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Effect of Aspect Ratio on the Mechanical Properties of Steel Fibre Reinforced Concrete

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Abstract: Concrete is one of the world's most widely used construction material. Concrete plays the major role in construction. It can take compressive load and not tensile load. Poor tensile strength with brittle behavior of concrete result in quick tensile failure without warning. This is clearly not acceptable for any construction material. To enhance the tensile properties steel rods are provided as reinforcement. Tensile property can also be increased by the addition of fibers. Of many fibers, a steel fiber plays the major part. Addition of steel fiber in concrete increases the tensile property. Concrete of M40 grade is used. Hooked Steel fibers of various aspect ratios (l/d) of 30, 42.8, 50 and 60 and volume fractions (Vf) of 2% is taken for study. The basic tests of compression, split tensile and flexure strength were done.
Keywords: Steel fiber, Aspect ratio, Compression, Tensile and Flexure, admixture

I. INTRODUCTION

Concrete is a unique material which has low tensile properties. Plain concrete has lower ductility and low resistance against cracks. For increasing its ability against tension, steels rods are used as reinforcement. To form the matrix in the concrete natural and artificial fibers are used. Steel fiber reinforcements are gaining importance hugely due to the increasing demand of better structural characteristics. Steel fibers are simply unique, short length of steel having ratio of its length to diameter (aspect ratio) in the range of 20 to 100 with any of the cross-sections, and that are sufficiently small to be easily and randomly dispersed in fresh concrete mix using conventional mixing procedure. This study investigates the effect of steel fiber in M40 grade of concrete. Steel fibers of different aspect ratios are used and are optimized by its compressive and tensile strength. The other mechanical properties like split tensile strength and flexural strength are found using steel fibers and is reported. Conventional concrete properties were also studied for comparison.

Steel fiber reinforced concrete (SFRC) show outstanding tensile and compressive strengths with low drying shrinkage, high toughness and high energy absorption with increased durability. This is due to the advancing of micro-cracks in cementitious matrices which is blocked or deflected by fibres, which is affirmed by the bond between fibres and cementitious matrix. Studies prove that fibre cementitious matrix bond is provided by the combination of both adhesion, friction and mechanical interlocking. Thus, steel fibre reinforced concrete has higher resistance to cracks and crack advancement.

II. MATERIALS USED

Cement of OPC 53 grade was used for the whole study, fine aggregate of maximum six 4.75 was used, coarse aggregate of maximum 20 mm was also used, hooked end steel fibres of various aspect ratio were also utilized and admixture for improving the workability was also used. Table 1 shows the physical properties of the materials used.

TABLE 1: Physical properties of the materials

Physical / Mechanical Properties	Coarse Aggregate	Fine Aggregate	Cement
Maximum size(mm)	20	4.75	-
Specific gravity	2.88	2.44	3.137
Fineness Modulus	8.63	3.8	-
Water Absorption	0.3%	3.02%	-

The fine aggregates were found to be in grading zone1 by sieve analysis. The percentage weight of admixture was decided based on experimenting as 2%. The cement was tested for standard consistency and was found to be at 36%, initial and final setting times were observed to be 102mins and 320 mins. The mortar cubes were cast and the compressive strength was tested. The compressive strength of the cement mortar cubes was found to be 23N/mm² at 7 days of curing and 56N/mm² at 28 days of curing.

Steel fibres of aspect ratio(l/d) of 30, 42.8, 50 and 60 with a constant fraction of 2% were taken to attain maximum compressive strength and maximum tensile strength. From the results of compression and tensile strength optimum aspect ratio (l/d) of the steel fiber is found. Using these parameters further studies on flexural test was carried out. The optimum result from compression test was used for compression specimens. And for tensile specimens the optimum result of split tensile was taken. The results obtained from testing steel fiber reinforced concrete was compared with that of plain cement concrete specimens. The steel fibers of various aspect ratio are as shown in table 2.

TABLE 2: Aspect ratio of steel fibres

Size	l/d	Aspect ratio
1mm x 60mm	60/1	60
1mm x 50mm	50/1	50
1mm x 30mm	30/1	30
0.7mm x 30mm	30/0.7	42.8

III. EXPERIMENTAL PROCEDURE

Production of normal concrete of grade M-40 in the laboratory is carried out by IS method of concrete mix design. Fiber reinforced concrete is produced by adding steel fibers of different aspect ratio. The volume fraction of the fibres were kept constant as 2% the weight of cement in the concrete.

