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BEHAVIOUR OF STEEL FIBRE REINFORCED CONCRETE UNDER FLEXURAL FAILURE

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Abstract: *Steel fiber reinforced concrete (S.F.R.C) is distinguished from plain concrete by its ability to absorb large amount of energy and to withstand large deformations prior to failure. The preceding characteristics are referred to as toughness. Flexural toughness can be measured by taking the useful area under the load-deflection curve in flexure. Detailed experimental investigation was carried out to determine flexural toughness and toughness indices of SFRC the variables used in investigation were: reinforcement, steel fiber percentage by volume. The aim of this project is to present the findings of the investigation and equations obtained for predicting the desired flexural toughness and in turn the toughness indices for SFRC. These equations are dependent on the ultimate flexural strength, first crack multiple deflections and concrete specimen size. They are independent of the concrete matrix composition.*

The experimental program consists of casting and testing of 3 beams with steel fibers to compare our results with the steel fiber reinforced concrete. The beams used for tests were SFRC beam of size (700 mm x 150 mm x 150 mm) used hook end steel fibers in the concrete for determining flexural strength of concrete . The fiber reinforced concrete beam contains steel fibers in at the rate of 0%, 0.5%, 1%, 1.5% volume fraction of the beams. This experiment requires lots of trail work as I need to find out the maximum strength.

1.INTRODUCTION

Concrete is the most commonly used material in various types of construction, from the flooring of a hut to a multi storied high rise structure from pathway to an airport runway, from an underground tunnel and deep sea platform to high-rise chimneys and TV Towers. In the last millennium concrete has demanding requirements both in terms of technical performance and economy while greatly varying from architectural masterpieces to the simplest of utilities. It is difficult to point out another material of construction which is as versatile as concrete.

Concrete is one of the versatile heterogeneous materials, civil engineering has ever known. With the advent of concrete civil engineering has touched highest peak of technology. Concrete is a material with which any shape can be cast and with any strength. It is the material of choice where strength, performance, durability, impermeability, fire resistance and abrasion resistance are required.

Cement concrete is one of the seemingly simple but actually complex materials. The properties of concrete mainly depend on the constituents used in concrete making. The main important materials used in making concrete are cement, sand, crushed stone and water. The properties of Cement, Sand, crushed stone and water influence the quality of concrete. In addition to these, workmanship, quality control and methods of placing also play the leading role on the properties of concrete.

Fiber reinforced concrete (FRC) is Portland cement concrete reinforced with more or less randomly distributed fibers. In FRC, thousands of small fibers are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties in all directions. FRC is cement- based composite material that has been developed in recent years. It has been successfully used in construction with its excellent flexural-tensile strength, resistance to spitting, impact resistance and excellent permeability and frost resistance. It is an effective way to increase toughness, shock resistance and resistance to plastic shrinkage cracking of the mortar. Fiber is a small piece of reinforcing material possessing certain characteristics properties. They can be circular, triangular or flat in cross-section. The fire is often described by a convenient parameter called ―aspect ratio‖. The aspect ratio of the fiber is the ratio of its length to its diameter.

The principle reason for incorporating fibers into a cement matrix is to increase the toughness and tensile strength and improve the cracking deformation characteristics of the resultant composite. For FRC to be a viable construction material, it must be able to compete economically with existing reinforcing system. FRC composite properties, such as crack resistance, reinforcement and increase in toughness are dependent on the mechanical properties of the fiber, bonding properties of the fiber and matrix, as well as the quantity and distribution within the matrix of the fibers. Fibers are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produced greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibres actually reduce the strength of concrete.

The amount of fibers added to the concrete mix is expressed as a percentage of total volume of the composite (concrete and fibers), termed volume fraction (Vf). Vf typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fiber is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fiber usually segments the flexural strength and the toughness of the matrix. However, fibers which are too long tend to ―ball‖ in the mix and create workability problems. Some recent research indicated that using fibers in concrete has limited effect on the impact resistance of the materials. This finding is very important since traditionally, people think that the ductility increases when concrete is reinforced with fibers. The results also indicated out that the use of micro fibers offers better impact resistance compared with the longer fibers.

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. 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.

MATERIALS

2.1 CEMENT

Ordinary Portland cement (53 grade) whose Fineness – 340 m2/kg ,Specific gravity- 3.1 Initial setting time - 90 min, Final setting time – 190 min. was used.

2.2 FINE AGGREGATES

In this study utilized sand of Zone-II, known from the strainer examination utilizing diverse sifter sizes (10mm, 4.75mm, 2.36mm, 1.18mm, 600μ, 300μ, 150μ) embracing IS 383:1963. Whose Specific Gravity is 2.65, Water absorption 0.6% and Fineness Modulus 2.47 was utilized.

