Reprinted from the *Journal* of the Institution of Engineers (India) vol 55 CI 2 November 1974

UDC 624.025

A Joist and Filler Block Type Floor/Roof Using Structural Clay Unit

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A joist and filler block type floor/roof construction using hollow structural clay units has been developed at the Central Building Research Institute, Roorkee. Only one type of unit is used as an element of the joist member as well as the filler unit, and deck concrete is provided over them. The clay unit is produced by extrusion and firing in a down-draught kiln. It has compressive strength of the order of 400 kg/cm² on net area. As concrete is used in topping, the concrete strength is taken into design consideration. The design for this type of floor is done on the same principles as for reinforced concrete construction. Test results of two prototype slabs of 4 m and 3.5 m spans are given. Provision of cantilevers various fittings and fixtures which are generally needed in the floor, have also been discussed. Such type of slab is found to offer an economy of 45% in cement and an economy of 10% in the overall cost when compared to conventional RCC slab.

INTRODUCTION

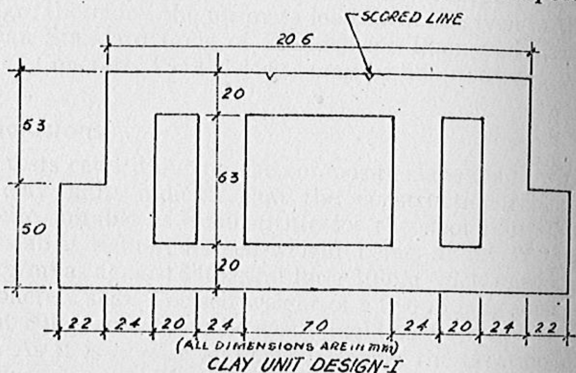
Hollow clay blocks have been used extensively as structural members for floor/roof construction in Italy, France, Holland and other developed countries. In India, floors with clay blocks have been constructed to a limited extent and these blocks have been used mainly as filler blocks to replace concrete in the tensile zone. When clay blocks are produced on an extrusion machine and fired in a down-draught kiln, these are found to have a high compressive strength. At the Central Building Research Institute, Roorkee, a hollow clay block has been designed and developed that can advantageously be used for construction of floor/roof.

CLAY UNIT

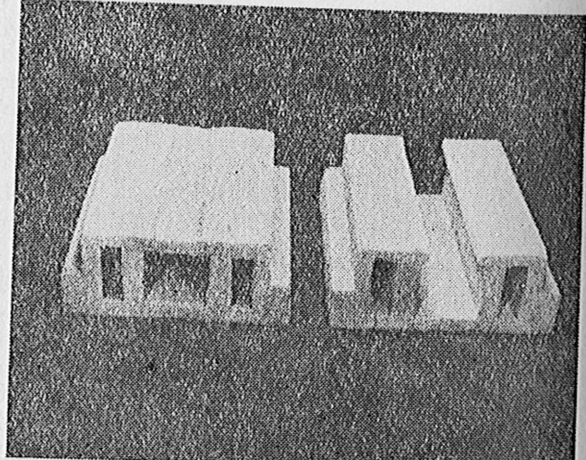
The structural clay unit is extruded from a brick making machine with the wider base on the cutting table. At the time of extrusion, two scored lines are marked on the top flange of the unit just over the central hollow. The extruded product is dried and fired in a down-draught kiln at a temperature range of 1 020° to 1 030°C. The overall fired dimensions of the unit are 25.0×27.0×10.3 cm deep and there are three rectangular hollows in it [Fig 1(i)]. The design of the unit is such that the same unit is used as an element for the joist member and also as a filler block. When the unit is used for the joist member, the panel between the scored lines is knocked off with a mason's hammer [Fig 1(ii)]. This makes space for placing the reinforcement and concreting inside the central hollow.

