to the vulnerable group and economically weaker section.(R.K.Garg, 2008)

Prefabrication as applied to `Low Cost Housing

(P.K.Adlakha and H.C.Puri, 2002)
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 conventional methods, the shuttering gets damaged due to its repetitive use because of 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, time is saved by the use of precast elements which are casted off-site during the course of foundations being laid. 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. Thus, saving of time attributes to saving of money.
4. In precast construction, similar types of components are produced repeatedly, resulting in increased productivity and economy in cost too.
5. Since there is repeated production of similar types of components in precast construction, therefore, it results in faster execution, more productivity and economy.
6. In prefabricated construction, the work at site is reduced to minimum, thereby, enhancing the quality of work, reliability and cleanliness.
7. The execution is much faster than the conventional methods, thereby, reducing the time period of construction which can be beneficial in early returns of the investment.

Concept of prefabrication / partial prefabrication has been adopted for speedier construction, better quality components & saving in material quantities & costs .Some of these **construction techniques** & **Materials** for **walls**, **roof & floor slab**, **doors & windows** are as follows:

In 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. which results in wastage of material poor quality.

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 using industrial wastes like blast furnace slag and fly ash.

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. (P.K.Adlakha and H.C.Puri, 2002)

i. Non erodable mud plaster:

The plaster over mud walls gets eroded during rains, which necessitates costly annual repairs. This can be made non erodable by the use of bitumen cutback emulsion containing mixture of hot bitumen and kerosene oil. The mixture is pugged along with mud mortar and wheat/ rice straw. This mortar is applied on mud wall surface in thickness of 12 mm. One or two coats of mud cow dung slurry with cutback are applied after the plaster is dry. The maintenance cost is low due to enhanced durability of mud walls.(R.K.Garg, 2008)

Fig. 1. Mud Plastered House

ii. Fly –Ash sand lime bricks:

By mixing of lime and fly ash in the presence of moisture, fly ash sand lime bricks are made. Fly Ash reacts with lime at ordinary temperature and forms a compound possessing cementitious properties. After reactions between lime and fly ash, calcium silicate hydrates are

produced which are responsible for the high strength of the compound. Bricks made by mixing lime and fly ash are therefore, chemically bonded bricks.
The bricks are manufactured with the help of hydraulic press and are dried in the autoclave. These bricks have various advantages over the clay bricks, It possesses adequate crushing strength, uniform shape, smooth finish and does not require plastering and also are lighter in weight than ordinary clay bricks. (R.K.Garg, 2008)

iii. Solid concrete and stone blocks:

This technique is suitable in areas where stones and aggregates for the blocks are available locally at cheaper rates. Innovative techniques of solid blocks with both lean concrete and stones have been developed for walls. The gang-mould is developed for semi-mechanized faster production of the blocks.
In the manual process, single block moulds are used wherein the concrete is compacted with help of a plate vibrator. With the use of a portable power screw driven egg laying type machine, solid concrete blocks are made with higher productivity at low cost. Six blocks of 30 x 20 x 5 cm size are cast in single operation with an output of 120-150/hr. (R.K.Garg, 2008)

In 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 building. Traditional Cast-in-situ concrete roof involve the use of temporary Shuttering which adds to the cost of construction and time. Use of standardized and optimized 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. Prefabricated Brick Panels
iii. Precast RB Curved Panels.
iv. Precast RC Channel Roofing
v. Precast Hollow Slabs
vi. Precast Concrete Panels
vii. L Panel Roofing
viii. Trapezon Panel Roofing
ix. Un reinforced Pyramidal Brick Roof

i. Precast RC plank roofing system:

This system consists of precast RC planks supported over partially precast joist.
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.
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 2).
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 up to a span of 400 cm. For longer spans, the depth of the joist should be more and lifting would require simple chain pulley block.
The completely finished slab can be used as intermediate floor for living also
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%.(P.K.Adlakha and H.C.Puri, 2002)

