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Performance of Steel Fibre Reinforced Interlocking Hollow Block as Load Bearing Wall

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Abstract: *An interlocking hollow concrete block was designed with proper surface finish using M10 mix. As surface finish was of prime concern, the control mix was finalized by trial and error method. These blocks were strengthened using hooked end steel fibres. The respective block facilitates provisions for electrical conduits, water and sewer pipes wherever so desired, without causing much damage to the block. Hollow blocks strengthened with steel fibres can effectively be used as load bearing wall. The investigation was carried out to study and compare the load carrying capacity of 90 cm wide and 90 cm high wall made with the designed hollow block to that of the locally available solid as well as hollow block.*
Keywords: *Conduits, Hooked end steel fibres, Interlocking hollow block, Load carrying capacity, Wall*

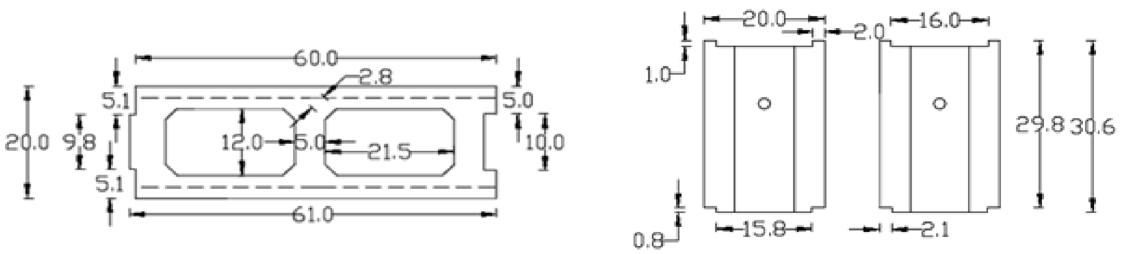
I. Introduction

Due to the growing population, housing is one of the major problems faced by India. More attention is paid to urban housing. In the process, rural housing gets neglected. A great majority of Indian population lives in rural areas. The movement of population from villages to metropolis has become a burning problem of the day. Rural & small town housings may slow down an excessive country - to - town movement of people and hence the housing problems of major cities may be controlled. Residential & non - residential constructions together are capable of swinging the national economy in any direction and to any extent. According to data available, non-residential construction has a very high share in total investment for buildings. Almost 80% of total resources are invested in constructions for non-residential purposes.

Studies reveal the need and scope for building construction in rural and urban areas for residential & non-residential purposes

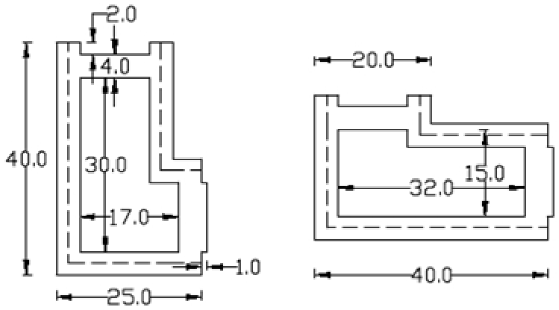
II. Steel Fibre Reinforced Interlocking Hollow Block

In this study, the geometry of the block is so arranged that the bonding is achieved by interlocking and cement grout. The side face of block is casted in good finish, thereby reducing the plastering cost. The inner hollow portions considerably reduce the dead load. The hollow portion serves as a conduit for electrical and plumbing utilities. The dimension of the interlocking hollow block is 60 x 20 x 29.8 and its weight is 53 kg. Blocks for corners, intersections and lintel were geometrically designed (Fig 2). The plan and inner vertical bonding face are shown below

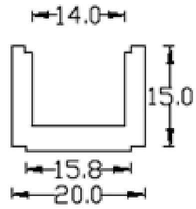


Plan Vertical Bonding Face

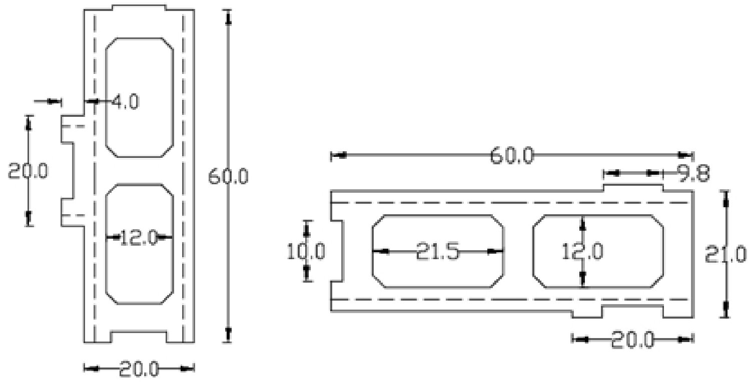
Fig 1 Plan and Inner Vertical Bonding Face of Interlocking Hollow Block