CONSTRUCTION METHOD

The floor/roof assembly is a joist and filler block type of construction with *cast-in-situ* deck concrete over it. To prefabricate the joist member, the units whose top panels are knocked off are placed in a row one after another with 1.0 cm thick 1:3 (cement:sand) mortar joint on a precasting platform to the desired length. A slight camber in the precasting floor is provided to allow for the camber in the joist member. The reinforcement as per design is provided with a cover of 1.0 cm in the space obtained by knocking off the portion



(i)



(ii)
Joist and filler element

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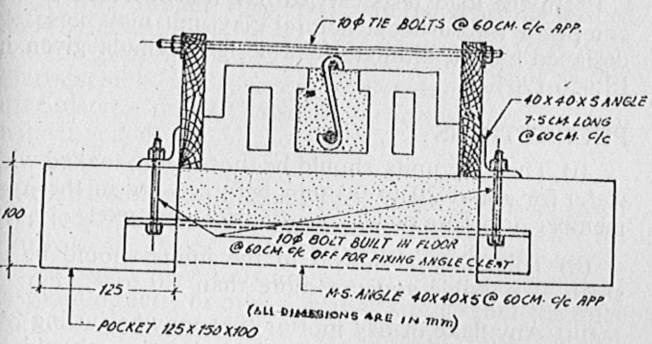
This paper was received on July 19, 1973. Written discussion on this paper will be received until January 31, 1975.



(iii)

Fig 1

between the scored lines and the space is then filled with concrete of the desired strength. The top surface of concrete is kept rough for better bond with *in-situ* deck concrete. It is cured with wet gunny bags a day after laying the concrete in the joist member. For clearing the precasting floor, the joist member may be shifted to stacking area 72 hr after casting where it is water cured for another 4 days and then air cured for 14 days.

After the curing period of 21 days is over, the joist members may be used for floor/roof. These are placed over the beam or wall supports as the case may be at a spacing of 46 cm centre-to-centre. The joist members are temporarily propped at a distance of about 2 m on centres. For proper levelling, a 1:3 cement-sand mortar pad of 1 to 2 cm thickness may be laid over the supporting element specially over wall support well in advance. In the intervning space between the joist members the same clay units are placed upside down, and joints filled with 1:3 cement-sand mortar. It is preferable to stagger the joints of the elements of joist member and filler units.

Over the joist and filler block assembly, the distribution reinforcement of 6 mm dia is placed at 46 cm centre-to-centre both ways for the *in-situ* deck concrete. The reinforcement thus laid is held by 6 mm dia stirrups projecting from the joist members. *In-situ* deck concrete of the desired strength and thickness is then poured over the entire slab and is cured in the normal way. In case of continuous slab, the joist and filler assemblies are built in adjacent spans and necessary reinforcement for support moment are provided in the *in-situ* deck concrete.

DESIGN PROCEDURE

The stress-strain characteristics of the clay unit assembly has been assumed to be the same as that of concrete. Since the top layer of the compression zone consists of concrete, the strength of concrete has been taken in design and the same formulae as those used in design of RCC (both working load method and ultimate load method) have been used for the design of clay unit floor/roof assembly.

In the design of precast flooring/roofing schemes using structural clay units, two different stages of loading and end conditions are considered. In the first stage, when the *in-situ* deck concrete has not attained strength, the joist member is simply supported and it carries its own weight, the dead load of the filler blocks and deck concrete and also part of the live load, *ie*, incidental construction load which is likely to be imposed on the joist. Without deck concrete acting monolithically with the joist and filler units, the joists act independently and hence the joist member must be propped temporarily at an interval of 2 m or so.

In the second stage of loading, when the *in-situ* deck concrete has attained full strength, the floor/roof assembly should be able to resist the simply supported bending moment due to the dead load as mentioned above and the positive moment at mid-span and negative moment over support due to subsequent superimposed dead load of wearing or water proofing course as well as full live load.

While calculating the shear resistance of the completed floor/roof assembly, the effective width may be taken as the width of the in-fill concrete plus four adjacent rib widths and the effective depth is to be calculated from the top of deck concrete.

TESTS

For determining the crushing strength of the clay unit, the end faces of the units were plastered with a thin layer of plaster of paris to make them truly level and perpendicular to the vertical face of the unit.

The test results are given in Table 1. The crushing strength of the clay units were found to vary within ±25% of the mean strength. However, it was found that the minimum crushing strength of the well-burnt units was of the order of 400 kg/cm² on the net area.

