Experimental Studies on Steel Fiber Reinforced Concrete

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Abstract: ***The objective of the study is to analyze systematically the effects of steel fiber reinforcement in concrete. Concrete mixes were prepared using M40 grade concrete and hooked end glued steel fiber with aspect ratio of 80 were added at a dosage of 0.5%, 1.0%, 1.5% volume fraction of concrete. The fiber reinforcement effects were analyzed for different types of distribution in the concrete beam. Fibers were dispersed in two different ways either homogeneously in concrete sections or localized in the tension zone or laid parallel to the beam axis. The mechanical properties such as the flexural strength using a third point loading and compressive strength properties were determined. Loadvs deflections were plotted for various fiber concrete specimens and toughness evaluations were made systematically using graph software in order to quantify the energy absorbing mechanism. Test results were compared with that of plain concrete specimen and the relative improvements on the toughness were measured. Significant conclusions were drawn and comparative analyses on the post elastic deformation capacity of different concrete specimens were measured.***

Keywords: Hooked end glued steel fiber, toughness, compressive strength, split tensile strength, flexural strength

1. Introduction

Concrete is weak in tension and strong in compression. The concept of using steel fiber in the concrete improves the mechanical characteristics. Earlier applications include addition of straw to the mud bricks, horse hair to reinforce plaster. Use of continuous steel fiber reinforcement in concrete increases strength and ductility, but it requires careful placement. Alternatively, introduction of fibers in discrete form in plain concrete or reinforced concrete gives better results. The modern development of steel fiber reinforced concrete (FRC) started in the early sixties[1]. The steel fibers are mostly used fiber, in fiber reinforced concrete. According to many researchers, the addition of steel fiber into concrete creates low workable or inadequate workability to the concrete. Therefore to solve this problem super-plasticizer is added, without affecting other properties of concrete [2]. Fiber reinforced concrete (FRC) reinforced with more or less randomly distributed fibers. In FRC, thousands of small fibers are dispersed and distributed randomly in the concrete during the mixing, and thus it improves concrete properties in all directions. It has been successfully used in construction during 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 concrete [3].Steel Fiber in concrete improves ductility and its load-carrying capacity. The mechanical properties of steel fiber reinforced concrete are much improved by the use of hooked fibers than straight fibers. Due to the addition of 1.5 percent steel fiber increase the flexure strength by 67 percent, the splitting tensile strength by 57 percent and the impact strength 25 times. The toughness index of FRC is increased up to 20 times (for 1.5 percent hooked fiber content) indicating excellent energy absorbing capacity [4].The flexural toughness of specimens with high strength self-compacting concrete is more than that of the specimens with medium strength self-compacting concrete [5].with an fiber volume fraction of 2%, the energy absorbed by the specimen during the test was 33 times higher than the flexural toughness of plain concrete [6].

2. Experimental Programme

2.1. Material Used

The materials used for this experimental work are cement, sand, water, Hooked-end steel fibers, and super plasticizer.

Cement: Portland Pozzolana Cement, of specific gravity 3.15 which is taken from Zuari Company.

Sand: Locally available sand zone II with specific gravity 2.65, water absorption 2% and fineness modulus 2.92, conforming to I.S 383-1970.

Coarse aggregate: Crushed stone with a maximum size of 20mm (passing) and uniform quality having specific gravity 2.71, conforming to IS 383-1970.

Water: Potable water was used for the experimentation.

Steel fiber: Fibrex Glued steel fiber of length 60mm and 0.75mm diameter with aspect ratio 80.
Super plasticizer: High range water reducing admixture of Cerahyperplast XR W40 having a specific gravity of 1.01-1.11 was used to maintain the workability of mix.

