Investigation of Steel Fiber Reinforced Concrete on Compressive and Tensile Strength

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Abstract

Based on the laboratory experiment on steel fiber reinforced concrete (SFRC), cube and cylindrical specimens have been designed with steel fiber reinforced concrete (SFRC) containing fibers of 0% and 0.5% volume fraction of hook end and crimped round Steel fibers of 50 , 53.85, 62.50 (copper coated) aspect ratio were used without admixture. Comparing the result of SFRC with plain M25 grade concrete, this paper validated the positive effect of steel fiber with 0.5 percentage increases in compression and splitting improvement of specimen at 7 and 28 days, analyzed the sensitivity of steel fiber to concrete with different strength.

Keywords —Compressive strength, Fiber Reinforced Concrete, Steel fiber, Split tensile strength, slump, volume fraction, workability

1. Introduction

Concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This characteristic, which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibers (steel, glass, synthetic and natural) and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, etc. Steel fiber reinforced concrete (SFRC) has the ability of excellent tensile strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest. Therefore, it has been applied abroad in various professional fields of construction, irrigation works and architecture.

Steel fibers intended for reinforcing concrete are defined as short, discrete lengths of steel having an aspect ratio in the range of 20-100, with any cross section and that are sufficiently small to be randomly dispersed in an unhardened concrete mixture using usual mixing procedures. The most significant properties of steel fiber reinforced concrete (SFRC) are the improved flexural toughness, impact resistance and flexural fatigue performance. For this reason SFRC has found applications in flat slabs on grade where it is subject to high wheel loads and impact. There are currently 300,000 metric tons of fibers used for concrete reinforcement. Steel fiber remains the most used fiber of all (50% of total tonnage used) followed by polypropylene (20%), glass (5%) and other fibers (25%) (Banthia ,2012). Steel fiber reinforced concrete under compression and Stress-strain curve for steel fiber reinforced concrete in compression was done by Nataraja.C. Dhang, N. and Gupta, A.P. They have proposed an equation to quantify the effect of fiber on compressive strength of concrete in terms of fiber reinforcing parameter. Mechanical properties of high-strength steel fiber reinforced concrete were done by Song P.S. and Hwang S. They have marked brittleness with low tensile strength and strain capacities of high strength concrete can be overcome by addition of steel fibers. Tdyhey investigated an experimental study were steel fibers added at the volume of 0.5%, 1.0%, 1.5% and 2.0%. The observation indicate that compressive strength of fiber concrete reached a maximum at 1.5% volume fraction, being 15.3% improvement over the HSC. The split tensile and Flexural Strength improved 98.3% and 126.6% at 2.0% volume fraction. Fibers help to improve the compressive strength, tensile strength, flexural strength, post peak ductility performance, pre-crack tensile strength, fatigue strength, impact strength and eliminate temperature and shrinkage cracks. Essentially, fibers act as crack arrester restricting the development of cracks and thus transforming an inherently brittle matrix, i.e. cement concrete with its low tensile and impact resistances, into a strong composite with superior crack resistance, improved ductility and distinctive post-cracking behavior prior to failure. Hence this study explores the feasibility of steel fiber reinforcement; aim is to do parametric study on compressive strength, and tensile strength study etc. with M25 grade of concrete, aspect ratio and percentage of steel.

1.1 Reinforcement Mechanisms in Fiber Reinforced (FRC):

In the hardened state, when fibers are properly bonded, they interact with the matrix at the level of micro-cracks and effectively bridge these cracks thereby providing stress transfer media that delays their coalescence and unstable growth. If the fiber volume fraction is sufficiently high, this may result in an increase in the tensile strength of the matrix [1]. Indeed, for some high volume fraction fiber composite, a notable increase in the tensile/flexural strength over and above the plain matrix has been reported. Once the tensile capacity of the composite is reached, and coalescence and conversion of micro-cracks to macro-cracks has occurred, fibers, depending on their length and bonding characteristics continue to restrain crack opening and crack growth by effectively bridging across macro-cracks. This post peak macro-crack bridging is the primary reinforcement mechanisms in majority of commercial fiber reinforced concrete composites (Banthia N. 2012) [1].