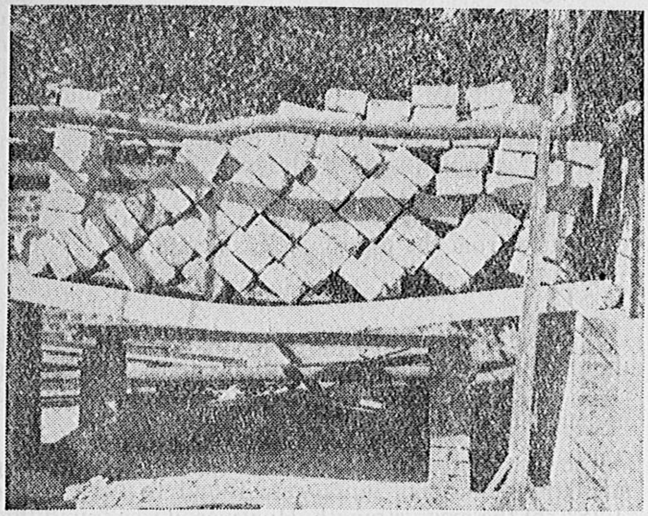
TABLE 1 TEST RESULTS FOR CRUSHING STRENGTH

Description	No of Specimens	Load at Failure, t	Crushing Sstrength on Net Area, kg/cm²	Averag-Crusheing Srength,-kg/cm²
Well burnt clay units	1	79.25	485	
	2	83.32	510	
	3	84.53	518	
	4	71.12	436	463
	5	75.18	460	
	6	67.06	410	
	7	69.08	422	
Underburnt clay units	1	33.53	205	
	2	45.72	280	231
	3	35.49	218	

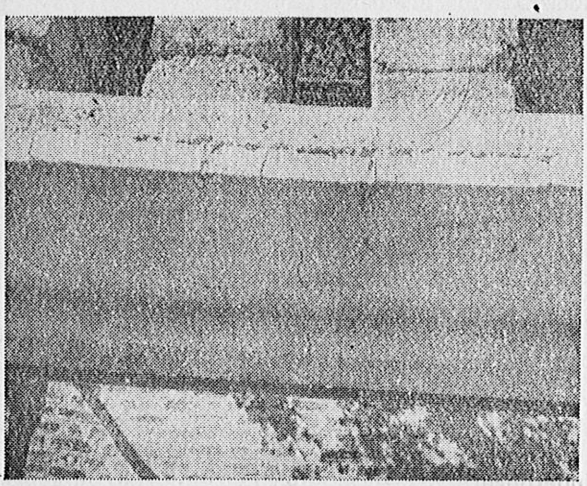
Two test slabs of 4 m span and 0.76 m width and 3.5 m and span and 1.2 m width were made, with one 16 mm dia deformed bar placed in each joist member. The test results are given in Table 2. Concrete cubes were taken on the day of *in-situ* deck concreting and their crushing strengths determined on the day of slab testing. The yield stress of the deformed bars was also determined. The test slabs were found to carry higher load than that calculated by Whitney's ultimate load design formula. The deflections of the slab under the loads were found to be within admissible limit. In both the tests, the failure patterns were tensile and no sign of distress from shear was noticed. The tensile cracks were mostly limited to the mortar joints between the units except in two or three cases where the cracks were in the unit also.

A load West was also made on a slab continuous over two spans each 3.65 m and 0.71 m wide. The continuous slab under test carried the calculated ultimate load without much of distress after which the test was abondoned because of some difficulties in loading the slab.

Figs 2(i) and 2(ii) show respectively the load test on test slab 2 and the crack pattern at the bottom of slab at about 80% of the total failure load.



(i)
A test slab after failure



(ii)
Crack pattern
Fig 2

From the load tests carried out, it is observed that a composite slab using structural clay unit may be safely designed by the ultimate load-design formula given in IS:456-1964.

PRECAUTIONS

(i) The clay units should be thoroughly soaked with water for about 20 to 30 min before using in the joist member or before placing *in-situ* deck concrete.

(ii) Thickness of mortar in the joints should be as small as possible and not more than 1.0 to 1.2 cm.

(iii) Any flake of dry mortar that may be jutting out inside the grout space of the joist member should be removed before concreting.

(iv) While placing the filler units in position, care should be taken in adjusting the bottom level of the filler unit flush with the joist member by adjusting the thickness of mortar in the joint.

(v) A mortar pad 1 to 2 cm thick should be provided over the supporting structure specially over brick wall so that the joist members and the filler units get a uniform bearing and no point bearing.

(vi) Both the joist member and the filler unit should be provided with 7.5 cm minimum bearing over the support in the direction of the span and 4 to 5 cm in other direction.

