Experimental Study on Strength of Fiber Reinforced Concrete

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Abstract— Investigation to overcome the brittle response and limiting post-yield energy absorption of concrete let development of the fiber reinforced concrete using discrete fiber within the concrete mass. A wide variety of fiber have been proposed by the researchers such as steel, glass, polypropylene, carbon polyester, acrylic and aramid etc. fiber reinforced concrete (FRC) is an emerging field in the area of concrete technology. Here an attempt has been made to investigate particularly “Steel Fiber” as fiber reinforcement in concrete. A concrete mix design has been designed to achieve the minimum grade of M30 as required by IS 456-2000. The investigation contains three phases. In first phase, to identify the effect on workability due to addition of fibers. Second phase contain test on standard specimen such as compressive strength, split tensile strength and flexural strength by varying the fiber percentage from 0.5% increasing by 0.5% up to 3.0%. Third phase compare the strength of various fiber specimen with plain concrete strength. Totally 42cubes, 42 cylinders and 42 prism were casted and tested. Based on the experimental workability and mechanical strength studied, volume fraction from 0.5% to 3.0% and two aspect ratio of 45 to 60 have taken for the investigation.

Key words: Fiber Reinforced, M30

I. Introduction

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of cement and water. This is a brittle material which is strong in compression and weak in tension. This weakness of concrete makes it to crack under small loads, at the tensile end. These cracks gradually propagate to the compression end of the member and finally, the member breaks. The formation of cracks is also occurs due to dry shrinkage. These cracks are generally called as micro cracks. The formation of cracks is main reason for the failure of the concrete. To increase the tensile strength of concrete many attempt have been made. One of the successful and most commonly used method is providing steel reinforcement. Steel bars, however, reinforce concrete against local tension only. Cracks in the reinforced concrete members extend freely until encountering are bar. Thus need for multidirectional and closely spaced steel reinforcements arises. That cannot be practically possible. FRC gives the solution for this problem. So to increase the tensile strength of concrete a technique of introduction of fibers in concrete is being used. The main reason for adding fiber to concrete matrix is to improve the post cracking response of the concrete, i.e., to improve its energy absorption capacity and apparent ductility, and to provide crack resistance and crack control. Also, it helps to maintain structural integrity and cohesiveness in the material.

II. Material used

A. Cement:

Ordinary Portland cement confirming to IS 12262-1987 was used. Ultra tech cement 43 grade procured from single source, properties of which are tested in the laboratory are given in the table 2.1 below.

Sl. No	Properties	Test Results	As Per Is:8112-1989
1	Specific Gravity	3.15	3.15
2	Normal Consistency	26%	-
3	Initial Setting Time	50 Min	>30 Min
4	Final Setting Time	230 Min	<600 Min

Table 2.1: Physical Properties of cement

B. Fine Aggregate (Fa):

Natural and conforming to zone 1 with specific gravity 2.62. Fineness modulus as 4.1 was used. The maximum size of fine aggregate was taken to be 4.75mm. The testing on sand was done as per IS 383-1970 specifications. Test results are shown in table 2.2 below.

Sl No	Properties of CA	Test Results
1	Shape of CA	Angular
2	Specific gravity	2.927
3	Bulk Density	1.54gm/cm^3
4	Fineness Modulus	8.11

Table 2.2: Properties of FA

C. Coarse Aggregate (Ca):

As per IS 383-1970 the aggregate shall consist of natural occurring stones, gravel and sand or combination of there. The present investigation the locally available aggregate from crushes was used. This consist of 20mm down size and 12mm retained. Result of preliminary tests are presented in table 2.3 below.

Sl No	Properties of FA	Test Results
1	Bulk Density	1.669gm/cm^3
2	Specific Gravity	2.62
3	Fineness modulus	3.25%
4	Slit Content	1.95%
5	Water Absorption	4.16%

Table 2.3: Properties of CA

D. Water:

Water used for both mixing and curing should be free from injurious amount of deleterious material. Portland water is generally considered satisfactorily for mixing and curing concrete. In present work potable water is used.

