Steel Fibre Reinforced Concrete

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Abstract

The purpose of this research is based on the investigation of the use of steel fibres in structural concrete to enhance the mechanical properties of concrete. The objective of the study was to determine and compare the differences in properties of concrete containing without fibres and concrete with fibres. This investigation was carried out using several tests, compressive test and flexural test. A total of eleven mix batches of concrete containing 0% to 5% with an interval of 0.5% by wt. of cement. 'Hooked' steel fibres were tested to determine the enhancement of mechanical properties of concrete. The workability of concrete significantly reduced as the fibre dosage rate increases.

Key words: Steel fibres, FRC, Workability, Strengths.

1. Test Conducted On Harden Concrete: Confirming To IS 516-1959 [15]

In present work weigh batching hand mixing is used to study cube compression test, flexural test on beams, on plain and Steel Fibre Reinforced Concrete (SFRC) were carried on number of samples. The experimental set up for various tests were described below.

1.1 Hooked Steel fibres

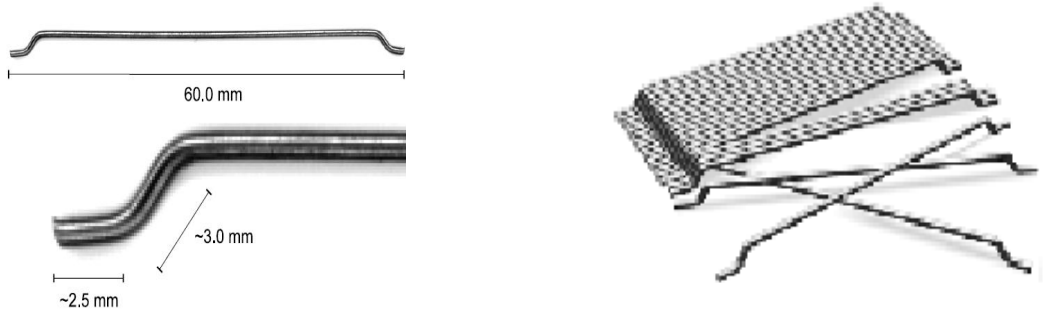

Figure 1.1: Hooked Shape Steel Fiber

Table 1.1: Physical Properties of Steel Fibers

Sr. No.	Property	Values
1.	Diameter	0.75 mm
2.	Length of fiber	60 mm
3.	Appearance	Bright in clean wire
4.	Average aspect ratio	80
6.	Deformation	Hooked at both ends
7.	Tensile strength	1050 MPa
8.	Modulus of Elasticity	200 GPa
9.	Specific Gravity	7.8

1.2 Mix Design of Concrete

IS method of mix designed was used for mix design of M-35 grade of concrete. The quantities of ingredient materials and mix proportions as per design are as under.

Table 1.2: Quantity of Materials per Cubic Meter of Concrete

Material	Proportion by weight	Weight in Kg/m^3
Cement	1	479
F.A.	1.087	521
CAI (20mm) (60%)	1.419	679.98
CAII (10mm) (40%)	0.947	453.33
Water	0.400	191.61

1.3 Compressive strength test on cube

A cube compression test performed on standard cubes of plain and SFRC of size 100 x 100 x 100mm after 7 days and 28 days of immersed in water of curing plain concrete and SFRC specimens. Results are shown in Table (2.2). The compressive strength of specimen was calculated by the following formula:

$$f_{cu} = \frac{P_C}{A} \qquad (1)$$

Where,

P_c = Failure load in compression, KN

A = Loaded area of cube, mm^2

f_{cu} = compressive strength

Expressions for compressive strength in 3 rd degree polynomial in terms of V_f are given by the following equations

7 Days: $f_{cu} = 0.047\ V_f^3 - 1.143\ V_f^2 + 4.689\ V_f + 29.08$ (2)

28 Days: $f_{cu} = -0.068\ V_f^3 + 0.213\ V_f^2 + 0.828\ V_f + 42.77$ (3)

Experimental results and results of regression analysis are presented in Table 3.0

V_f Volume Fraction of Fibers (%)

1.4 Flexural test on plain concrete and SFRC

Standard beams of size 100 x 100 x 500mm were supported symmetrically over a span of 400mm and subjected to two points loading till failure of the specimen. The deflection at the center of the beam is measured with sensitive dial gauge on UTM.