2.3 COARSE AGRREGATE

The coarse aggregate utilized here with having most extreme size is 12.5mm. We utilized the IS 383:1970 to discover the extent of blend of coarse aggregate. Whose Specific Gravity is 2.65, Water absorption 0.4% what's more, Fineness Modulus 4.01 was utilized.

2.4 WATER

Portable water free from any harmful amounts of oils, alkalis, sugars, salts and organic materials was used for mixing and curing of concrete.

2.5 .STEEL FIBERS

There are a number of different types of steel fibres with different commercial names basically steel fibres can be categorized in to four groups depending on the manufacturing process viz; cut wire , slit sheet, melt extract and mill cut. It can also be classified according to its shape and/or section, various notations were previously used to nominated the specific type of the steel fibres but the this dissertation the following notation are used

- (hxwxl) to nominate the straight rectangular section steel fibres .(h-depth ,w-width ,l-length)
- (d x l) was used to name circular (or) semi circular section straight (or) deformation steel fibres.
- Hook –ended steel fibre. (I.e. 65/80 it means aspect ratio / length of steel fibres).

The typical diameter lies in the range of 0.25-0.75 mm hook end steel fibres are being used in this project. Length of these fibres is 30 mm and the aspect ratio of 65 and 80.Density of steel fibre is7900 kg/cum.

Mechanical Properties of Steel fiber

Different types of steel fiber

S.No	Properties	Description
1	Cross section	Straight, hooked end, deformed
2	Diameter	0.3-0.7mm(max 1mm)
3	Length	25-35 mm
4	Density	7900 kg/m^3
5	Young's modulus	2.1x10^5 N/mm^2
6	Resistance of alkalis	good
7	Resistance of acids	poor
8	Heat resistivity	good
9	Tensile strength	500-2000 N/mm^2
10	Specific gravity	7.90
11	Aspect ratio	45,55,65,80
12	General views	10 kg/m^3
13	elongation	5-35 %

3.DETAILS OF TESTS CONDUCTED

1. Compressive Strength of concrete.
2. Split Tensile Strength of concrete.
3. Flexural Strength of concrete.

3. 1. Compressive Strength

Compression test is done as per IS 516-1959. All the concrete specimens were tested in a 2000KN capacity compression-testing machine. Concrete cubes of size 15cm x 15cm x15cmare tested for crushing strength, crushing strength of concrete is determined by applying load at the rate of 140kg/sq.cm/minute until the specimens failed. The maximum load applied to the specimens has been recorded and dividing the failure load by the area of the specimen the compressive strength has been calculated. Variations of the compressive strength with various variables studied are examined. The 2000KN capacity compression-testing machine with specimen.

$$\text{Compressive strength} = \frac{Load}{Area} \text{ in N/mm}^2$$

3. 2. Split Tensile Strength

This test is conducted in a 2000KN capacity compression-testing machine by placing the cylindrical specimen horizontally direction, so that its axis is horizontal between the plate's of the testing machine. Narrow strips of the packing material i.e., ply wood is placed between the plates and the cylinder, to receive compressive stress. The load is applied uniformly at a constant rate until failure by splitting along the vertical diameter takes place. Load at which the specimens failed is recorded and the splitting tensile stress is obtained using the formula based on IS 5816-1970.

The following relation is used to find out the split tensile strength of the concrete.

$$F_t = \frac{2p}{\pi DL} \text{ in N/mm}^2$$

Where p = Compressive load on the cylinder
L = Length of the cylinder
D = Diameter of the cylinder

The results have been tabulated and graphical variations have been studied.

3.3. Flexural Strength

The loading setup arrangement to test the specimens for flexure is as follows. The element is simply supported over the span of 700 mm. The specimen is checked for its placement longitudinally and adjusted if necessary. Required packing is given using rubber packing. Care is taken to make sure that two loading points are at the same level. The loading is applied on the specimen using 15 tones pre calibrated proving ring at regular intervals. The load is transmitted to the element through the I-sections and two 16mm diameter rods are placed at a distance of 20 mm from each support. For each increment of loading the deflection at the center of the span is recorded using by dial gauge. Continuous or unbroken observations are made. Well before the ultimate stage the deflection meters are removed and the process of load application is continued. As the load is increased the cracks are widened and extended to top and finally the specimen collapsed in flexure. At this stage the load is recorded as the ultimate load. Making use of the above data flexural strength has been calculated.

The testing of beam as shown in Plate -4

$$f = \frac{M}{Z} \text{ in N/mm}^2$$

Where M = Bending moment

$$Z = \frac{I}{y} \text{ Section modulus}$$

MIX DESIGN M25

TABLE 4.1 Compressive Strength of SFRC with 0% fibers M25 grade.