Fig. 2 Precast R.C. Planks

Fig. 3 R.C. Planks laid over partially precast joists

ii. 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 to120 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 requires 19 bricks (Figure 4). (P.K.Adlakha and H.C.Puri, 2002)

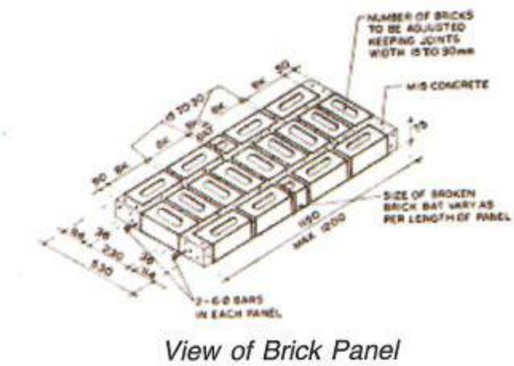

Fig. 4 Brick Panel

(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.(Figures 5 and 6). (P.K.Adlakha and H.C.Puri, 2002)

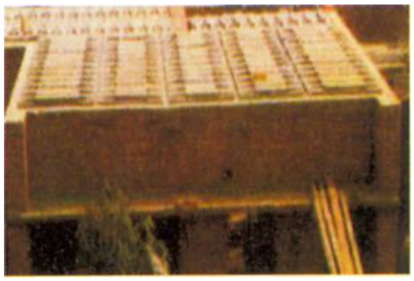

Fig. 6 Precast R C Plank and Joist System

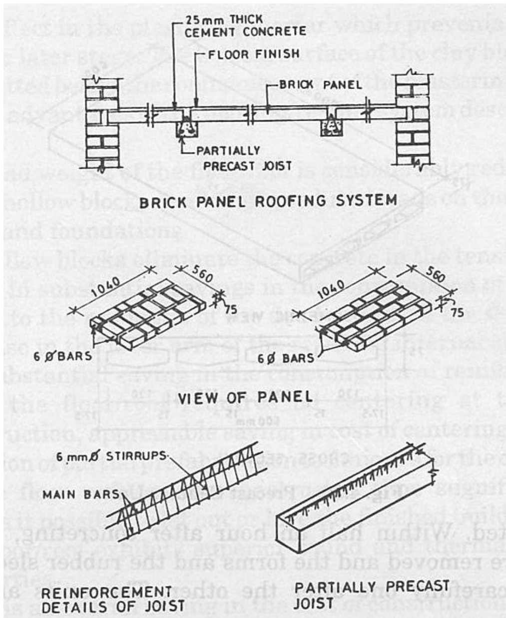

Fig. 5 Details of Precast Joist

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 up to a span of 120 cms.
The partially precast RC joist, is designed as simply supported Tee-beam with 3.5cm 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. (P.K.Adlakha and H.C.Puri, 2002)

iii. 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 (Figure 7). (P.K.Adlakha and H.C.Puri, 2002)

Fig. 7 Pre Fab Brick Arch Panel

iv. 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 is 300 mm or 600 mm with overall depths of 130 mm to 200 mm (Figure 8). The lengths of the units are adjusted to suit the span. The flange thickness is 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. (P.K.Adlakha and H.C.Puri, 2002)

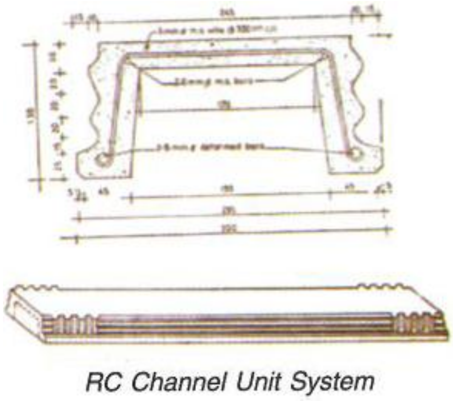

Fig. 8 RC Channel Unit System

v. 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.