Block for Corners



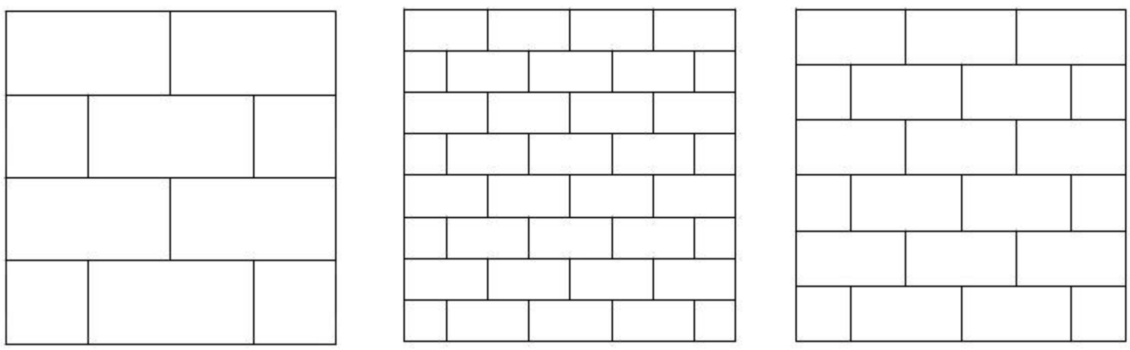
Block for Lintel



Block for Intersections

Fig 2 Interlocking Hollow Block for Corner, Intersections and Lintels.

For covering an area of 60 x 30 cm, one steel fibre reinforced concrete hollow block is sufficient and it weighs about 53 kg. To cover the same area, 4 solid blocks of standard dimension 30 x 20 x 15 cm and 3 hollow blocks of standard dimension 40 x 20 x 20 cm are required. The required solid block and hollow block weighs about 74 kg and 60.75 kg respectively. Thus the steel fibre reinforced concrete hollow block reduces the dead load by 21 kg with respect to solid block. The area of 120 cm x 120 cm, that can be covered by different types of blocks is visualized in the Fig.3.



Designed Hollow Block   Locally Available Solid Block   Locally Available Hollow Block

Fig 3 Wall with Hollow Block having Interlocking Ends, Locally Available Solid and Hollow Block

Advantages of steel fibre reinforced concrete hollow blocks are

- Larger size reduces the joints, and increase load carrying capacity and decrease mortar volume.
- The face shells are in a good finish which helps in avoiding plastering and thus save the cost of plastering.
- The large width hollow portions concealed the plumbing and electrical pipes and hence wall chasing cost can be avoided
- Improve architectural aesthetics because of fewer joints.
- Speedy construction.
- Dead load reduction.

- Thermal insulation (having dual character of keeping building cool in summer and warm in winter).
- Sound insulation (to decrease disturbance due to external noise).

III. Objectives

The main goal of the work is to design a steel reinforced concrete hollow block as a load bearing wall. The objectives of the work are listed as follows

- To determine a suitable mix satisfying the codal provisions (IS: 456 - 2000) by trial and error method that provides workability, strength, suitable surface finish and economy.
- To investigate the load carrying capacity of the wall made with the interlocking hollow blocks strengthened with steel fibres.
- To compare the load carrying capacity of the walls made with steel fibre reinforced concrete block with the one made with locally available solid and hollow block respectively.
- To study the failure pattern of the masonry wall constructed using steel fibre reinforced concrete hollow block.
- To compare the failure patterns of the masonry walls constructed using steel fibre reinforced concrete block, locally available solid block and hollow blocks.

IV. Methodology

The key points of the study are

- Fixing the dimension of the block.
- Various tests were conducted on cement, fine aggregate and coarse aggregate to determine its physical properties.
- Mix design of M10 grade concrete by trial and error method.
- Casting of cubes, cylinders and beams with and without steel fibres.
- Compressive strength test of cubes, splitting tensile strength test of cylinders and flexural strength test of beams were conducted.
- Casting of hollow block with steel fibres
- Construction of wall using steel fibre reinforced hollow block, locally available hollow and solid block respectively.
- Comparing the load bearing capacity of the walls.
- Comparing the failure pattern of the respective walls.

V. Materials Used

Cement, fine aggregate, coarse aggregate, steel fibres and water were tested as per IS specifications and the properties are listed below.