2. EXPERIMENTAL PROGRAMME

2.1 Material Used

In this experimental study, Cement, sand, coarse aggregate, water and steel fibers were used.
Cement: Ordinary Portland cement of 43 grade was used in this experimentation conforming to I.S-8112-1989.

Sand: Locally available sand zone II with specific gravity 2.45, water absorption 2% and fineness modulus 2.92, conforming to I.S. – 383-1970.

Water: Potable water was used for the experimentation.

Steel Fibers: - In this experimentation, two different Hook end Steel fibers were used.

The Steel fibers with aspect ratios, its length and diameter adopted were shown in table 1.

Table 1: Dimensions of steel fibers used:

Notation	Aspect Ratio	Length (mm)	Diameter (mm)	Shape of fiber
SF1	50.0	50	1.0	Hook end
SF2	53.85	35	0.65	Hook end
SF3	62.50	50	0.8	Crimped Round-Copper Coated

2.2 Concrete mix proportions.

Concrete for M25 grade were prepared as per I.S.-10262:2009. A mix proportion of 1:1.508:2.465 with 0.44 water cement ratio to get a characteristic strength of M25 was considered for this study. The exact quantity of materials for each mix was calculated. The constituent of materials used for making the concrete were tested and the results are furnished in Table2. The cement, fine aggregate, coarse aggregate were tested prior to the experiments and checked for conformity with relevant Indian standards. Concrete was mixed using a tilting type mixer and specimens were cast using steel moulds, compacted with table vibrator.
Mix proportion for M25 grade concrete for tested material as follows:

Table 2: Details of Quantity of Constituent Materials

Material	Quantity
Cement	435.45 Kg/ m3
Sand	656.60 Kg/ m3
Coarse aggregates	1073.34 Kg/ m3
Water	192 Kg/ m3
Steel Fibers	0.5% by volume of concrete
Slump	75-100 mm

2.3 EFFECT ON WORKABILITY OF STEEL FIBER:

Slump tests were carried out to determine the workability and consistency of fresh concrete. The efficiency of all fiber reinforcement is dependent upon achievement of a uniform distribution of the fibers in the concrete, their interaction with the cement matrix, and the ability of the concrete to be successfully cast or

sprayed (Brown J. & Atkinson T.2012) [05]. Essentially, each individual fiber needs to be coated with cement paste to provide any benefit in the concrete. Regular users of fiber reinforcement concrete will fully appreciate that adding more fibers into the concrete, particularly of a very small diameter, results in a greater negative effect on workability and the necessity for mix design changes. The slump changed due to the different type of fiber content and form. The reason of lower slump is that adding steel fibers can form a network structure in concrete, which restrain mixture from segregation and flow. Due to the high content and large surface area of fibers, fibers are sure to absorb more cement paste to wrap around and the increase of the viscosity of mixture makes the slump loss (Chen and Liu, 2000)[06].
The consistency and workability of all the concrete mixtures was determined through slump tests. The slump tests were performed according to IS 1199- 1959 [23]. The vertical distance between the original and displaced positions of the centre of the top surface of the concrete was measured and reported as the slump. In this work, 0.5% volume fraction reduces workability of concrete to low workable concrete.

