"Behaviour of Rectangular SFRC Beam Specimens under Combined State of Flexure, Compression and Shear

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ABSTRACT: What makes concrete a good construction material is its high compressive strength. However, since the early 1800's, it has been known that concrete is very weak in tension. This comes from the brittle nature of the material. Weak tensile strength combined with brittle behaviour results in sudden tensile failure without warning. This is obviously not desirable for any construction material. Thus, concrete requires some form of tensile reinforcement to make up for its brittleness and to improve its tensile strength and strain capacity for it to be used in structural applications. Unlike conventional reinforcing bars, which are specifically designed and placed in the tensile zone of the concrete member, fibers are thin, short and distributed randomly throughout the concrete member. The random distribution results in a loss of efficiency as compared to conventional reinforcement bars, but the closely spaced fibers improve toughness and tensile properties of concrete and help to control cracking. In many situations it is prudent to combine fiber reinforcement with conventional steel reinforcement to improve performance. The main objective of present study is to investigate the behaviour of composite rectangular beam of size 14.14cm X 7.07 cm and 50cm long which are M20 grade with varying percentage of steel fiber i.e. 0%, 0.5%, 0.75% and 1.0% by volume under the combined state of flexure, compression and shear. Simply supported rectangular beams with above mentioned variations were tested in flexure with variation of compression as 0.0 kN, 40 kN, 50 kN, and 60 kN.

Key Words: ***SFRC, Shotcrete, concrete mix, splitting tensile strength, Compression***

1.INTRODUCTION

Given its long history, it is surprising that the introduction of fibers to improve the material properties had not advanced a great deal in the period up to the early 1930's. However, post 1930 progress has been more impressive with the most significant gains made after 1960. This can be attributed to both the appearance of man-made fibers and the evolution of a more meticulous scientific approach to the computation of cement based composite behaviour.

Adding steel as fiber reinforcement to concrete makes it Steel Fiber Reinforced Concrete (SFRC). Added fiber in concrete acting as crack arrestors thus increasing the required energy for crack propagation and then maintains some measures of load carrying capacity after cracking is developed. Conventional reinforcement in the form of bars or mesh also provide load carrying capacity after cracking is established, but has a negligible effect in terms of slowing down crack development. When loaded, FRC first exhibits an approximately linear response before reaching its tensile strength. After cracking, the load deflection response becomes highly non- linear. The shape of the load- deflection curve depends upon the type of fiber, fiber geometry number of fibers, the orientation with respect to the crack faces, and pull out behaviour. This is observed when carrying out closed-loop compression tests, uniaxial tests or flexural tests on FRC.

2. LITERATURE REVIEW

N. Banthia, Vivek Bindiganavile, S Mindess (2003) [1] this study gives a progress report which provides the current understanding of dynamic fracture in fibre reinforced concrete with emphasis on bond slip responses, crach growth resistance and the engineering properties.

A.M. Shende, A.M. Pande, M. Gulfam Pathan (2012) [2] They have used M-40 grade of concrete to study the compressive strength, flexural strength, and split tensile strength of steel fiber reinforced concrete (SFRC) containing fibers of 0%, 1%, 2% and 3% by volume fraction with different aspect ratio. Result data clearly shows percentage increase in 28 days' compressive strength, Flexural strength and Split Tensile strength for M-40 Grade of Concrete over concrete without fibres.

Abdoladel Shoaib, Adam S Lubell, Vivek Bindiganavile (2014) [3] it was reported that specimen contained normal or high strength SFRC with 1 % volume fraction of hooked end steel fibers and different longitudinal reinforcement ratios but no stirrups. Results show that the steel fibers increase the shear capacity relative to the geometrically similar reinforced plain concrete members.

Patil Shweta, Rupali Kavilkar (2014) [4] They have studied properties of steel fiber reinforced concrete like flexure and compressive strength. Tests were conducted to study the flexural and compressive strength of steel fiber reinforced concrete with varying aspect ratio and varying percentage of fiber. It was that the addition of steel fiber into concrete significantly increases the flexural strength. It also indicates that at constant percentage of fiber, that is 1.5% by increasing the aspect ratio of fiber from 40 to 70, flexural strength increased from 36.7% to 58.65%

M S Jafri and Mohd Israil (2015) [5] This study is to investigate the behaviour of composite beams of M20 Grade of concrete mix with varying percentages of fiber content under a combined state of flexure and direct compression. These beams were tested as simply supported beams in flexure along with direct compression of 0, 50, 100, and 125 KN. It has been observed that the value of ultimate bending strength and deflection increases with the increase in the value of compression for a particular percentage of fiber content. The ductility increases as the value of compression increases for a particular percentage of fibers.

