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Research as an Aid to Economy and Efficiency in Buildings*

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The Central Building Research Institute is the premier national research laboratory working on almost all aspects of buildings. During the last three decades, it has worked on a number of problems of the building industry. A few of the achievements regarding foundations, walls, roofs, building systems and materials are highlighted here.

INTRODUCTION

Research on basic sciences started in India almost at the beginning of this century. Since then significant contributions of international repute have been made. Research in engineering and technology started only after independence with the establishment of a chain of national laboratories by the Council of Scientific and Industrial Research (CSIR) and five Institutes of Technology in different regions of the country. During the last three decades the tempo of research has gradually picked up and now there are a substantial number of engineers with post-graduate qualifications and with a good record of published research papers. The Central Building Research Institute (CBRI), established in 1951 at Roorkee, is the premier national research laboratory working on almost all aspects of buildings. It celebrated its silver jubilee in 1972, which was attended by Directors of Building Research from a number of countries. During the past 29 years of its existence, it has worked on a number of problems of the building industry, and in this lecture, a few of the more important achievements of the Institute are highlighted. The achievements have served as an aid to economy and efficiency in buildings.

FOUNDATIONS

Of the various improved foundation techniques, the under-reamed pile foundation, developed by CBRI in the late fifties and its subsequent developments in the form of multi-under-reamed piles[1] and bored compaction piles[2] are well known. These have been extensively used in India and on a limited scale abroad (Figs 1 and 2). Although single bulb piles were originally recommended for black cotton soils, these have subsequently been developed into multi-under-reamed piles and compaction piles which make them economical for all types of buildings and other structures in poor soils. In order to simplify these further and make them even more economical for single storey low-cost housing in semi-urban and rural areas, pedestal piles have recently been developed. The technique consists of making a borehole of 30 cm diameter and 3 m deep and filling it up with concrete to a height of 30 cm from the bottom. A 10-cm² precast concrete pile is next lowered while the concrete of the borehole is still green. The pile toe is pushed through the concrete and made to rest on the soil below. The hole is then backfilled with soil after carefully tamping it around the pile. Load tests carried out in normal soils show that the safe load in compression is 3.5 t and uplift 1.75 t. These are adequate for single-storey housing.

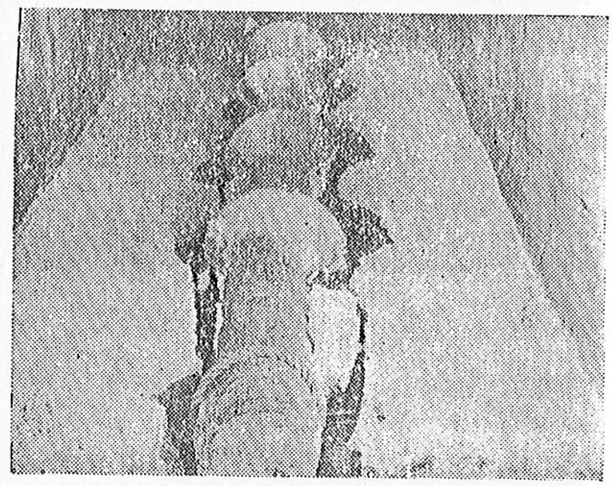

Fig 1 Multi-under-reamed pile

A cost analysis show is that there is a saving of approximately 40 % compared to the cost of a aminimum size (15 cm diameter) normal under-reamed pile.

WALLS

STONE MASONRY BLOCK WALLS

In some parts of the country, building stones are abundantly available and random rubble masonry with wall thickness of 30 to 38 cm is commonly used. This, apart from being massive, requires more labour and materials and is time consuming. To overcome this, a technique of producing precast stone masonry blocks (30 cm × 20 cm × 15 cm) has been developed[3]. In this technique, stones upto 15 cm in diameter are loose packed in a steel mould with larger pieces at the bottom,

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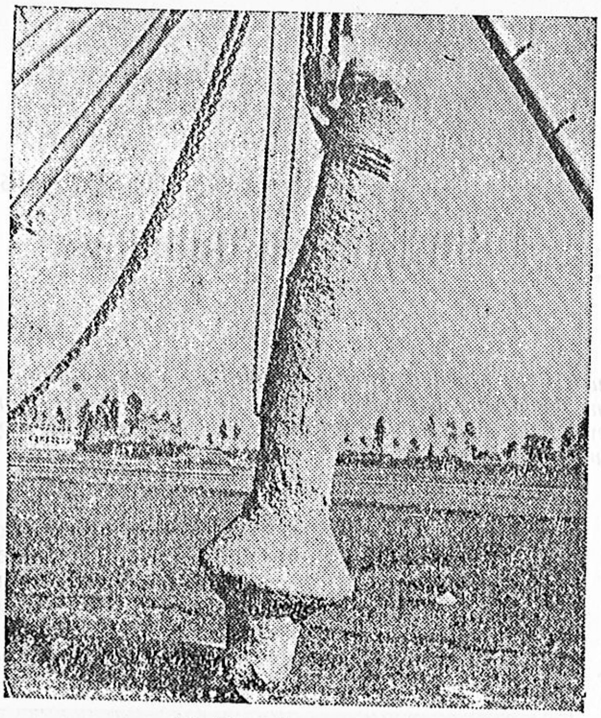

