PERFORMANCE OF SFRC BEAMS UNDER COMBINED STATE OF FLEXURE, DIRECT COMPRESSION AND SHEAR

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***ABSTRACT**: In recent years, considerable work has been performed on steel fibers to increase the load carrying capacity of concrete members. Fiber reinforcement is in the form of short discrete fibers, they act effectively as rigid inclusions in the concrete matrix. Debonding and pulling out of fibers require more energy, giving a substantial increase in toughness and resistance to cyclic and dynamic loads. Fibers substantially reduce the brittleness of concrete and improve its engineering properties, such as tensile, flexural, impact resistance, fatigue, load bearing capacity after cracking, toughness etc. The influence of steel fibers on flexural strength is much greater on tensile strength. Behaviour of SFRC in compression and flexure is already studied separately but no work is reported on the behaviour of SFRC in combined state of Flexure and compression in general by now.*

KEYWORDS-SFRC (Steel Fibre Reinforced Concrete), Flexure, Aspect Ratio

1. INTRODUCTION

Fiber addition modifies the fracture process of concrete and can be considered to act on the material and structural scale. The mode of action on a material scale involves the fibres acting as crack arrestors thus increasing the required energy for crack propagation. On a structural scale, the fibres span across cracks and transmit tensile stress across the cracks even when the crack bridging capacity by aggregates have failed thus providing structural stability. The result of this mechanism is an increase in the ductility of the structure. The sudden brittle failure associated with unreinforced plain concrete is avoided and the structure is able to bear loads.

When loaded, FRC first exhibits an approximately linear response before reaching its tensile strength. After cracking, the load deflection response becomes highly non-linear with the shape of the load-deflection curve and depends upon the type of fibre, fibre geometry, number of fibers, the orientation with respect to the crack faces, and the pull out behaviour. This is observed when carrying out closed-loop compression tests, uni-axial tests or flexural tests on FRC. The fiber reinforcement may be used in the form of three – dimensionally randomly distributed fibers throughout the structural member when the added advantages of the fibre to shear resistance and crack control can be further utilized. On the other hand, the fibre concrete may also be used as a tensile skin to cover the steel reinforcement when a more efficient two – dimensional orientation of the fibers could be obtained.

2. LITERATURE REVIEW

Shende, Pande, Gulfam Pathan [1] observed that compressive strength, split tensile strength and flexural strength are on higher side for 3% fibres as compared to that produced from 0%, 1% and 2% fibres. Result data clearly shows percentage increase in 28 days Compressive strength, Flexural strength and Split tensile strength for M-40 Grade of Concrete.

Chen S. [2] investigated the strength of 15 steel fibre reinforced and plain concrete ground slabs. The slabs were 2mx2mx0.12m, reinforced with hooked end steel fibres and mill cut steel fibres.

Rossi et al [3] analyzed that the effects of steel fibres on the cracking at both local level (behaviour of steel fibres) and global level (behaviour of the fibre/cement composite) were dependent to each-other.

Sharma et al [4)] suggested that steel fibres are effective in increasing the shear strength of concrete. Fibre reinforced concrete has more ductility and significant amount of energy absorption than normally reinforced concrete beams. SFRC beams have high post cracking strength, which is a desirable characteristic in design. The presence of fibres in concrete resists and allows more uniform cracking.

Swami and Saad [5] had done an investigation on deformation and ultimate flexural strength in the reinforced concrete beams under 4 point loading with the usage of steel fibres, where consists of 15 beams (dimensions of 130×203×2500mm^3) with same steel reinforcement (2Y-10 top bar and 2Y-12 bottom bar) and variables of fibers volume fraction (0%, 0.5% and 1.0%).

3. EXPERIMENTAL PROGRAM

To ascertain the flexural behavior of steel fiber reinforced concrete beams when the beams are under combined state of shear and compression, the experiments are conducted on concrete mixes with different percentages of fibers 0%, 0.5%, 0.75% and 1.0% by volume. The experiments involved the evaluation of the flexure and shear strength of concrete beams with different values of compression 0, 50, 100 and 125 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.

