A RC filler slab with non-autoclaved cellular concrete blocks for sustainable Construction

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Abstract
Flyash is a major industrial waste which pollutes the atmosphere. The thermal plants in India will generate about 100 million tonnes of flyash per year by the turn of the century. Acres of usable land are wasted for dumping of ash. Transportation poses handling problems; besides, the proposition is uneconomical. In this context, utilisation of this waste material in building construction will go a long way in solving its disposal problem. Towards this end, a technology has been developed at the Central Building Research Institute (CBRI), Roorkee, India, to construct reinforced floor/roof slab with non-autoclaved cellular concrete filler blocks cast with flyash, lime, cement and a foaming agent. Autoclaved cellular concrete blocks are being used in the building industry to some extent in India. But as they require autoclaving for the production, they are costly. Hence non-autoclaved units have been developed with a suitable proportion of the constituents. The blocks are of size 260 x 560 mm, tapering down to 250 x 550 mm and are 110 mm thick. The floor/roof slab is cast with cement concrete of grade Ml 5 with these blocks as fillers. Reinforcement bars are provided in two perpendicular directions in the space between the blocks. Room size filler slabs were tested for their structural and functional performance at CBRI. Deflection recovery tests, failure load tests and impact load tests were conducted. Functional properties like thermal performance index, sound absorption coefficient, leak proofness etc. were also studied. The paper describes the experimental studies and results.

Housing shortage is a common problem in most of the developing countries and there is a need for appropriate construction techniques which are economical and affordable. The requirement of housing in India by the turn of the centuary is expected to be 39 million units and even if 10 percent of the construction is done with this technique, it will result in utilisation of 10 million tonnes of flyash. Compared to conventional insitu RC slab, this technique is economical and will result in saving of cement and steel and is an ideal step towards generation of affordable housing, for developing countries.
Keywords: Construction, filler slab, flyash, non-autoclaved cellular concrete blocks.

1 Introduction

Flyash is a major industrial waste and large scale use of this material in building construction will go a long way in solving the disposal problem of this pollutant material. Hence filler slab technology for flooring/roofing has been developed at CBRI. In this technique, the slab is cast with non-autoclaved cellular concrete filler blocks, produced from flyash, lime, cement and a foaming agent. Utilisation of flyash in large quantities for the production of the blocks is an advantage and also the technique results in saving of cement and steel and cost of construction, compared to conventional reinforced concrete slab for floor and roof.

2 Construction technique

The floor/roof consists of a cast insitu RC filler slab with non-autoclaved cellular concrete filler blocks as shown in Fig. 1. The filler blocks are 110 mm thick and 260 x 560 mm at top tapering down to 250 x 550 mm at bottom. The slab is cast with cement concrete of grade M15. Spanning in two perpendicular directions, the slab can be designed as a grid with compression taken by the deck concrete at top and tension taken by the reinforcement at the bottom in the rib portion. The cellular concrete blocks act as non-structural fillers. The technique can be adopted for floor/roof in single and multistoreyed residential and other types of buildings. Conventional roof/floor finish could be laid above the filler slab. Ceiling plaster could be avoided in low cost constructions and also where better acoustic performance is called for. In other situations the ceiling may be plastered.

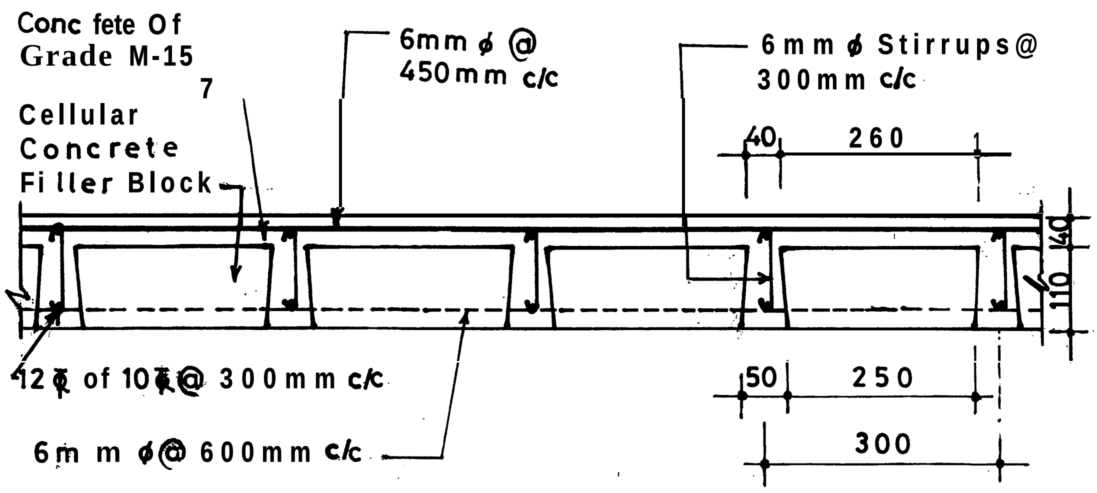

Fig. 1 RC filler slab (section)