OTHER CONSTRUCTIONAL DETAILS

In any flooring/roofing scheme, provision of various fittings and fixtures, cantilever, etc are required. The various constructional details that may be followed are given below:

(i) Cantilever projection in floor/roof may be either in the direction of the span of the joist member or across it. For cantilevers, along the span necessary reinforcement may be provided in the top deck concrete. However, the cantilever joist should be propped temporarily till the reinforced deck concrete at the top attains strength.

Cantilever across the span may be provided by projecting the primary beams on which the joist members are supported and then making the floor/roof assembly as usual over it. Alternatively, the cantilever projection may be cast in RCC with the reinforcement of the cantilever slab anchored with the main reinforcement of the joist member (Fig 3).

TABLE 2 RESULTS OF TEST SLABS

Test Slab No	Span, m	Width, cm	Reinforcement	σ_{cu}, kg/cm²	σ_{sy}, kg/cm²	Self-weight of Slab, kg	Superimposed Failure Load, kg	Moment at Failure kg m	Ultimate Moment Whitney, kg m	Ratio of Failure Moment Ultimate Moment	Remarks
1	4.00	76	2-16 mm ϕ deformed bars	165	4 320	76	2 640	1 700	1 507	1.13	Failure by yield of reinforcement
2	3.50	120	3-16 mm ϕ deformed bars	155	4 190	1 050	4 158	2 280	2 160	1.05	Failure by yield of reinforcement

(ii) The Indian type WC pan is generally placed sunk by about 3 cm or so from the general floor level. For the proper placement of WC pan, the joist and filler assembly is depressed by the desired height and after placing the WC pan, it is finished in the usual manner (Fig 4).

(iii) In bath and kitchen, floor traps are to be fitted over joist member. The particular joist over which the trap is to be placed is depressed to the desired extent. The adjacent filler unis are placed over the depressed joist unit directly or over a mortar pad so that the filler units rests squarely on other adjacent joist member which is at a higher level. The floor trap is placed in position and the space is filled while placing the *in-situ* deck concrete (Fig 4).

(iv) Fixtures like wooden plug, fan hook, electrical conduits, etc are fitted as follows:

Wooden Plugs

These can be fixed in the central hollow space of a filler unit with the help of rawl plags or nails and grouting the space with concrete. The filler unit is then placed at its proper place [Fig 5(i)].

Fan Hook

The bottom flange between the scored lines of the filler block is to be knocked off. Fan hook is fitted with its legs embedded inside the hollow and the space is grouted with concrete [Fig 5(ii)]. The filler unit with the fan hook fixed to it is then placed in position in between the joist member.