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

For the assessment of compressive strength of concrete at various fibre contents cubes of 150x150x150 mm and cylinders of 150 mm diameter and 300 mm height were cast. For the assessment of flexural strength of concrete at various fibre content 36 SFRC circular cross section beams were casted. The cylindrical moulds of beams of 100 cm^2 cross section area and 50 cm in length were used

3.4 Mixing, Casting and Curing

After the preliminary tests on the constituents of concrete confirmed, the suitability of ingredients and the design mix was found satisfactory, the task of casting the beams, cubes and cylinders was taken up. The available laboratory equipments were utilized in the accomplishment of this experimental program. The guidelines in the IS: 10262 [1982] were strictly adhered to in the process of mixing of concrete. The coarse aggregate which was free from silt etc. was mixed with the fine aggregate. The fibers were added gradually during mixing fibrous concrete mixes. The process of mixing was performed by hand mixing. The compaction of concrete was performed using a platform vibrator with speed range of 12000 ± 400 rpm, and amplitude of 0.555 mm. The concrete was filled in three layers in all moulds. About half an hour after casting, the surface was smoothened with trowel. The beams were de-moulded 24 hours after casting and after labeling 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 central deflection was noted.

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 were tested under two point loading to determine their central deflection using a plate to support the dial gauges on both sides. To achieve a condition of pure bending the, the beams were very carefully leveled and the loads were applied exactly at one-sixth of the span on both sides from the centre of the beam. 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 centre and at one-third span. Load was applied using hydraulic jack of 500kN capacity. Fig. 1 shows the details of the setup for combined state of flexure, compression and shear and location of dial gauges. Fig. 2 shows the tested beam specimen.

4. RESULTS AND DISCUSSION

Behaviour of SFRC beams under combined state of flexure, compression and shear

In the present experimental work the cylindrical beams of cross sectional area 100 cm^2 and length 50 cm were casted with 0.0, 0.5, 0.75 and 1.0 % fibers were used in the casting of beams. Also cubes and cylinders with the above percentage of fibers were casted. These beams were tested under a combined state of flexure, compression and shear. The specimens were fixed on a particular value of compression and then flexure and shear were applied till failure. For testing of beams under combined state of flexure, compression and shear after setting the beam in flexure testing machine, the pre-decided compression was applied on the beam through hydraulic jack and then the flexural load was applied on the beam through hydraulic jack. The readings of dial gauges were recorded against the decided values of flexural loads. In this way for every percentage of fibre three specimens were tested.

Along with these beams, cubes and cylinders were also cast. Cubes were casted and tested to determine the compressive strength of the mixes with different percentages of fibers while the cylinders were used to determine the splitting tensile strength again at different fiber contents. The testing set up for cubes and cylinders is shown in fig. 3. Fig. 4 & 5 shows the stress & strain curve for cubes and cylinders at different percent of fibers. The results obtained after testing the specimens are put forth in the form of tables and their corresponding deflection curves are plotted. Fig. 6 shows Combined Load - Deflection Curves for 0.75% Fiber with different value of compression. Fig. 7 shows relationship between ultimate bending stress & compression with varying percentage of fiber.

Fig 1. Experimental setup for the combined application

Fig. 2 shows the tested beam specimen of flexure, tension and shear

Fig. 3 Arrangement for testing Cylinders for splitting Fig.

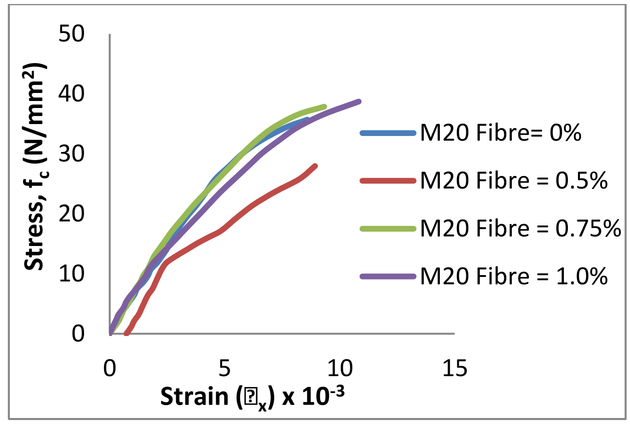

Fig 4: Combined stress strain curve for M20 cubes compressive strength added with different fibre content