SI.NO	Curing Period	Average Compressive strength (N/mm^2)
1	3-Days	17.30
2	7-Day	23.85
3	28-Days	34.56
4	90-Days	36.80

TABLE 4.2Test Result for Compressive Strength (aspect ratio@65) @ Different curing period of SF

S.NO:	Curing Days	Compressive Strength (N/mm^2)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	17.30	17.91	18.74	20.53
2	7	23.85	19.77	21.00	23.28
3	28	34.56	35.68	38.26	39.36
4	90	36.80	36.56	39.24	40.92

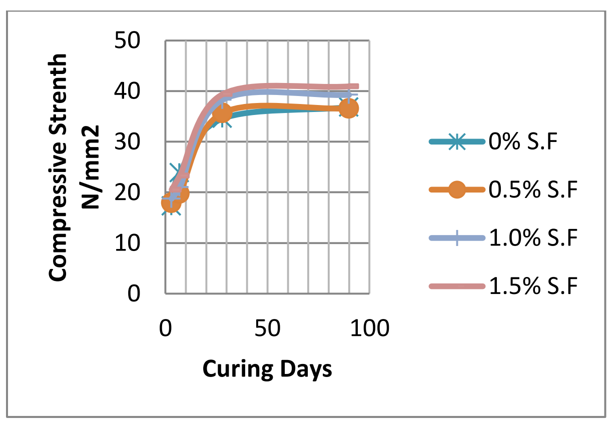


FIG 1 Test Result for Compressive Strength at different Percentages of SF.

TABLE 4.3Flexural strength of SFRC with 0% fibers M25

SI.NO	Curing Period	Average Flexural Strength (N/mm²)
1	3-Days	7.47
2	7-Days	7.80
3	28-Days	8.00
4	90-Days	8.40

TABLE4.4 Test Result for Flexural strength (aspect ratio@65) @ Different curing period of SF

S.NO:	Curing Days	Flexural strength (N/mm²)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	7.47	8.8	9.47	10.40
2	7	7.80	9.76	10.38	11.20
3	28	8.00	10.00	10.73	11.40
4	90	8.40	10.40	11.00	11.6

FIG 2 .Test Result for Flexural strength (aspect ratio@65) @ Different curing period of SF

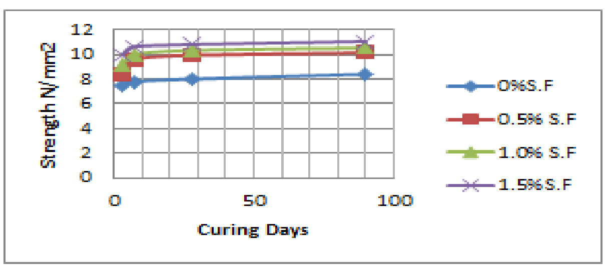


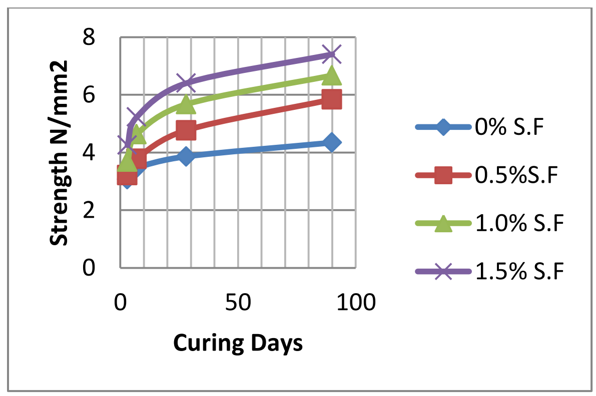
TABLE 4.5 split Tensile strength of SFRC with 0% fibers M25 Grade

SI.NO	Curing Period	Average Split Tensile Strength (N/mm²)
1	3-Days	3.07
2	7-Days	3.46
3	28-Days	3.86
4	90-Days	4.34

TABLE 4.6 Test Result for Spilt Tensile strength (aspect ratio@65) @ Different curing period of SF

SI.NO:	Curing Days	Spilt Tensile strength (N/mm²)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	3.07	3.21	3.68	4.25
2	7	3.46	3.78	4.63	5.23
3	28	3.86	4.77	5.67	6.40
4	90	4.34	5.84	6.67	7.40

FIG 3.Result for Spilt Tensile strength (aspect ratio@65) @ Different curing period of SF



CONCLUSIONS

The following conclusions could be drawn from the present investigation.

1. It is observed that compressive strength, split tensile strength and flexural strength are on higher side for 1.5% fibers as compared to that produced from 0%, 0.5% 1% and 1.5 fibers.
2. All the strength properties are observed to be on higher side for aspect ratio of 65.
3. It is observed that compressive strength of M25 grade concrete increases from 0.24% to 11.9% with addition of steel fibers for aspect ratio 65 .
4. It is observed that flexural strength of M25 grade concrete increases from 23%

to 38.09% with addition of steel fibers for aspect ratio 65 .

5. It is observed that split tensile strength of M25 grade concrete increases from 34.56% to 70.5% with addition of steel fibers for aspect ratio 65 .

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