E. Steel Fibers:

Fiber is discrete material having some characteristic properties. The fiber material can be anything. But not all will be effective and economical. Some fibers that are most commonly used fibers are Steel, Glass, Carbon, Natural, and NBD etc. Steel fiber is the most commonly used fiber. The Straight and round fibers are selected for our investigation. Load transfer in the cracks is very good with this shape. Thus after the appearance of the first crack the loss of load-bearing capacity occurs quickly, but then stabilizes and in some cases even begins to increase again after large cracks have developed. Steel fibers have lengths in the range of 35 to 60mm, diameters range from 0.5 to 1mm and tensile wire strengths range from 100 to 1900MPa.

III. OBJECTIVE

The aim of our project is to use the steel fibers as fiber reinforcement to concrete. Our objective is to add the steel fibers to the concrete and to study the strength properties of concrete with the variation in fiber content. i.e., to study the strength properties of concrete (M30 grade) for fiber content of 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0% at 28 days. In this investigation an attempt has been made to study the feasibility of making use of FRC.

1) The strength properties being studied in our work follows.
   - Compressive strength
   - Split tensile strength
   - Flexural strength
2) To obtain the optimum percentage of fiber to be used for making FRC for different aspect ratio i.e., 45 and 60.
3) Compare the different fiber specimen strength with plain cement concrete strength.

IV. METHODOLOGY

A. Concrete Mix Design:

Concrete mix design is done by use of IS 10262:1982, this method is used for both medium and high strength concrete. The mix design proportion for M30 grade concrete is given in the below table 4.1

SL NO	Grade of concrete	W/C Ratio	Cement	Fine Aggregate	Coarse Aggregate
1	30	0.45	1	1.731	2.90

Table 4.1: Mix proportion for M30 grade Concrete

B. Casting:

Totally 42cubes, 42 cylinders and 42 prisms were casted and tested. Based on the experimental workability and mechanical strength studied, volume fraction from 0.5% to 3.0% and two aspect ratio of 45 to 60 have taken for the investigation. The specimen name, size and test conducted is given in the table 4.2

SL NO	Specimen	Size (in mm)	Test Conducted
1	Cube	150X150X150	Compressive Strength
2	Cylinder	150X300	Split Tensile Strength
3	Prism	500X100X100	Flexural Strength

Table 4.2: Casting detail

C. Curing:

After casting the molded specimen were stored in the laboratory and at a room temperature for 24hrs from the time of addition of water to dry ingredients. After 24hrs the specimens were demolded and immediately submerged in clean and fresh water. The specimens cured for 28 days in our work.

V. RESULTS AND DISCUSSION

A. Compressive Strength Test:

At the end of curing period that is 20 days for compressive test cube specimens were taken out of curing tank and kept exposed to laboratory temperature, till the surface becomes dry. Specimens were placed on the bearing surface of UTM, of capacity 100tonnes without eccentricity was applied till the failure of cube. The maximum load was noted and the compressive strength was calculated. The rate of loading is maintained at 140kg/sq.cm/min.

SL NO	% of Fiber Used	Specimen No	Load in TON	Load in KN(P)	Compressive Strength in N/mm^2	Average Comp. Strength in N/mm^2
1	0	1	83	814.23	36.18	37.91
		2	86	843.66	37.49	
		3	85	833.85	37.06	
2	0.5	1	88	863.285	38.36	39.38
		2	90	882.9	39.24	
		3	93	912.33	40.54	
3	1.0	1	95	931.95	41.42	42.58
		2	98	961.38	42.72	
		3	100	981	43.6	
4	1.5	1	103	1010.43	44.90	45.04
		2	101	990.81	44.03	
		3	106	1039.86	46.21	
5	2.0	1	110	1079.1	47.96	49.26
		2	115	1128.15	50.14	
		3	114	1118.34	49.70	
6	2.5	1	112	1098.72	48.83	47.66
		2	107	1049.67	46.65	

		3	109	1069.29	47.52	
7	3.0	1	104	1020.24	45.34	44.17
		2	101	990.81	44.03	
		3	99	971.19	43.16	

