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Behaviour of SFRC under the Combined State of Flexure, Torsion and Shear

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Abstract

The objective of this study is to investigate the behavior of cylindrical composite beams of M 20 grade of concrete mix having size 100 × 100 × 500 mm with varying percentage of fibre content under the combined state of flexure, torsion and shear. Straight fibers of length 28 mm and diameter 0.28 mm with aspect ratio of 100 were used. Eighteen beams were cast with 0, 0.40, 0.70 and 1% fibre content each and total of 72 beams were cast. Three beams with a particular percentage of fibers content were tested under a particular value of compression, flexure and shear. Similarly, two beams with a particular percentage of fiber content were tested under particular value of torsion, flexure and shear. The experimental program involved the evaluation of the ultimate load and deflections for all the specimens with different value of compressions 0, 50, 100, 150 KN and torsion by applying the load of 0, 5, 10 and 15 kg at a lever arm of 1.3m which gives torsion of 0, 60.15, 117.48 and 179.63 Nm respectively. For pure bending, the beams were carefully leveled and the loads were applied at exactly one-sixth span on both the sides from the centre of the beam and central deflection was noted by placing two dial gauges on the opposite faces at the bottom Load deflection curves for each fiber content for a particular torsion, ultimate bending stress vs. percentage of fibers for each torsion value were plotted..

Keywords: *Fiber, beam, Concrete, bending stress*

1. Introduction

An extensive experimental program has been executed to ascertain the behaviour of steel fiber reinforced concrete with varying composite mixes and percentages of fibers. The experiments were conducted on the beams of size 100×100×500mm of concrete mix M20 with different percentage of fibers i.e. 0%, 0.40%, 0.70% and 1% by weight. The experiment was designed to study

(1) Combined effects of flexure, compression and shear
(2) Combined effect of flexure, torsion and shear.

The experimental program involved the evaluation of the ultimate load and deflections for all the specimens with different value of compressions 0, 50, 100, 150 KN and torsion by applying the load of 0,5,10 and 15 kg at a lever arm of 1.3m which gives torsion of 0, 60.15, 117.48 and 179.63 Nm respectively. The description of the aforementioned experimental program is put forth in the chapter under various heads giving insight into the material properties, mix proportions, casting procedure, curing and the testing of created specimens carried out to achieve the objectives.

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2. Properties of Concrete Constituents

2.1 Cement

Ordinary Portland cement of 43 grades was used throughout the experimental investigation.

Table 2.1 The properties obtained by the tests

Characteristics	Experimental values	Recommended values
Specific Gravity	3.15	3.15
Soundness, mm Le Chatelier's test	03	10(max)
Normal consistency (% by weight of cement)	29.5	30
Setting time (minutes) (i) Initial (ii) Final	 34 450	 30(min) 600(max)
Compressive strength (MPa) (i)7-days (ii) 28-days	 27 41	 33 43

2.2 Fine Aggregate

The fine aggregate used was locally available coarse sand. The results of sieve analysis and physical properties are summarized in the Table 2.2:

Table 2.2: Physical properties of fine aggregate

Physical Properties	Observed values	Recommended values
Grading Zone	1	-
Fineness modulus	3.17	2.9-3.2
Specific Gravity	2.59	2.6-2.67

2.3 Coarse aggregate

The observed value for fitness modules for coarse aggregate is 6.11 for 10mm and 8.17 for 20mm.specific gravity is 2.76 and 2.79 respectively.

2.4 Water

As per recommendations 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.

2.5 Steel fibers

Commercially available steel wires were cut in the length of 2.8 cm (0.28 mm dia, aspect ratio = 100) and used as steel fibers in the concrete mix in the proportion of 0, 0.40, 0.70 and 1.0% by weight. .

3. Experimental Work

To design a concrete mix for a desired strength, first we need to decide the constituents of concrete mix such as cement, fine aggregate, coarse aggregate, admixtures etc. and their optimum quantity that will result in achievement of the requisite performance. In general, the acceptance criteria of a concrete mix are its workability in fresh state and compressive strength at the age of 28 days. As per the guidelines of IS-10262: (1982), the normal strength concrete mix M20 was designed. To obtain normal strength fibrous concrete, plain steel fibers were added at the rate of 0.0, 0.40, 0.70 and 1.0% by weight to the normal strength mixes. After the preliminary tests on the constituents of concrete confirmed the suitability of ingredients and the design mix was found to be satisfactory, the task of casting the beams was taken up. Firstly, the coarse aggregate was washed a day before casting in order to make it silt free and was laid to dry. On the following day, the coarse aggregate was found to be satisfactorily moist to prevent absorption of moisture by the aggregate from the water being added to the mix. Next, the coarse aggregate was mixed with the fine aggregate. The fibers were added gradually during mixing in fibrous concrete mixes. The process of mixing was performed by hand mixing. The concrete was filled in three layers in all the moulds. About an hour after casting, the surface was smoothened with a trowel. The specimens were demoulded 24 hours later 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 at room temperatures. The beams were tested under two point loading arrangement and the central deflection was noted.