Fig 2 Bored compaction pile

and cement concrete of 1:5:8 mix is poured in and vibrated. Even poor quality stones such as laterites can be used. The blocks weigh about 18 kg each and have one face with stone texture. They can be easily produced at the site with semi-skilled labour and the only equipment needed is a pan vibrator. An average compressive strength of 75 kg/cm^2 has been attained which makes them suitable for load-bearing walls upto four storey construction (Figs 3 and 4).

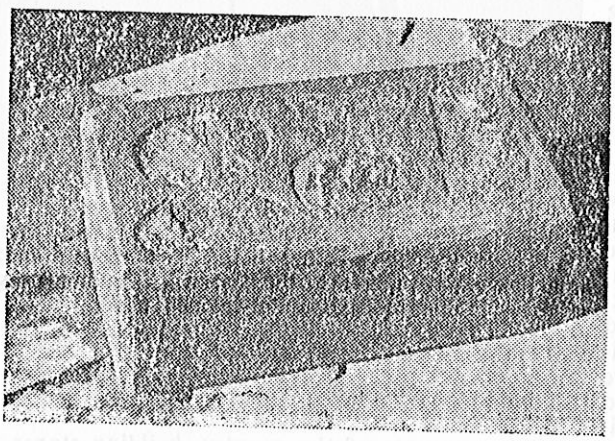

Fig 3 Composite stone block

The main advantages of the stone block masonry construction are that (i) casting of blocks can be done by a semi-skilled worker and higher productivity in walling is achieved because of their larger size, (ii) wall thickness is also reduced (from 30 cm to 20 cm) thereby saving in material and leading to larger usable floor area, (iii) the internal plaster can be eliminated with proper care during production and laying, and (iv) if plastering is to be done, only 1 cm thickness is required

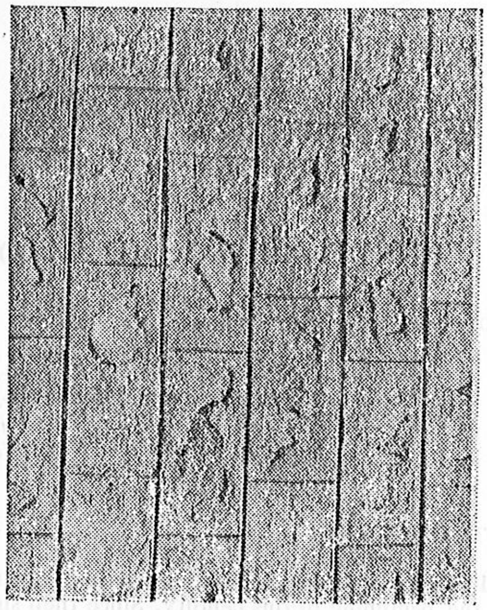

Fig 4 Stone block masonry

against 2.5 to 3 cm thickness in conventional stone masonry.

The technique has been successfully adopted in Rajasthan, Andhra Pradesh and hilly regions of UP and economy to the extent of 15% has been reported. Recently it has been successfully used in 5000 houses built for cyclone victims in coastal areas of Andhra Pradesh.

ROOF

A roof takes maximum time and is the most expensive component of a building. Several techniques have been developed to cut down on both time and cost and also effect a saving in scarce materials like cement and steel. These are prefabricated roofing schemes with channel units, L-pan units, solid planks, doubly-curved tiles, etc.

Channel Units[4]

These are reinforced concrete trough type units 30 to 60 cm wide and 15 cm deep and are suitable for spans of 2.5-4.5 m. Casting is done manually on a concrete platform and the units are removed for curing after 24 hr. The joints are filled with concrete after placing reinforcements for negative moments (Figs 5 and 6). This results in a saving of 40% cement and an overall saving of 15% against cast-in-situ 11 cm thick RC slab. These have been successfully adopted in about 2 500 primary schools in rural areas of Uttar Pradesh.