Table 3 shows the slump of plain concrete and SFRC

Concrete	0 %	SF1 (0.5%)	SF2 (0.5%)	SF3 (0.5%)
Slump (mm)	104	80	85	68

3. EXPERIMENTAL METHODOLOGY

3.1 Compressive Strength Test:

For compressive strength test, both cube specimens of dimensions 150 x 150 x 150 mm and cylindrical specimens of length 200 mm and diameter 100 mm were cast for M25 grade of concrete. The moulds were filled with 0% and o.5% fibers. Vibration was given to the moulds using table vibrator. The top surface of the specimen was leveled and finished. After 24 hours the specimens were demoulded and were transferred to curing tank where in they were allowed to cure for 7 days and 28 days. After 7 and 28 days curing, these cubes and cylinders were tested on digital compression testing machine as per I.S. 516-1959. The failure load was noted. In each category, three cubes and three cylinders were tested and their average value is reported.

The compressive strength was calculated as follows:
Compressive strength (MPa) = Failure load / cross sectional area.

3.2 Tensile strength test:

For tensile strength test, cylinder specimens of dimension 100 mm diameter and 200 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 7 and 28 days. These specimens were tested under compression testing machine. In each category, three cylinders were tested and their average value is reported as per IS 5816-1999 [24].
Tensile strength was calculated as follows as split tensile strength:
Tensile strength (MPa) = $2P / \pi DL$,
Where, P = failure load, D = diameter of cylinder,
L = length of cylinder.

4. EXPERIMENTAL RESULTS

4.1 Compressive Strength Test:

4.1.1 Using cube Specimen:

The compressive strength test is consider the most suitable method of evaluating the behavior of steel fiber reinforced concrete for underground construction at an early age, because in many cases such as in tunnels, steel fiber reinforced concrete is mainly subjected to compression [8]

Results of Compressive strength for M-25 grade of concrete on cube and cylinder specimen with 0% and 0.5% steel fibers for SF1, SF2 and SF3 fibers are shown in table 4 and figure 1 below:

Table 4: Results of Compressive strength using cubes specimen

Days	Average Compressive Strength (Mpa)			
	0%	0.5%(SF1)	0.5%(SF2)	0.5%(SF3)
7	27.88	28.79	29.58	32.12
28	36.92	38.46	39.74	43.46

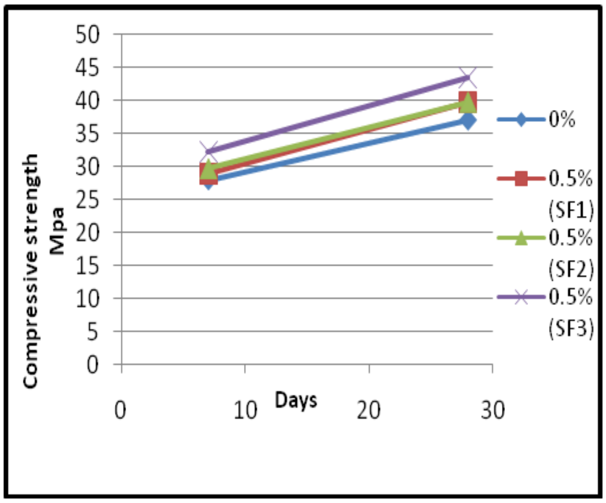

Figure 1: Compressive strength using cube

Figure.1 indicates the comparison of result of compressive strength using cube specimen of M25 grade of concrete. It is observed that for addition of 0.5% Fiber SF3 gives slightly more compressive strength than other type of fiber at same volume fraction.

4.1.2 Using cylindrical Specimen:

Results of Compressive strength for M-25 grade of concrete on cylinder specimen with 0% and 0.5% steel fibers for SF1, SF2 and SF3 fibers are shown in table and Figure below:

Table 5: Results of Compressive strength using cylinder specimen

Days	Average Compressive Strength (Mpa)			
	0%	0.5%(SF1)	0.5%(SF2)	0.5%(SF3)
7	16.04	15.93	17.36	19.86
28	26.69	27.83	28.16	31.47