3 Cellular concrete blocks

Autoclaved cellular concrete blocks are being used in the building industry in India to some extent. But as they require autoclaving for their production, they are costly. To make it economical, non-autoclaved cellular concrete blocks have been developed using flyash, cement, lime and a foaming agent. Several mix proportions were tried before arriving at a suitable mix from considerations of density and strength to withstand the stresses to which the blocks are subjected to, during construction. Quantities of materials required per cu.m of concrete for the selected mix are given below :

Cement	:	140 kg
Lime	:	35 kg
Flyash	:	528 kg
Foaming agent (Aluminium powder)	:	0.32 kg

Since flyash is available in fine particle state, it requires no further grinding. Cement [1, 2] lime [3] and flyash [4], as per the proportion mentioned above, are wet mixed in a high speed mixer to a homogeneous slurry. Aluminium powder is then added and mixed thoroughly. Hydrogen gas liberated by the aluminium powder, due to its reaction with lime,aerates the slurry. The slurry is then poured into steel moulds of size 560 x 260 mm tapering to 550 x 250 mm in plan and having a height of 110 mm. The slurry is filled only to three fourth the depth of the mould. Due to aeration, it rises upto the top or slightly above the top of the mould. Setting takes place in 10 to 12 hours in tropical climate. After setting, the part of the concrete above the mould is trimmed off and demoulding is done 24 hours after casting. The blocks are kept at casting platform for 2 days and after they have attained strength to withstand handling stresses, they are shifted to curing yard and cured under wet gunny bags for 14 days. The blocks are then allowed to air dry, for another 14 days.

4 Construction of floor/roof slab

The reinforcing bars for the bottom of the slab in two perpendicular directions are tied together and placed over the shuttering with concrete cover blocks tied to them. Cellular concrete blocks are then assembled over the shuttering in the space between reinforcement bars, leaving a gap of 40 mm between adjacent blocks in the two perpendicular directions. The blocks are then aligned properly and reinforcement cage for the flange portion is tied and placed over the cellular concrete blocks (Fig.2). Concrete cover blocks shall be tied to the reinforcement in the flange also to ensure required cover. The blocks are sprinkled with water repeatedly so that the surface is at a near saturation point. This is necessary to ensure that the blocks do not absorb excessive quantity of water from the fresh concrete. Concrete of grade M 15, made of coarse aggregate of maximum size 12 mm, is then laid in the space between the blocks and compacted using a needle vibrator. Immediately, the flange concrete above the filler blocks is laid and compacted using plate vibrator. The top surface is then finished properly. A camber of 1 in 250 may be provided to the shuttering in case of floor slab so that the ceiling of floor is level after removal of shuttering. In case of roof, a slope of 1 in 60 may be provided to the shuttering so that the top of the roof will have a slope of about 1 in 80 after the shuttering is removed. The concrete shall be cured for 14 days byponding water over it. The shuttering shall be removed after that. The ceiling may be plastered one month after removal of shuttering.

Fig. 2 RC filler slab under construction

5 Structural design

The filler slab may be analyzed as a two way spanning grid slab. The midspan section is designed as a T-beam with cast-in-situ concrete of flange taking compression and reinforcement at the bottom of the slab in the web portion taking tension. In case of continuous slab, the support section is designed as doubly reinforced rectangular beam with the width of beam equal to the thickness of web. To control deflection, the span/depth ratios have been considered as per the relevant Indian Standard Code of Practice. A 150 mm thick slab can span upto 3.6 m in case of simply supported and upto 4.5 m in case of continuous spans. In case of larger spans, a higher slab thickness is called for the control of deflection. In this case, filler blocks of thickness more than 110 mm may be used.

6 Structural/ Functional performance

6.1 Deflection recovery test

Deflection recovery test was carried out on the RC filler slab of clear span 3.6 m (Fig.3) considering residential floor load as per IS:456-1978 [5]. The slab was subjected to full dead load and 1.25 times imposed load for a period of 24 hours and the deflection measured. The measured deflection was only 1 in 750 of the span. The imposed load was then removed and after 24 hours, the deflection recovery was more than 90 percent indicating that the slab passes the test.