L-pan Unit[5]

These consist of full span precast concrete L-shaped units. In this case, the shorter legs form the purlins or battens normally used for a conventional sloping roof, and longer legs as a tile or part of the sheet. The units rest on gable walls or trusses. The flanges (longer legs) of the unit rest on the ribs of adjacent lower panels with an overlap as in the case of tiles. A special channel unit may be provided at the eave in case of a verandah or where wide facia is desired from aesthetics. The roof costs nearly the same as asbestos cement

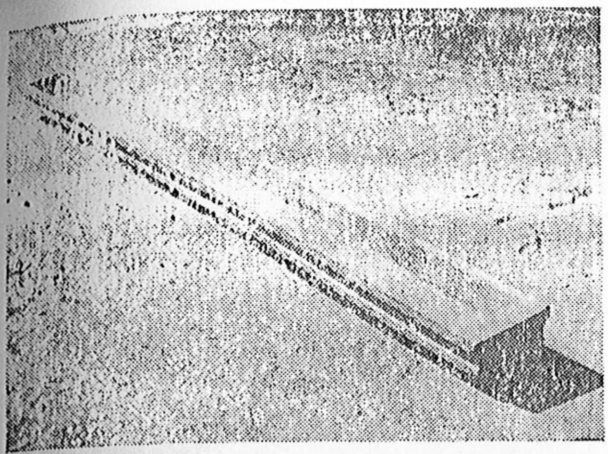

Fig 5 Channel unit

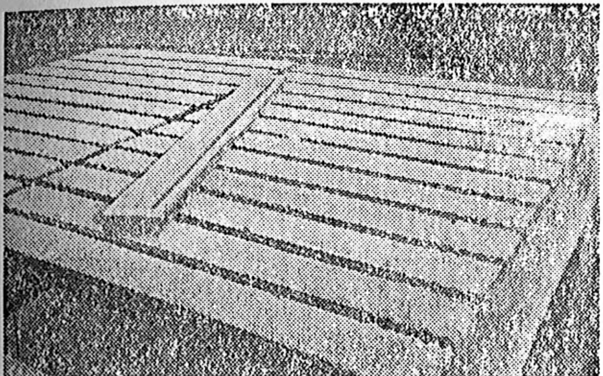

Fig 6 Channel unit laid for roofing

sheets and is more durable (Figs 7 and 8). It is also reusable to suit temporary constructions. About 10 000 residential units have been constructed by the Maharashtra Housing Board at Poyser and Ghatkopar in Bombay.

Solid Planks[6]

These are precast 40 × 120 cm concrete slabs. The thickness varies from 6 cm near the centre to 3.5 cm at the end. They are supported by partially precast concrete joists 120 cm apart and concrete is poured into the haunches to come upto the level of the centre. The final thickness of the roof is, therefore, 6 cm all along. These units give an economy of 35% in cement and 15%

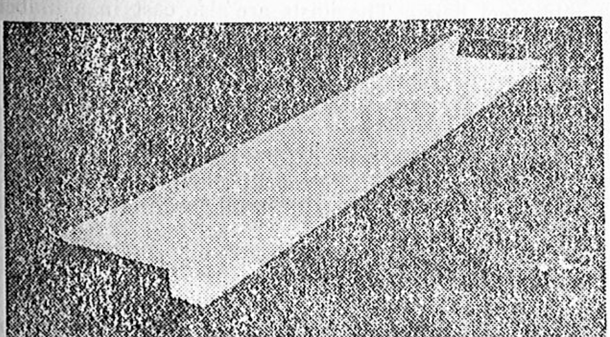

Fig 7 L-pan unit

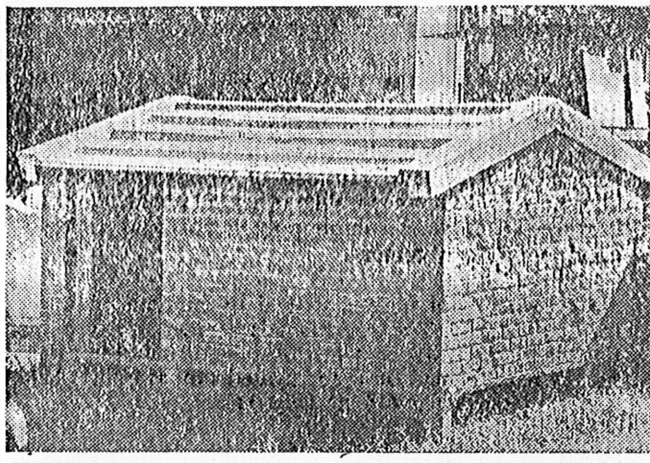

Fig 8 L-pan unit roof

in steel and an overall economy of 25% when compared to a normal 9 cm cast-in-situ RC slab (Figs 9 and 10).

