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Study on Compressive Behavior of Steel Fiber Reinforced Concrete

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Abstract : *Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Addition of closely spaced and uniformly dispersed fibers to concrete acts as crack arrestor and substantially improves its static and dynamic properties. This paper presents effect of reinforcing index on mechanical properties of fiber reinforced concrete such as density, workability, compressive strength and split tensile strength. The reinforcing index is defined as product of volume fraction and aspect ratio of fiber, aspect ratio of the fiber is the ratio of its length to its diameter. Cube and cylindrical specimens have been designed with steel fiber reinforced concrete containing fibers of 0.3, 0.7, 1.1% volume fraction of hooked end steel fibers of 65 and 80 aspect ratio. The test results indicated that the compressive strength of SFRC with two different aspect ratios at same volume fraction shows same value, but the tensile strength of SFRC increased with the increase in aspect ratio of fiber. Addition of fiber to the concrete affects the workability of concrete and is overcome by using superplasticiser.*

Keywords: *Reinforcing index, Aspect ratio, Hooked end fibers, Compressive strength, Split tensile strength.*

1. INTRODUCTION

The weak matrix in concrete, when reinforced with steel fibers, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete[2]. Because of the vast improvements achieved by the addition of fibers to concrete, there are several applications where Fibers Reinforced Concrete (FRC) can be intelligently and beneficially used. These fibers have already been used in many large projects involving the construction of industrial floors, pavements, highway-overlays, etc. The principal fibers in common commercial use for Civil Engineering applications include steel, glass, carbon and aramid. These fibers are also used in the production of continuous fibers and are used as a replacement to reinforcing steel. High percentages of steel fibers are used extensively in pavements and in tunneling. This invention uses Slurry Infiltrated Fiber Concrete (SIFCON). Fibers in the form of mat are also being used in the development of high performance structural composite. Continuous fiber-mat high performance fiber reinforced concrete (HPFRCs) called Slurry Infiltrated Mat Concrete (SIMCON) is used in the production of High performance concrete. Use of basalt fibers are picking up in western countries. Steel fibers are also used in the production new generation concretes such as Reactive Powder Concrete (RPC), Ductal and Compact Reinforcing Concrete (CRC)

2. TEST PROGRAMS

This section presents the experimental details and typical test data for concrete reinforced with different fibers.

2.1 Materials

Portland cement with specific gravity of 3.15, coarse aggregate was crushed stone with a maximum size of 20 mm and a bulk saturated surface-dry (SSD) specific gravity of 2.67. The fine aggregate was river sand with a fineness modulus of 2.77 and a bulk SSD specific gravity of 2.59. A polycarboxylic acid-based type G superplasticizer with a specific gravity of 1.04 was used to increase the workability of concrete. The steel fibers used in this study, with a tensile strength of 1,000 MPa, were hooked at both ends. A total of two types of steel fiber were studied. Fibers SFA and SFB were studied for volume fraction of fibers of 0.3, 0.7, 1.1%. The reinforcing index RIv is defined by RIv = Vf l/ϕ in which RIv= reinforcing index; Vf = volume fraction of fibers; and l and ϕ = length and diameter of fibers, respectively

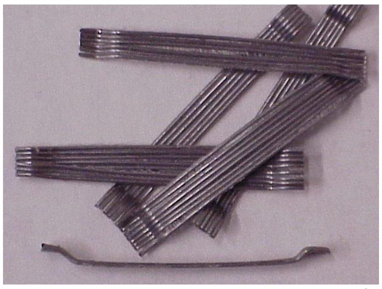

Figure 2.1 Collated hooked end steel fibers

Table 2.1 Details of fibers

Fibre	Designation material	Aspect ratio	Length of fiber (mm)	Shape of fibre
SF A	Steel(wire)	65	35	Hooked ended,collated
SF B	Steel(wire)	80	60	Hooked ended,collated

.

2.2 Concrete Mix Proportions

Table 2.2 Mix design of concrete matrix

Components	Quantity (Kg/m³)
Water	175.58
Cement	390.17
Coarse Aggregate	795.65
Fine Aggregate	976.56
W/C Ratio	0.45

2.3 Mixing procedure

Mixing was performed using a horizontal shaft mixer. First, coarse and fine aggregates were mixed for 1 min. Cement is then added and mixing was continued for another minute. Next, water and superplasticizer were slowly added to the mixer, and mixing was continued for another 2 min. Next, steel fibers were added, and mixing was continued for another minute. No segregation, bleeding of concrete, balling of fibers was observed in the mixes considered herein.

2.4 Methodology

Details of the standard test specimens, namely, cubes, cylinders are given in Table2.4. Five specimens each were casted using concrete of 35 MPa and tested. All the specimens were cured in water for a period of 28 days and then tested. The cube and cylinder specimens were tested to determine the compressive strength according to IS: 516 (BIS 1959). Cylinder specimens were tested for split tensile strength according to IS: 5816 (BIS 1999).

