Performance of Steel Fiber Reinforced Self Compacting Concrete

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Abstract:
Construction of durable concrete structures requires skilled labor for placing and compacting concrete. Self Compacting Concrete achieves this by its unique fresh state properties. In the plastic state, it flows under its own weight and homogeneity while completely filling any formwork and passing around congested reinforcement. In the hardened state, it equals or excels standard concrete with respect to strength and durability.

This work is aimed to study the performance of steel fiber reinforced self compacting concrete as plain self compacting concrete is studied in depth but the fiber reinforced self compacting concrete is not studied to that extent.

Key words: Self compacting concrete, fibers, compressive strength, flexure strength.

I Introduction
Though concrete possess high compressive strength, stiffness, low thermal and electrical conductivity, low combustibility and toxicity but two characteristics limited its use are, it is brittle and weak in tension. However the developments of Fiber Reinforced Composites (FRC) have provided a technical basis for improving these deficiencies. Fibers are small pieces of reinforcing materials added to a concrete mix which normally contains cement, water, fine and course aggregate.[1] Among the most common fibers used is steel, glass, asbestos, polypropylene etc. When the loads imposed on the concrete approach that for failure, crack will propagate, sometimes rapidly, fibers in concrete provides a means of arresting the crack growth. If the modulus of elasticity of fiber is high with respect to the modulus of elasticity of concrete or mortar binder the fiber helps to carry the load, thereby increasing the tensile strength of the material. Fibers increase the toughness, the flexural strength, and reduce the creep strain and shrinkage of concrete. [2] Several European countries recognized the significance and potentials of SCC developed in Japan. During 1989, they founded European federation of natural trade associations representing producers and applicators of specialist building products (EFNARC). The utilization of SCC started growing rapidly. EFNARC, making use of board practical experiences of all members of European federation with SCC, has drawn up specification and guide lines to provide a framework for design and use of high quality SCC, during 2002[3].

Self Compacting Concrete has been desired as “The Most Revolutionary Development in Concrete Construction for Several Decades”.

Ii Objective
The objective of this study is to optimize the Steel Fiber Reinforced Self Compacting Concrete (SFRSCC) in the fresh and in hardened state. But the literature indicates that some studies are available on plain SCC but sufficient literature is not available on SFRSCC with different mineral admixtures. Hence an attempt is made in this work to study the mechanical properties of both plain SCC and SFRSCC.

Iii Materials Used
For the present study ordinary Portland cement of 53 Grade, Natural sand from river Godavari (Paithan) confirming IS 383-1970 along with potable water and natural aggregates were used for preparation of concrete.

The super plasticizer used for the present study was supplied by the manufacturer Sika India Pvt. Ltd., Mumbai complies IS: 9103- 1999 (Amended 2003).

The viscosity modifying agent (VMA)was also supplied by the manufacturer Sika India Pvt. Ltd.

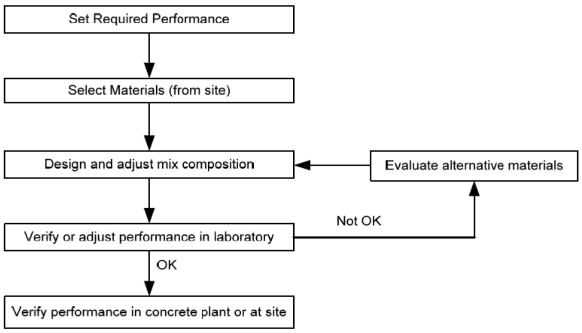
Dramix steel fibers conforming to ASTM A820 type-I are used for experimental work. Dramix RC - 80/60 - BN are high tensile steel cold drawn wire with hooked ends, glued in bundles & specially engineered for use in concrete. Fibers are made available from Shakti Commodities Pvt. Ltd., New Delhi.

Fly Ash (FLA) which is available in dry powder form and is procured from Dirk India Pvt. Ltd., Nashik. It is available in 30Kg bags, color of which is light gray under the product name "**Pozzocrete 60**" was used for the present study.

Iv Methodology
After performing all required tests on the ingredients of concrete such as cement, sand, coarse aggregates etc. mix design for SCC was done.

