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Optimization of Steel Fiber in M40 Concrete with varying Aspect ratio and Volume Fraction

Sindhu Nachiar S, Satyanarayanan K S, Lakshmipathy M

Abstract: ***Concrete plays the major role in construction. Concrete can withstand compressive load and not in tensile load. 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 50, 60 and 80 and different volume fractions (Vf) of 0.5%, 1% and 2% is taken for study. The basic tests of compression, split tensile, flexure and impact strength were done. The steel fibers were optimized and were used in the shape study of compression and tension members.***

Index Terms: Optimization, Steel fiber, Volume Fraction, Aspect ratio, Compression, Tensile and Flexure.

I. INTRODUCTION

In construction, Concrete is a unique material with low tensile properties. Plain concrete is having fewer amounts of ductility and low resistance against cracks. For increasing concrete ability against tension, steels are used as reinforcement[1]. To form the matrix in the concrete natural and artificial fibers are used. This paper 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, flexural strength, impact strength are found using optimized steel fibers and is reported[2]. Conventional concrete properties also were studied without fibers for comparison.

II. MATERIALS USED

Cement of OPC 53 grade was used throughout this study[3]. Maximum size of fine aggregate and coarse aggregate used was 4.75 mm and 10 mm respectively[4]. Table1 shows the physical and mechanical properties of the materials used.

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Sindhu Nachiar S, Assistant Professor in Department of Civil Engineering at SRM Institute of Science and Technology, Chennai

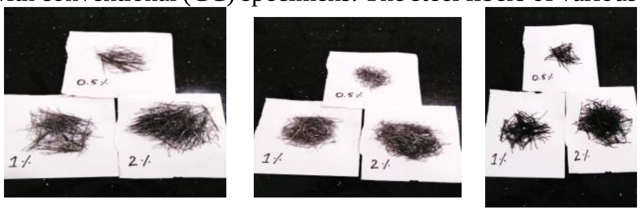
Satyanarayanan K S, HOD in Department of Civil Engineering at SRM Institute of Science and Technology, Chennai

Lakshmipathy M, Professor in Department of Civil Engineering at SRM Institute of Science and Technology, Chennai, India

Table 1. Physical and Mechanical properties

Physical / Mechanical Properties	Cement	Coarse Aggregate	Fine Aggregate
Maximum size (mm)	-	10	4.75
Specific gravity	3.15	2.64	2.67
Fineness Modulus	-	6.94	2.56
Bulk density (kg/m^3)	-	1650	1680

Steel fibers of different aspect ratio (l/d = 50, 60 and 80) and volume fraction (Vf = 0.5%, 1% and 2%) were tried to attain the maximum compressive and tensile strength. From the results of compression and tensile strength, optimum l/d and Vf of steel fiber was found[5]. Using these two parameters further studies on flexural test was carried out. The optimum result from compression test was used for the compression specimens. And for tensile specimens, the optimum result of split tensile was taken. The results of the steel fiber reinforced concrete (SFRC) were then compared with conventional (CC) specimens. The steel fibers of various aspect ratio used were shown in Fig 1 and volume fraction of these steel fibers were shown in Fig 2.



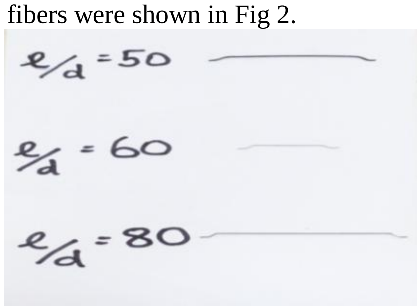


Fig 1. Steel Fibers used of Various Aspect Ratio

Fig 2. Volume fraction of different aspect ratio (a) l/d=50; (b) l/d=80; (c)l/d=60

III. EXPERIMENTAL PROCEDURE

For conventional concrete (CC) and Steel fiber reinforced concrete (SFRC), 28 days target compressive strength was 40 N/mm^2. CC and SFRC mix ratio were 1:1.036:2.664 with the cement content of 450kg/m^{3}and w/c ratio of 0.4. This proportion was reference mix without steel fiber. Then to this mix, steel fibers were added in different aspect ratio 50, 60 and 80 and volume fraction of 0.5%, 1% and 2% to find their optimum which produces the maximum compressive and tensile strength.

A 100 x 100 x 100 mm cube was tested to find the compressive strength. The tests were conducted for 7, 14 and 28 days. Fig 3 shows the testing of cubes.

Fig 3 Compressive strength test

Split tensile strength was found with a cylinder of 100 mm diameter and 200 mm length. 2P/L is used to calculate split tensile strength, where P,D and L are the applied load in N, diameter and length of the specimen in mm respectively. The results were obtained for 7, 14 and 28 days. Fig 4 shows the testing of cylinders.

Fig 4 Split Tensile strength test

Specimen of size 100 x 100 x 500 was used to determine flexural strength. PL/bd^2, is the formula used to calculate the flexural strength, where P, L, b and d are the load in N, length, breadth and depth of the specimen in mm respectively. 7, 14 and 28days results were presented. Fig 5 shows the testing of beams.