Table 2.4 Specimens for the assessment of strength properties of SFRC

Strength property	Specimen	Dimension	Number of specimens for each mix
Cube compressive strength	Cube	150x150x150	5
Split tensile strength	cylinder	150Φx300	5

2.5 Results and Discussion

The details of the mixes, the fresh concrete properties and the compressive strength and tensile strengths of SFRC are given in table2.5.1 and 2.5.2. The fiber dosages ranges between 30 and 90 kg/m³ (0.3, 0.7, 1.1% volume fraction), which is the typical range for applications such as pavements and industrial floors. It can be seen that all the unit weights of the concretes in the fresh state are in the range 0f 2300-2500 kg/m³. The density was not affected by the aspect ratio of steel fiber. The fresh concrete density was mainly affected by fiber volume fraction. It was possible to get required slump of about 50-100mm in all the cases by adjusting the superplasticizer dosage.

Figure 2.5.1 Slump cone test

Table 2.5.1 Fresh properties of concrete

Mix ID	Fiber type	Fiber dosage (kg/m³)	Unit weight of fresh concrete (kg/m³)	Slump (mm)
M30SFA30	SFA	30	2404	112
M30SFA60	SFA	60	2416	92

M30SFA90	SFA	90	2440	70
M30SFB30	SFB	30	2404	107
M30SFB60	SFB	60	2428	84
M30SFB90	SFB	90	2452	65
M30SF0	-	-	2392	130

Table 2.5.2 Compressive strength of different mixes

Mix ID	Fiber type	Fiber dosage (kg/m³)	Compressive strength (MPa)	
			7 days	28 days
M30SFA30	SFA	30	40.97	51.22
M30SFA60	SFA	60	39.37	50.48
M30SFA90	SFA	90	37.83	49.14
M30SFB30	SFB	30	40.79	50.36
M30SFB60	SFB	60	39.53	50.68
M30SFB90	SFB	90	40.15	50.83
M30SF0	-	-	38.04	46.97

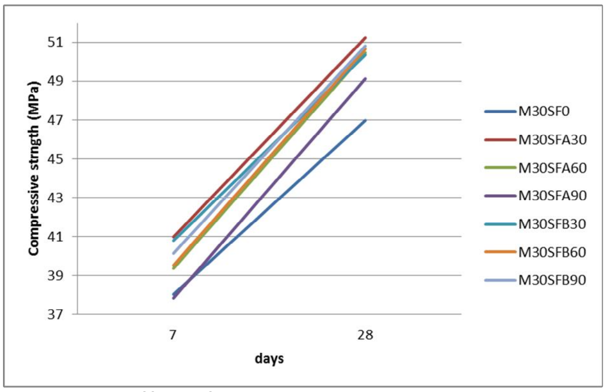

Figure 2.5.2 Effect of aspect ratio on compressive strength of SFRC.

Test results shows that compressive strength varied from 46.97 to 51.22 MPa. It clearly demonstrates that the compressive strength increases with increasing fiber volume fraction and aspect ratio. The incorporation of steel fiber into matrix serves to increase the ultimate compressive strength by the resultant arresting growth of cracks based on the bond of steel fiber and cement paste.

Table 2.5.3 Split tensile strength of different mixes

Mix ID	Fiber type	Fiber dosage (kg/m³)	Tensile strength (MPa)
			28 days
M30SFA30	SFA	30	3.37
M30SFA60	SFA	60	4.44
M30SFA90	SFA	90	5.31
M30SFB30	SFB	30	3.45
M30SFB60	SFB	60	4.56
M30SFB90	SFB	90	5.69
M30SF0	-	-	2.74

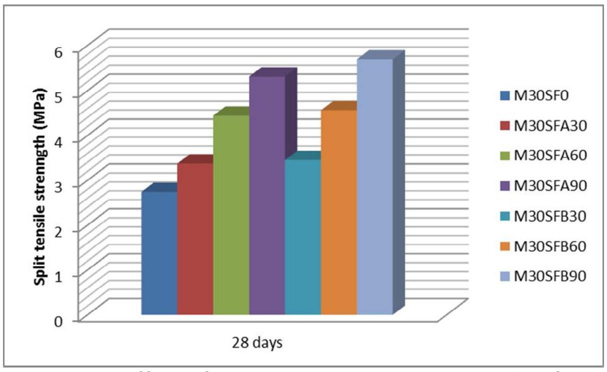

Figure 2.5.3 Effect of aspect ratio on tensile strength of SFRC

Test results shows that tensile strength varied from 2.74 to 5.69 MPa. It clearly demonstrates that the tensile strength increases with increasing fiber volume fraction and aspect ratio. For a lower fiber volume fraction, any improvement in the splitting tensile strength of concrete is hardly effective.

3. CONCLUSION

The following conclusions could be drawn from the present investigation.

1) Compressive strength of SFRC with two different aspect ratios at same volume fraction shows same results with minor increase in value
2) Compressive strength of SFRC with increasing volume of fiber fraction shows same results
3) Tensile strength of SFRC increases with increase in aspect ratio of fiber
4) Tensile strength of SFRC increases with increase in volume of fiber fraction
5) Addition of steel fibers to the concrete effects the workability of concrete and overcome by addition of appropriate dosage of superplasticizer.

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