

Out of Plane Strength of Hollow Core Concrete Masonry Unit

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ABSTRACT: Precast construction techniques have gained huge popularity in the recent times due to rapid construction, excellent quality control and lesser labor costs and more overall savings. The most advanced type of precast construction is wall panel construction, which essentially consists of huge concrete panel units cast to the required wall dimensions. However wall panel construction is associated with the requirement of huge machinery for transportation, hoisting and placing operations. The present study proposes a new precast hollow core masonry unit which combines the advantages of precast wall panels, omitting all of its disadvantages. The individual units are smaller in size and are modular based. Hoisting and placing equipments with lower capacity will be sufficient for operation. The proposed system was cast and was experimentally tested by subjecting it to out-of-plane static loads. The results were found to be superior to conventional concrete brick block masonry wall. An FEM model was also developed using NX NASTRAN to study the behavior of the units analytically.

KEYWORDS: concrete, precast, wall panel

I. INTRODUCTION

Masonry unit is the one of the oldest building material known to man. About 80% of the buildings in India are constructed using masonry units, usually burnt clay bricks. Various researchers have focused on techniques to improve the quality of these masonry units and increase the speed of construction in low cost. Consequently, numerous varieties of bricks including concrete masonry blocks, interlocking bricks etc. exhibiting quality improvements in various aspects have been introduced.

However, the sizes of the units being constructed have undergone little moderation compared to the traditional sizes. Hence, such methods have never been able to show a steep decline in labour requirements and speed of construction. Another approach in construction works, namely "prefabricated construction" is the new trend in foreign countries.

Nowadays prefabricated units are also used for constructing walls of the buildings. Precast construction is gaining significance in the Indian scenario in general, especially in the urban areas. Precast concrete construction is a process to build concrete structures using prefabricated components which are manufactured on or off at site and assembled into their final position at the construction site. This is a more mechanized construction method, which is faster, neater and demands lesser manual labour.

Even though the practice of prefabricated construction using steel has been gained momentum during recent times, prefabricated construction using concrete is not in an applicable stage. Manufacture of large wall panels is mostly seen in this industry. This, however, faces transporting, hoisting and placing problems. This project thus focuses on the manufacture of smaller, lighter and more manageable type of prefabricated masonry units. Thus, the units require lighter equipments for handling operations.

II. EXPERIMENTAL PROGRAM

A. MATERIALS

2.1.1 Cement

OPC 53 grade cement of specific gravity 3.14 was used.

2.1.2 Fine aggregate

M sand of grade zone II was used. Specific gravity of m sand was 2.43.

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2.1.3 Coarse aggregate

6 mm and 12 mm aggregates were used as coarse aggregate. Specific gravity of 6 mm aggregate was 2.7 and for 12 mm aggregate were 2.74.

2.1.4 Quarry Dust

Quarry dust was used as a partial replacement of fine aggregate. Specific obtained as 2.54.

2.1.5 Fly Ash

Fly ash for these researches was obtained from Thermal Power Plant Thoothukudy. The specific gravity of fly ash was 1.9.

B. MIX PROPORTIONS

There are 6 mix proportions were tested for getting a suitable mix for making hollow concrete block. Material contents for the mixes as shown in table 1.

C. HOLLOW CORE CONCRETE MASONRY UNIT

The dimensions of Hollow core concrete masonry are of length 1.4m, depth 0.6m and width 0.2m. It contains seven numbers of 10cm diameter holes along the depth. Plan and side views of hollow core concrete as shown fig. 1(a) and fig. 1(b).