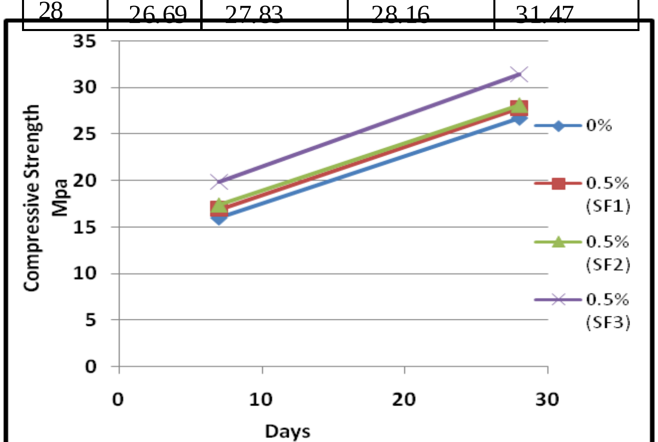

Figure.1 indicates the comparison of result of compressive strength using cylindrical specimen of M25 grade of concrete. It is observed that for addition of 0.5% Fiber SF3 gives maximum compressive strength than other fibers at same volume fraction

4.2 Splitting Tensile Strength Test:

Results of splitting tensile strength for M-25 grade of concrete with 0% and 0.5% steel fibers for SF1, SF2 and SF3 fibers are shown in table and Figure below:

Table 6: Results of splitting tensile strength using cylinder

Days	Average Splitting Tensile Strength (Mpa)			
	0%	0.5%(SF1)	0.5%(SF2)	0.5%(SF3)
7	1.68	1.92	2.05	2.35
28	2.81	3.14	3.42	3.73

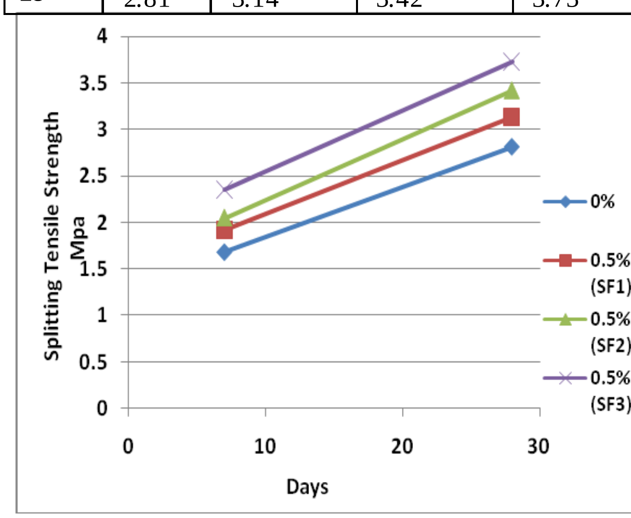

Figure 3: Splitting Tensile strength of Concrete

Figure 3 indicates the result for M25 grade of concrete. It is observed that for addition of 0.5% SF3 fiber gives maximum tensile strength at 28 days.

5. CONCLUSIONS:

The study on the effect of steel Fibers with different aspect ratio (l/d) can still be a promising work as there is always a need to overcome the problem of brittleness of concrete.

The following conclusions could be drawn from the present investigation-

1. It is observed that the compressive strength for M25 grade of concrete from three different cut length fibers at same volume fraction shows nearly same results with minor increase.
2. By addition of 0. 50%, SF3 Fibers shows maximum compressive strength.
3. With same volume fraction, change in length of fiber result nearly minor effect on compressive strength of Fiber Reinforced concrete.
4. It was observed that, the split tensile strength of fiber reinforced concrete was dependent on length of fiber used. By addition of longer length fiber, the split tensile strength increases.
5. By addition of 0. 50%, SF3 Fibers shows maximum split tensile strength over fiber SF1 and SF2.
5. Addition of steel fiber in the concrete effect the workability of concrete. Addition of 0.50% steel Fibers reduces the slump value of fresh concrete. This problem of workability and flow property of concrete can be overcome by using suitable admixtures such as Superplasicizers.

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