Improved Construction Techniques and Materials—Some Developments

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ABSTRACT

India is faced with a shortage of more than 83 million houses. For such a construction programme to undertake, there will not only be shortage of finance but also of material, skilled craftsmen and time. With this in mind, conscious efforts are being made by different individuals and organisations to bring forth innovations in the conventional construction system by reduction of consumption of scarce materials like cement and steel, by using locally available alternative materials and agro-industrial wastes in its natural or processed form and by adoption of prefabrication and improved construction methods.

Central Building Research Institute has been working in this direction during the last three decades and has evolved a few construction schemes using conventionally used reinforced concrete and other non-conventional materials like light weight concrete, cellular concrete ond fired clay products. In the prefabricated reinforced concrete schemes described in the paper, full advantage of size, shape and geometry has been derived. The schemes are so evolved that they are labour intensive, save in cost and material and require no heavy equipment for handling, transportation and erection. D.C. tiles, cellular units, R.C. Planks, channel units, cored units, waffle units, L-pan units are some of the precast schemes described in the paper along with the economy obtained at actual construction sites.

Brick panel scheme described in the paper is an example of improvisation of existing construction practice with the advantages of prefabrication, thereby leading to economy in materials. The flooring/roofing schemes using structural clay products hold promise for substantial replacement of cement and economy in the consumption of steel.

In absence of naturally occuring lightweight aggregate, efforts were made to utilise industrial wastes like clinker, flyash, foamed slag etc. for the production of lightweight aggregate and to produce cellular concrete from lime and flyash and their adoption in building construction. The paper throws some light on these aspects also.

Introduction

India is a developing country. The economic necessity of the country demands greater emphasis in the allocation of resources to other priority sectors like energy, industry, agriculture etc. At the same time, India being a social welfare state, the ever growing consciousness of the welfare needs of the society demands larger allocation of resources not only for providing shelter but for other social welfare needs of the people like education, health-care etc. Though, it has become a difficult task to balance the needs of investment in priority sectors of economic development and those in welfare sector; over the recent years, there has, however, been a better realisation of the need of building activities since shelter, education and health are the first pre-requisites before any developmental activity in any field can take place.

Like all other developing countries, India is also faced with a huge shortage of houses both in rural and urban areas due to the past back-log, large population growth, shortage of material, financial

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resources and skilled craftsmen. To house the present population of 600 million, the requirement is for 120 million houses, of which only 37 million houses (1) are available (Figures given are relevant to 1975). To meet this gigantic need, it is seen that apart from the financial difficulty to fund such a huge construction programme, there will also be shortage of construction materials and skilled craftsmen. With the present day conventional construction system, it is simply impossible to keep up the pace. With these problems in the forefront, Central Building Research Institute (CBRI), Roorkee has been carrying out research in various aspects of buildings leading to quick, efficient and economic methods of construction, reduction in the consumption of scarce materials like cement and steel by partial or full replacement with locally avilable alternative materials, development of new materials and innovation of construction techniques. Over the last few years, a number of prefabricated construction schemes with reinforced concrete, light weight concrete, cellular concrete, bricks and structural clay products has been developed. These make efficient utilisation of scarce materials like cement and steel and of alternative materials from natural deposits and industrial wastes. The techniques are quite simple, labour intensive, do not need heavy investment and machinery and provide strong and durable structures within reasonable cost. The paper describes the salient features of a few important developments of the Institute.

PRECAST CONCRETE SCHEMES

(a) Doubly Curved Tile Roof :

The roofing system is based on the use of simple roofing units comprising of 70 cm square doubly curved tiles and partially precast R.C. joists. The tiles are designed on the principle of simple shell of double curvature. The size of the unit (70 cm square) is so chosen that the thickness of the tile can be limited to 2 cm and that R.C. edge beam or any other reinforcement in the shell unit is not required. A simple method of precasting the tile units has been described else where (2). The tiles are laid over partially precast joists laid at 76 cm centre. The partially precast joists are to be supported by two props at the middle third points before placing the tiles. After placing the tiles in position, the haunches are filled up with 1 : 2 : 4 concrete (Fig. 1). The temporary supports from below the partially precast joist should be removed after concrete in the haunches has hardened. The usual waterproofing-cum-insulating treatment is then provided over the roof in the conventional manner. The D.C. tile roofing leads to considerable saving in material, labour and overall cost as compared to in-situ R.C.C. slab.