Karthik, M.Kalaivani, P. Easwaran (2016) [6] The addition of fiber in the concrete mix improves the monotonic flexural strength, flexural fatigue strength, impact strength, shock resistance, ductility, and flexural toughness in concrete, besides delaying and arresting crack proportion. Fatigue is described by a parameter, which essentially represents the number of cycles the material can withstand under a given pattern of repetitive loading, before falling.

3. EXPERIMENTAL PROGRAMME:

Experimental program has been executed to ascertain the behaviour of SFRC with varying composite mixes and percentages of fibers. The experiments were conducted on the standard cube (150mm x 150mm x150mm), standard cylinders (150mm diameter and 300mm long) and composite rectangular beams of cross section 14.14cm X 7.07 cm and 50cm long. These specimens were casted with M20 concrete mix with different percentage of fibers i.e. 0%, 0.5%, 0.75% and 1% by volume. All the SFRC beam specimens were tested under combined loading of flexure, compression and shear. The ultimate load and deflections data was recorded for different value of compression of 0.0, 40 kN, 50 kN, and 60 kN.

3.1 Properties of Concrete Constituents

The properties of the constituents of concrete were determined in the laboratory to ensure that they may confirm to the specified requirement as per relevant to achieve necessary standard of performance.

3.1.1 Cement

Ordinary Portland cement of 43 grade was used in the experimental investigation. The IS 4031: (1999) have been strictly adhered to during the investigation. The experimental values are as given in Table -1.

3.1.2 Fine Aggregate

The coarse sand as fine aggregate used was locally available lying in grading zone II. The specific gravity and fineness modulus were determined as 2.45 & 2.83 respectively. The test procedures as mentioned in IS 383: (1970) were followed to determine the properties of fine aggregate.

3.1.3 Coarse Aggregate

Crushed stone aggregate of 10 mm and 20 mm was used as coarse aggregate which was locally available and mainly quartzite in mineralogical composition. The fineness modulus and specific gravity of 10 mm and 20 mm aggregate as determined as per IS code is given in table – 2.

TABLE – 1

S. No.	Experimental parameters	Results	Recommended Values
1	Normal Consistency	29.5%	30%
2	Setting Time: a.Initial setting time b.Final setting time	34 Minutes < 600 Minutes	30 Minutes 600 Minutes
3	Specific gravity	3.15	3.15
4	Soundness (by Le-Chatelier's Test)	2 mm	10 mm (max)
5	Compressive strength: c.At 7 days d.At 28 days	21 MPa 40 MPa	33MPa 43 MPa

TABLE – 2

S.No.	Size of stone Aggregate	Results	
		Fineness Modulus	Specific gravity
1	10 mm	2.92	2.98
2	20 mm	2.60	2.64

3.1.4 Water

As per recommendation of IS: 456 (2000), the water to be used for mixing and curing of concrete should be free from deleterious materials. Potable water was used in the present study in all operations demanding control over water quality.

3.1.5 Steel Fibers

Steel wires as available in the market were used as fibers and cut in the length of 2.8 cm (0.28 mm diameter & aspect ratio 100) and mix in the concrete in the proportion of 0%, 0.5%, 0.75% and 1.0% by volume.

3.2 Mix Design Procedure

As per guidelines of IS: 10262 [1982], the normal strength concrete mix (M20) was prepared. To obtain normal strength fibrous concrete Plain steel fibers were added at the rate of 0%, 0.5%, 0.75% and 1.0% by volume to the normal strength mixes to obtain normal strength fiber reinforced concrete. The acceptance criterion of concrete mix is its workability in fresh state and compressive strength after 28 days of curing.

3.3 Specimens

Compressive strength of concrete for various fiber contents was evaluated using cubes of 150x150x150 mm and cylinders of 150 mm diameter and 300 mm height. The flexural strength of concrete at various fiber contents was evaluated by casting and testing 36 SFRC rectangular beams. The beams of rectangular molds are of 14.14cm X 7.07 cm in cross section and 50 cm long.