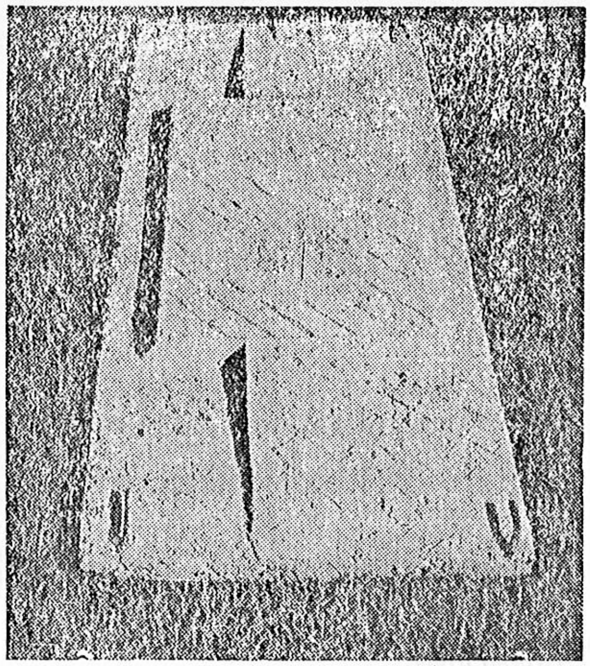

Fig 9 Precast solid plank unit

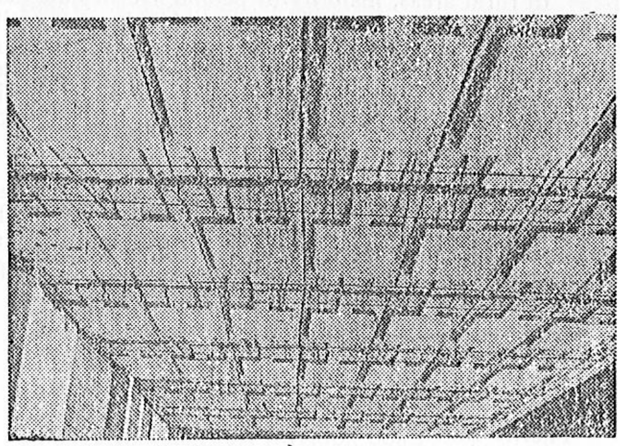

Fig10 Precast solid plank unit in position for roofing

Corrugated Woodwool/Coir Roofing Sheets[7]

Woodwool is largely used as a packing material and is obtained mostly from soft woods such as fir, chir and deodar. Use of hard woods require judicious selection as many of them hinder the setting and strength development of cement. Instead of woodwool, coconut fibre may be used since unlike other cellulosic materials it is free from water soluble polyphenols and makes a good bond with cement.

Coir/woodwool fibre is soaked in mineralised water for about 2 hr. The free water is drained off and the fibre is mixed with cement. A mat of suitable thickness is next formed on a corrugated mould and is held under pressure for 6-8 hr (Fig 11).

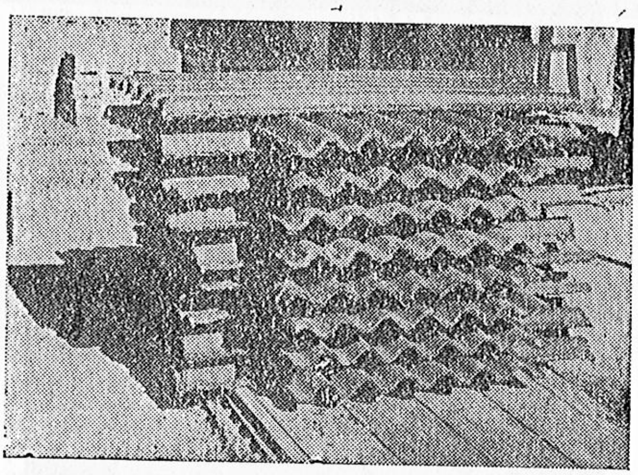

Fig 11 Corrugated woodwool roofing sheets

The sheets require 30 % less cement when compared to asbestos cement sheet. They are tough and can be carried over rough roads without any breakage. The sheets possess good thermal insulation properties and their preparation does not require either expensive machinery or high capital investment. They cost roughly half the cost of a sbestos cement sheets and are fire-resistant.

Thatch Roof

In rural areas, majority of people live in huts made of mud and thatch. The latter is highly combustible and easily ignitable. To confer a measure of fire protection and to reduce fire hazard, the Institute has developed a cheap and effective treatment which consists of plastering both sides of the thatch with 2 % bitumen stabilized mud[8].

Fire retardant and water-repellent thatches made in the above manner mitigate the risk of fire and can last from 6 to 8 years (Fig 12). This was proved in a village where houses which were given such a treatment escaped while other were destroyed in a fire.