Fig 5 Flexural strength test

IV. RESULTS

The results are presented and discussed.

4.1 CC mix - Fresh and Hardened Concrete Properties

Concrete without fibers was found to have a slump value of 12-15 mm. Density of fresh concrete is was 2610 kg/m^3 and the density of hardened concrete was 2615 kg/m^3 for 7 days; 2620 kg/m^3 for 14 days and 2628 kg/m^3 for 28 days. For CC, compressive strength was found to be 25.17 N/mm^2 at 7 days; 39.07 N/mm^2 at 14 days and 44.73 N/mm^2 at 28 days.

4.2. SFRC mix - Fresh and Hardened Concrete Properties

Concrete with steel fiber of varying aspect ratio and Vf was found to have a slump of 7-10mm. Fibers with varying aspect ratios(50, 60 and 80) are added at varying percentages (0.5, 1 and 2%). The density of fresh concrete for l/d=50 with 0.5, 1 and 2% fiber are 2587 kg/m^3, 2646 kg/m^3 and 2610 kg/m^3, for l/d= 60 with 0.5, 1 and 2% are 2596 kg/m^3, 2643 kg/m^3 and 2646 kg/m^{3}and for l/d=80 with 0.5, 1 and 2% are2594 kg/m^3, 2623 kg/m^3 and 2613 kg/m^{3}respectively. By the addition of fiber, the slump gets reduced and there is reduction in density by the addition of fibers. With every increase in percentage of addition the density of concrete gets reduced. Though the workability of SFRC is less than the CC, there is no much difference is found in practice. The hardened concrete densities of SFRC and CC at 7, 14 and 28 days for different Vf (0.5%, 1% and 2%) are given in Table 2.

Table 2. Hardened concrete density

Concrete	% Fibre	Hardened concrete density (kg/m^3)		
		7th day	14th day	28th day
CC	-	2615	2620	2628
SFRC - 50	0.5	2606	2614	2624
	1	2598	2601	2613
	2	2586	2592	2604
SFRC- 60	0.5	2599	2612	2621
	1	2591	2605	2617
	2	2589	2598	2611
SFRC- 80	0.5	2603	2616	2620
	1	2594	2608	2609
	2	2587	2596	2601

4.3. Compression Test Results

It was necessary to optimize aspect ratio and volume fraction to achieve maximum compressive.[2] Three aspect ratios with three different mixes were done. The aspect ratios used were 50, 60 and 80 with 0.5, 1 and 2% were the volume fraction considered. Only hardened concrete properties were considered since optimizing the l/d and Vf of the steel fiber is the main aim for further shape study. Totally 9 mixes were tried. Total of 9 cubes were cast and three were tested at 7th, 14th and 28thday. The average of three cubes was presented. It can be concluded that conventional concrete with fibers of l/d = 50 and Vf = 2% gives the maximum compressive strength and is highlighted in

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red colour font. The comparison of 28 days compressive strength of CC and SFRC with various l/d and Vf is shown in the Fig 6 and Table 3.

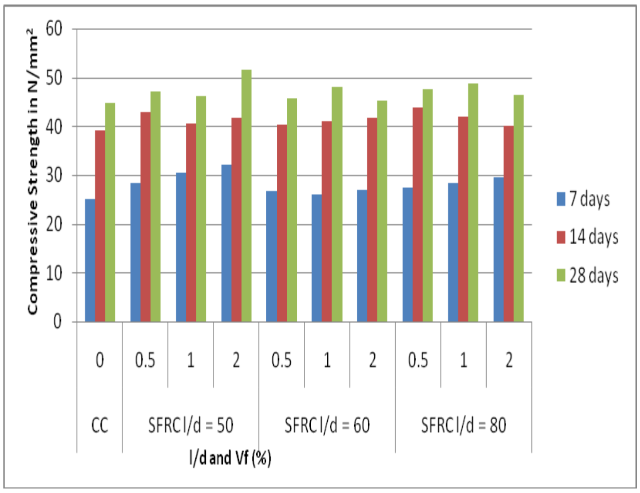
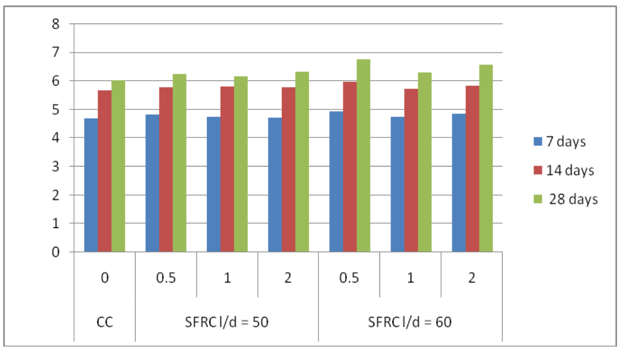


Fig 6. CC and SFRC Compressive strength vs l/d &Vf(%)

From the Figure 6, the maximum compressive strength for CC mix is 44.73 N/mm^2 it can be concluded that the l/d = 50 and Vf = 2% of steel fiber can be used into this CC mix which produces the compressive strength of 51.65 N/mm^2.