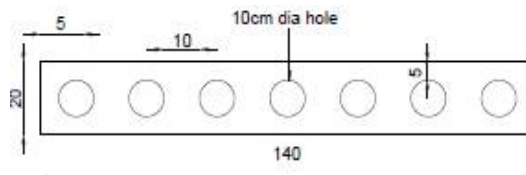


Fig. 1(a). Plan of hollow concrete block

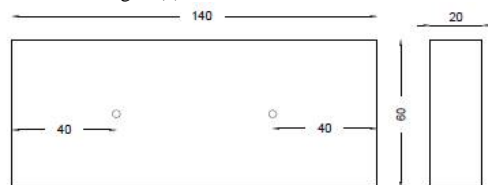


Fig. 1(b). Side views of hollow concrete block
(All Dimensions are in CM)

TABLE 1
MIX PROPORTIONS

Mix	Material Content in kg/m ³						
	C	W	12 mm	6 mm	M sand	Quar ry dust	Fly ash
M1	315	150	397.5	596.25	493.125	476.25	-
M2	252	120	424	636	526	508	-
M3	189	90	450.5	675.75	558.875	539.75	-
M4	315	150	397.5	596.25	493.125	-	356.25
M5	252	120	424	636	526	-	380
M6	189	90	450.5	675.75	558.875	-	403.75

D. CASTING OF HOLLOW CORE CONCRETE MASONRY BLOCK

The mould was fabricated using 8mm MS sheets, two of which were 600mm x 1400mm, two having dimensions of 200mm x 1400mm and a bottom sheet of 200mm x 600mm. The sheets were joined together by means of nuts and bolts. MS sheet strips were weld to the corners of the mould to give chamfers to the specimen. Seven holes of

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100 mm diameter equally spaced at a centre-to-centre distance of 100 mm were cut out from the opposite two sheets of dimensions 200 mm x 1400 mm, for inserting GI pipes. The GI pipes had 100 mm diameter, a thickness of 4 mm and length 750 mm. Figure 2 shows mould after arranging and figure 3 shows GI pipe.



Fig. 2.Mould after arranging



Fig. 3.GI pipe

Concrete was placed through the top opening of the mould. Concrete was placed till the holes on the side plates. This was followed by compaction using needle vibrator. The GI pipe is then inserted to this hole. Concreting is then carried out till the hole and was repeated till all the pipes were inserted.

After eight hours, all GI pipes were removed and all sheets were removed after 24 hours and the specimen was then left for water curing. Curing was done by using gunny bags. Figure 4 shows the hollow core concrete masonry block after demoulding.

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Fig. 4.Hollow core concrete

E. EXPERIMENTAL SETUP

The experimental setup was arranged outdoors, near the concrete technology laboratory. The rear end of the hydraulic jack (20T push-pull) was fixed to an I-section of ISMB 300 @ 46 Kg/m, which was fixed to the ground. To avoid the backward deflection of the I-section during loading, it was tied to a tree, owing to its high lateral resistance. The plunger was pointed to the top region of the specimen. Uniform load distribution to this region was ensured by attaching a steel I-section of ISMB 150 @ 14.9 Kg/m. An LVDT was also arranged to measure deflection during loading, as shown in Fig 5. The data acquisition systems of the hydraulic jack and the LVDT were located at safe distances from the testing apparatus.



Fig. 5.Experimental setup

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TABLE 2
MATERIAL PROPERTIES

Component	Modulus of elasticity N/mm ²	Poisson's ratio
Concrete used for constructing hollow core concrete masonry unit	18329	0.18
Steel reinforcement	2x10 ⁵	0.25
Concrete used for joining the hollow core concrete blocks	26123	0.18

The walls were supported on brick masonry foundation. The foundation was 600mm deep, with 300 mm below ground level. A PCC layer was laid over the foundation prior to the placement of the test specimens. The foundation was aligned to the tree and I-section loaded with the hydraulic jack such that the load applied is exactly perpendicular to the mid-region of the upper zone of the specimen. Fixity to the basement was facilitated by means of eight clamps.

F. ANALYTICAL MODELLING

Analytical modeling of hollow core concrete masonry unit wall was done by using the software NASTRAN NX9. Three precast unit were modelled and wall was created by arranging those units one above another. The precast units were joined by reinforced concrete of grade M20 and one 8 mm HYSD bar was used. The reinforced concrete was filled in three holes of precast units, one at the middle and two at the ends. Material properties given to the different components of wall were shown in table 2. Hexahedron meshing was used. Load was given at the top region of wall. Load increment was taken as 1kN.