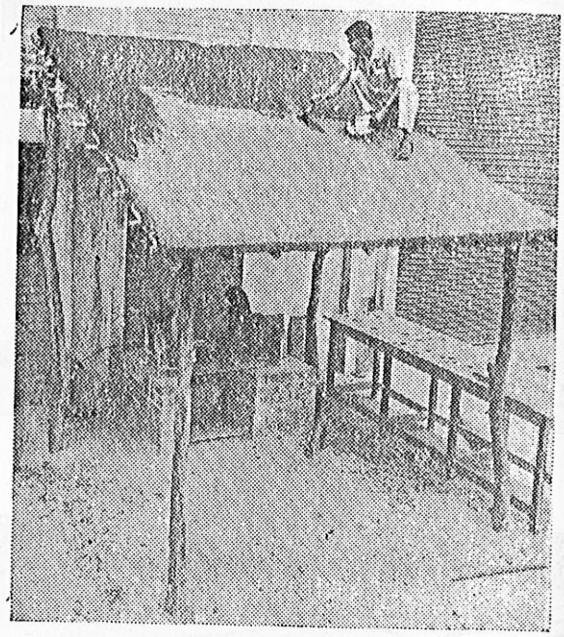

Fig 12 Application of fire proof mud plaster on thatch roof

BUILDING SYSTEMS

Prefab Brick Panel Systems[9]

In this a 7.5-cm thick, (flat) brick panel 1.5 × 0.5 m in size is cast. It is supported over partially precast concrete joists spaced at 125 cm centres. A 5-cm thick concrete screen is finally laid on the top (Fig 13).

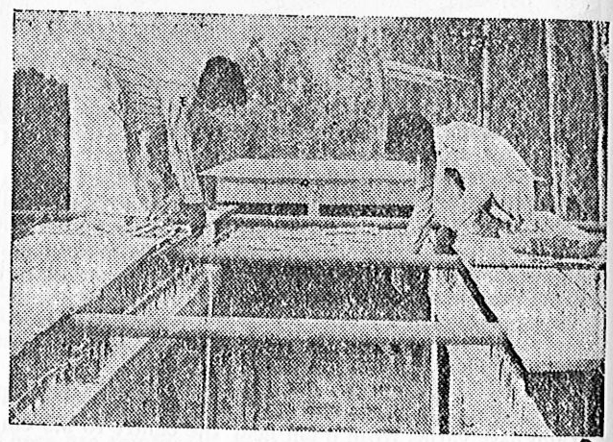

Fig 13 Prefab brick panels being laid for roofing

The panels are cast by arranging bricks flat on a level ground in a wooden mould and filling the joints with 1:4 cement mortar after placing two 6 mm diameter mild steel bars. The joists are also cast in a timber mould with the stirrups exposed. The use of the system effects a saving of about 30 % in bricks, 35 % in cement and 40 % in steel compared to a building with a conventional RB roof.

The system has been used for construction of 1 550 EWS houses by the Ghaziabad Development Authority, and 50 houses by UP Rural Engineering Services at Hastinapur.

Concrete Skeleton System[10]

This system comprises five types of precast components, *viz*, pocket footings, hollow columns, small beams, joists and unreinforced doubly curved tiles (Fig 14). The components can be cast at the site itself or at an urban centre. They are designed for manual handling during the erection and placement. After the skeleton is erected and the roof is laid, cladding walls and doors and windows of locally available materials may be put up. This system, apart from being durable, offers flexibility and is labour intensive.

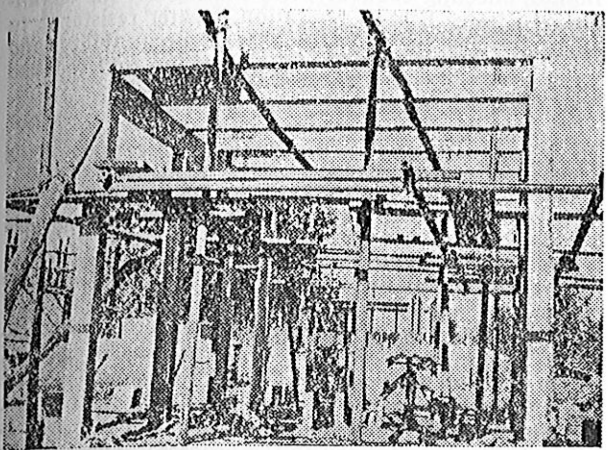

Fig 14 Concrete skeleton system

PORTABLE TIMBER HUT[11]

There is a need to provide shelter of reasonable durability and living comfort, in a short time and in some regions which are not easily accessible. To meet the situation, the Institute has worked out a portable timber hut. The hut is made of collapsible wooden trusses made of uniform timber sections 5 × 10 cm and 2.5 m long. They have a span of 6.4 m. The trusses are provided at 2.41 m centres and are held together by purlins. For the roof, one can use GI sheets, AC sheets, thatch, tiles, etc, and for the wall, bamboo mat and plaster, reeds and plaster. These huts have been extensively used by the Border Roads Organization and recently a tourist hut has been put up at Gaurikund on the way to Kedarnath (Figs 15 and 16).