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 9). 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%.(P.K.Adlakha and H.C.Puri, 2002)

Fig.9 Hollow Slabs Roofing System

vi. L- Pan roofing

The pre cast full span RC L-panel is of section 'L'. The L- panels are supported on parallel gable walls and are used for sloped roof of a building. The RC units can be cast with simple timber/ steel moulds and are easy for manual handling with simple lifting and hoisting gadgets. L-Panel roofing is quite lighter in weight, economic in construction and sound in performance and durability. In addition to roof, the L-panels can be used for making loft, cooking platforms, parapets and many other minor elements of buildings and structures. The techniques has been used widely in many mass housing programme in the country. (figure:10) (R.K.Garg, 2008)

Fig.10 L Pan Roofing System

vii. Trapezonpan roofing flooring

Typical precast RC trapezonpanel has trapezium section in orthogonal directions. The components are sound and can be manually handled with ease. These components are placed in position to form roof/floor and haunch filling is done with in-situ concrete to make a monolithic surface.

Trapezo-panels can be produced in stacks one above the other and have advantage in production, stacking and supply. These units are used for floors/ roofs with / without deck concrete.(figure:11) (R.K.Garg, 2008)

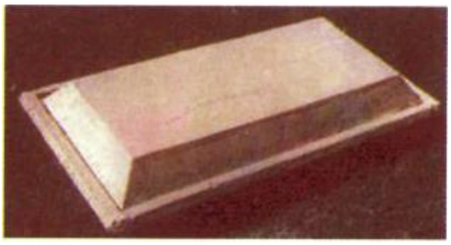

Fig.11 Trapezonpan Roofing System

viii. Un-reinforced pyramidal brick roof

Un-reinforced pyramidal brick roof construction system is suitable for low cost houses in cyclone affected and other coastal areas. Corrosion of reinforcement was found to be the major cause of failure of RCC structure in coastal areas and a pyramidal roof with brick and cement concrete without reinforcement was therefore developed.

The roof is provided with peripheral RCC Ring beam. The beam is supported on eight brick columns or walls and is cast as integral part of the pyramidal roof using suitable shuttering. The roof can be of different sizes and shapes. (Figure. 12) (R.K.Garg, 2008)

Fig.12 Un Reinforced Pyramidal Brick Roof

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. (P.K.Adlakha and H.C.Puri, 2002)

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 Ferro cement tanks, precast staircase steps, precast

Ferro cement drains (P.K.Adlakha and H.C.Puri, 2002)

(a) Thin precast RCC lintel

Normally lintels are designed on the assumption that the load from a triangular portion of the masonry above, acts on the lintel. Bending moment will be WL/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 centering. Adoption of thin lintels results in upto 50% saving in materials and overall cost of lintels. (P.K.Adlakha and H.C.Puri, 2002)

(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) Standardizing and optimizing dimensions;

(ii) Evolving restricted number of doors and window sizes; and

(iii) Use of precast door and window frames.(Fig. 13)

Fig.13Frame Less Door

Materials used:-

(BMTPC- Building Materials & Technology Promotion Council, Govt. of India)

By and large, conventional building materials like burnt bricks, steel and cement are higher in cost, utilize large amount of non-renewable natural resources like energy, minerals, top soil, forest cover,etc,. The continued use of such conventional materials has adverse impact on economy and environment. Environment friendly materials and technologies with cost effectiveness are, therefore, required to be adopted for sustainable constructions which must fulfill some or more of the following criterion :-

- Not endanger bio-reserves and be non-polluting.
- Be self sustaining and promote self reliance.
- Recycle polluting waste into usable materials.
- Utilize locally available materials.
- Utilize local skills, manpower and managing systems.
- Benefit local economy by being income generating.
- Utilize renewable energy sources.
- Be accessible to people.
- Be low in monetary cost.

1. Bamboo Mat Board

Raw material source	Bamboo grass(plant), Species
Materials for production	Bamboo, polymeric resin, chlorinated hydrocarbons and boron and cashew nut shell liquid.
Applications	Flooring, walling, structural membrane, false ceiling, door/window frames.