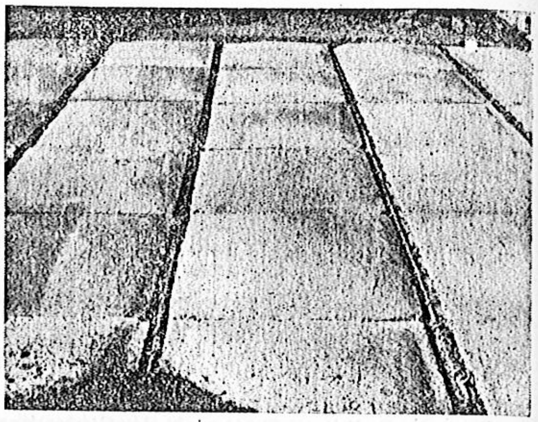

Fig. 1 Construction of d.c. tile roof

(b) Precast Cellular Units for Floor and Roof :

These are unreinforced precast concrete elements having hexagonal hollows running along their length. These are generally made in the size $60 \times 120 \times 7.5$ cm thick, with four hollows and having a minimum thickness of 1.5 cm (Fig. 2). Each such unit weighs 80 kg. The units are placed side by side over partially precast joists laid at predetermined interval. A layer of 3 cm thick M 150 (1:2:4) concrete having nominal temperature reinforcement is laid over the assembled units to give monolithicity to the floor/roof assembly and to make the structural slab complete (3). In addition to speed of construction, there is saving of material, labour and formwork.

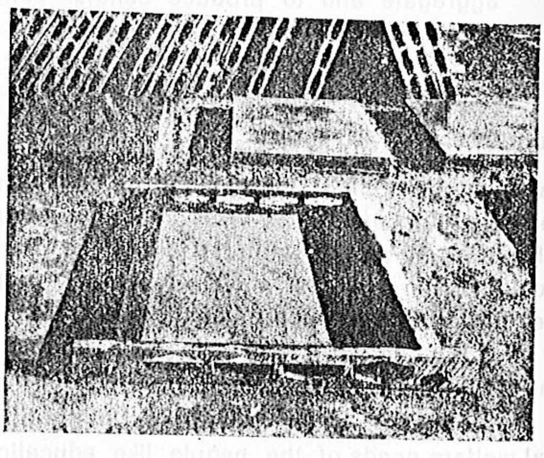

Fig. 2 Precast cellular units

Versatility of the intrinsic shape of the unit has also been exploited in its use as a precast wall unit. Using the same cellular unit, a complete system known as "Holopan System" has been developed and used in construction of houses wherein the same cellular unit has been used both as an element of wall and floor/roof (Fig. 3).