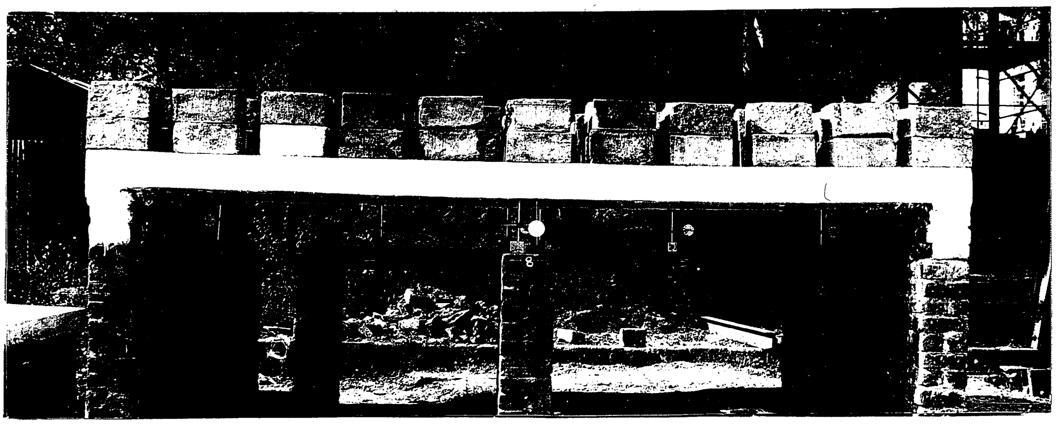

Fig. 3 Deflection recovery test

6.2 Failure load test

The slab was further subjected to failure load test. Deflections were measured and development of cracks noted at each stage of loading. The first crack was noticed at a total load of 6.7 kN/m2. The loading was stopped at a total load of 13.4 kN/m2 which is almost 1.5 times the design limit state load of 9 kN/m2. Further loading could not be done due to problems in stacking concrete blocks/sand bags over the layers already stacked. Pattern of cracks in the slab at penultimate stage of loading is shown in Fig.4.

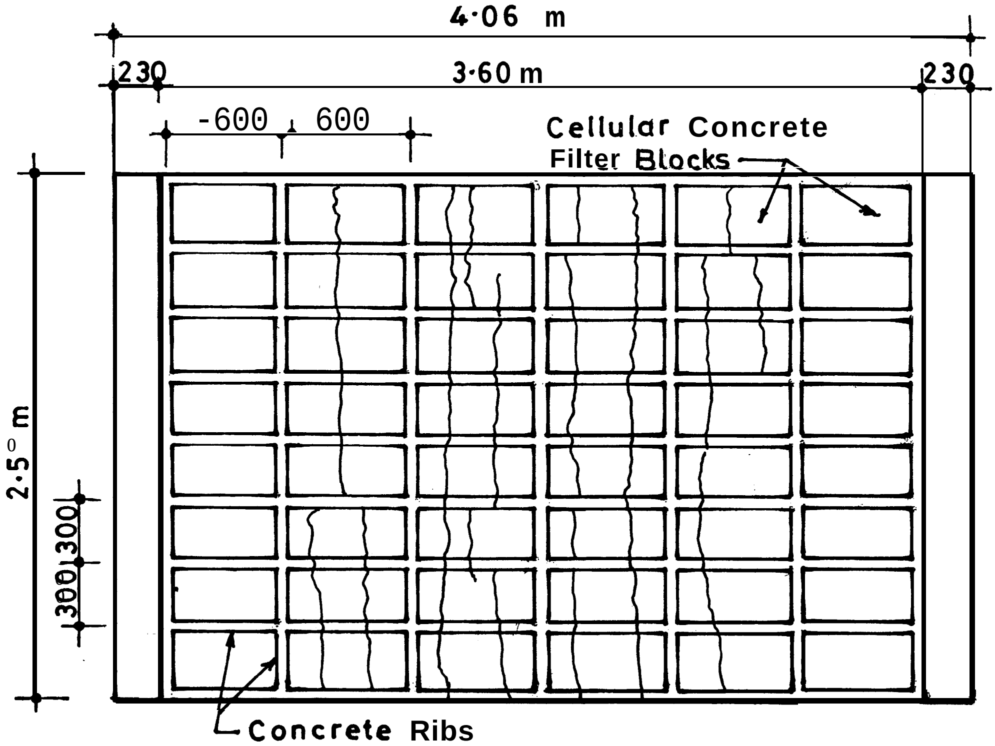

Fig. 4 Crack pattern in slab (ceiling)