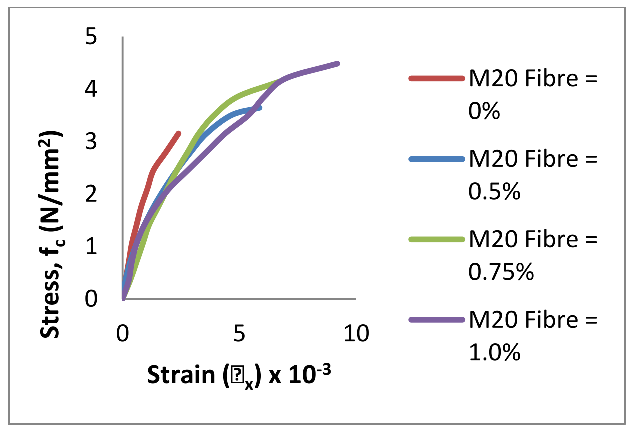

Fig. 5: Combined stress strain curve for M20 cylinders added with different fibre content

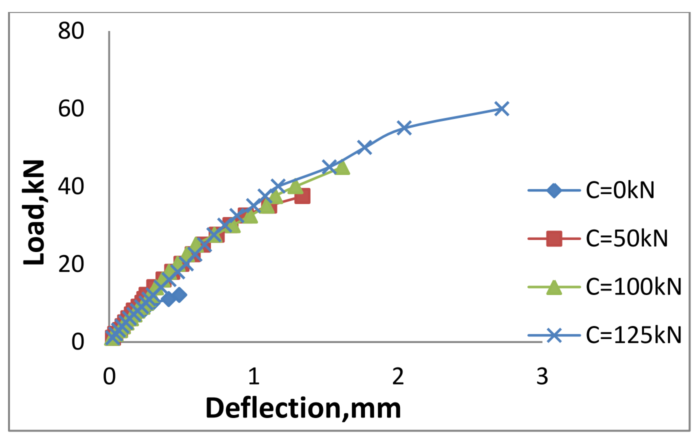

Fig. 6: Combined Load Deflection Curves for 0.75% Fibre with different values of compression

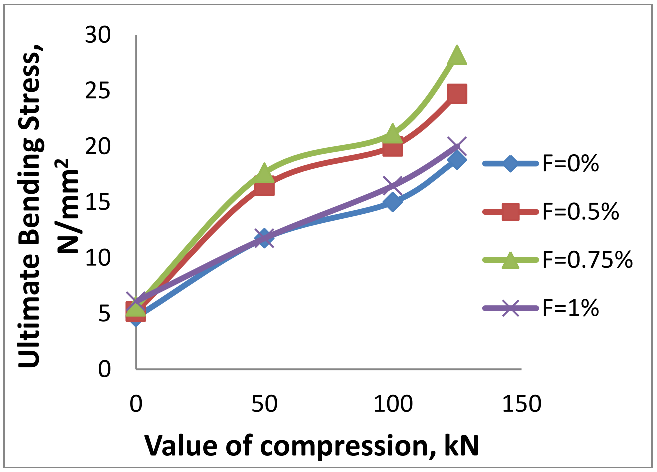

Fig. 7: Ultimate bending stress vs. Compression curve with varying percentage of fibre

5. CONCLUSIONS

On the basis of present experimental investigation undertaken, following conclusions are drawn.

1. In all beams the ultimate bending strength 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 bending strength increases the percentage of fibers increases up to 0.75% but on further addition of fibers, the ultimate bending strength decreases for all values of direct compression.
3. However the beams without compression the ultimate bending strength 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 0.75% of fiber content, the value of ultimate bending strength increases from 5.65MPa to 28.20MPa by a maximum of 399% when the value of direct compression was 125kN and its central deflection also increased the most at this point from 0.485 mm to 2.72 mm (by 460.8%).
6. For a direct compression of 125kN, the value of ultimate bending strength increases from 18.8MPa to 28.20MPa by a maximum of 50% as the percent of fibre content increases from 0 to 0.75% but on further increase in fibre content, it decreases.

6. REFERENCES

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[7] IS: 456-2000 "Indian code of practice for plain and reinforced concrete (Fourth Revision)".

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: a) At 7 days b) 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