Table 3. Compressive Strength of CC and SFRC mix with different l/d and Vf

Concrete	Vf (%)	Compressive strength, N/mm^2		
		7th day	14th day	28th day
CC	0	25.17	39.06	44.73
SFRC - 50	0.5	28.29	42.83	47.13
	1	30.36	40.65	46.25
	2	32.12	41.74	51.65
SFRC - 60	0.5	26.65	40.19	45.59
	1	26.12	41.05	47.95
	2	26.85	41.81	45.19
SFRC - 80	0.5	27.35	43.79	47.52
	1	28.35	41.95	48.81
	2	29.54	40.17	46.34



4.4. Split tensile Test results

Maximum split tensile strength of CC is 4.28 N/mm² and for SFRC is 4.71 N/mm²in l/d = 60 and V_f = 0.5% is shown in Fig 7 and Table 4[2].

Fig 8 CC vs SFRC Flexural Strength vs l/d vs Vf (%)

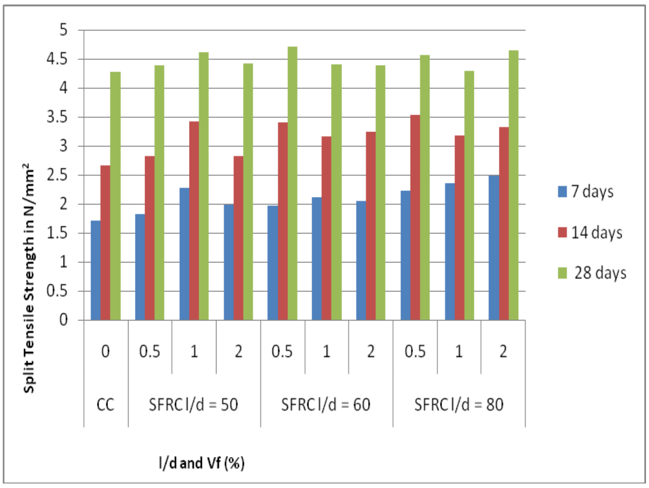


Fig 7. CC and SFRC Split Tensile strength vs l/d &Vf (%)

Table 4. Split TensileResults of CC and SFRC mix with different l/d and Vf.

Specimen	% of Fiber	Split Tensile Strength, N/mm²		
		7th day	14th day	28th day
CC	0	1.71	2.66	4.28
SFRC l/d = 50	0.5	1.82	3.42	4.62
	1	2.28	2.28	3.13
	2	1.98	2.82	4.42
SFRC l/d = 60	0.5	1.96	3.40	4.71
	1	2.12	3.16	4.41
	2	2.05	3.24	4.39
SFRC l/d = 80	0.5	2.23	3.54	4.57
	1	2.36	3.18	4.29
	2	2.48	3.32	4.65

4.5. Flexural strength tests results

Fig 8 shows flexural strength resultsof CC and SFRC mixes respectively[2]. The optimized fiber l/d and Vf which produces maximum compression and tensile strength alone is considered for flexural strength. Maximum flexural strength in CC mix was 6 N/mm^2 at 28 days, whereas for SFRC the maximum flexural strength of 6.75 N/mm^2 was found in l/d = 60 and Vf= 0.5%.

V. CONCLUSION

Conventional Concrete(CC) and Steel Fiber Reinforced Concrete (SFRC) were studied to attain strength of M40. Steel fibers of various aspect ratio (l/d) and volume fraction (Vf) were used to increase the tensile strength. Five different shapes of compression member (round, square, stepped, tapered and mimicked) and five shapes of tension members (rectangle, rectangle with parabolic curve, rectangle with circular curve, rectangle with holes at both ends and circular) were considered.

The maximum compressive strength for CC mix is 44.73 N/mm^2 it can be concluded that the l/d = 50 and Vf = 2% of steel fiber can be used into this CC mix which produces the compressive strength of 51.65 N/mm^2.

Maximum split tensile strength of CC is 4.28 N/mm^2 and for SFRC is 4.71 N/mm^2 in l/d = 60 and V_f = 0.5%.

The optimized fiber l/d and Vf which produces maximum compression and tensile strength alone is considered for flexural strength. Maximum flexural strength in CC mix was 6 N/mm^2 at 28 days, whereas for SFRC the maximum flexural strength of 6.75 N/mm^2 was found in l/d = 60 and Vf = 0.5%.

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AUTHOR PROFILE

Sindhu Nachiar S, Assistant Professor in Department of Civil Engineering at SRM Institute of Science and Technology, Chennai, India. She has done her B.Tech. Degree in Civil Engineering and M.Tech. Degree in Structural Engineering. She has published many papers in International Journals

Dr. Satyanarayanan K S, HOD in Department of Civil Engineering at SRM Institute of Science and Technology, Chennai, India. He has published papers in many international journals.

Dr. Lashmipathy M, Professor in Department of Civil Engineering at SRM Institute of Science and Technology, Chennai, India. He has published papers in many international journals.