Mix Design For Scc:-

Rational method is used for mix design of M-30 grade of concrete. The optimum percentage of fly ash to give maximum compressive strength was achieved by making trial mixes with fly ash at a constant interval of 3% by weight of cement. The trial mixes were made for fly ash from 12% to 36%. The compressive strength went on increasing up to 33% at it decreased at 36%. The maximum compressive strength was achieved at 33%. Hence, fly ash at 33% by weight of cement was added to concrete in this experiment. A



Flow-chart describing the procedure for design of SCC mix is

Figure 1: SCC Mix Design Procedure (EFNARC, 2005) [3].

shown in figure No.1

At the end after performing the entire test following mix proportion was used for the present study.

The quantity of ingredient materials and mix proportions as per EFNARC guide lines is shown in the Table No.1.

Table1 Quantity of Materials per Cubic Meter of Concrete

Material	Proportion by Weight	Weight in Kg/m^3
Cement	1	450.00
F.A.	2.18	983.63
Fly ash	0.33	148.50
C.A. (<12 mm)	1.78	803.00
W/C	0.40	180.00

After finalizing the proportion of ingredients following mix proportions with different designations according to Steel Fiber content were used. The details are shown in Table No.2

Table No.2 Mix Designations Used

Sr.no.	Mix designation	FLA (%)	Steel Fiber content (%)	W/C ratio
01.	M0	33.0	0.0	0.40
02.	M1	33.0	0.5	0.40
03.	M2	33.0	1.0	0.40
04.	M3	33.0	1.25	0.40
05.	M4	33.0	1.5	0.40
06.	M5	33.0	1.75	0.40
07.	M6	33.0	2.0	0.40
08.	M7	33.0	2.25	0.40
09.	M8	33.0	2.5	0.40
10.	M9	33.0	2.75	0.40
11.	M10	33.0	3.0	0.40

TEST SPECIMENS USED FOR THE STUDY:-

The specimens used were cubes, beam specimens. Dimensions of each test specimen are as under:
Cube: 100 mm x 100 mm x 100 mm
Beam: 100 mm x 100 mm x 500 mm
Above specimens were used to determine the compressive strength test and flexural strength test respectively.

V Test Results and Discussion.

Compressive Strength Test on Cube

A cube compression test was performed on standard cubes of plain and SFRSCC of size 100 x 100 x 100 mm after 7 days and 28 days of immersion in water for curing. Results are shown in Table No.3 and graphical presentation between compressive strength and percentage fiber volume fraction is shown in graph No.1.(Appendix I)

Table N0.3 Compressive Strength of Normal SCC and SFRSCC, MPa

Sr. No.	Fiber Content (%)	Compressive Strength (f_{cu}) MPa		% Variation in Compressive Strength Over Control Concrete	
		7 Days	28 Days	7 Days	28 Days
01.	0	35.55	45.63	00.00	00.00
02.	0.5	35.75	48.41	0.619	6.092
03.	1.0	36.92	50.33	3.854	10.256
04.	1.25	37.03	52.14	4.163	14.267
05.	1.5	37.85	54.95	6.469	20.425
06.	1.75	38.92	57.38	9.479	25.751
07.	2.0	39.49	61.75	11.083	35.328
08.	2.25	39.68	63.82	11.617	39.864
09.	2.5	40.84	65.89	14.880	44.401
10.	2.75	41.97	68.97	18.059	51.151
11.	3.0	43.14	70.04	21.350	53.496

Flexural Strength Test on Beam:

Flexural strength is obtained for various fiber volume fractions and results are presented in Table No. 4 and the variation of flexural strength with respect to fiber volume fraction is shown in Graph
No.2 (Appendix I)

Table No.4 Variation of Flexural Strength Normal SCC and SFRSCC, MPa

Sr. No.	% of Steel Fiber	Flexural Strength in N/mm^2		% variation in Flexural Strength Over Control Concrete	
		7 days	28 days	7 days	28 days
01	0	4.31	5.29	0.000	0.000
02	0.5	4.46	5.55	3.48	4.91
03	1.0	4.63	5.86	7.42	10.77
04	1.25	4.74	5.94	9.97	12.28
05	1.5	5.02	6.13	16.47	15.87
06	1.75	5.41	6.32	25.52	19.47
07	2.0	5.45	6.44	26.45	21.73
08	2.25	5.60	6.48	29.93	22.49
09	2.5	5.74	6.68	33.17	26.27
10	2.75	6.02	6.97	39.67	31.76
11	3.0	6.11	7.14	41.76	34.97