Table 1: Properties of steel fiber

Type of steel fiber	Length (mm)	Diameter(mm)	Aspect ratio (L/D)
Hooked end steel	60	0.75	80

2.2 Preparation and Casting of Specimens

The different concrete specimens such as cubes (100mmX100mmX100mm) to determine compressive strength, cylinders (100mm diameter and 300mm length) to determine split tensile strength and beams (100mmX100mmX500mm) to determine flexural strength were cast. All the specimens were prepared in accordance with Indian Standard Specifications IS: 516-1959. All the mouldswere cleaned and oiled properly. These were securely tightened to correct dimensions before casting. Care was taken that there is no gaps left from where there is any possibility of leakage of slurry.Additional beams were prepared for the calculation of toughness properties. Also beams prepared in such a way that fiber added in the below neutral axis A careful procedure was adopted in the batching, mixing and casting operations.Vibrations were stopped as soon as the cement slurry appeared on the top surface of the Mould. The specimens were removed from mould after 24 hours and cured in water till testing or as per requirement of the test.

2.3 Experimental Procedures

Experiment investigation has been carried out with reference to mix M40 grade concrete. Seven concrete mixes were prepared. Reference mix (M) was prepared for M40 grade of concrete as per IS: 10262-2009. Three concrete mixes were prepared (MSF1, MSF2 and MSF3) were prepared where steel fiber added homogenously with a percentage of 0.5%, 1% and 1.5% volume fraction of concrete, and again three concrete mixes (MSW1,MSW2 andMSW3) were prepared where steel fiber added with a percentage of 0.5%, 1% and 1.5% volume fraction of concrete. For the above three mixes specimens were prepared only steel fiber added homogenously below the neutral axis of the beam (i., e in tension zone). The mix proportion of all mixes are shown in table 2

Table 2: Mix proportions of concrete mixtures.

Materials	Unit	M	MSF1	MSF2	MSF3	MSW1	MSW2	MSW3
cement	Kg/m^3	394	394	394	394	394	394	394
Fine aggregate	Kg/m^3	672.5	672.5	672.5	672.5	672.5	672.5	672.5
Coarse aggregate	Kg/m^3	1238.29	1238.29	1238.29	1238.29	1238.29	1238.29	1238.29
Steel fibers	%	0	0.5	1	1.5	0.5	1	1.5
Super-plasticizer	% kg	1 3.94	1 3.94	1 3.94	1 3.94	1 3.94	1 3.94	1 3.94
water	kg	157.6	157.6	157.6	157.6	157.6	157.6	157.6
w/c	%	0.4	0.4	0.4	0.4	0.4	0.4	0.4

3. Results and Discussions

3.1 Compressive Strength

From results it is observed that by adding steel fiber there is increase in compressive strength by adding 1.5% steel fiber to the volume of concrete will give higher compressive strength than 0.5%,1% addition of steel fibers. By adding steel fibers the compressive strength increases 8% to 21% for 7 days and 6 % to 12% for 28 days. Graphical representation of the results was shown in below fig 1.values of compressive strength was shown in table 3.

3.2 Split Tensile Strength

By the addition of 1.5% steel fiber shows higher split tensile strength than 0.5%, 1% addition of steel fiber. By the addition of steel fiber to the volume of concrete as percentage wise there is an increase in split tensile strength from 14% to 36% for 7 days and from 15% to 39% for 28 days. Graphical representation of split tensile strength values for varying percentages is shown in below fig 2 .values of split tensile strength was shown in table3.

3.3 Flexural Strength

For flexural strength test, specimens of beam having dimensions 100mmx100mmx500mm were cast with M40grade concrete. The mould were filled with 0%, 0.5%, 1% and 1.5% hooked end glued steel fibers for flexure test, also prisms were casted with hooked-end glued steel fibers with 0.5%, 1% and 1.5% homogenously only below the neutral axis. Third-point loading over an effective span of 400mm,on flexural testing machine to study toughness. Graphical representation of flexural strength values for varying percentages is shown in below fig 3. Values of flexural strength for mixes (M, MSF1, MSF2 and MSF3) were shown in table 3.