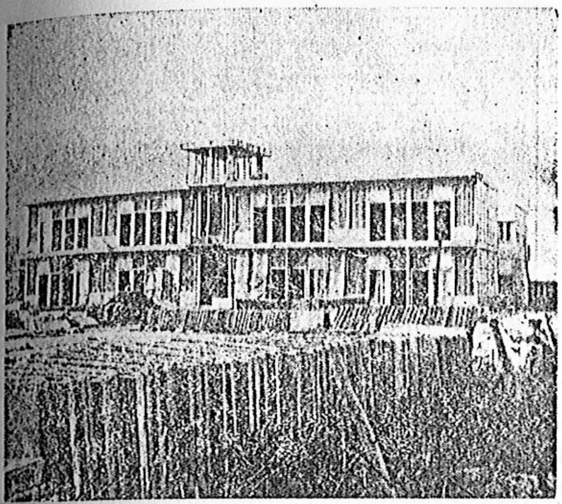

Fig. 3 Construction with holopan

(c) Precast R.C. Plank Flooring/Roofing Scheme

R.C. planks are partly 5 cm and partly 2.5 cm thick precast reinforced concrete units in sizes ranging upto 120×45 cm and 130×40 cm (Fig. 4). R.C. planks are supported on trapezoidal shaped partially precast R.C. joists. The haunches between the planks are filled with M 150 concrete with the top levelled flush with the middle portion of the plank. Before placing the haunch concrete, distribution reinforcement of 3 mm dia m.s. wire, two numbers parallel to the joists and another two per plank across the joist tied up properly with the projecting reinforcement of the joists is laid in the haunch portion of the precast planks (4). This scheme has been widely adopted in rehabilitation of cyclone affected people in Andhra Pradesh and construction of residential, school and factory buildings at several places in India. Saving achieved is about 20 per cent in steel, 35 per cent in cement and about 20 to 25 percent in overall cost.

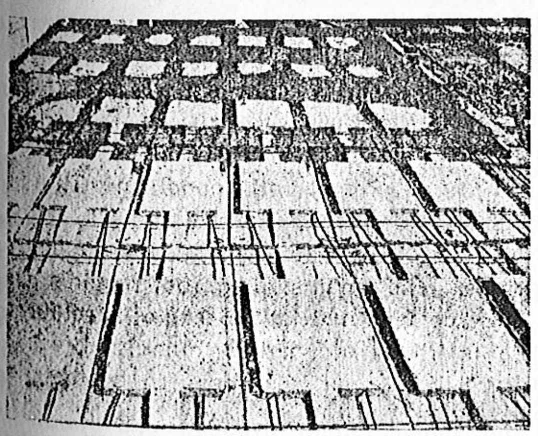

Fig. 4 Construction of floor/roof with precast r.c. planks

(d) Channel Units for Floor/Roof

The cross-sectional shape of channel unit is in the form of a trough with the outer side-faces corrugated and grooved at the ends to provide monolithicity in the assembled slab when, after placing, positioning and levelling of the units, the joints between the adjacent units are filled with 1:2:4 concrete (5). The length of the units generally ranges from 2.8 to 4.2 metres, with 30 or 60 cm nominal width and 13 cm overall depth (Fig. 5). Minimum flange thickness

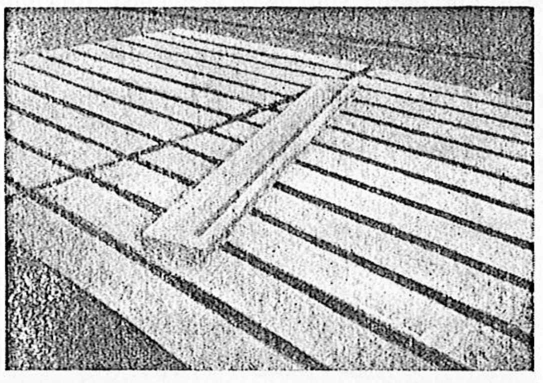

Fig. 5 Construction of floor/roof using precast channel units

is 2.5 and 3.5 cm respectively for 30 and 60 cm wide units weighing 36 and 54 kg per metre respectively. In case, reinforcement is required for continuity of the slab over the support, the same is provided in the joints between the adjacent units before placing in-situ concrete. No structural deck concrete is required to be provided over the units. The assembled slab appears like a ribbed slap from the ceiling. The scheme has been adopted in a big way in the construction of school and residential buildings in several parts of India. A simple equipment based on vibro-stamping principle has also been developed for mechanised production of channel units at a rate about 40 units per day. Apart from 20 percent saving in construction time, it has resulted in a saving of about 30 per cent in cement, about 2 percent in steel and 15 to 20 percent in overall cost.

(e) Precast Cored Unit for Floor/Roof:

These are precast R.C.C. units having two circular cores throughout its length (Fig. 6). The nominal width of the unit is kept as 30 cm and overall depth as 13 cm for normal situations. The minimum thickness of web and flange is kept 2 cm. The weight of such unit is ahout 46 kg/m and the units can easily be handled manually. If mechanical handling facilities are available, 60 and 90 cm wide units with multiple cores can be used. The unit is similar to channel unit in all its essential features except that it provides a flush ceiling. Apart from manual method of production, a mechanised method using 'pressure-cum-vibration' technique capable of producing, 35 to 40 units per day has been developed. These units have been adopted by various construction agencies in India like DDA, LIC, M.P. PWD and others. The scheme results in a saving of 25 percent in cement, nominally in steel and about 15 percent in overall cost campared to traditional in-situ R.C.C. slab (6).