3.4Mixing, Casting and Curing

The constituents of concrete were tested in the laboratory to confirm the suitability of ingredients and when the design mixes were found satisfactory, the casting the cubes and cylinders was taken up. Equipment's as available in the laboratory were used in the completing of the experimental program. The mixing of the concrete was carried over as per IS-10262: (1982). After casting the specimens were taken out from molds after 24 hours and then the marking on the specimen was done. Now the specimens were put under water in curing tank for a period of 28 days. The concrete specimens were taken out after 28 days and dried sufficiently and were tested at room temperatures.

The coarse aggregates which were free from silt etc. were mixed with the fine aggregate. The fibers were then sprinkled gradually over the above mix by hand so that the fibers distributed equally in whole of the mix. By doing this balling of fibers in the mix was avoided. This SFRC was then filled in three layers in all molds. The compaction of concrete was performed using a platform vibrator with speed range of 12000 ± 400 rpm, and amplitude of 0.555 mm. About half an hour after casting, the surface was smoothened with trowel.

The beams were taken from the molds 24 hours after casting and then marking the specimens was done. Now the specimens were put under water for a period of 28 days for curing. After 28 days, the concrete specimens were taken out and dried sufficiently and were tested under room temperatures. The beams were tested under two point load arrangement and the load and central deflection was recorded.

3.5 Testing of Specimens

The experiment involves the assessment of the compressive as well as flexural behaviour of plain and fiber reinforced concrete.

3.5.1 Measurement of Flexural Behaviour of SFRC Beams

The fiber reinforced concrete beams after leveling were tested under two point loads to achieve pure bending. The load and central deflection were recorded. Central deflection was read using dial gauges on both sides supported on a plate. The central deflection was measured in the area of pure bending. The dial gauges having least count of 0.01mm were used for the measurement of deflection at center and at one-third span. Load was applied using hydraulic jack of 500kN capacity. Fig. 1 & 2 shows the details of the setup for combined state of Flexure, Compression and Shear and location of dial gauges.

4. RESULTS AND DISCUSSION

A. Behaviour of SFRC Cubes under Compression:

The study involves the testing of M20 grade concrete with varying percentage of fiber content varying from 0 to 1.0 percent (0, 0.5, 0.75 and 1.0%) by volume. The cubes were tested under uniaxial compression and the compressive strength is found to be increased by 2.54%, 6.02% and 8.43% respectively when 0.5%, 0.75% and 1% by weight fibers were added over the cubes without fibers. Combined load deflection curve for different percentage of fibers are shown in fig. 3.

B. Behaviour of SFRC Cylinders in Splitting Tensile Strength Test:

Splitting tensile tests were performed on cylinders of 150 mm diameter and 300 mm height. The study involves the testing of M20 grade of SFRC with varying percentage of fiber content varying from 0 to 1.0 percent (0, 0.5, 0.75 and 1.0%). When 0.5%, 0.75% and 1% of fibers were added to concrete the corresponding percentage increase in split tensile strength is 8.33%, 22.92% and 33.33% respectively over that of without fibers. Similarly the corresponding percentage increase in peak tensile strain is 66.27%, 88.95% and 160.62% respectively for 0.5%, 0.75% and 1% of fibers. Combined load deflection curve for different percentage of fibers are shown in fig. 4.

Fig. 1: Testing of SFRC under combined state

Fig. 1: Testing of SFRC under combined state of of flexure, compression and shear

Fig. 2:Testing of SFRC under combined state of of flexure, compression and shear front view

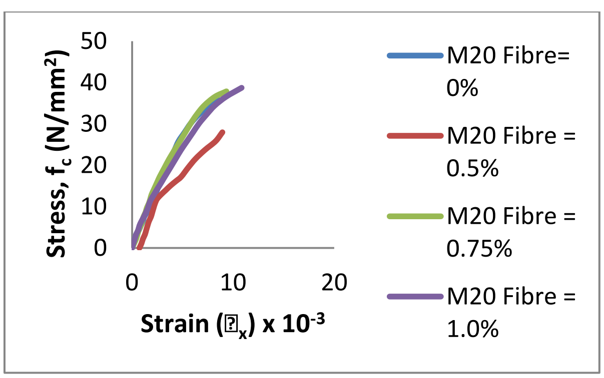

Fig. 3: Combined stress strain curve for M20 cubes added with different fibre content