III. RESULTS

A. COMPRESSIVE STRENGTH

7th, 14th and 28th days of Compressive strength of various mix proportions were tested. Out of the six mixes mix 1 and mix 4 shows higher compressive strengths compared to other mixes. In mix 4, fly ash was used for getting smooth surface and in mix 1 quarry dust was used. Fly ash is not readily available in market. But quarry dust is a locally available material. Thus mix 1 was selected for preparing the hollow core precast unit. Compressive strength obtained for different mixes as shown in Table 3.

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TABLE 3
COMPRESSIVE STRENGTH

Mix	Compressive Strength (N/mm ²)		
	7 th Day	14 th Day	28 th Day
M1	6.155	8.102	11.905
M2	5.100	7.055	8.552
M3	4.654	5.251	6.454
M4	6.553	8.942	12.208
M5	5.355	7.130	9.144
M6	5.057	5.958	6.755

B. OUT OF PLANE STRENGTH

1) *Out of plane strength of hollow core masonry unit wall joined with shear keys*

The precast units were supported on brick masonry foundation. The foundation was 600mm deep, with 300 mm below ground level. A PCC layer was laid over the foundation prior to the placement of the test specimens. Fixity to the basement was facilitated by means of eight clamps. The hollow core blocks were jointed together by using shear keys as shown in **Fig 6**. Shear keys were made by using GI pipes and provide a 20 mm projection on both sides.

When the wall specimen was subjected to the out of plane loading, the joint between the bottom and middle unit failed immediately at 0.5 kN load. The shear keys provided at the joint were not sufficient to resist movement at the joint. The failure occurred since the effect of bending moment was more predominant at that joint. In this test, no provisions were provided to prevent bending failure at the joints.



Fig. 6. Shear key

2) *Out of plane strength of hollow core concrete masonry unit wall joined with reinforced concrete*

Three masonry units were placed one over the other as shown in the figure 5. There among the hollow cores were filled with reinforced concrete to study about enhancement of the out of plane strength of the units. Concrete were filled at the two hollow cores at the ends and one at the middle. One 8 mm HYSD bar was used in each of the three fills and M20 grade concrete were used. The lower most unit was restrained to the foundation using eight clamps. After 14 days, out of plane capacity of the wall was tested. The load vs deflection characteristics are shown in table 4 and figure 7.

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TABLE 4

LOAD AND DEFLECTION OF HOLLOW CORE CONCRETE MASONRY UNIT WALL CONNECTING WITH REINFORCED CONCRETE

Load (kN)	Deflection (mm)
0.5	0.125
1	0.302
1.5	0.387
2	0.444
2.5	0.821
3	0.976
3.5	1.07
4	1.118
4.2	5.4

The three masonry units acted as a single unit during loading. At failure, the whole specimen overturns about the foundation without forming of cracks between the masonry units. The wall failed at 4.2 kN load a corresponding deflection of 5.4 mm was obtained at that load. The maximum bending stress obtained at failure stage was 0.810 N/mm². Up to 4 kN, a steady increase in deflection was noted. However at failure load, i.e. 4.2 kN very high deflection was observed. The rapid increase in deflection was due to the loss of fixity at the foundation.

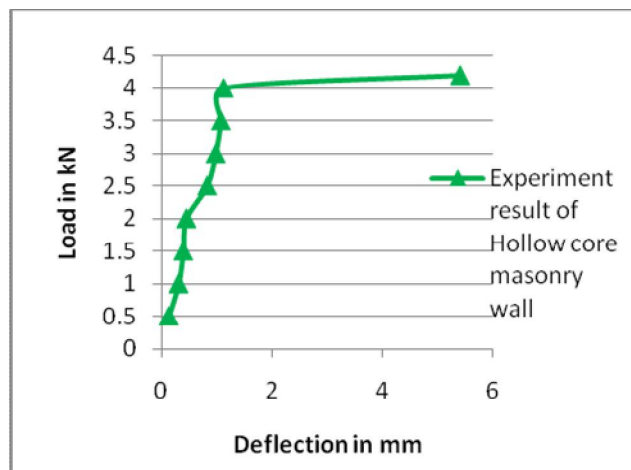


Fig. 7. Load v/s Deflection curve of hollow core concrete masonry unit wall connecting with reinforced concrete