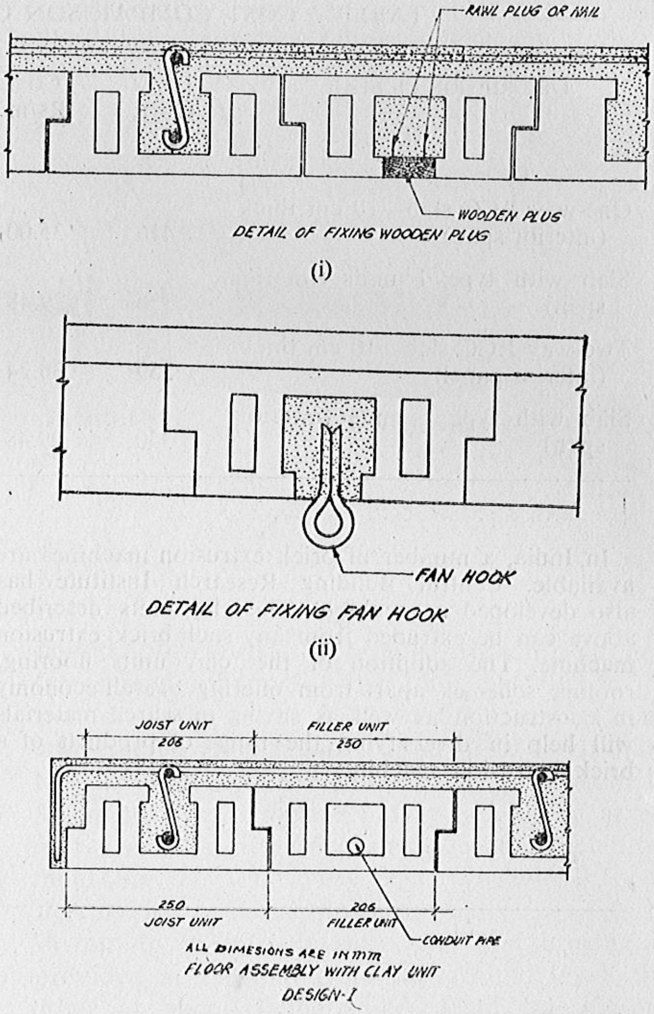


Fig 5

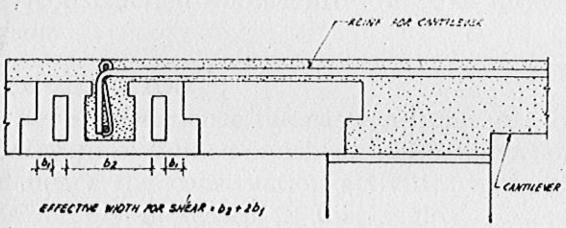


Fig 3 Details for cantilever projection

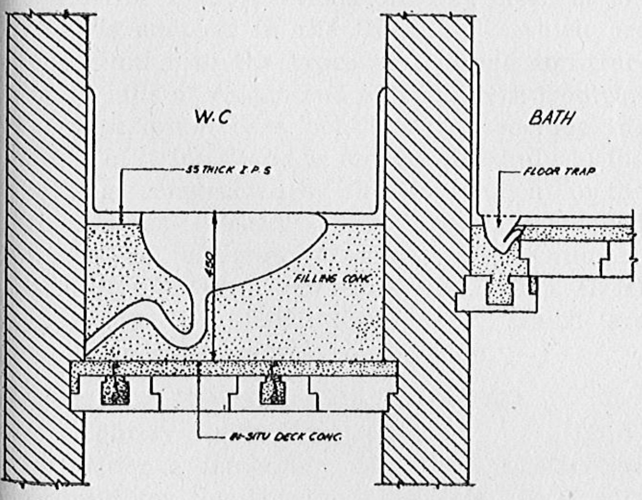


Fig 4 Details for services

Concealed Electrical Conduit

These are to be placed along the span, only. The conduit is placed inside the central hollow of the filler block [Fig 5(iii)]. The draw-off conduit may be provided by knocking off the scored panel of the filler unit which makes allowance for taking out the pipes. The hollow of the filler block in which the draw-off point is located is later grouted.

COST AND ECONOMY

On the basis of experience gained in the production of the clay units at Central Building Research Institute, Roorkee, their cost has been taken as Rs 400 per thousand. For comparison, cost analysis with the prevalent rates at Roorkee has been completed for a structural clay unit slab of 3.3 m × 3.5 m size and for one- and two-way RCC slab of the same dimensions (Table 3).

CONCLUSION

Such joist and filler block type of floor/roof construction with structural clay units is quite suitable for residential buildings up to a span of 4.3 m when designed as a simply supported floor/roof. Also with suitable provision for continuity, such floors can be used for spans up to about 4.8 m.

TABLE 3 COST COMPARISON OF CLAY UNITS AND RCC SLABS

Description of Slab	Total Cost, Rs	Cost, Rs/m²	Saving	Cement		Steel	
				Quantity, bags per m²	Saving	Quantity, kg/m²	Saving
One-way RCC slab—10 cm thick (interior span)	416	35.00	—	0.650	—	7.79	—
Slab with type 1 units (interior span)	350	29.48	15%	0.356	45%	5.80	25%
Two-way RCC slab—10 cm thick (interior panel)	359	30.24	—	0.650	—	4.91	—
Slab with type 1 units (interior span)	350	29.48	2.5%	0.356	45%	5.80	(—)18%

In India, a number of brick extrusion machines are available. Central Building Research Institute has also developed a machine. The clay units described above can be extruded from any such brick extrusion machine. The adoption of the clay units flooring/roofing schemes apart from offering overall economy in construction as well as saving in scarce materials will help in diversifying the range of products of a brick extrusion machine.

ACKNOWLEDGMENT

The study forms a part of the research programme on the design and development of structural clay unit slab and is being published with the permision of the Director, Central Building Research Institute, Roorkee.

REFERENCE

1. 'IS:456-1964—Code of Practice for Plain and Reinforced Concrete (Second Revision)'.