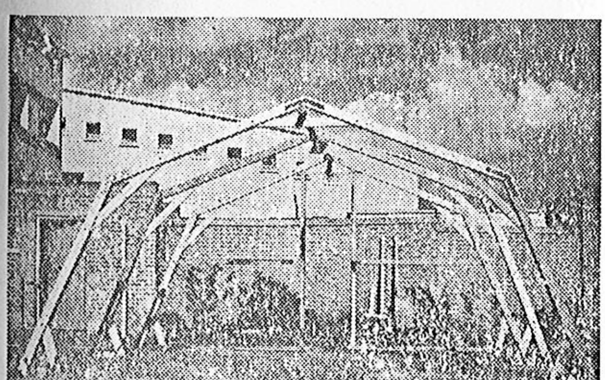

Fig 15 Portable timber hut (skeleton)

NO CEMENT, NO STEEL (*Sarvatogriha*) TECHNOLOGY[1]g

Attempts have also been made to develop buildin[2] technologies which greatly reduce or eliminate the use of cement and steel. *Sarvatogriha* is one such attempt. Its method of construction is similar to that of shell but without shuttering. The bricks are placed in a manner such that bending stresses are very small and the load is transmitted primarily by direct stresses (Figs17and18).

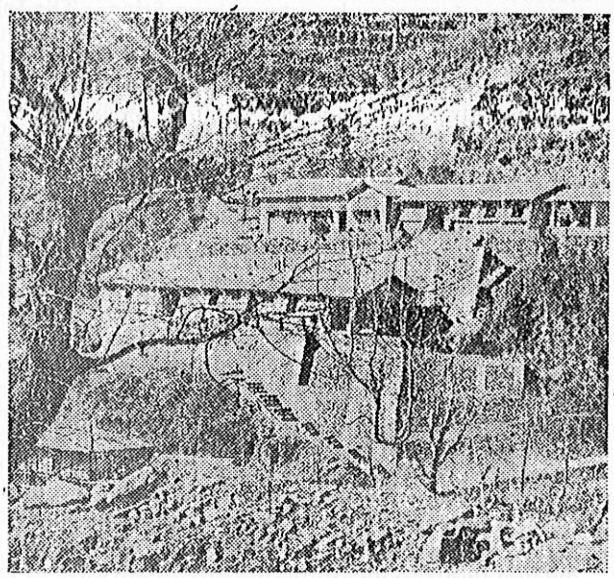

Fig 16 Portable timber (Tourist hut) at Gaurikund, on way to Kedarnath

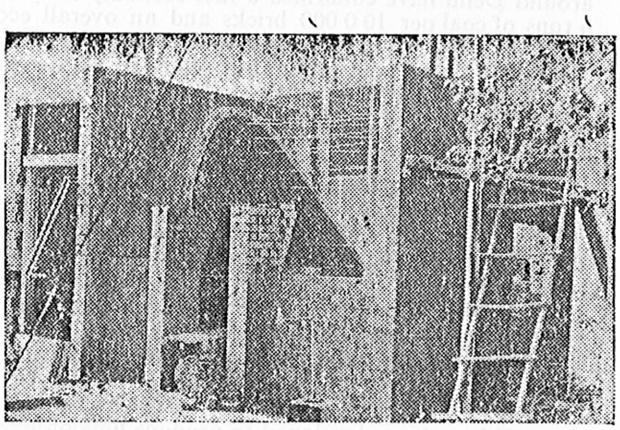

Fig 17 No cement, no steel (Sarvatogriha) house under construction

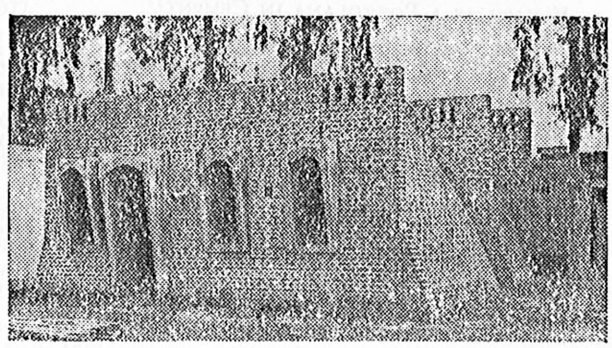

Fig 18 No cement, no steel house (Sarvatogriha)