Table 3: Strength Properties Of M40 Grade Concrete

MIX ID	Compressive strength 7 days (N/mm^2)	Compressive strength 28 days (N/mm^2)	Split tensile strength 7 days (N/mm^2)	Split tensile strength 28 days (N/mm^2)	Flexural strength 7 days (N/mm^2)	Flexural strength 28 days (N/mm^2)
M	28.2	50	2.1	2.98	4.49	7.3
MSF1	30.5	53.06	2.4	3.45	5.03	8.85
MSF2	32	55	2.6	3.73	5.8	9.38
MSF3	34.33	56	2.86	4.15	6.18	11.33

4.4 Yoke Set Up For Load-Deflection Measurement

Yoke set up is used to determine the load – deflection plot for the prism specimen. The fabrication is made in such a way that the yoke is placed along longitudinal section of the prism specimen such the ends are restrained which avoids enormous deflection at the ends. Since the ends are restrained the mid- span is subjected to pure bending and hence the accurate load-deflection plot is available. The evaluation is done along y direction (direction to which load is applied).

3.5 Evaluation of Toughness

The toughness evaluation is made from the plot arrived from load and deflection values from yoke set up.

Figure 1: Yoke set up for load-deflection measurement.

Using Graph 4.3 version, the toughness values were evaluated.The following Toughness properties were evaluated for 7 days and 28 days of control concrete (M), MSF1, MSF2, MSF3, MSW1, MSW2, and MSW3. Absolute toughness was calculated under the area of entire load-deflection till the complete failure of specimen. Post peak toughness was measured from the area between the ultimate load and failure load.