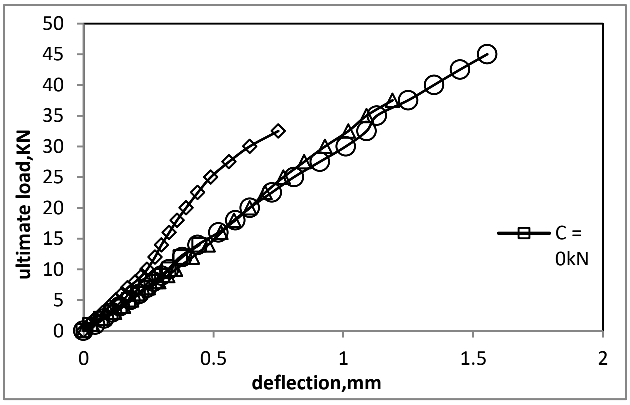
4. Results and Discussion

4.1 Behavior of SFRC Beams without Fibers

Four different magnitudes of compression were used to evaluate the flexural behavior of SFRC beams. These magnitudes were 0, 50, 100 and 125KN. The beam subjected to a compression of 0KN was found to carry an ultimate load of 12 KN and failed at a central deflection of 0.445 mm. When the value of compressive load was increased to 50KN, the beams failed at an ultimate load of 29KN at an ultimate deflection of 0.75 mm. on subjecting the beams to a compression of 100 KN, the load carrying capacity of the beams increased to 37.5KN. The deflection in these specimens was observed to be 1.19 mm. Fig shows the Ultimate load vs. deflection curve for fiber=0.00% with varying compressions value.

Table: 4.1 Values of ultimate bending stress and deflection for 0% Fiber

Compression applied (kN)	Ultimate Load (kN)	Ultimate bending stress, N/mm^2	Central Deflection, mm
0	12	4.85	0.435
50	29	11.55	0.695
100	37.5	14.50	1.25
125	45	18.25	1.535



4.2.1 Behaviour of SFRC Beams With 0.40% Fiber Content

In this case, the fiber content in the beams was taken to be 0.40% of concrete. These specimens were also subjected to four different values of compression ranging from 0KN to 125 KN. When the value of compressive load was 0KN, the beams failed at an ultimate load of 13 KN with an ultimate deflection of 0.5 mm. The load carrying capacity further increased to 42.5KN with the deflection rising to 1.650 mm on raising the compression to 50KN. The beams subjected to a compression of 100KN were found to carry an ultimate load of 50KN and failed at a central deflection of 2.25 mm. On subjecting the beams to a compression of 125 KN, the load carrying capacity of the beams increased to 62KN. The deflection in these specimens was observed to be 2.375 mm.

Table 4.2: Values of ultimate bending stress and deflection for 0.40% Fiber

Compression applied(KN)	Ultimate Load(kN)	Ultimate bending stress,N/mm^2	Central Deflection, mm
0	13	5.152	0.50
50	42.5	17.10	1.62
100	50	20.25	2.20
125	62	24.75	2.375

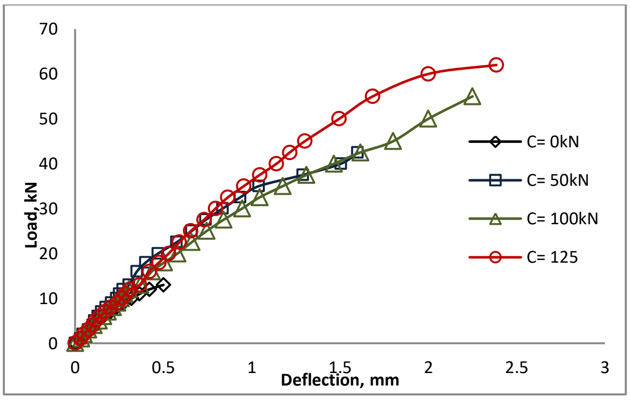


Fig 4.3: Ultimate load vs deflection curve for f=0.40% with varying compressions value