Table 1 Properties of Cement

Brand	Shankar Cement; Portland Pozzolana Cement - 43 grade
Standard Consistency	32%
Initial Setting Time	190 min
Final Setting Time	365 min
Specific Gravity	2.965
Mortar Cube Strength	43 N/mm^2

Table 2 Properties of Coarse Aggregate

Fineness Modulus	3.21
Nominal Size	12 mm
Specific Gravity	2.748
Water Absorption	0.15 %

Table 3 Properties of Fine Aggregate

Fineness Modulus	4.129
Zone	I
Specific Gravity	2.697
Water Absorption	0.2 %

Table 4 Details of Steel Fibre

Brand	Duraflex™ Hook End Steel Fibre
Product code	HKL 50/30
Material	Low Carbon Drawn Wire
Aspect ratio	50
Length (mm)	30 mm
Diameter (mm)	0.60 mm
Tensile strength	Greater than 1100 MPa
Appearance	Clear, Bright, Loose unglued with hook end anchorage
Conforms to	EN 14889-1,ASTH A820 M04 Standards

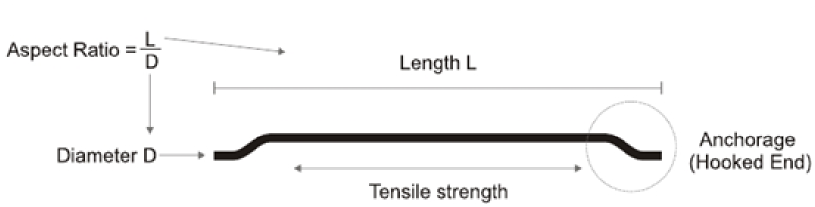


Fig 4 Details of Hooked End Steel Fibres

VI. Control Mix

M10 was adopted as per IS: 456 – 2000 (i.e.[6]) and IS: 2185 (Part 2) – 1992 (i.e. [11]). Considering proper surface finsh, a trial and error was adopted to arrive at a workable mix (TABLE 5).

Table 5 Mix Proportion – Control Mix

Material	Cement	Fine Aggregate	Coarse Aggregate	Water
Weight (kg/m^3)	280	914.403	1143	190.4
Ratio	1	3.26	4.08	0.68

VII. Casting Of Specimens

Specimens such as cubes, cylinders and beams were casted for the control mix (CM). Similarly specimens were casted with steel fibres (SF). Hollow blocks were also casted with steel fibres in it.

Previous studies (i.e.[1]) showed that on application of load a hollow block fails due to the detaching of web from the face shell due to poor tensile strength of the block. Hence to improve flexural strength steel fibres were added to hollow blocks with interlocking ends. Previous studies (i.e.[1]) also states that 1% of steel fibre in concrete mix can enhance early as well as long term compressive and splitting tensile strength of concrete. Also mode of failure changes from brittle to ductile nature. Considering economical factor also, this study utilizes 0.2% (by volume) of steel fibre. Three specimens were casted for each test and an average result was considered. Total numbers of specimens casted for the study are

Table 6 Total Number of Specimens Casted

Specimen	Dimension	Total Number
Cube	150 mm x 150 mm x 150 mm	18
Cylinder	150 mm diameter, 300 mm height	18
Beam	100 mm x 100 mm x 500 mm	18

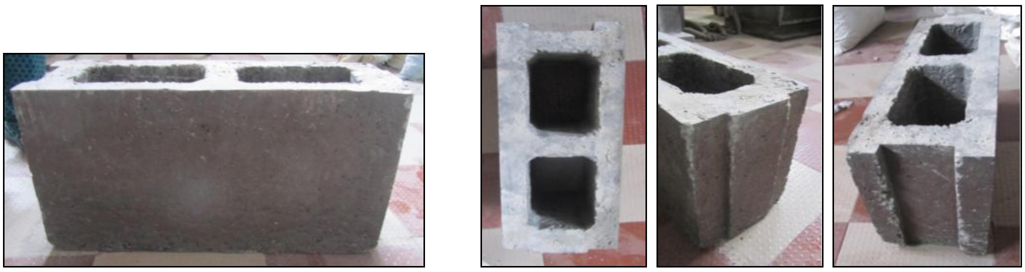
Fig 5 Casting and Curing of Specimens

For the purpose of the study the blocks are designated as

Table 7 Block Designation and Dimension

Block	Designation	Dimension
Locally available solid block	SB	300 mm x 200 mm x 150 mm
Locally available hollow block	HB	400 mm x 200 mm x 200 mm
Steel fibre reinforced hollow block with interlocking pattern	SHB	600 mm x 200 mm x 300 mm

Fig 6 Casting and Curing of Designed Hollow Block



Surface Finish Interlocking Ends

Fig 7 Designed Hollow Block with Interlocking Ends

The load carrying capacity of masonry wall was found out by building a wall of small dimension and loading it to its failure. Walls of 90 cm width and 90 cm height were built with SB, HB and SHB respectively. Cement mortar having a mix proportion of 1:5 were used. Wall was painted with white premier before testing.