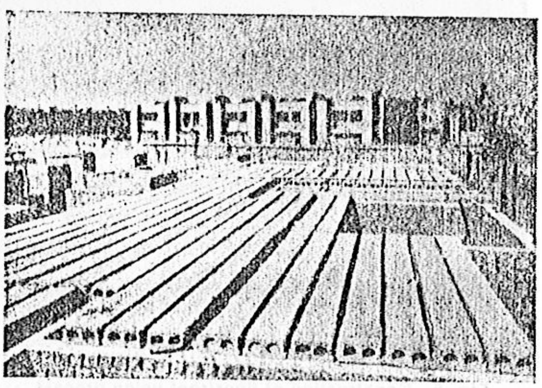

Fig. 6 Construction of floor/roof with precast cored units

(f) Waffle Unit Floor/Roof:

The waffle units (Fig. 7) are open box type precast units of nominal size 60 to 120 cm square and suitable for two-way slabs having span more than 6 metres. The depth of the units varies according to the span. The flange thickness of the units is 3.5 and 4.0 cm for 90 and 120 cm size units respectively. 30 cm or more deep units are provided with hard drawn steel wire fabric both in web and flange. In smaller units, the fabric is restricted to flange only. Precasting and assembly of the units are quite simple and described elsewhere (7). The units are placed on shuttering strip 20 cm wide placed at a spacing equal to the nominal size of the units. Reinforcement as per design is provided in the joint between adjacent units at right angles across the spans and in-situ concrete is laid upto the top level of the units properly compacted with needle vibrator. The shear keys provided at the sides of the waffle units ensure monolithic behaviour between the units, once in-situ concrete in the rib has attained strength. Provision of in-situ deck

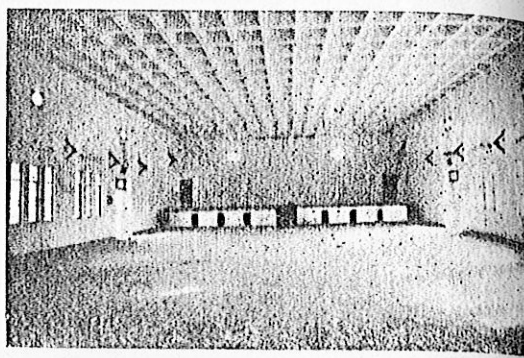

Fig. 7. Ceiling view of completed waffle unit roof

concrete over the troughs is thus eliminated resulting in substantial saving in cement and steel. This scheme results in a saving of 15 per cent in cement, 10 per cent in steel and 15 per cent in cost compared to traditional tee beam and slab construction. The scheme has gainfully been employed in a number of large roofs.

(g) L-pan Roofing:

Prefabricated L-pan roofing (8) mainly consists of full span R.C.C. L-shaped components which are structurally complete in themselves and do away with purlins, battens and sheets used for conventional sloping roof. Its smaller leg functions as rib of a L-beam and the wider leg (flange) as sheeting besides resisting the flexural compressive stress. These are cast upside down with M 150 concrete on a level platform in timber or steel moulds. The thickness of rib generally varies from 4 to 5 cm and that of flange is 3 cm. The panels are suitable for 2 to 4 metres span. The width of the units may vary from 30 to 60 cm. L-pan units are supported on parallel gable walls or trusses sloped 1:4 to 1:3 depending upon the climatic condition. The units are placed from lower end so that there is an overlap of 7 to 10 cm, the upper one overlapping the lower one. The L-pan sloping roof requires about 23 kg of cement and 4.8 to 5.0 kg of steel for one square metre of roof and is quick and easy to construct, light in weight, pleasing in aesthetic and more durable but comparable in cost to conventional G.I. sheet or A.C. sheet roofing. The scheme has found wide application in roofs of school and residential buildings at different parts of India and has been found 30 to 40 percentmore economic.