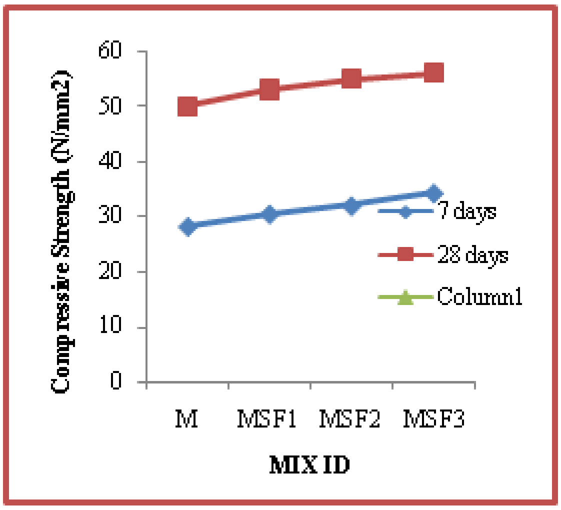

Figure 2: Relation between Mix ID and compressive strength at 7 and 28 days

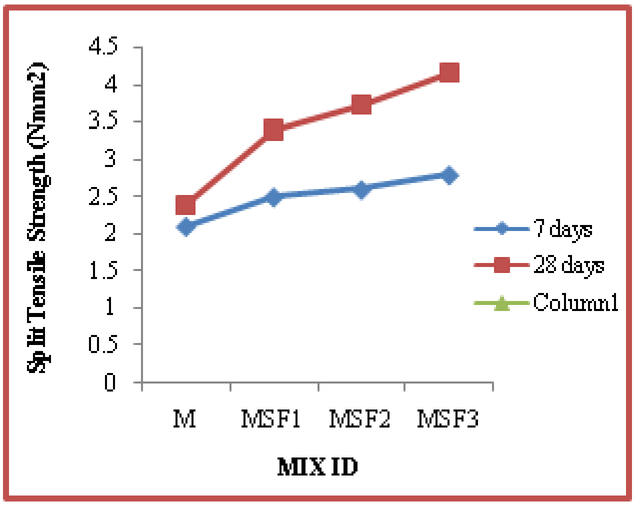

Figure 3: Relation between Mix ID and split tensile at 7 and 28 days

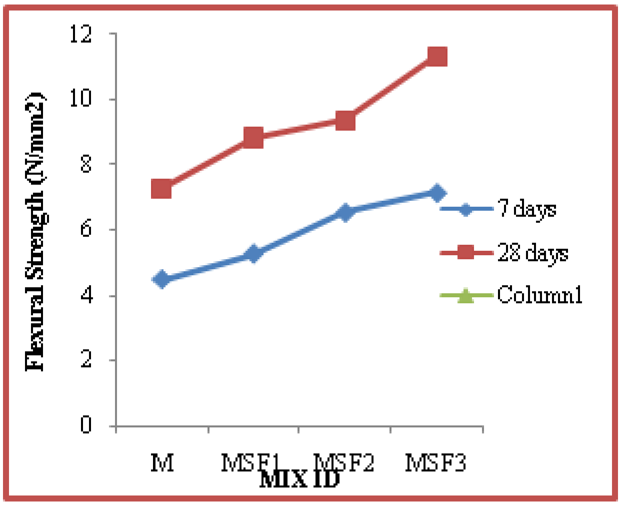

Figure 4: Relation between Mix ID and flexural strength at 7 and 28 days

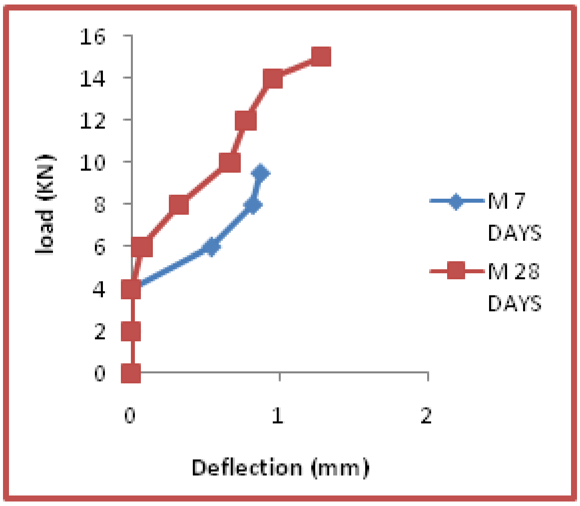

Figure 5: load –deflection curves of mix (M) at 7 and 28 days.