Table 5.1.1: Compressive Strength of the Fiber reinforced Specimens after 28 days curing, with Aspect Ratio L/D = 45. W/C = 0.45

SL NO	% of Fiber Used	Specimen No	Load in TON	Load in KN(P)	Compressive Strength in N/mm^2	Average Comp. Strength in N/mm^2
1	0	1	83	814.23	36.18	37.91
		2	86	843.66	37.49	
		3	85	833.85	37.06	
2	0.5	1	88	863.285	38.36	39.67
		2	91	892.71	39.67	
		3	94	922.14	40.98	
3	1.0	1	97	951.57	42.29	42.43
		2	95	931.95	41.42	
		3	100	981	43.6	
4	1.5	1	103	1010.43	44.90	46.06
		2	106	1039.86	46.22	
		3	108	1059.48	47.1	
5	2.0	1	112	1098.72	48.83	50.86
		2	117	1147.77	51.01	
		3	121	1187.01	52.74	
6	2.5	1	117	1147.77	51.01	49.55
		2	114	1118.34	49.70	
		3	110	1079.1	47.96	
7	3.0	1	106	1039.864	46.21	45.19
		2	104	1020.24	45.34	
		3	101	990.81	44.03	

Table 5.1.2: Compressive Strength of the Fiber reinforced Specimens after 28 days curing, with Aspect Ratio L/D = 60. W/C = 0.45

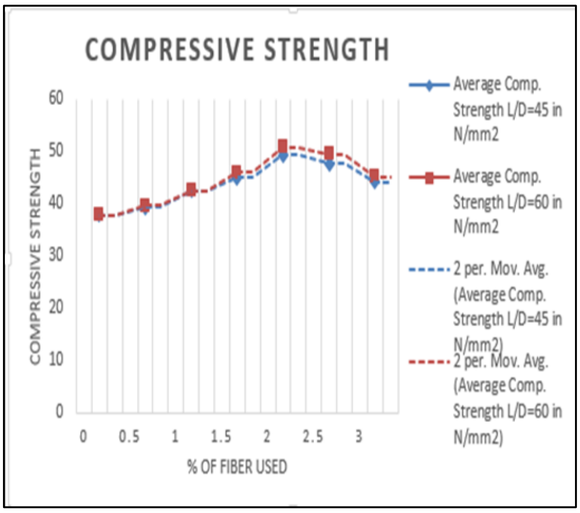

Fig. 1: Graph No 1: Compressive Strength L/D=45 & L/D=60

B. Split Tensile Strength Test:

At the end of curing period that is 28 days for split tensile test cylinder specimens were taken out of curing tank and kept exposed to laboratory temperature, till the surface becomes dry. Specimens were placed in UTM in a horizontal direction perpendicular to the direction in which they were cast. Rate of loading is maintained at 140kg/sq.cm/min.

SL NO	% of Fiber Used	Specimen No	Load in TON	Load in KN(P)	Compressive Strength in N/mm^2	Average Comp. Strength in N/mm^2
1	0	1	27	264.87	3.74	4.11
		2	32	313.92	4.44	
		3	30	294.30	4.16	
2	0.5	1	31	304.11	4.30	4.52
		2	33	323.73	4.57	
		3	34	333.540	4.71	
3	1.0	1	36	353.16	4.99	5.31
		2	38	372.78	5.27	
		3	41	402.21	5.69	
4	1.5	1	42	412.02	5.82	6.05
		2	45	441.450	6.24	
		3	44	431.640	6.10	
5	2.0	1	47	461.070	6.52	6.70
		2	50	490.5	6.93	

		3	48	470.88	6.66	
6	2.5	1	47	461.070	6.52	6.10
		2	43	421.83	5.96	
		3	42	412.02	5.82	
7	3.0	1	39	382.59	5.41	5.08
		2	34	333.540	4.71	
		3	37	362.970	5.13	

Table 5.2.1: Split Tensile Strength of the Fiber reinforced Specimens after 28 days curing, with Aspect Ratio L/D = 45. W/C = 0.45