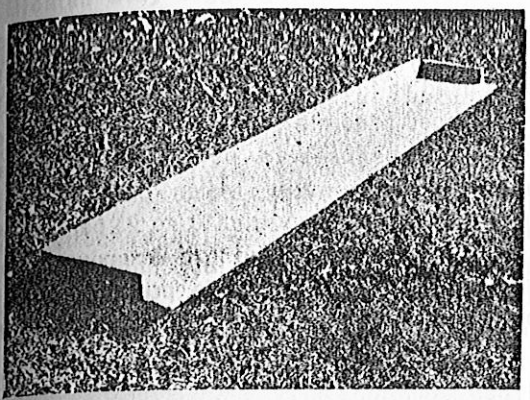

Fig. 8 L-pan unit

FIRED CLAY PRODUCTS

(a) Prefabricated Brick Panel Floor/Roof

This is a labour intensive prefabricated flooring/roofing system, wherein conventional reinforced brick concrete slab has been improvised by utilising the potentialities of moderately good quality brick (crushing strength 50 kg/cm^2 and above) and of prefabrication (9). The technique includes precas-

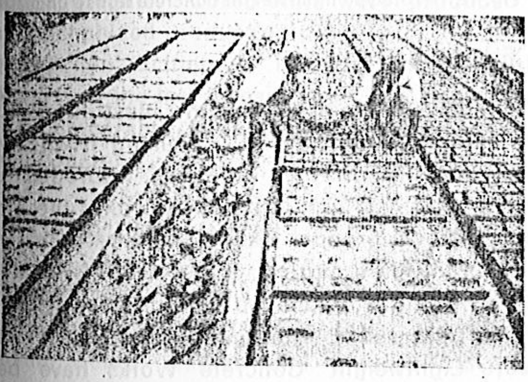

Fig. 9 Precasting of Brick panels

ting of reinforced brick panel (maximum size 56×120 cm, reinforced with 2 bars of 5 mm diameter) and partially precast R.C.C. joists designed for the particular span. The prefab brick panels (Fig. 9) are placed on the concrete joists after propping them at two intermediate points. The joints between the panels are filled with cement-sand mortar. In-situ deck concrete (1:2:4) with temperature and negative reinforcement for the precast joists is laid to 2.5 cm thickness all over the roof to form the flange of the tee-beam along with the joists and to provide monolithicity to the roof. The system has been adopted in a large scale for construction of houses for landless poor, refugees and economically weaker section of people effecting considerable saving in overall cost and material.

(b) Prefab Floor/roof using structural clay Products :

Two different forms of structural clay products have been designed for flooring/roofing schemes. One of the two forms is suitable for joist and in-fill scheme of construction, thereby leading to a light weight and labour intensive construction system. The shape of the unit is designed in such a manner that the same unit can be used as an element of joist and in-fill. The joist members are made by joining the fired clay unit with 1:3 (cement : sand) mortar and subsequently filling the side spaces with M 160 concrete after placing suitable reinforcement as per design (10). The joists when fully cured are placed over the support at 30 cm c'c and the same clay units placed in between the joists and finally the slab is completed by filling the gap with M 150 concrete. Negative reinforcement, if necessary, may be provided over the supports before concreting the gap (Fig. 10).

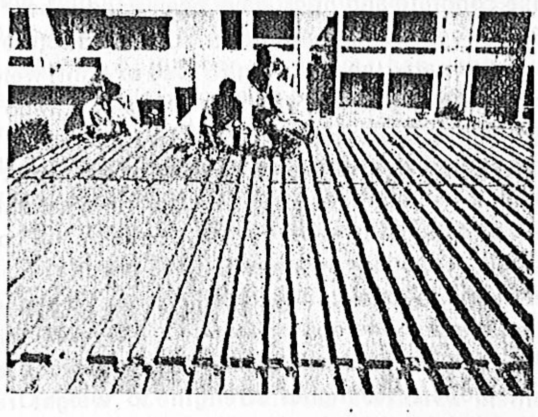

Fig. 10 Construction of roof (joist and infill type) using structural clay products

The shape of the other unit is such that floor/roof panels are built vertically with 1 : 3 mortar just like a brickwall with the required reinforcement placed in the grooves of the units at each bed joint level (Fig. 11). The panels are made 36 to 60 cm high for ease in handling and erection. The panels are placed over the support with the plumb face containing reinforcement towards the ceiling side. The long joints between adjacent panels are filled with mortar to make the slab complete (11).