BUILDING MATERIALS

QUALITY BRICKS FROM INFERIOR SOILS

One major problem with the brick industry is the non-availability of suitable soil for brick making in many regions of the country. For example, bricks moulded from black cotton soils develop cracks during drying and have very low strength on firing. The Institute has found a solution to this problem where about 30% 'grog' (partially calcined black soil) is added as an opening material. This reduces the plasticity of the soil and prevents the bricks from cracking. It also improves the strength of the bricks[13]. Brick kilns using this technique are successfully operating at Indore and Bhopal and a number of private parties have adopted the process. Likewise, the Institute has developed processes for manufacturing bricks of improved quality from inferior soils such as *kalar* or *usar* soils, red soils, coastal aluvium, etc.

Clay Bonded Flyash Bricks[14]

Another recent development of interest to the brick industry is the clay-bonded flyash brick. In this process, 40-60% of flyash is mixed with clay depending upon its plasticity and the resultant mix is moulded into bricks, which are dried and fired in the usual manner. The main advantages are (i) better burnt products with an economy in fuel consumption since flyash generally contains about 5-6% of unburnt carbon, (ii) reduction in losses due to drying and firing, (iii) increase in the proportion of first class bricks, and (iv) economy in clay. Large scale trials conducted in brick kilns around Delhi have confirmed a fuel economy of about 4 tons of coal per 10 0 000 bricks and an overall economy of about 10%. More than 2 000 000 clay-flyash bricks have been made at Obra by the UP State Electricity Board.

Building Lime

Due to the impact of rapid industrialization of the country, high calcium limestone deposits are getting depleted and the remaining ones are being reserved for the use of paper, sugar and other industries. The building lime industry has, therefore, to fall back on the use of lower calcium stones. Lime obtained from some of these sources is characterized by the presence of higher quantities of magnesia which does not easily hydrate when brought in contact with water. An improved method of burning[15] and a semi-mechanized lime hydrator[16] have been developed to produce lime of acceptable quality.

Flyash as a Pozzolana in Cement[17]

The increased demand for cement prompted the Institute to investigate the possibilities of increasing its productivity by pozzolanic substitution or by use of substitute raw materials. These have shown that flyash produced as an industrial waste from thermal power stations can replace upto 20 % cement by weight (Table 1).

Flyash cement can be produced either at the cement works by grinding together cement clinker, flyash and the requisite quantity of gypsum, or at the site by mixing flyash directly with ordinary portland cement in the concrete mixer. It can be used in all types of in-situ and precast concrete works, in reinforced concrete construction, in mass concrete and in marine structures. Besides effecting economy, this cement has the advantages of lesser heat of hydration, greater resistance to attack of aggressive waters, lesser permeability and leaching, lesser bleeding and segregation and reduced alkali aggregate reaction.

Hydraulic Binder from Waste Lime and Rice Husk[18]

The binder is composed essentially of lime and rice husk which has very high silica in amorphous form. Its setting and hardening behaviours are similar to those of hydraulic cements, by virtue of which it can be used in masonry mortars, plasters, foundation concrete and soil stabilization. The binder is prepared by firing cakes made after burning lime and rice husk together. Apart from acting as an integral fuel for burning the calcium carbonate of the lime sludge, rice husk also provides silica to the lime formed in the process. This process controls the lime-silica ratio as well as the temperature of firing as a result of which the variations in the quality of the product are narrowed down considerably. Since the temperature of firing of the binder is in the same range in which lime is generally produced (900-960 °C), there is little danger of the product getting overburnt or becoming unsound even if magnesium lime is used (Figs 19 and 20).

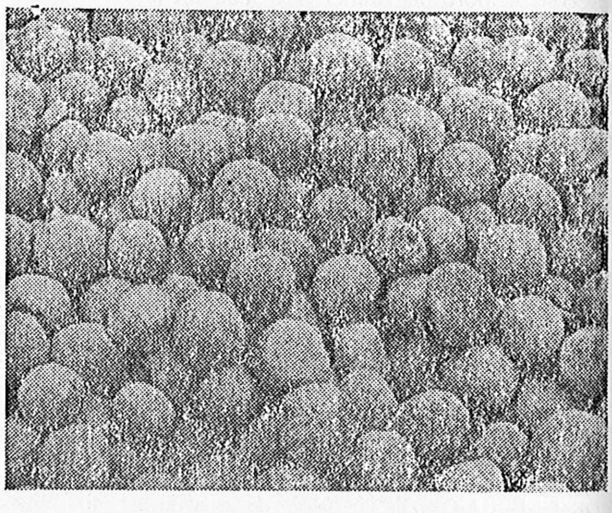

Fig 19 Rice husk and lime sludge balls

TABLE 1 MIX PROPORTIONS OF SOME STRUCTURAL CONCRETE MIXES WITH FLYASH

Grade of Concrete	Quantities of Materials (kg) for 1 m³ of Concrete				
	Cement	Fly Ash	Sand	Coarse Aggregate	Water
M 150	247.2	85.0	680.0	1190.0	168.0
M 200	312.5	108.3	515.5	1202.0	194.6
M 250	433.0	148.8	314.0	1200.0	214.0