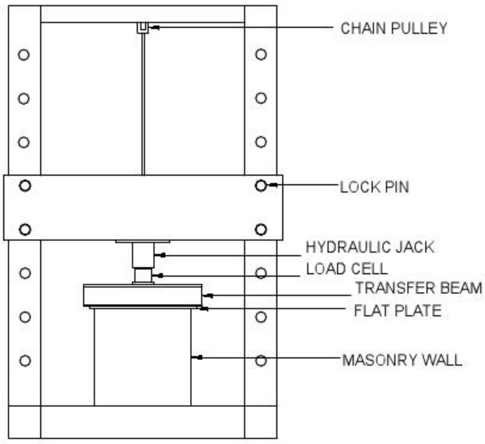


Fig 8 Schematic Diagram of Test Setup

SB SHB HB

Fig 9 Masonry Wall Built using SB, SHB and HB

Table 8 Total Number of Blocks Required for Casting Respective Wall

Specimen	Total Number
SB	18
SHB	5
HB	10

VIII. Test Results And Discussions

8.1 Compressive Strength of Concrete

On addition of steel fibres, compressive strength of concrete cube increased by 21% when compared to that of CM (Fig 10). This is due to the better bonding of the concrete achieved by hooked end anchorage of steel fibre. It was noticed that there is less crack in the cube during failure and the crack width was comparatively smaller.

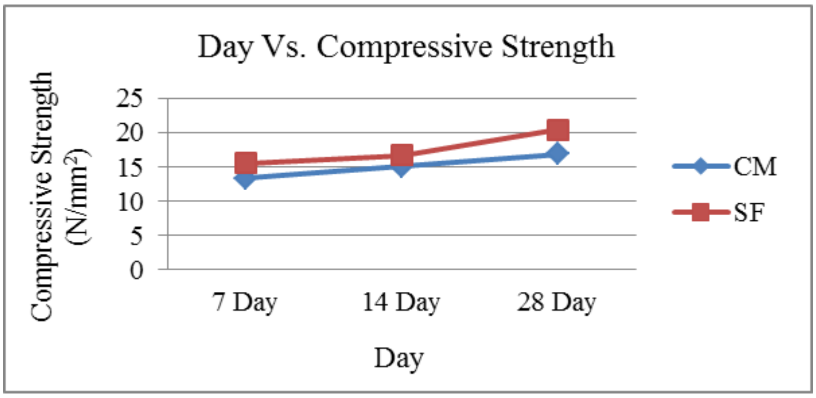


Fig 10 Variation in Compressive Strength of Concrete

8.2 Splitting Tensile Strength of Concrete

Split tensile strength of SF increased due to increase in tensile strength of concrete which was achieved by addition of steel fibres (Fig 11). Tensile strength increased by 8% when compared to CM.

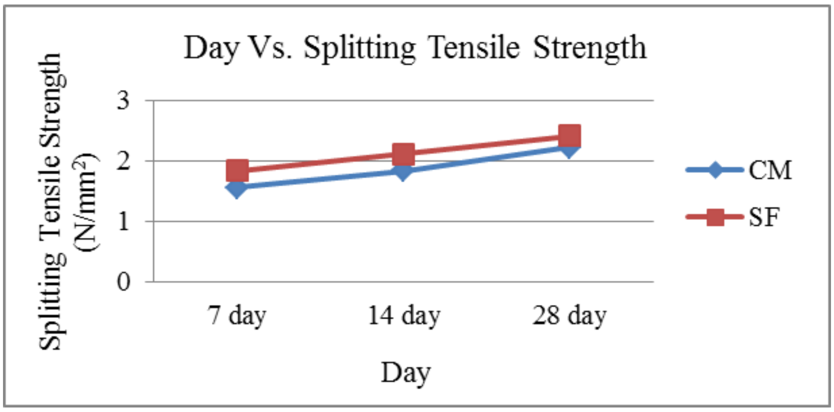


Fig 11 Variation in Splitting Tensile Strength of Concrete.

