

Parametric Study of Longitudinal Hollow Steel Fibre Reinforced Concrete (SFRC) Beams

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Abstract. The main aim of this study is to investigate on the crack patterns and flexural strength of simply supported RC rectangular hollow beams and SFRC rectangular hollow beams (with a circular hole in longitudinal direction) under a loading frame with a gradual increasing load. The experimental program consists of casting and testing of 4RC and 4 SFRC beams of size 1400 x 150 x 150. M 25 grade of concrete was used for the casting of all the beams. Hollow beams were made using pipes of diameters 32mm, 40mm and 50mm and the position of placing the pipes are at a distance of 3 to 4 cm from bottom reinforcement. All other properties of the beam were kept constant such as the cross section of the beam and the amount of longitudinal steel. In this study we also focus on the material management by the introduction of a hollow core. By this material optimization we can decrease the dead loads which contributes to the seismic effect in high rise buildings. The influence of area of hole is taken as reference for the study. A comparison of experimental results of RC and SFRC were made to predict the crack behaviour and the flexural load carrying capacity of hollow beams.

Keywords: Hollow beams, Circular hole, Steel fibre reinforced concrete, Crack pattern

1. Introduction

Concrete is a versatile building material that it is only second to that of water according to the per capita consumption in the world. Understanding the basics and fundamentals of concrete is necessary to produce a good quality concrete. The term concrete relate to a mixture of cement, sand, aggregate held together into a pasting substance. The paste is made up of substances such as cement and water and can also contain substantial materials like



superplasticizers. In this experimental study we have used FOSROC SP 430 as the superplasticizer. Every year billions of buildings are being built up such as industrial buildings, commercial buildings, dwelling units, bridged etc. In these buildings another billions of RC beams are being built. Although a good information is available about the strength of normal RC beams, no valid datas are available about the strength of hollow RC and hollow SFRC beams.

Introduction of a longitudinal hole in the beam helps in reducing the self weight of the beams. As a result of this, it helps in reducing the size of the structural members which supports the beams such as columns and foundations, thus leading to the material saving in large amounts. In addition to these advantages other utility services can be laid through these without much difficulty such as telephone lines, electrical lines, sewage ducts and water service lines whenever necessary. In the RC beams, the hollow section can be made in a shapes such as circular, trapezoidal, triangular, diamond and many irregular shapes. But circular and rectangular holes are more commonly seen.

The properties of the normal concrete can be further be improved in terms of workability, durability and strength characteristics from reducing porosity by compaction, improved characteristics of cement paste and by increasing the aggregate paste bond. In addition to this, the strength can be further improved by the introduction of fibres into the normal mix. The fibres used can be steel, carbon or glass fibres. These type of concrete made are named as fibre reinforced concrete. It has being revealed that the reinforced concrete with a acceptable amount of fibre acquires large strength and better performance in terms of their flexure, toughness, compression, in which the degree of increased performance lies in the type of fibre used. Steel fibre is a versatile fibre used in constructions by the majority of architects and builders.

Advantages of hollow cross section

- Reduced the weight, which helps in reducing the cost of transportation, ease of handling and assembling of the specimen.
- Substantial reduction in material quantities, the materials required are much less than that used for conventional systems.

2. Objectives and Scope

The main aim of this experimental study is to:

- To study the flexural behavior of hollow RC and SFRC beams of different diametrical holes.
- To determine the ultimate load carrying capacity of the hollow RC and SFRC beams.
- To study the crack patterns of the different beams.
- To make an investigation on the relation between the diameters of the holes to that of the occurrence of the cracks.

3. Methodology

To study the behaviour of hollow reinforced concrete beams and hollow steel fibre reinforced concrete beams. This research will help us to focus on the material optimization which results in the overall economy of a structure. The methodology which should be followed is discussed in the next paragraph.

Properties of materials such as sand, aggregate, cement are being found. It is very important to find out the properties as they are the ones which impart strength and durability to the concrete. Then the mix design is formulated. It is being formulated using IS – 10262. The average compressive strength of concrete at 7 days and 28 days are found. This provides us with the information whether the mix designed gave us with an expected strength as that provided by M 30 concrete. If this strength is upto the limit, then the design mix can be used for the beam. If otherwise, redesign the mix. Next reinforced beams and the fibre reinforced beams are casted as simply supported beams. The curing of the beams are being done for 28 days. The composite beams are tested using two-point loading. Atlast the formulation and interpretation of results is done.