S L N O	% of Fiber Used	Specimen No	Load in TON	Load in KN(P)	Compressive Strength in N/mm^2	Average Comp. Strength in N/mm^2
1	0	1	27	264.87	3.74	4.11
		2	32	313.92	4.44	
		3	30	294.30	4.16	
2	0.5	1	32	313.92	4.44	4.66
		2	34	333.540	4.71	
		3	35	343.35	4.85	
3	1.0	1	37	362.97	5.13	5.59
		2	40	392.40	5.55	
		3	44	431.64	6.10	
4	1.5	1	48	470.88	6.66	6.61
		2	45	444.450	6.24	
		3	50	490.50	6.93	
5	2.0	1	53	519.93	7.35	6.30
		2	54	529.74	7.49	
		3	51	500.31	7.07	
6	2.5	1	53	519.30	7.35	6.89
		2	50	490.50	6.93	
		3	46	451.23	6.38	

7	3.0	1	44	431.64	6.10	5.73
		2	41	402.21	5.69	
		3	39	382.59	5.41	

Table 5.2.2: Split Tensile Strength of the Fiber reinforced Specimens after 28 days curing, with Aspect Ratio L/D = 60. W/C = 0.45

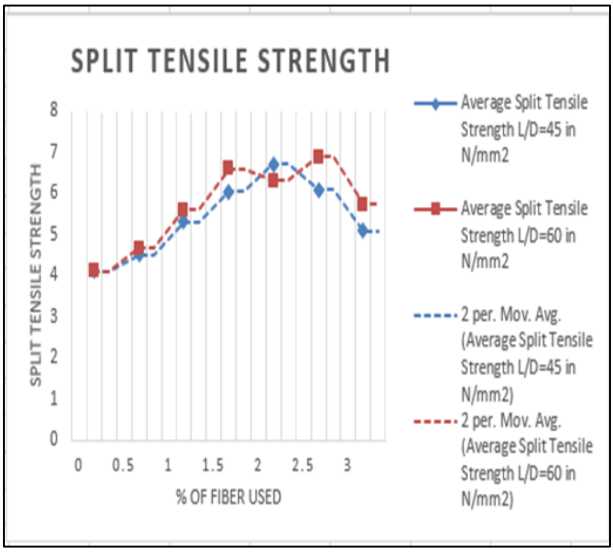

Fig. 2: Graph No 2: Compressive Strength L/D=45 & L/D=60

C. *Flexural Strength Test:*

At the end of curing period that is 28 days for flexural strength test beam specimens were taken out of curing tank and kept exposed to laboratory temperature, till the surface becomes dry. Specimens were placed in UTM the Rate of loading is maintained at 180kg/sq.cm/min. the flexural strength of the specimen shall be expressed as the modulus of rupture fb, if 'a' equals the distance between the line of fraction and the nearest support, measured on the center line of tensile side of the specimen in cm and when 'a' is greater than 13.3cm then equation shall be as follows.

$fb=p_1/bd^2$

If 'a' is less than 13.3cm then equation shall be

$fb=3pa/bd^2$

Where,

P= maximum load in kg applied to the specimen

1= length in cm of the span on which the specimen was support

b= measured width in cm of specimen

d= measured depth in cm of the specimen at the time of failure.

S L N O	% of Fiber Used	Specimen No	Load in TON	Load in KN(P)	Compressive Strength in N/mm^2	Average Comp. Strength in N/mm^2
1	0	1	0.8	7.848	3.92	4.08
		2	0.8	7.848	3.92	

		3	0.9	8.829	4.41	
2	0.5	1	0.9	8.829	4.41	4.65
		2	0.95	9.319	4.65	
		3	1.00	9.810	4.90	
3	1.0	1	1.00	9.810	4.90	5.14
		2	1.05	10.300	5.15	
		3	1.10	10.79	5.39	
4	1.5	1	1.25	12.62	6.13	6.12
		2	1.20	11.772	5.88	
		3	1.30	12.753	6.37	
5	2.0	1	1.30	12.753	6.37	6.04
		2	1.20	11.772	5.88	
		3	1.20	11.772	5.88	
6	2.5	1	1.10	10.791	5.39	5.63
		2	1.15	11.281	5.64	
		3	1.20	11.772	5.86	
7	3.0	1	1.20	11.772	5.88	5.55
		2	1.10	10.791	5.39	
		3	1.10	10.791	5.39	