8.3 Flexural Strength of Concrete

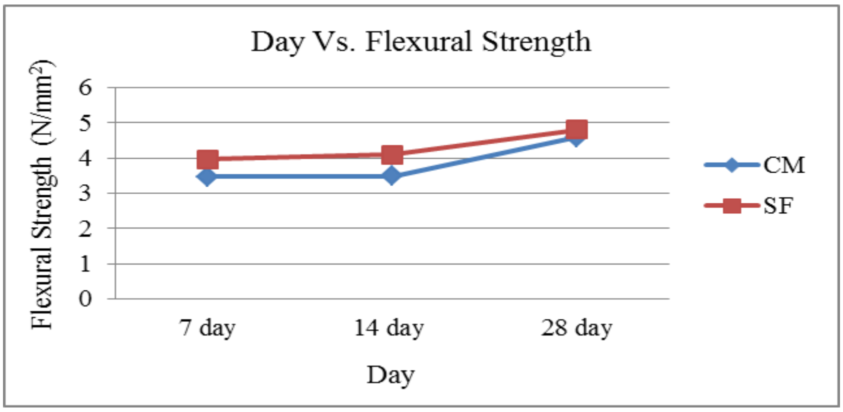


Fig 12 Variation in Flexural Strength of Concrete

The flexural strength improved by 5% due to addition of steel fibre (Fig 12). Spalling of SF was comparatively less.

8.4 Ultimate Load Carrying Capacity of Walls

The SB wall failure was through the mortar joints (Fig 14). The damage was more on the top layer of the wall. The crack propagated from top to bottom of wall. The failure of HB was due to the detaching of face shells from the web (Fig 15). The crack propagated from top to bottom of the wall. The SHB had a better load carrying capacity compared to other two blocks. The face shells were not detached as seen in the case of HB (Fig 14). Cracks were found only at the top layer of the wall.

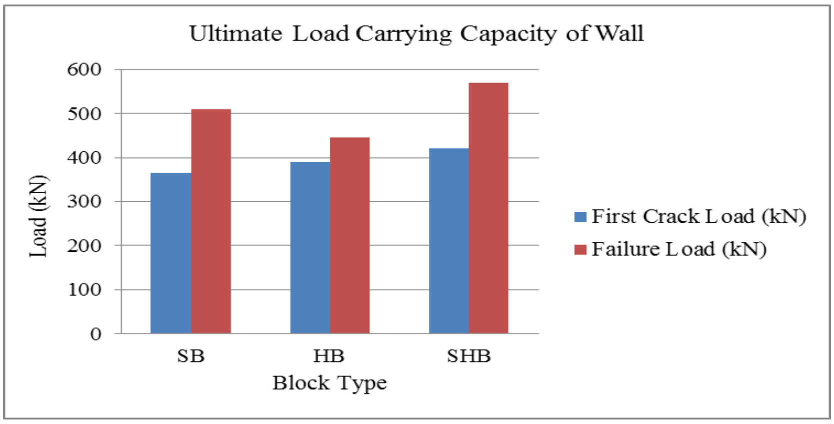


Fig 13 Variation in Ultimate Load Carrying Capacity of Masonry Walls

SB SHB

Fig 14 Failure Pattern of SB and SHB

Fig 15 Failure Pattern of HB

IX. Conclusion

A study of hollow block strengthened with steel fibre was performed in this present work. The study showed that the block with an interlocking ends and sufficient surface finish provides considerable strength and reduces the cost of construction. The extra cost of steel fibers can be compensated by saving time of construction, avoiding plastering of walls and minimizing the quantity of bonding mortar. The block also provides provisions for concealing plumbing and electrical conduits. The conclusions derived from this work are listed below:

- The interlocking pattern helps in proper alignment and faster construction.
- The load carrying capacity of masonry wall with steel fibre reinforced hollow block was greater than that with locally available solid and hollow block by 12% and 22% respectively.
- The failure of solid block masonry wall developed from the joints.

- Hollow block masonry wall failed due to the detaching of face shells.
- Cracks were developed only at the top layer in the case of hollow blocks strengthened with steel fibres. Also the face shells were not detached as seen in the case of hollow block.
- Steel fibre reinforced hollow block reduces the dead load by 28% and 11% compared to locally available solid and hollow block.

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Apart from the efforts made by me, the success of this work depends largely on the encouragement and guidelines of many others. I take this opportunity to express my gratitude to the people who have been instrumental in the successful completion of this work. The guidance and support received from all the members who contributed to this work, was vital for the success of the project. I am grateful for their constant support and help.

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Authors Profile

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