A. Mix design of concrete

ACI method of mix design was used for preparing the M40 mix of concrete which is used throughout the study. The optimum percentage of the fibre was assumed by doing the literature reviews of various studies and finally decided to go with volume fraction of 2% to give max strength and retaining the workability. For plain concrete and steel reinforced concrete the 28-day target mean compressive strength was 40N/mm². The mix ratio was derived to be 0.4: 1: 2.024: 3.89. The cement content was 345.03kg/m³ with water cement ratio of 0.4. Fine aggregates and coarse aggregates were found to be 698.21kg/m³ and 1343.15 kg/m³ respectively. Chemical admixture was used to improve the workability. The amount of super plasticizer to be used was found to be 1% of the cement content. The optimum percentage of admixture was achieved by making trial mixes with varying content of admixture.

B. Compressive strength test

Cubes of size 150 x 150 x 150 were tested to find the compressive strength after 28 days of curing by immersing in water. Three cubes were cast and tested for each of the mix using compression testing machine. The figure1. shows testing of the cube.

Fig.1. Compression testing

C. Splitting tensile strength test

Cylinders of size of diameter 150mm and height of 300mm were tested to find the splitting tensile strength of the concrete mix. The cylinders were tested using the compression testing machine after 28 days of curing by immersion in water. Three cylinders were cast for each of the mix and tested for the split tensile strength. The split tensile strength is calculated using the formula

$T = 2P/\pi LD$ where,

T = splitting tensile strength

P is the maximum applied load, N

D is the diameter of the specimen, mm

L is the length of the specimen, mm

The figure.2. shows the testing of the cylinder,

Fig.2. Split tensile strength testing

D. Flexural strength test

Beam of size 100mm width 100mm height with 500mm length was used to determine the flexural strength. The beams were tested using the universal testing machine after 28 days of curing. Beams were supported symmetrically over a span of 400mm and subjected to two points loading till failure of the beam occurred. The bed of universal testing machine is provided with two steel rollers, 38mm in diameter on which the sample is to be supported. The formula to find the flexural strength is stated as

$f_b = PL/bd^2$, where

P is the load in N

L the length of the specimen in mm

b is the breadth of the specimen in mm

d depth of the specimen in mm

The figure.3. shows the testing of the beam specimen

Fig.3. Flexural strength testing

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IV. EXPERIMENTAL RESULTS

The aspect ratio is optimized to obtain the maximum compressive strength, split tensile strength and flexural strength. Fibres of four different aspect ratios were used to make a total of five mixes including the mix of conventional concrete. The aspect ratio used were 30,42.8,50 and 60 with 2% volume fraction was considered. Total of 15 cubes and cylinders were cast with three samples for each of the five mixes. The average of the three values is considered as the respective strength of that particular mix. The following table.3. gives the mean values of the strength obtained from the test for compressive strength, split tensile strength and flexural strength for each of the aspect ratios.

TABLE.3. Experimental results of the various mixes

Sl.no	Size of fibre	Aspect ratio (l/d)	Compressive strength (N/mm2)	Split tensile strength(N/mm2)	Flexural strength(N/mm2)
1	plain concrete	-	48.1	2.53	8.75
2	1mm30mm	30	63.85	3.5	10.25
3	.7mm,30mm	42.8	68.43	3.8	11
4	1mm,50mm	50	70.96	4.4	11.25
5	1mm,60mm	60	69.77	3.89	11.75

A. Compression Test Results

The comparison of 28 days compressive strength of plain concrete and SFRC with various aspect ratio is shown in the fig.4.

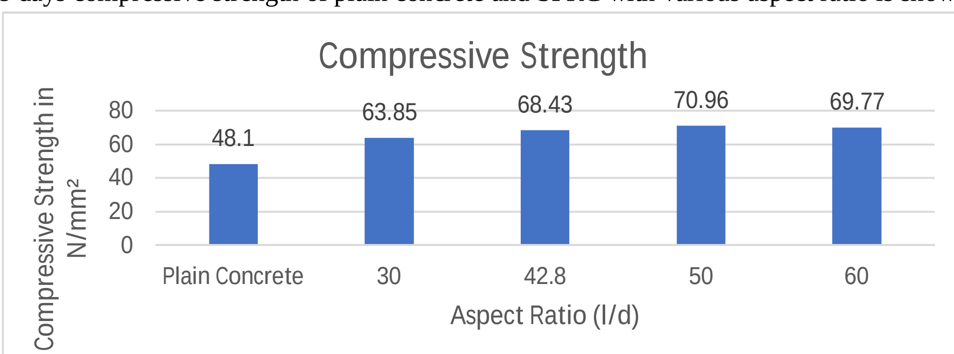

Fig.4. Compressive strength vs aspect ratio

Three cubes of each of the mix is tested and the average value is taken as the compressive strength. From the results it can be seen that the plain concrete cubes had a strength of 48.1N/mm². Meanwhile the mix with the aspect ratio (l/d) 50 has the maximum compressive strength of 70.96N/mm² with a volume fraction of 2%.