Table 5.3.1: Flexural Strength of the Fiber reinforced Specimens after 28 days curing, with Aspect Ratio L/D = 45. W/C = 0.45

S L NO	% of Fiber Used	Specimen No	Load in TON	Load in KN(P)	Compressive Strength in N/mm^2	Average Comp. Strength in N/mm^2
1	0	1	0.8	7.848	3.92	4.08
		2	0.8	7.848	3.92	
		3	0.9	8.829	4.41	
2	0.5	1	0.92	9.025	4.51	4.77
		2	0.95	9.319	4.65	
		3	1.05	10.3	5.15	
3	1.0	1	1.10	10.791	5.95	5.31
		2	1.05	10.3	5.15	
		3	1.10	10.791	5.39	
4	1.5	1	1.25	12.262	6.13	6.29
		2	1.35	13.243	6.62	
		3	1.25	12.262	6.13	
5	2.0	1	1.30	12.753	6.37	5.79
		2	1.25	12.262	6.13	
		3	1.20	11.772	5.88	
6	2.5	1	1.15	11.281	5.64	5.72
		2	1.20	11.772	5.88	
		3	1.15	11.281	5.64	
7	3.0	1	1.20	11.772	5.88	5.71
		2	1.10	10.791	5.39	
		3	1.20	11.772	5.88	

Table 5.3.2: Flexural Strength of the Fiber reinforced Specimens after 28 days curing, with Aspect Ratio L/D = 60. W/C = 0.45

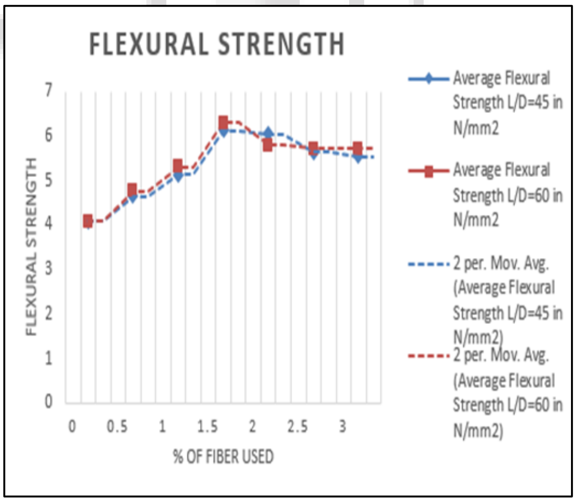

Fig. 3: Graph No 3: Compressive Strength L/D=45 & L/D=60

D. Discussions of Compressive Strength Result:

Comparing the compressive strength of plain concrete and concrete with various percentage of fibers after 28 days of curing.

Plain concrete in N/mm^2	SFRC in N/mm^2	% of increase in strength
0.0% - 37.91	0.5% - 39.38	3.87

	1.0% - 42.58	12.31
	1.5% -45.04	18.80
	2.0% - 49.23	29.86
	2.5% - 47.66	25.71
	3.0% - 44.17	16.51

Table 5.4.1: Comparison of plain concrete and reinforced concrete aspect ratio (L/D) =45

Plain concrete in N/mm^2	SFRC in N/mm^2	% of increase in strength
0.0% - 37.91	0.5% - 39.67	4.47
	1.0% - 42.43	11.95
	1.5% -46.06	22.92
	2.0% - 50.86	34.79
	2.5% - 49.55	30.74
	3.0% - 45.15	19.43

Table 5.4.2: Comparison of plain concrete and reinforced concrete aspect ratio (L/D)=60

From the above tables it is clear that the strength of SFRC with 2% fiber has increased by 29.86% for L/D=45 and 34.79% for L/D=60 for compression compared to the plain concrete.