4. Materials

The fundamental components of concrete mix are water, cement, coarse aggregate and fine aggregate. Addition of admixture with concrete mix will helps to increase its properties. For this thesis work superplasticizer is used as admixture, which helps to maintain workability without adding more water

4.1 Cement

Cement is the binder material which starts to set when mixed with water which causes a series of hydration chemical reactions. The constituents will slowly hydrate and the mineral hydrates solidify; the interlocking of the hydrates gives cements its strength. Cement used in the work was PPC (Portland Pozzolana Cement). 53 grade Portland pozzolana Ambuja cement is adopting for experimental programme.

4.2 Fine Aggregate

In this study M sand which belongs to zone II is free from impurities is used. The size of it is lesser than 4.75 mm. The specific gravity and fineness modulus of this fine aggregate where found to be 2.88 and 2.87 respectively. The percentage of passing is within the limits as per IS:383-1970.

4.3 Coarse Aggregate

The coarse aggregate used here is 20mm in size belongs to zone II, crushed angular shape and is free from dust particles. The specific gravity and fineness modulus was found to be 2.79 and 6.93 respectively and the impact value was found to be 9.44 %. The percentage of passing is within the limits as per IS: 383-1970.

4.4 Fibre

Steel fibres of 30mm length and 0.5mm diameter is being used for the thesis work Fig:1. These fibres provide greater flexibility with various types of Portland cements and admixtures. Its loose and unglued characteristics provides even distribution mix in a fast and convenient manner thus effective in avoiding balling.

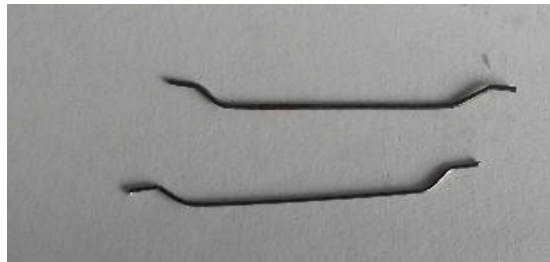


Fig: 1: Hooked end fibre

4.5 Admixture

Admixture used for this project is superplastizer, FOSROC SP430 which is free of chloride. It will help to reduce the amount of water demand and also it will help in early strength gain of concrete. It also increases the permeability and durability of the concrete

5. Experimental Investigation

5.1 The Details of Test Specimens

A total of 8 beams of the dimensions of 1400x150x150mm were casted and tested. The details of the beams are are given in table 1. The beams are having longitudinal holes of diameters 32, 40 and 50 mm. For making the longitudinal holes with ease, frictionless PVC pipes are used and these pipes are tied to the reinforcements as given in Fig:2. The reinforcements were given a cover of 20mm.

Table 1: Test specimen

NO.	BEAM DESIGNATION	DIAMETER OF HOLE(mm)	TYPE OF FAILURE
1	NO PIPE NC	0	FLEXURE
2	32mm PIPE NC	32	FLEXURE
3	40mm PIPE NC	40	FLEXURE
4	50mm PIPE NC	50	FLEXURE
5	NO PIPE FRC	0	FLEXURE
6	32 mm PIPE FRC	32	FLEXURE
7	40 mm PIPE FRC	40	FLEXURE
8	50 mm PIPE FRC	50	FLEXURE



Fig:2: Reinforcement cage of the beam

5.2 Concrete Saving

Volume of 1 beam, $v_1 = 1400 \times 150 \times 150 = 31500000 \text{ mm}^3$

Volume of 50mm pipe, $v_2 = \pi \times 25^2 \times 1400 = 2748893.572 \text{ mm}^3$

% reduction of concrete = $(v_2/v_1) \times 100 = 8.72\%$

Since we have assumed for a small beam, the percentage of reduction of concrete is small. But in actual cases, that is for a huge building the percentage of saving will also be more. Hence making the project economical.