A few prototype roofs with these two units have been laid and found to be performing satisfactorily. These floors are lighter by about 20 percent compared to 10 cm R.C.C. slab and save cement and steel by 40 to 60 and 20 to 25 per cent. For intermediate floors, the finishing coat is laid directly over the clay products and for roof, bitumen painting is done before laying the waterproof course.

LIGHTWEIGHT CONCRETE

Dead weight forms a large proportion of design load. In multistoreyed buildings, where conventional

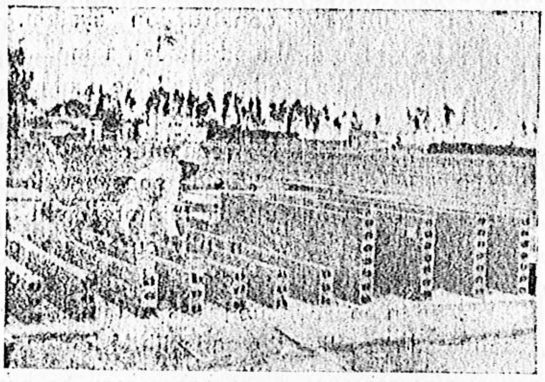

Fig. 11. Prefabrication of floor/roof panels using structural clay products

dense concrete and brick have been used, about 60 to 65 per cent of the strength of the structure is utilised to carry the self weight. Use of light weight concrete having higher strength to weight ratio in walls, floors, roofs and cladding of a building would reduce self weight by about 30 to 40 percent, thus leading to reduction in sizes of supporting members and foundation and also overall economy in cost. Besides reduction in weight, it has got the advantage of low thermal conductivity, greater resistance to fire, good sound absorption and easy nailability and sawability in some cases. The most important single property ie. higher strength to weight ratio implies reduction of dead load, faster building rate and lower haulage and handling cost. Consequently the material is highly suitable for prefabrication in building.

India has got very few naturally occuring rock deposits suitable for lightweight aggregate. At the same time, it has got large quantities of industrial wastes or natural clay which can be processed to produce light weight aggregate. The emphasis at Central Building Research Institute has, therefore, been on the development of lightweight aggregate from furnace cinder or celinder, foamed or expanded slag, sintered flyash aggregate and bloated clay aggregate.

(a) Cinder :

Cinder or clinker is a well burnt residue produced by high temperature boiler furnaces where lump coal is used as fuel. The aggregate is not suitable for reinforced concrete jobs. But, blocks made out of cinder can be used for both load bearing and non-load bearing walls. Indian clinkers contain high combustible material (10 to 25 percent) and when used in blocks lead to excessive volume changes. To reduce this, it is preferred that the blocks be steam cured at atmospheric pressure (12).

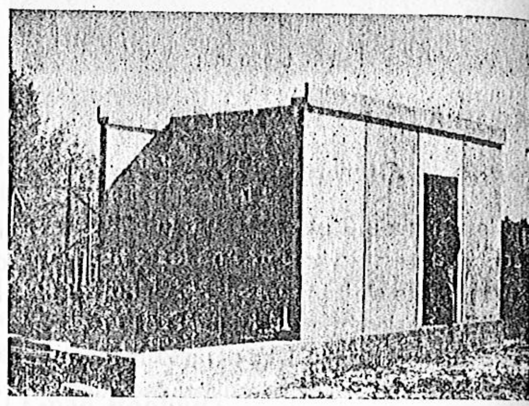

Fig. 12. Prototype light-weight concrete house under construction

(b) Foamed Slag :

The molten slag comes out of the blast furnace at a temperature of 1400-1600°C. Chilling it with controlled quantity of water produces hydrogen sulphide gas which gets entrapped within the mass and a porous product known as foamed slag is formed. Studies carried out at this Institute (13) has shown the suitability of Durgapur slag to be used as light-weight aggregate for making concrete. Mysore Lightweight Concrete Works have been using foamed slag obtained from Bhadrabati slag as aggregate in the production of prefabricated building components adopting some of the CBRI techniques eg. doubly curved tiles, cellular unit roofing, door and window frames, etc.