The flexural strength was determined by the formula

$$f_{cr} = \frac{P_f L}{bh^2} \quad (4)$$

Where,

f_{cr} = Flexural strength, MPa

P_f = Central point through two point loading system, N

L = Span of beam, mm

b = Width of beam, mm

h = Depth of beam, mm

Expressions for flexure strength in 3rd degree polynomial in terms of V_f are obtained

7 Days: $f_{cr} = -0.0149\ V_f^3 + 0.0301\ V_f^2 + 0.27\ V_f + 5.098$ (5)

28 Days: $f_{cr} = -0.0262\ V_f^3 + 0.245 V_f^2 - 0.3963\ V_f + 6.114$ (6)

Experimental results and results of regression analysis are presented in Table 4.0

2. RESULT AND DISCUSSIONS

2.1 Experimental Analysis

The main objective of the test program is to study the effect of hooked steel fibres on various concrete strengths in hardened and wet condition at their various percentages. The test on harden concrete are carried out according to relevant standards wherever applicable. Results of various strengths are computed according to the

strength of material theory. Various tables presented in this chapter shows the results obtained from the test on wet and harden concrete. Results of harden SFRC are discussed in comparison with those of normal concrete.

2.2 Compressive strength test on cube

The compressive strength of concrete with various fibre volume fractions is calculated and presented in Table 2.2

Sr. No.	Mix. Design.	Fibre Content Vf (%)	Compressive Strength fcu , MPa		% variation in Compressive Strength over Control Concrete	
			7days	28 days	7days	28 days
1	M0	0.0	29.00	43.33	-	-
2	M1	0.5	31.00	42.34	06.89	-2.29
3	M2	1.0	32.34	43.67	11.51	0.77
4	M3	1.5	33.34	44.50	14.96	2.69
5	M4	2.0	34.34	44.67	18.41	3.08
6	M5	2.5	34.67	45.33	19.53	4.62
7	M6	3.0	35.00	46.0	20.68	6.15
8	M7	3.5	33.00	45.0	13.79	3.85
9	M8	4.0	32.33	44.67	11.48	3.08
10	M9	4.5	31.33	44.33	8.034	2.31
11	M10	5.0	30.00	44.0	3.448	1.54

Table 2.2: Compressive strength of normal and SFRC concretes, MPa

Results of compressive strength are shown in Table (2.2). It indicates the optimum volume fraction of fibers which gives maximum strength at 28 days is 3.0%. The percentage augment in strength at this volume fraction of fibers over normal concrete at 7 and 28 days is 20.68% and 6.15% respectively. Cracks occur in microstructure of concrete and fibers reduce the crack formation and propagation. After optimum level, there is drop in compressive strength which indicates air entrapment in the concrete due to incorporation of high fiber volume fraction.

2.3 Flexural strength test on Beam

Flexural strength is obtained for various fibre volume fraction and results are presented in Table 2.3.

Sr. No.	Mix. Designation.	Fibre Volume fraction V_f (%)	Flexural strength N/mm^2 From Eq^n (6)		% variation in Flexural Strength	
			7 days	28 days	7 days	28 days
1	MO	0.0	5.12	6.05	-	-
2	M1	0.5	5.22	6.03	02.03	-00.44

3	M2	1.0	5.33	6.01	04.14	-00.66
4	M3	1.5	5.57	5.95	08.85	-01.76
5	M4	2.0	5.69	6.11	11.20	00.88
6	M5	2.5	5.73	6.29	11.98	03.96
7	M6	3.0	5.75	6.21	12.34	02.64
8	M7	3.5	5.76	6.53	12.50	07.94
9	M8	4.0	5.83	7.01	13.80	15.86
10	M9	4.5	5.49	6.93	07.29	14.54
11	M10	5.0	5.39	6.91	05.20	14.10

Table 2.3: Flexural strength of fibre reinforced concrete, MPa

Table 2.3 shows that the flexural strength increases with increase in fiber content up to 4.0% and then it decreases. The maximum values at 7 and 28 days are 5.83 and 7.01 respectively. Thus, there is enhancement in flexural strength of concrete from 2.03% to 13.80% at 7 days and from 0.88% to 15.86 % at 28 days.

3 MATHEMATICAL ANALYSES

3.1 Compressive strength

Mix. Desi.	Fibre Volume fraction V_f (%)	Compressive strength f_{cu} (MPa)			
		Exp. Value 7 days	From Eq^n(4) 7 days	Exp. Value 28 days	From Eq^n (5) 28 days
M0	0.0	29.00	29.08	43.33	42.77
M1	0.5	31.00	31.14	42.34	43.23
M2	1.0	32.34	32.67	43.67	43.74
M3	1.5	33.34	33.70	44.50	44.26
M4	2.0	34.34	34.26	44.67	44.73
M5	2.5	34.67	34.39	45.33	45.11
M6	3.0	35.00	34.13	46.0	45.34
M7	3.5	33.00	33.50	45.0	45.36
M8	4.0	32.33	32.56	44.67	45.14
M9	4.5	31.33	31.32	44.33	44.61
M10	5.0	30.00	29.83	44.0	43.74

Table 3.1 Compressive strength

From Table 3.1 the experimental values and values obtained from regression analysis are in good agreement with each other.