Discussion on Test Results:

Results of compressive strength are shown in Table 3. It indicates the optimum volume fraction of fibers which gives maximum strength at 28 days is 3.0%. The percentage increase in strength at this volume fraction of fibers over normal SCC at 7 and 28 days is 21.35% and 53.49% respectively. Cracks occur in microstructure of concrete and fibers reduce the crack formation and propagation. Also fly ash improves the microstructure of concrete. Here, this might be the reason for the enhancement of compressive strength.

From above Table 4, it is observed that the flexural strength increases with increase in fiber content up to 3.0%. The maximum values at 7 and 28 days are 6.11 and 7.14 respectively. Thus, there is enhancement in flexural strength of concrete from 3.48% to 41.76% at 7 days and from 4.91% to 34.97% at 28 days.

Vi Conculsions

Following conclusion are drawn based on the result discussed above

1. In general, the significant improvement in various strengths is observed with the inclusion of Hooked end steel fibres in the plain concrete. However, maximum gain in strength of concrete is found to depend upon the amount of fibre content. The optimum fibre content to impart maximum gain in various strengths varies with type of the strengths.
2. In general the compressive strength and the flexural strength increase with increase in the percentage of fibre content.
3. In addition to the compressive strength and the flexural strength on the concrete split tension test was also performed on the SFRSCC the results of which are not mentioned in the paper (because the scope is limited to compressive and flexural strength of the SFRSCC) and it was found that the split tensile strength went on increasing with the addition of fibers. The optimum fiber content for increase in split tensile strength is 1.75% and percentage increase is 24.49% of SFRSCC over normal SCC.
4. The increase in compressive strength is 25.75% and increase in flexural strength is 19.47% of SFRSCC over normal SCC for the fibre content of 1.75%.
5. Satisfactory workability was maintained with increasing volume fraction of fibers by using super plasticizer.
6. With increasing fiber content, mode of failure was changed from brittle to ductile failure when subjected to compression and bending.

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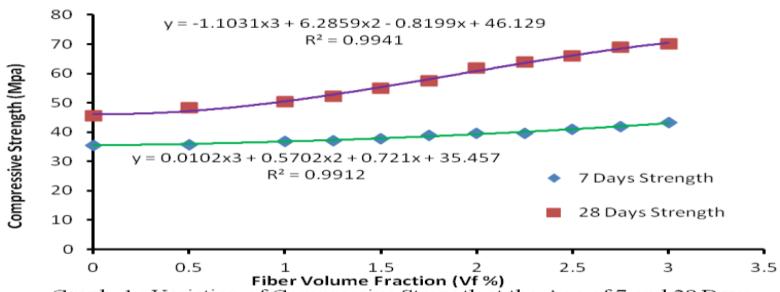
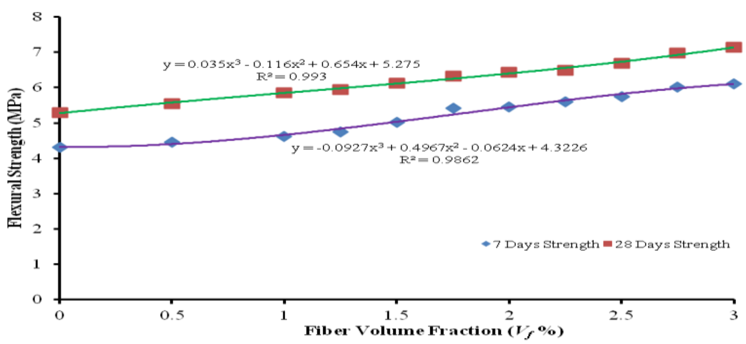
APPENDIX-I



Graph 1 : Variation of Compressive Strength at the Age of 7 and 28 Days with respect to Percentage Fiber Volume Fraction



Graph 2 : Variation of Flexural Strength at The Age of 7 and 28 Days with respect to Percentage Fiber Volume Fraction