3) *Out of plane strength of conventional concrete brick masonry wall*

A wall thickness of 20 mm and wall dimension of 1400 mm width and 1800 mm height was used for the test. Mortar mix of 1:4 mix proportions was used to join the bricks and was constructed in 8 layers. 28 full bricks and 8 half bricks were used. Load versus deflection characteristics of the specimen as shown in table 5 and figure 8.

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TABLE 5
LOAD AND DEFLECTION OF CONCRETE BRICK MASONRY WALL

Load (kN)	Deflection (mm)
0.5	0.211
1	0.32
1.5	0.68
2	1.02
2.5	1.57
2.8	4.2

The specimen failed at 2.8 kN load with a top end deflection of 4.2 mm. Maximum of 0.54 N/mm² stress was obtained at failure stage. Up to 2.5 kN, a steady increase in deflection was noted. At 2.8 kN, a brittle failure of the test specimen was observed. The failure was noted at the mortar joint between the third and fourth layers of masonry.

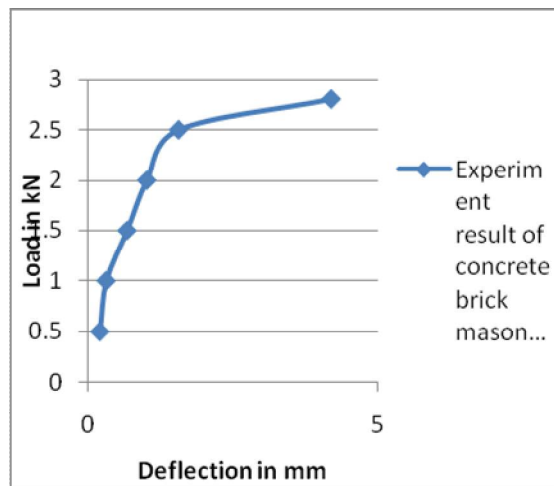


Fig.. 8.Load v/s Deflection curve of concrete brick masonry wall

4) Out Of Plane Strength of Hollow core concrete masonry unit wall joined with reinforced concrete by Finite Element Analysis

The analytical model of the precast hollow core masonry wall connecting with reinforced concrete was modelled using NX NASTRAN. When the model was subjected to out of plane load, it was observed that the wall unit was capable of withstanding a maximum load of 10.67 kN. The corresponding deflection was found to be 1.378 mm. Maximum stress was found to be 2.831 N/mm² as shown in figure 11. In the finite element analysis, top hollow core masonry unit was failed. The maximum displacement of hollow core masonry unit wall, which has been drawn from analytical analysis, is shown in Fig 10. Load versus deflection characteristics of the specimen as shown in table 6 and figure 9.

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TABLE 6
LOAD AND DEFLECTION OF HOLLOW CORE MASONRY UNIT WALL USING FEA

Load (kN)	Deflection (mm)
1	0.1174
2	0.235
3	0.387
4	0.516
5	0.587
6	0.775
7	0.904
8	1.033
9	1.162
10	1.174
10.67	1.378