2. Bamboo Mat Veneer Composite

Raw material source	Plantation wood, bamboo plant
Materials for production	Plantation wood veneer, bamboo mat, polymeric resin,

	chlorinated hydrocarbons, boron, cashew nut shell liquid
Applications	Door skin in flush doors, structural use as roofing, web construction, prefab and portable shelters, packing, modular partitions, furniture.

3. Bamboo Corrugated Roofing Sheet

Raw material source	Bamboo grass(plant), Species
Materials for production	Bamboo, polymeric resin, chlorinated hydrocarbons and boron and cashew nut shell liquid. coating for UV Protection and to improve impermeability to water.
Applications	Roofing sheets as substitute to corrugated Asbestos Cement sheets, Galvanized Iron sheets, Aluminium sheets and Fibre-reinforced Plastic (FRP) sheets.

4. Bamboo-Rice Husk Composite

Raw material source	Rice mills, bamboo plants (grass)
Materials for production	Rice husk, bamboo mat, cashew nut shell liquid phenolic resin.
Applications	Temporary shelters, ware houses, false ceilings, insulation, partition and stage settings, industrial and domestic floorings

5. Fly Ash Polymer Composite

Raw material source	Fly ash from coal based power generating plants.
Materials for production	Fly ash, Polymeric material
Applications	Partitions, door shutters, roofing sheets

6. Blast Furnace Slag Composite

Raw material source	Waste from steel plants
Materials for production	Blast furnace slag, polymeric resin, laminating material
Applications	Partitions and interior finishing on walls

7. Sandwitched Fly Ash Panel

Raw material source	Fly ash from coal based power generating plants.
Materials for production	Fly ash, cement, sand, foaming agent
Applications	Partitions and walling panels

8. Plantation Timber Doors/ Windows

Raw material source	Rubber wood, popular wood and other soft woods
Materials for production	Rubber wood and popular wood plants, thermoplastic and thermosetting resin, adhesives
Applications	Doors and window frames , flush and paneled door shutters

Case histories in India
Demonstrations Construction Using Cost- Effective & Disaster Resistant Technologies – BMTPC's Initiatives

BMTPC has been promoting cost-effective & environment- friendly building materials & construction techniques in different regions of the country. During recent past the council has been laying emphasis on putting up demonstration structures utilising region specific technologies . Such efforts for demonstrating innovative technologies have created a much better impact and helped in building up confidence and acceptability in private & public construction agencies, professional & contractors. Details of the major projects handled by them are given as under:-

1. Demonstration Housing Project at Laggerre, Bangalore, Karnataka.
(Figures 14 and 15)

Project Profile:-

Name of scheme	:	VAMBAY – Ministry of HUPA
Location of site	:	Laggere, Bangalore
No. of Units	:	252 (Ground +2)
Built-up area of a unit	:	275sq.ft
Unit consist of	:	2 rooms 1 kitchen, 1 bath room, 1WC
Cost per unit	:	Rs.60000
Cost per Sqft	:	Rs.218/-
Nodal State Agency	:	Karnataka slum clearance Board

Technologies / Specification

Foundation
- Random Rubble Stone Masonry

Walling
- Solid Concrete blocks for 200mm thick walls
- Clay Bricks for partition walls
- RCC Plinth Band for Earthquake resistance

Roof/Floor
- RC Filler slab using clay bricks as fillers in ground
- RC slab for second floor
- IPS flooring

Doors & Windows
- Pre-cast RCC door frames
- Coir polymer Door shutters
- Steel Sheet window shutters
- Clay jalli in ventilators

Others
- External Cement plaster
- White wash on internal walls
- Water proof cement paint on external walls
- Precast Ferro cement lofts , shelves , chajjas.