As the test slab was constructed as a one way spanning member, cracks had occurred perpendicular to the span. **Major cracks had** occurred at the junction of filler blocks and cast in-situ ribs, specially in case of three ribs in the middle. Other cracks had occurred within the filler blocks and the cracks had passed through the ribs parallel to the span. The cracks were wider at bottom and tapering down towards top. No cracks were noticed in the flange portion

6.3 Impact load test

Though codes of practice **do not suggest any** procedure for testing slab against impact, some tests were carried out to check the impact resistance of the slab. A gunny bag filled with 40 kg of sand was dropped from a height of 1.5 m. No damage was observed. A 5 kg weight was dropped from a height of 1.2 m over an area of 700 mm2. Though indentation of about 2 mm was noticed at the top of the slab, where the weight struck it, no other damage was observed. The slab was also subjected to another type of impact test by pounding turmeric, one of the hardest materials used in Indian kitchens, in a "Hamam Dasta" (a heavy steel vessel), kept over the unfinished slab. No cracks or signs ofweakness had developed during or after the tests. Hence filler slab is safe against impact expected in residential and office buildings.

6.4 Thermal performance

The thermal performance [6] for the RC cellular concrete filler slab roof and the conventional RC slab roof with same roof treatment above are given below.

	Specification of roof slab	**TPI**
1.	150 mm thick cellular concrete filler slab with 90 mm thick lime concrete	85
2.	100 mm thick RC slab with 90 mm thick lime concrete	134
3.	150 mm thick filler slab with 75 mm thick mud-phuska & 50 mm thick tiles	75
4.	100 mm thick RC slab with 75 mm thick mud-phuska & 50 mm thick brick tiles	110

It can be seen that with the same roof treatment, the filler slab is thermally superior to conventional RC slabs.

6.5 Sound absorption

The sound absorption properties of cellular concrete and dense concrete are 0.27 percent and 0.1 percent respectively. Thus, it can be concluded that, if the ceiling of the filler slab is kept unplastered, it is superior to conventional RC slab in sound absorption and it is suitable for class rooms, lecture halls, conference halls, auditorium etc.

6.6 Leak proofness

The slab without any treatment over it was tested for leakage by ponding water over it continuously for one week. No dampness was seen below. This indicates that if the construction is done properly, there is no chance of leakage in filler slab. However, as an ample measure of caution, it is advisable to have a waterprooftreatment above the roof slab.

7 Economy

A comparison of the consumption of materials and cost of construction of the filler slab with conventional RC slab is given in Table 1. In case A, the comparison has been made for a 3.6 m x 3.6 m two way spanning continuous slab and in case B for a one way spanning simply supported slab of span 3.6 m.

Slab	Item	Cement (kg/n?)	Steel (kg/m^2)	cost (Rs./m^2)
A. Two way spanning continuous slab	a) Conventional slab 120 mm thick	38.4	7.1	415
	b) Filler slab 150 mm thick	32.0	4.0	346
	c) Savings (percentage)	16	44	17
B. One way spanning simply supported slab	a) Conventional slab 120 mm thick	48.0	6.5	450
	b) Filler slab 150 mm thick	32.0	3.5	338
	c) Savings (percentage)	33	46	25

Table 1. Comparison of cost and consumption of materials

It can be seen that adoption of filler slab in place of conventional RC slab will result in a saving of about 17 percent in cost. In addition, there is a saving of 16 to 33 percent in cement and about 45 percent in steel.

8 Conclusion

This technique of construction can be easily adopted for the construction of all types of buildings, once the cellular concrete blocks are available in the market. This is possible if entrepreneurs set up production units near Thermal Power Plants, where they are given flyash free of cost and space and facilities like power and water supplied at no-profit, no-loss basis. The large scale production of the blocks will help in the problem of disposal of flyash to a great extent. In addition, it will result in saving of cement and steel and will lead to affordable housing

9 Acknowledgements

The paper is based on R&D work conducted at the Central Building Research Institute and is published with the permission of the Director. The authors are thankful to their colleagues Dr. M. Khalid, Mr. S.P. Tehri, Dr. K.N. Agrawal and Dr. P.S. Bhandari for their contributions.

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