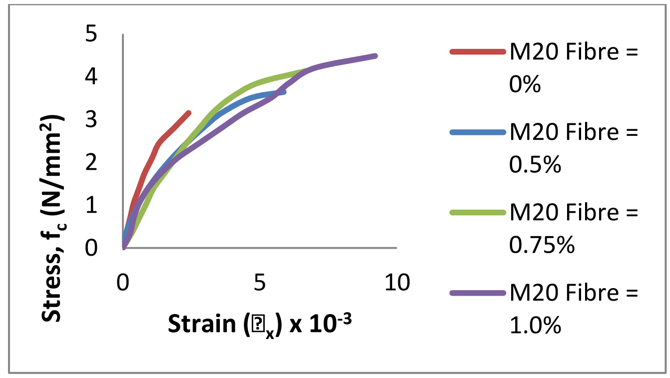

Fig. 4: Combined stress strain curve for M20 cylinders added with different fibre content

C. Behaviour of SFRC beams under combined state of flexure, tension and shear:

Four different values of compression were used to evaluate the flexural behaviour of SFRC beams under compression and shear. These magnitudes of the load were 0, 40, 50 and 60 kN. As for the other beams with fibers 0.0, 0.75 and 1.0% the beams with 0.5 % fibers when subjected to a tension of 0.0kN was found to carry an ultimate bending stress of 3.96 MPa and failed at a central deflection of 0.390 mm. When the value of tensile load was increased to 40 kN, the beams failed at an ultimate bending stress of 17.53 MPa and at an ultimate deflection of 4.29 mm. Further on subjecting the beams to a tensile load of 50 kN, the load carrying capacity of the beams further increases to 21.9MPa. The deflection in these specimens was observed to be 4.8 mm at failure. The load carrying capacity again increased to 24.75 MPa with the deflection rising to5.23 mm on raising the compressive load to 60 kN. The Load Deflection curves for 0.5 % fibers with different values of compression are shown in Fig. 5.

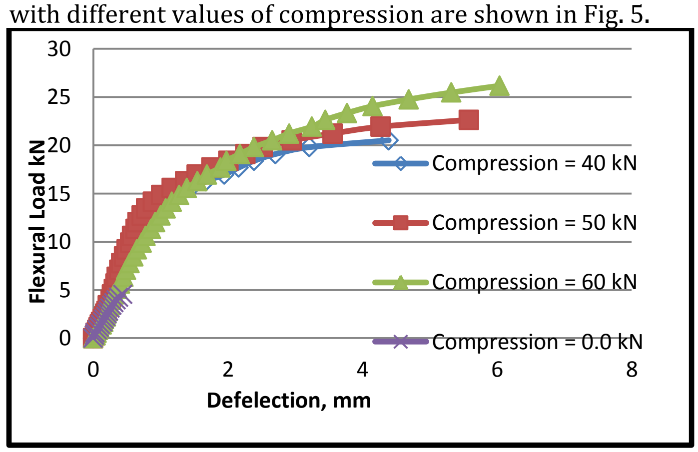

Fig. 5: Load Deflection Curves for 0.75% Fiber with Different values of tcompression

CONCLUSIONS

On the basis of limited experimental investigation undertaken, following conclusions were drawn:

1. In all the beams tested for combined effect of flexure, compression and shear the ultimate bending stress and ultimate central deflection increases as the compression increases for a particular percentage of fibers.
2. For every value of direct compression, the value of ultimate flexural stress increases as the percentage of fibers increases upto 0.75% but on further addition of fibers, the ultimate bending stress decreases for all values of direct compressions.
3. However in the beams without compression the ultimate bending stress and central deflection increases with increase in the fiber content even after 0.75%.
4. The value of central deflection at ultimate load increases with the increase of percentage of fibers for a particular value of compression in the beams.
5. For compression of 40 kN the value of bending stress increases from 15.560 N/mm^2 to 20.510 N/mm^2 by a maximum of 31.81% as the fiber content is increased from 0.0 to 0.75% but on further increase in fiber content, it decreases.
6. For fiber content 0.75%, the value of ultimate bending stress increases from 4.526 N/mm^2 to 26.168 N/mm^2 by a maximum of 478.17% when the value of direct compression was 60 kN and its central deflection also increases the most at this point from 0.44 mm to 6.04 mm by 1272.73%.

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