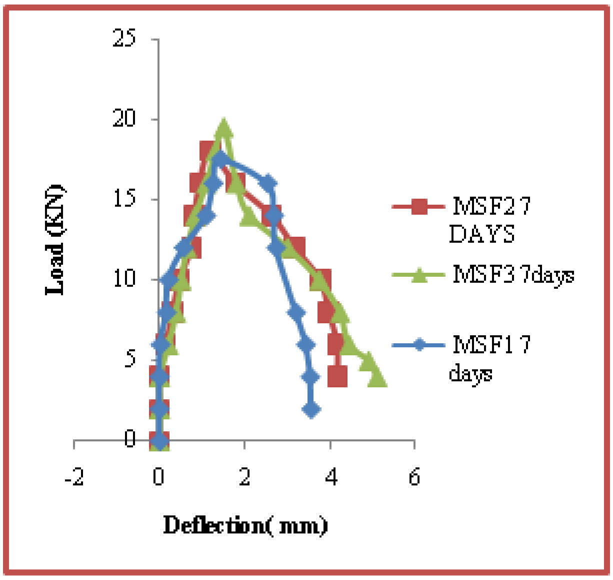

Figure 6: load- deflection graph for various Mix ID at 7 days

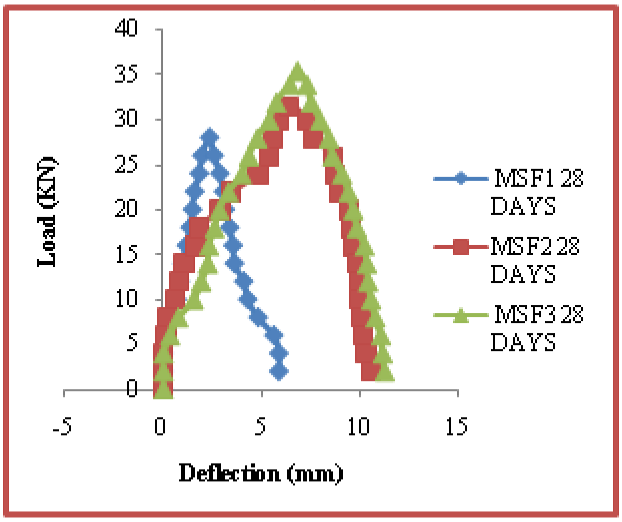

Figure 7: load-deflection graph for various Mix ID at 28 days

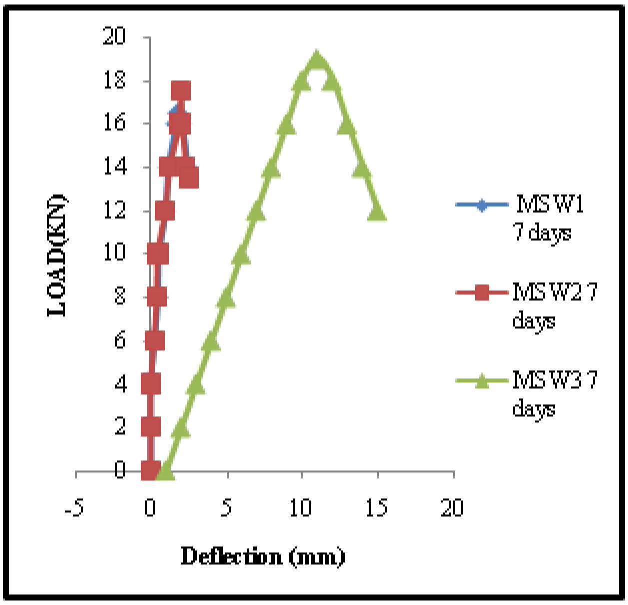

Figure 8: load-deflection graph for various Mix ID at 7 days.

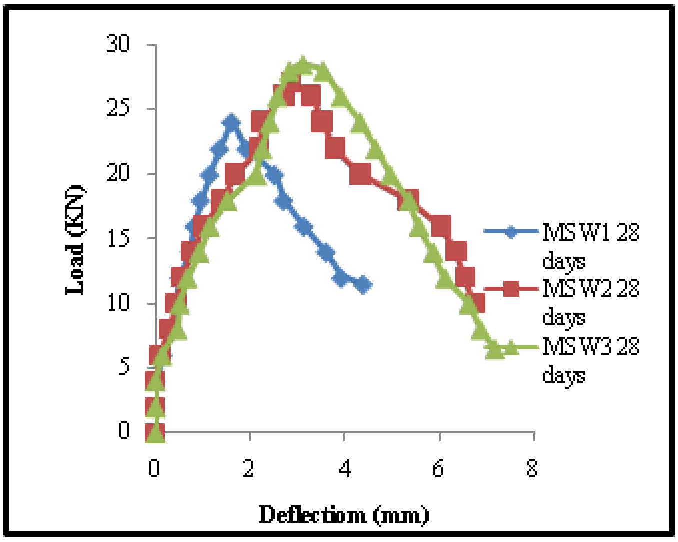

Figure 9: load-deflection graph for various Mix ID at 28 days.