Fig. 14

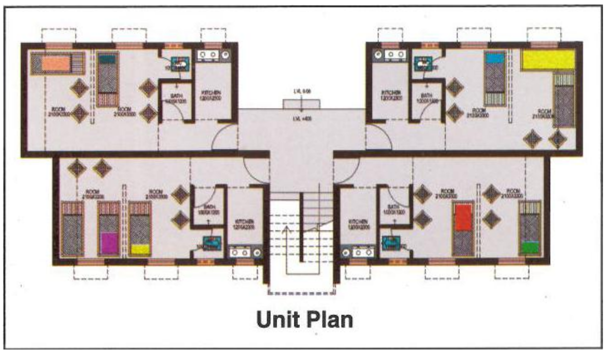

Fig. 15 Typical Plan of A Unit

2. Demonstration Housing Project at Dehradun, uttarakhand
(Figures 18 and 19)

Project Profile:-

Name of scheme	:	VAMBAY – Ministry of HUPA
Location of site	:	Dehradun • Ram Kusth Ashram, Ryagi Road{28 Double Units(DUs)} • Rotary club kusth Ashram,(Bhagat Singh Colony (34 DUs) • Shanti Kusth Ashram, Bhagat singh Colony (38DUs)

No. of Units	:	100
Built-up area of a unit	:	181sq.ft
Unit consist of	:	1room,kitchenspace, 1 bath room, 1WC
Cost per unit	:	Rs.45000
Cost per Sqft	:	Rs.249/-
Nodal State Agency	:	District Urban Development Agency

Technologies / Specification

Foundation

- Step footing in solid concrete blocks

Walling

- Solid /Hollow concrete blocks
- RCC plinth, lintel, roof level band, vertical reinforcement in corners for earth quake resistance

Roof/Floor

- RCC planks & joist with screed
- IPS flooring

Doors & Windows

- Pre-cast RCC door frames
- Wood substitute door shutters
- Fly ash polymer door shutter for toilet.
- Cement jalli in ventilators and windows

Others

- Internal and external pointing
- White wash on walls
- Precast ferrocement chajjas

Fig. 18

Unit Plan

Fig. 19 Typical Plan of A Unit

Conclusions

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.

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 essence lies in the systematic approach in building methodology and not necessarily particular construction type or design.

The methodology for low cost housing has to be of intermediate type- less sophisticated involving less capital investment. (P.K.Adlakha and H.C.Puri, 2002)

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References

[1] "Faster Production of Stone Blocks and Concrete Blocks', CBRI-Annual Report, 1999-2000.

[2] Garg R.K., `Sustainable Human Settlements and Cost Effective Housing Technologies.' BMTPC

[3] Garg R.K., Garg N. K. & Batra Y. K.(2004), Sanitation and Waste Water Disposal Systems inRural Areas, Journal of Indian Building Congress, Vol. 11, No. 2, 2004; Seminar on "Up gradation of Housing & Amenities in Rural Areas", Bhubaneswar, December, 22nd-23rd2004. BMTPC.

[4] Gupta B.S., Jain S.K., Hira B.N. "Trapezonpan Roofing/Flooring Scheme", Indian Concrete Journal, July 1982, India.

[5] Hira B.N. & Negi S.K., Journal of Indian Building Congress, Vol. 11, No. 2, 2004; ; Seminar on "Up gradation of Housing & Amenities in Rural Areas", December, 22nd-23rd2004. at Bhubaneswar Appropriate Building Techniques for Rural Housing. BMTPC.

[6] IS 4326: Earthquake Resistant Design and Construction of Materials, 1993

[7] Lal A.K., `Hand Book of Low Cost Housing.'

[8] National Urban Housing and Habitat Policy, 2007, Govt. of India.

[9] `Standards and Specifications for Cost Effective Innovative Building Materials and Techniques.' BMTPC.

[10] 'Study on Low Cost Incremental Housing for UP State.' BMTPCD, Adlakha and Associates.

[11] Verma. N., 1985, CBRI Building Research Note No. 34 on Low Cost Sanitation for Rural & Urban Houses.