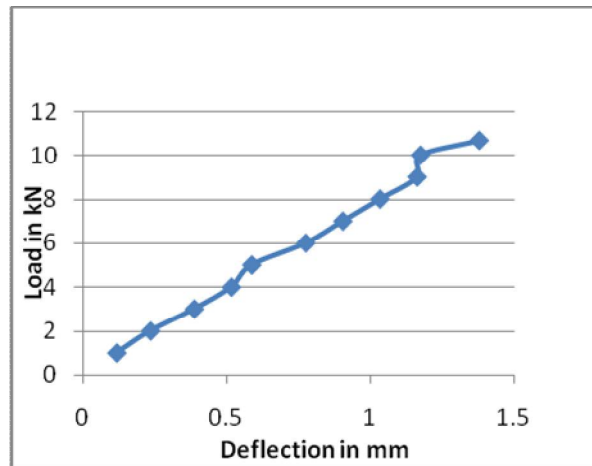


Fig. 9. Load v/s Deflection curve of hollow core masonry unit wall using FEA

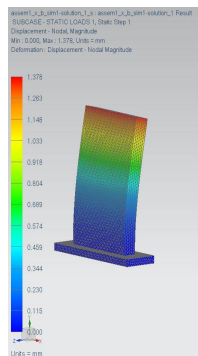


Fig. 10. Maximum deflection of wall

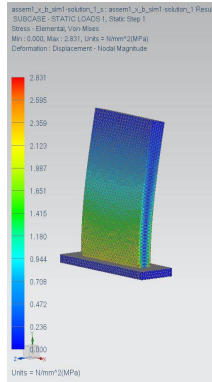


Fig. 11. Maximum stress at wall

C. COMPARISON

1) Comparison of experimental result of out of plane strength of hollow core masonry unit wall and conventional Concrete brick masonry wall

The load versus deflection plots show that, the proposed precast hollow core masonry unit performed better than conventional concrete masonry wall. The precast wall failed at 4.2 kN while the conventional concrete masonry wall failed at 2.8 kN.

From the experiments, it was found that the precast masonry units acted as a single monolithic unit for resisting the out of plane load. However the conventional concrete masonry wall acted as discrete layers, which led to the initiation of crack. Conventional brick wall shows brittle failure due to loading. However hollow core masonry unit wall failed due to improper fixity to the foundation.

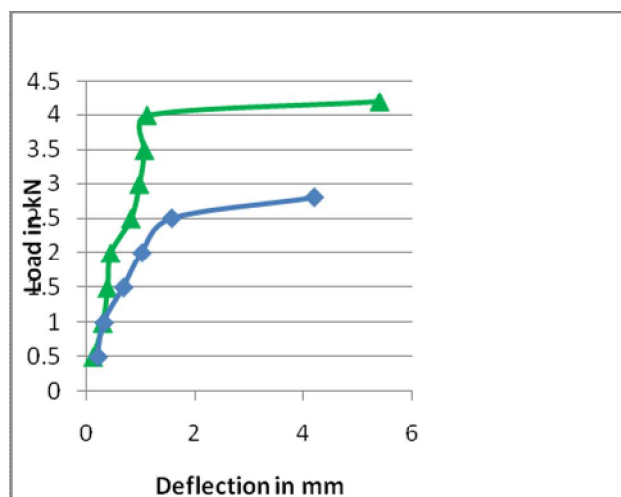


Fig. 12. Load v/s Deflection curve of Hollow core masonry unit wall and Concrete brick masonry wall

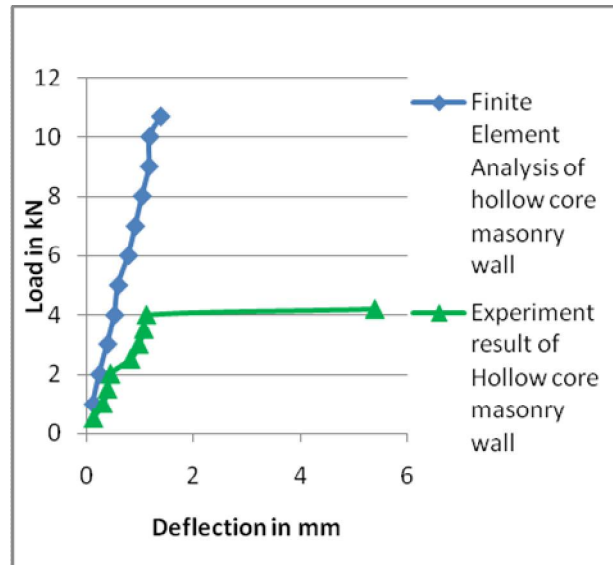


Fig. 13. Load v/s Deflection curve obtained from analytical and experimental results of hollow core concrete masonry wall