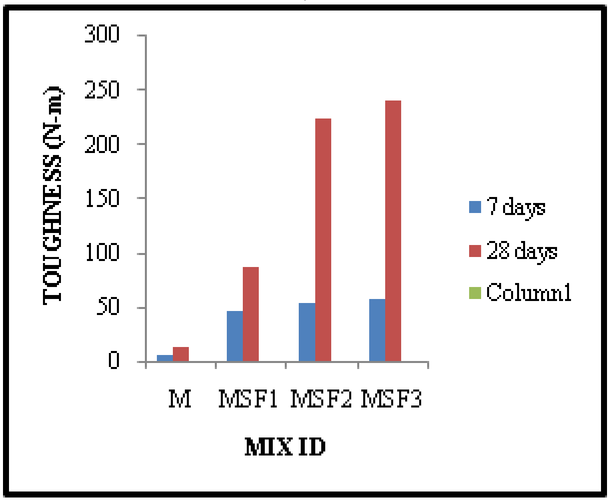

Figure 10: Absolute toughness for various Mix ID at 7 and 28 days

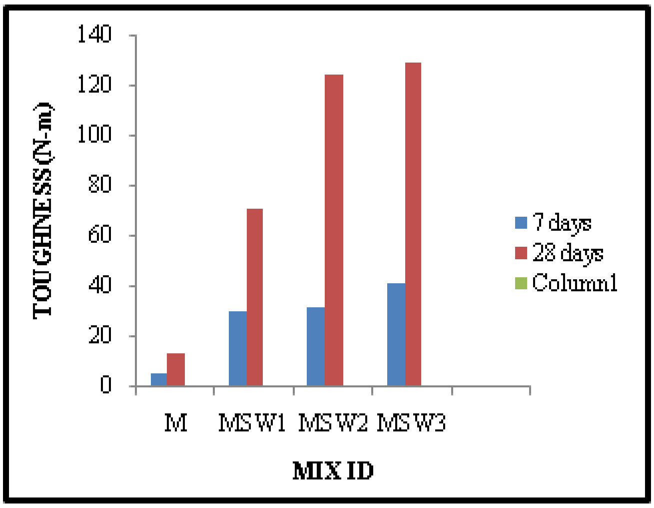

Figure 11: Absolute toughness for Various Mix ID at 7 and 28 days

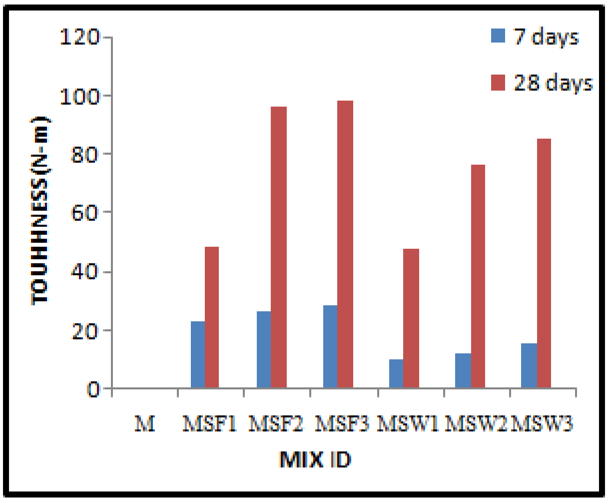

Figure 11: Post peak toughness

4. Conclusions

The experimental results and analysis of various percentages of steel fiber reinforced concrete in this study can be summarized as follows:

The major conclusions derived from the research study are

- It is observed that compressive strength, split tensile strength, flexural strength, are on higher side for 1.5% fibers as compared to that produced from 0%, 0.5%, 1% fibers. It is observed that compressive strength increases from 8 to 21% for 7 days, 6 to 12% for 28 days, split tensile strength increases from 14 to 36% for 7 days and 15 to 39% for 28 days and flexural strength increases 13 to 37% for 7 days and 17 to 55% for 28 days.
- With a fiber volume fraction 1.5% the absorbed energy by the specimens during the tests was 8 times for 7 days and 10 times for 28 days higher than flexural toughness of plain concrete
- The post peak value increases 0 to 28 times in 7 days and 0 to 98 times in 28 days increases with increase in percentage of steel fiber. And 0 to 16 times in 7 days and 0 to 86 times in 28 days increases with increase in percentage of steel fiber in below neutral axis.
- By the above conclusions we can also adopt steel fiber in below neutral axis, because this method results also will give post peak value which will not occur in plain concrete.

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