(c) Sintered Flyash Aggregate :

Flyash, a waste material from thermal power stations, consists of minute spherical particles. These spherical particles can be made to cohere by heattreatment at 1000-1200°C. Sintered flyash aggregate has been successfully produced from Indian flyash (14). The aggregate is quite suitable for use in both plain and reinforced concrete.

(d) Bloated Clay Aggregate :

Certain clays when heated to semi-plastic stage at a temperature of 1200-1300°C expand or bloat. There are certain gas producing minerals in these clays which produce gases within the mass at fusion temperature. The gases are entrapped in the mass and as a result, volume expansion takes place. The cellular structure so formed retains its shape on cooling and thus the product obtained is a light weight aggregate. Bloated clay aggregates from alluvial clays and Palta Water works silt (15) have been successfully bloated in a pilot rotary kiln of 20 tonnes capacity per day. The aggregate can be used both for plain and reinforced concrete.

Realising the structural potential of bloated clay aggregate, a prototype precast lightweight concrete house with three different walling schemes and two roofing schemes (16) was erected. The front walls were built with 120 cm wide storey high precast stave panels, the rear walls with large size panels 120 cm wide and ½ storey high and the cross walls made of 15 cm thick load bearing solid blocks (fig. 12). Precast cored and waffle units were used in the roof. All the units were of bloated clay lightweight aggregate. Cored units were produced by semi-mechanised production process of 'pressure-cum-vibration' technique. The performance of the building over the last 8 years or so has been found to be comparable to any other prefab house of dense concrete.

CELLULAR CONCRETE

At present cellular concrete is being produced at the Hindustan Prefab Ltd., New Delhi, Tamil Nadu Housing Board, Madras and Siporex India Ltd., Poona under various trade names. The material is based on cement and ground sand and used as cladding blocks, panels and reinforced floor/roof panels. Lightness is achieved by incorporating a large proportion of closed macroscopic pores in the slurry with the help of air-entraining or foaming agent. It has been estimated that the use of lime flyash in place of cement and sand would bring down the cost of cellular concrete by about 15 per cent. After laboratory study at the Institute, full scale trials with lime-flyash cellulor concrete were carried out at Hindustan Prefab Ltd., New Delhi (17). The slurry consisting of lime, flyash, gypsum and aluminium powder in predetermined proportions was poured in beam moulds upto two-thirds of their depth. After a few minutes, the slurry started rising, filled up the moulds and hardened in 5 to 6 hours time. The material was demoulded and cut into blocks of size 50×25×10cm thick. After 24 hours of air curing, the blocks were autoclaved at a pressure of about 10.5 kg/cm^2 for 8 hours. The blocks met all the requirements laid down in IS Code (IS 5482-1969). The lime-flyash cellular concrete has also been tried for precast reinforced flooring units and found to be suitable (18). However, on account of porous matrix of the material, reinforcement is prone to corrosion even under normal exposure condition and therefore requires protection. A rubber latex cement coating (19) from indigenously available raw materials has been developed at the Institute and is recommended as a protective coating to reinforcement.

Conclusions

'Housing the Millions' is a gigantic problem and requires the most serious attentions of all concerned. Conscious efforts to solve the problem of housing are continuously bringing forth innovations from different individuals and organisations. Some of the important work carried out at this Institute in this direction has been described very briefly in this paper. A number of them has got quite extensive application in the field leading to substantial economy in cost and consumption of materials like cement and steel. Still, the effort made so far is very modest considering the alarming proportion of the problem and much more remains to be done.

Acknowledgement

The paper is presented with the kind permission of the Director, Central Building Research Institute, Roorkee, India. The author gratefully acknowledges the Scientists of the Institute whose studies have been included in this paper.

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