4.2.2 Behaviour of SFRC Beams With 0.70% Fiber Content

Similar to the previous cases, the beams containing 0.70% of fiber were also subjected to a confining compression 0, 50, 100, 125 KN. When the value of compressive load was 0 KN, the beams failed at an ultimate load of 14 KN with an ultimate deflection of 0.59 mm. The load carrying capacity further increased to 45 KN with the deflection rising to 1.885 mm on raising the compression to 50 KN. The beams subjected to a compression of 100 KN were found to carry an ultimate load of 53 KN and failed at a central deflection of 2.50 mm. On subjecting the beams to a compression of 125 KN the load carrying capacity of the beams increased to 66KN. The deflection in these specimens was observed to be 3.25 mm. The Beams carried an ultimate bending stress of 5.25, 17.25, 20.45, 25.65 N/mm^2 at a confining compression of 0, 50,100 and 125KN.

Table 4.4: Values of ultimate bending stress and deflection for 0.70% Fiber

Compression applied (kN)	Ultimate Load (kN)	Ultimate bending stress, N/mm^2	Central Deflection, mm
0	14	5.25	0.585
50	45	17.25	1.875
100	53	20.45	2.505
125	66	25.65	3.252

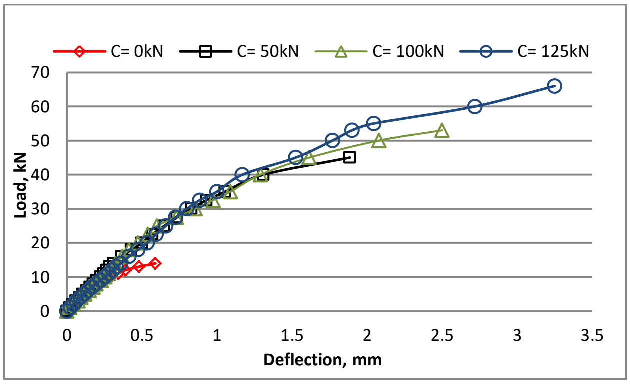


Fig 4.5: Ultimate load vs. deflection curve for f=0.70% with varying compressions value

4.2.3 Behaviour of SFRC beam with 1.0% fiber

Similar to the previous cases, the beams containing 1.0% of fiber were also subjected to a confining compression 0, 50, 100, 125 KN. When the value of compressive load was 0 KN, the beams failed at an ultimate load of 15 KN with an ultimate deflection of 0.68 mm. The load carrying capacity further increased to 29 KN with the deflection rising to 2.2 mm on raising the compression to 50 KN. The beams subjected to a compression of 100 KN were found to carry an ultimate load of 43 KN and failed at a central deflection of 3.15 mm. On subjecting the beams to a compression of 125 KN, the load carrying capacity of the beams increased to 49 KN. The deflection in these specimens was observed to be 3.305mm. The beams carried an ultimate bending stress of 6.15, 10.25, 15.55, 19.75 N/mm^2 at a confining compression of 0, 50, 100 and 125 KN respectively.

Table 4.6: Values of ultimate bending stress and deflection for 1.0% Fiber

Compression applied (KN)	Ultimate Load (KN)	Ultimate bending stress, N/mm2	Central Deflection, mm
0	15	6.15	0.674
50	29	10.25	2.132
100	43	15.55	3.174
125	49	19.75	3.258

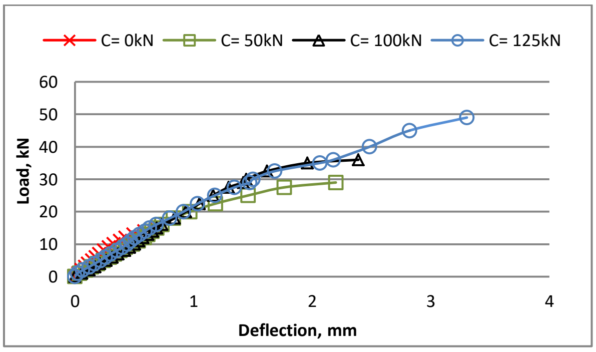


Fig 4.7: Ultimate load vs deflection curve for f=1.00% with varying compressions value

Table 4.8: Values of ultimate bending stress and ultimate central deflection

Percentage of fibers	Compression applied, KN	Load, KN	Central deflection, mm	Ultimate bending stress
0.0	0	12	0.43	4.85
	50	29	0.69	11.55
	100	37.5	1.2	14.50
	125	45	1.5	18.25
0.40	0	13	0.5	5.152
	50	42.5	1.6	17.10
	100	50	2.2	20.25
	125	62	2.3	24.75
0.70	0	14	0.6	5.25
	50	45	1.8	17.25
	100	53	2.5	20.45
	125	66	3.2	25.65
1.00	0	15	0.6	6.15
	50	29	2.2	10.25
	100	43	3.2	15.55
	125	49	3.3	19.75