Increase of fiber content beyond 2% will decrease the workability and compaction and thereby reduce the strength of concrete.

E. Discussions of Split Tensile Strength Result:

Comparing the split tensile strength of plain concrete and concrete with various percentage of fibers after 28 days of curing.

Plain concrete in N/mm^2	SFRC in N/mm^2	% of increase in strength
0.0% - 4.11	0.5% - 4.52	9.97
	1.0% - 5.31	29.19
	1.5% - 6.05	47.20
	2.0% - 6.70	63.01
	2.5% - 6.10	48.41
	3.0% - 5.08	23.60

Table 5.5.1: Comparison of plain concrete and reinforced concrete aspect ratio (L/D) =45

Plain concrete in N/mm^2	SFRC in N/mm^2	% of increase in strength
0.0% - 4.11	0.5% - 4.66	13.38
	1.0% - 5.59	36.00
	1.5% - 6.61	60.82
	2.0% - 7.30	77.61
	2.5% - 8.89	67.63
	3.0% - 5.73	39.41

Table 5.5.2: Comparison of plain concrete and reinforced concrete aspect ratio (L/D)=60

From the above tables it is clear that the strength of SFRC with 2% fiber has increased by 63.01% for L/D=45 and 77.61% for L/D=60 for split tensile, compared to the plain concrete.

Increase of fiber content beyond 2% will decrease the workability and compaction and thereby reduce the strength of concrete.

F. Discussions Of Flexural Strength Result:

Comparing the flexural strength of plain concrete and concrete with various percentage of fibers after 28 days of curing.

Plain concrete in N/mm^2	SFRC in N/mm^2	% of increase in strength
0.0% - 4.08	0.5% - 4.65	13.97
	1.0% - 5.14	25.98
	1.5% - 6.12	50.00
	2.0% - 5.63	37.99
	2.5% - 6.04	48.03
	3.0% - 5.55	36.02

Table 5.6.1: Comparison of plain concrete and reinforced concrete aspect ratio (L/D) =45

Plain concrete in N/mm^2	SFRC in N/mm^2	% of increase in strength
0.0% - 4.08	0.5% - 4.77	16.91
	1.0% - 5.31	30.14
	1.5% - 6.29	54.16
	2.0% - 5.72	40.19
	2.5% - 5.79	41.19
	3.0% - 5.71	39.95

Table 5.6.2: Comparison of plain concrete and reinforced concrete aspect ratio (L/D) = 60

From the above tables it is clear that the strength of SFRC with 1.5% fiber has increased by 50.00% for L/D=45 and 54.16% for L/D=60 for flexure, compared to the plain concrete.

Increase of fiber content beyond 1.5% will decrease the workability and compaction and thereby reduce the strength of concrete.

VI. CONCLUSION

1) Adding of fibers to concrete decrease the workability of concrete whereas increase the tensile strength of concrete.
2) The steel fibers used in this project has shown considerable improvement in all the properties of concrete when compared to conventional concrete such as,
   - Compressive strength by 29.86% (L/D=45) and 34.79% (L/D=60) for 2% of the steel fibers.
   - Split tensile strength by 63.01% (L/D=45) and 77.61% (L/D=60) FOR 2% of steel fibers.
   - Flexural strength by 50% (L/D=45) and 54.16% (L/D=60) for 1.5% of steel fibers.
3) The steel fibers are free from water absorption.
4) The increase in the tensile strength of concrete depends upon the aspect ratio of the fibers added and fiber percentage.
5) When compared to percentage increase in the strength of compression, split and flexural strength percentage has increased more.

VII. Scope for the Further Study

1) Further study can be done for determining the deflections and durability of concrete
2) Further study on the seepage characteristics of the steel fibers.
3) As the failure of SFRC is ductile further studies on retrofitting of damaged structure constructed of this concrete can be under taken.
4) Study of compressive behavior on high temperature of fiber reinforced concrete.
5) Computation of formulae to determine the percentage of fiber for maximum strength using non dimensional parametrical analysis.

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