B. Split Tensile Strength Test Results

The comparison of the mean tensile strength of the mixes with fibres of various aspect ratio is shown in the figure below,

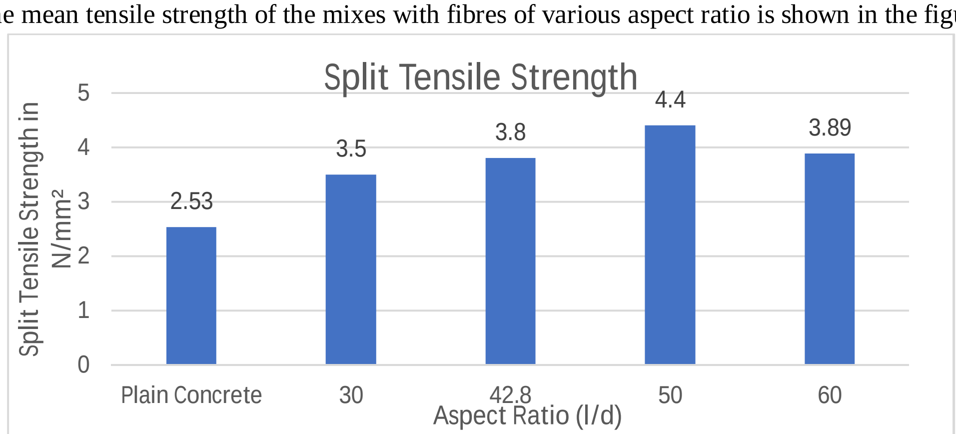

Fig.5. Split tensile strength vs aspect ratio

The cylinders were tested for the split tensile strength using the testing machine. The average value from testing the three samples of each of the mix is taken as the mean split tensile strength. The plain concrete sample had an average value of 2.53N/mm². The maximum split tensile strength was showcased by the mix with fibres of aspect ratio of 50 with the strength reading out to be 4.4N/mm². It is seen that the split tensile strength drops as the aspect ratio passes 50. So the optimum aspect ratio is 50.

C. Flexural Strength Test Results

The flexural strength of the mixes with various aspect ratio is compared to the flexural strength of the beam of plain concrete in the graph shown,

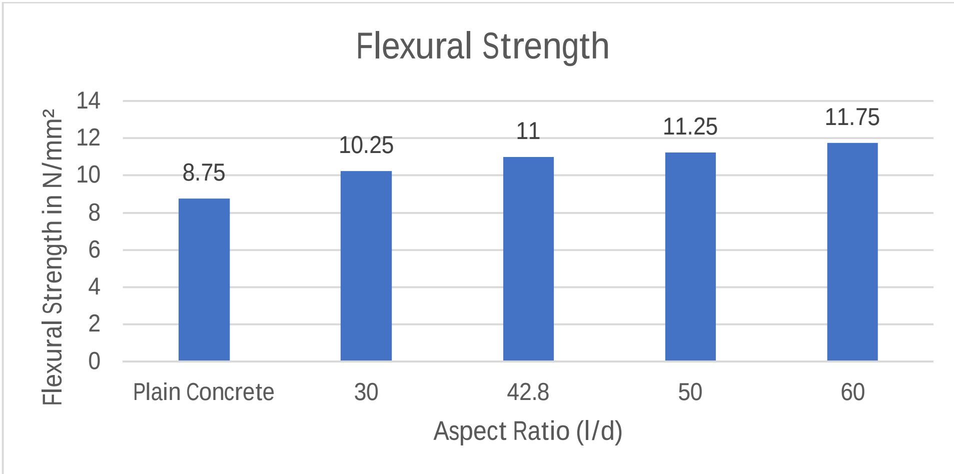

Fig.6. Flexural strength vs aspect ratio

The beams are tested using the universal testing machine by two-point loading. The maximum flexural strength was exhibited by the mix with fibres of aspect ratio of 60. The flexural strength of the beam with plain concrete was 8.75N/mm². It was seen that the flexural strength had a trend of increasing as the aspect ratio was increased. The maximum flexural strength was 11.75N/mm² with the aspect ratio of 60.

V. CONCLUSION

Both conventional concrete and steel fibre reinforced concrete of M40 grade was used for this study. Steel fibres of varying aspect ratio and constant volume fraction of 2% was used for the comparison hooked end fibres of aspect ratios of 30,42.8,50 and 60 was used. A plain concrete mix was also made without the fibres for the comparative studies.

The maximum compressive strength of the plain concrete was 48.1N/mm² and it can be concluded that the addition of fibres of the aspect ratio 50 with a volume fraction of 2% is best for the maximum compressive strength with a value of 70.96N/mm².

The maximum split tensile strength of the plain concrete was 2.53 while the SFRC had a maximum strength of 4.4N/mm² with the aspect ratio of 50.

The maximum flexural strength was found to be 11.75N/mm² with aspect ratio of 60, while the plain M40 concrete had a flexural strength of 8.75N/mm².

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