2) Comparison of out of plane strength of analytical and Experimental result of hollow core concrete masonry wall

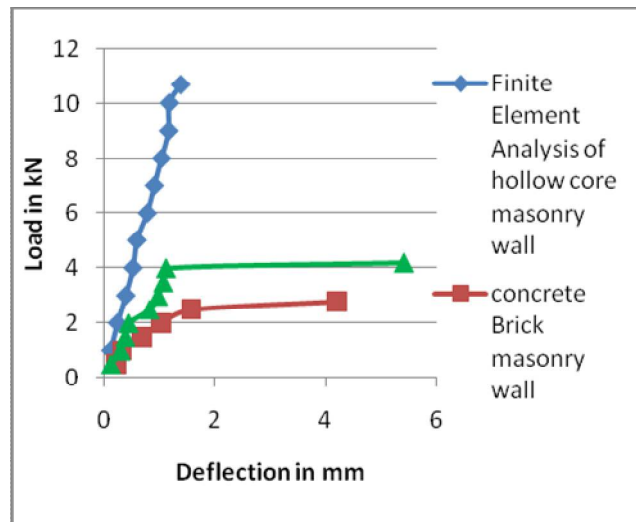
In the FEM modelling of the precast masonry unit, the capacity of the model was found to be much higher than the experimental specimen. The analytical model failed at 10.67 kN, while the experimental model failed at 4.2 kN. Load versus deflection characteristics as shown below,

The basic reason for these differences arises from the idealization of the fixity conditions in the analytical model. Since the foundation was assumed to be fixed, the behaviour of the model in the simulation was different from the experimental observation. In the analytical model, only the topmost precast masonry unit failed at the failure stage. However, in the experimental study the whole precast masonry wall overturned about the base as a single unit. This is due to the improper fixity of wall and the foundation. In experiment, the failure occurred due to the failure of fixity condition, not by the excessive bending of wall specimen.

In reality, however, fixity condition which was intermediate to fixed and hinged support was developed. Thus, the experimental result showed lesser capacity of the specimen.

3) Comparison of hollow core concrete masonry block and conventional concrete brick masonry block

From the current study it was observed that the implementation of precast hollow core concrete masonry wall was much superior to conventional concrete brick masonry wall construction. The load versus deflection curve of hollow core concrete masonry block and conventional concrete brick masonry block shows that the out of plane load carrying capacity of hollow core concrete masonry block wall was higher than the conventional concrete brick masonry wall. The analytical model exhibited great flexural capacity when subjected to out of load, which is favorable for seismic resistant design. However in the experimental study, the specimen failed at a lower value, since the foundation was not able to withstand the overturning force induced by the out of plane loading. The load versus deflection characteristics of the specimen showed close similarity until the above mentioned failure. In spite of this failure, the experimental model performed better than the conventional concrete wall. This implies that, if an ideal fixed condition was attained by any means, the specimen would have performed in close similarity to the analytical model. Load deflection curve is shown below



1.
2. Fig. 14. Load v/s Deflection curve of analytical and experimental result

IV. CONCLUSIONS

The major conclusions drawn from this research are presented below:

- Hollow core concrete masonry block with smooth surface was obtained.
- Out of plane strength of hollow core concrete masonry wall was found to be superior to that of conventional concrete brick masonry wall.
- Hollow core concrete masonry unit wall acted as a single monolithic unit for resisting the out of plane load, where as conventional concrete brick masonry wall acted as discrete layers.
- Conventional concrete brick masonry wall showed brittle failure during loading.
- Finite element analysis of out of plane load carrying capacity of hollow core masonry unit wall was higher than the experimental result.
- In the experimental study, the hollow core concrete masonry block wall failed due to improper fixity to the foundation, however in the analytical study of out of plane load carrying capacity, only the top most unit failed

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