Note : For calculating the nominal mix proportions by volume, determine the loose bulk density of flyash, sand and coarse aggregate at site and then divide the batch mix by loose bulk density to find the mixp roportion by volume The bulk density of cement may be taken as 1 442 kg/m³ (90 lb/ft³)

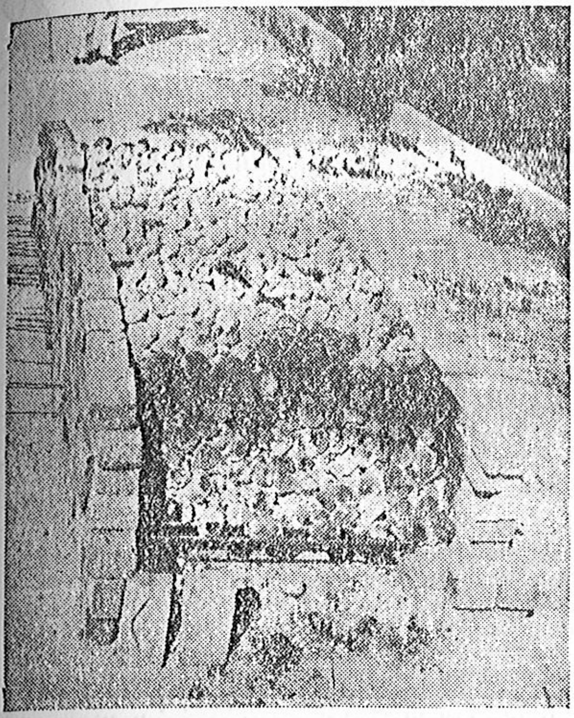

Fig 20 Firing lime sludge and rice husk balls

Functional Efficiency in Buildings

Various problems of functional efficiency in relation to thermal, acoustic, illumination and ventilation aspects of buildings have been investigated and the findings have been made available to architects and engineers in the form of convenient ready-to-use charts and tables[19]. For example, laboratory and field investigations on transmission of heat through building materials and components have resulted in helping to evaluate the thermal performance of buildings and adoption of suitable measures to improve the performance. In the tropics, when the sky is clear, suitable guidelines for the design of windows to take maximum advantage of daylight have led to better illumination in residential, office and school buildings with lesser cost. Similarly, guidelines for better ventilation and acoustic performance of buildings have been provided. Simple roof spray method of cooling of buildings has been developed (Fig 21)[20]. Besides housing, suitable designs have also been developed for improving the functional efficiency of educational, health, office and factory buildings, some of which have been extended to other countries also.

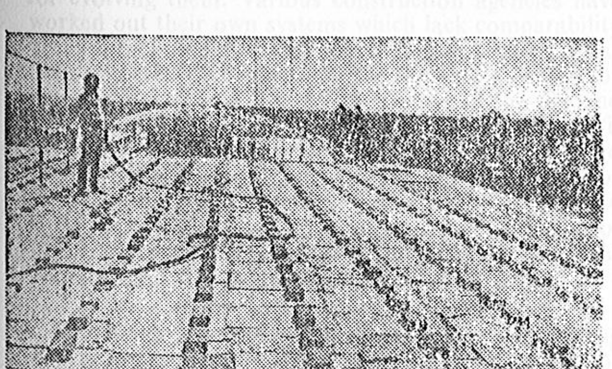

Fig 21 Roof spray method of cooling of buildings

CONCLUDING REMARKS

In this short lecture an attempt has been made to make brief mention of some CBRI research findings which have led to savings in cost and have added to the efficiency of buildings. Full details could not obviously be given but most of these findings have been published by the CBRI in the form of Building Digests, Building Material Notes, Data Sheets, Technical Notes and Project Proposals. Actual users can be given further assistance in the form of consultancy and the Institute can even take up new research projects to solve specific problems of the building industry. Actual demonstration of the construction techniques can also be arranged by our Extension and Experimental Construction Division and by the five Extension Cells functioning at Delhi, Ahmedabad, Calcutta, Bhopal and Hyderabad.

It is finally hoped that this talk today will make research work better known to all fellow members. Needless to say CBRI will give all help in extending its findings to industry and the profession.

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