5.3 Experimental Setup

All the beams casted were tested in a loading frame of capacity 500 kN and were loaded until the failure of the specimen occurred using a two-point loading system. Also the load was given gradually using a hydraulic jack and were distributed uniformly to the two points using a steel joist. The experimental setup can be seen in the Fig:3.

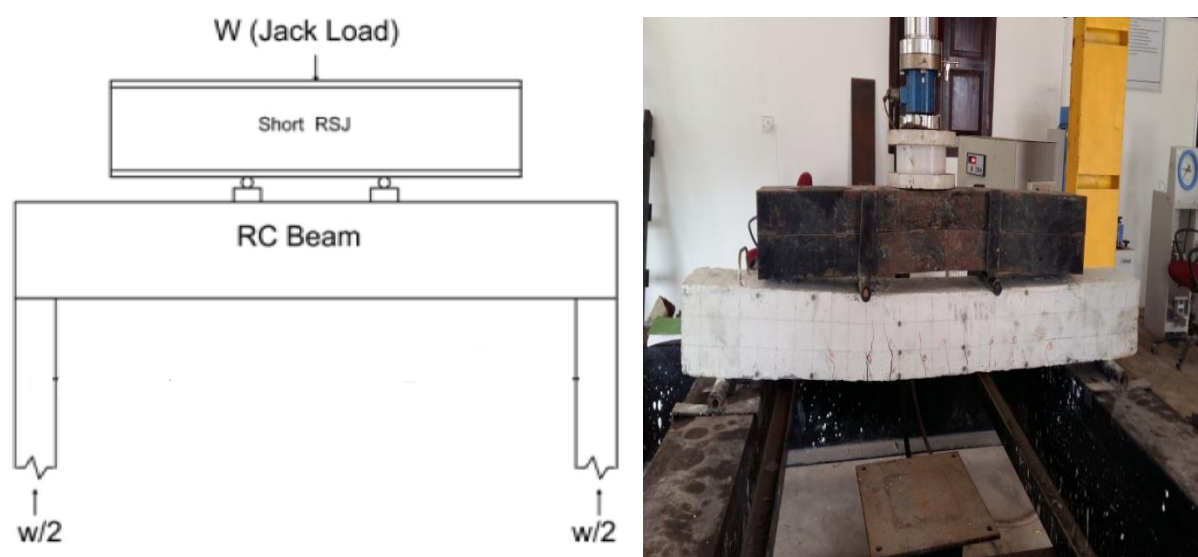


Fig:3 Experimental Setup

6. Result

6.1 Load Carrying Capacity

The presence of hollow recess in reinforced concrete beams was found to decrease the load carrying capacity by only a small value. Thus these hollow sections can be successively used in structures where relatively smaller load carrying capacity is needed. The decrease in load carrying capacity w.r.t no pipe is shown in Table 2.

Table 2: Decrease in Load Carrying Capacity

PIPE DIAMETER	NC(%)	FRC(%)
32mm	2.5	1.05
40mm	4	2.95
50mm	7.85	8

6.2 Load- Deflection Responses

The load-deflection curves for SFRC are shown in Fig:4. All the beams followed the same pattern of load-deflection response. After yielding of steel reinforcement we can see there an enormous rate of increase in deflection for subsequent loads.