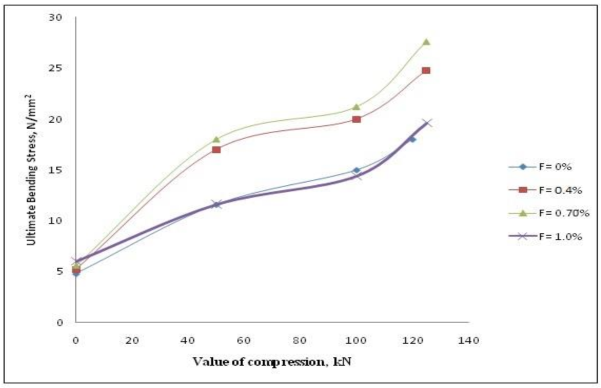


Fig 4.9: Ultimate bending stress vs compression curve with varying fiber values

4.2.4 Behaviour of Beams with Varying Percentage of Fibers at a Particular Compression

Table 4.10: Values of ultimate bending stress and deflection

Compression applied (KN)	Percentage of fibers	Load KN	Central deflection, mm	Ultimate Bending stress, N/mm^2
0	0.0	12	0.435	4.85
	0.40	13	0.541	11.55
	0.70	14	0.584	14.50
	1.00	15	0.648	18.25
50	0.0	29	0.755	5.152
	0.40	42.5	1.625	17.10
	0.70	45	1.885	20.25
	1.00	43	2.241	24.75
		37.5	1.192	5.25
		50	2.254	17.25

Table 4.11: Ultimate Bending stress of beams with varying percentage of fibers at a particular compression

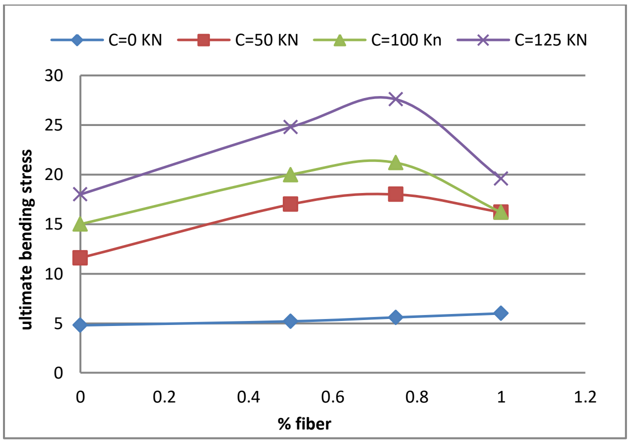


Fig. 4.12 Ultimate bending stress vs. Percentage of fibers curve with varying compression value

Conclusion

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

1) In the beams tested for combined effect of flexure, compression and shear the ultimate bending strength and ultimate central deflection increases as the compression increases for a particular percentage of fibers.
2) For each value of direct compression, the value of ultimate bending strength increases as the percentage of fibers increases up to 0.70 %. But on further addition of fibers, the ultimate bending strength decreases for all values of direct compression
3) However in beams without compression the ultimate bending strength and central deflection increases with the increase in the percentage of fibers even after 0.70%.
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 0.70% fiber content, the value of ultimate bending strength increases from 5.25 MPa to 25.65 MPa by a maximum of 392.85% when the value of applied direct compression is increased from 0 KN to 125 KN.
6) For 0.70% fiber content, the value of central deflection increases from 0.585 mm to 3.252 mm by a maximum of 450.84% when the compression is increased from 0 to 125 KN.
7) For a direct compression of 125 KN, the value of ultimate bending strength increases from 18.25 MPa to 26.6 MPa by a maximum of 51.61% as the percentage of fiber content increases from 0 to 0.70% but on further addition, it decreases.
8) In the beam tested for combined effect of flexure, torsion and shear the ultimate bending stress and ultimate central deflection decreases as the torsion increases for a particular value of fiber.

9) The value of central deflection at ultimate load increases with the increase of percentage of fibers for a particular value of torsion in the beams.
10) For fiber content 1.00%, the decrement in bending stress is maximum which is from 6.0 N/mm^2 to 4.4 N/mm^2 by a maximum of 26.66%, as the torsion applied is increased from 0 Nm to 176.53 Nm.

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