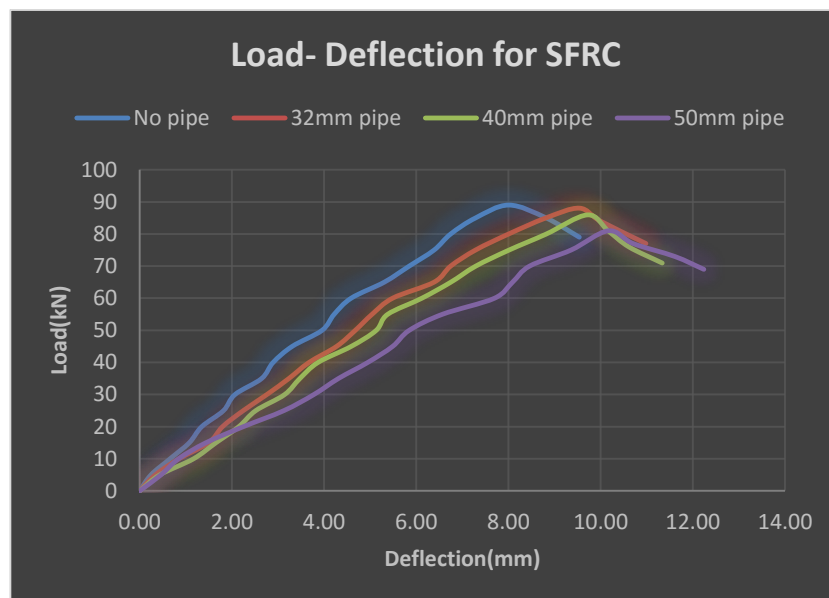


Fig:4 : Load - Deflection Graph for SFRC

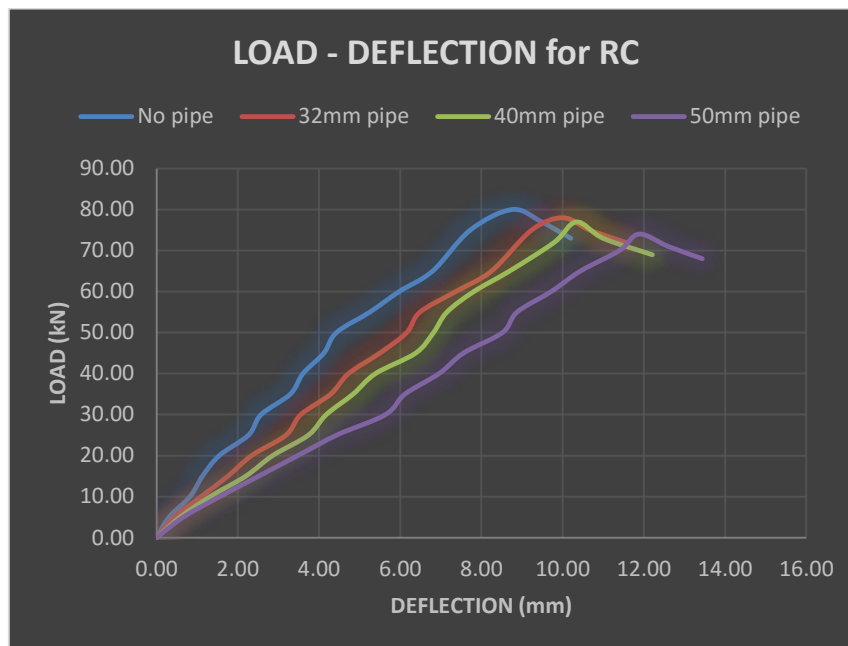


Fig:5: Load - Deflection Graph for RC

6.3 Crack Pattern

Initial stages of loading, all beams were un-cracked beam. When the applied load reached to the rupture strength of the concrete on specimens, the concrete started to crack. The failure pattern in the all the tested beams was observed as a flexure failure. The beams showed initial cracking in the constant bending moment region and then the cracks patterns in the vertical direction as the load was increased further. All the beams showed the same pattern of failure and the failure modes are shown in Fig:5.



Fig:6:

Formation of Cracks

7. Conclusion

- In general, the no. of crack is larger in the hollow section than solid one.
- But the addition of steel fibre can reduce the cracks and the load carrying capacity can be tolerated.

- The RC beams and the SFRC beams having a longitudinal hole, failed under flexural mode.
- The beams failed as a result of the initiation of yielding of reinforcing steel and the subsequent crushing of concrete in the compression zone.
- There is scope for taking essential utility services, such as water supply, sewage, air-conditioning ducts, and electrical and telephone cables, through the longitudinal holes of these beams whenever necessary.
- The propagation of crack in hollow beams was relatively slower than RC solid beams. Also the number of cracks is less when compared with cracks in RC solid beams. This may be caused due to the fact in bending effect in tensile zone is restricted by introducing hollow longitudinal hole.
- The presence of hollow section in reinforced concrete beams does not result in any appreciable decrease in the load carrying capacity. And thus these hollow sections can be successively used in structures where relatively smaller load carrying capacity is needed.

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