3.2 Flexural strength

Mix. Desi.	Fibre Volume fraction V_f (%)	Flexure strength (f_f) MPa			
		Exp. Value 7 days	From Eq^n(7) 7 days	Exp. Value 28 days	From Eq^n (8) 28 days
M0	0.0	5.12	5.10	6.05	6.11
M1	0.5	5.22	5.24	6.03	5.97
M2	1.0	5.33	5.38	6.01	5.93
M3	1.5	5.57	5.52	5.95	5.97
M4	2.0	5.69	5.64	6.11	6.07
M5	2.5	5.73	5.73	6.29	6.22
M6	3.0	5.75	5.78	6.21	6.38
M7	3.5	5.76	5.77	6.53	6.55
M8	4.0	5.83	5.71	7.01	6.70
M9	4.5	5.49	5.56	6.93	6.82
M10	5.0	5.39	5.34	6.91	6.88

Table 3.2Comparison of flexure strength by regression analysis.

From table 3.2 with addition of specific amount of fibres to the concrete, higher ductility is achieved. Results of experimental and regression analysis are in good agreement with each other.

From Table 4 the experimental values and values obtained from regression analysis are in good agreement with each other.

4. CONCLUSIONS

1. Workability decreases with increase in fibre content.
2. The wet and dry density (7 and 28 Days) goes on decreasing as the percentage fibre volume fraction increases.
3. The maximum percentage increase in compressive strength, flexural strength, achieved are 6.15, and 7.94, respectively at 3.0%, 4.0%, of fibre volume fractions.
4. In general, the satisfactory improvement in various strengths is observed with the inclusion of Steel fibres in the plain concrete. However, maximum gain in strength of concrete is found to depend upon the amount of fibre content. The optimum fibre content to impart maximum gain in various strengths varies with type of the strengths.
5. Ductility of concrete is found to increase with inclusion of fibres at higher fibre content. The width of cracks is found to be less in SFRC than that in plain cement concrete beam.

REFERENCES

[1]. Singh S.P, Kaushik S.K, "*Fatigue Strength of Steel Fibre Reinforced concrete in Flexure*", ACI Material Journal, Vol.98, No.4, 2001pp.306-312.

[2]. Balendran R.V., Zhou F.P, A. Nadeem, A.Y.T. Leung, "Influence *of Steel Fibres on Strength and Ductility of Normal and Lightweight High Strength Concrete*", Building and Environment, Vol.37, No.12, (2002), pp. 1361-1367.

[3]. Remigijus Salna, Gediminas Marciukaitis, "*The Influences of Shear Span Ratio on Load Capacity of Fibre Reinforced Concrete Elements with Various Steel Fibre Volumes*", ISSN 1392-3730 print / ISSN 1822-3605 online Journal of civil Engineering and Management, Vol XIII, No. 3, 2007,pp 209-215

[4]. Job Thomas and Ananth Ramaswamy, "Mechanical *Properties of Steel Fiber-Reinforced Concrete*", ASCE Journal of Materials in Civil Engineering, Vol. 19, No. 5 , 2007, pp.385-395.

[5] Jacek Katzer, "*Steel Fibers and Steel Fiber Reinforced Concrete in Civil Engineering*". The Pacific Journal of Science and Technology, Vol.7, No.1, May 2006 (Spring), pp. 53-58

[6]. Julie Rapoport, Corina-Maria Aldea, Surendra P. Shah, Bruce Ankenman and Alan Karr, "*Permeability of Cracked Steel Fiber-Reinforced Concrete". Journal of Materials in Civil Engineering*, Vol. 14, No. 4, August 1, 2002, pp.355-358.

[7]. Jean-Louis Granju and Sana Ullah Balouch, "*Corrosion of steel fibre reinforced concrete from the cracks*". Cement and Concrete Research, Vol. 35, 2005, pp. 572 – 577.

[8]. Calogero Cucchiara, Lidia La Mendola and Maurizio Papia, "*Effectiveness of stirrups and steel fibers as shear reinforcement*". Cement and Concrete Research, Vol.26, 2004, pp. 777-786.

[9]. Bayramov F., Tasdemir C. and Tasdemir M.A., "*Optimisation of steel fiber reinforced concretes by means of statistical response Surface method*". Cement & Concrete Composites, Vol. 26, 2004, pp.665–675.

[10]. IS.383, "*Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete*," Bureau of Indian Standards, New Delhi, 1970.

[11]. I.S.1489-1991, "*Specification for Portland pozzolonas cement Part 1 Fly ash based (Third Revision)*", Bureau of Indian Standard, New Delhi, 1991.

[12]. I.S.456-2000, "Indian *Standard Code of Practice for Plain and Reinforced Concrete, (fourth Revision)*", Bureau of Indian Standard, New Delhi, 2000 .

[13]. I.S.10262-1982, "*Indian Standard Recommended Guidelines for Concrete Mix Design*", Bureau of Indian Standard, New Delhi, 1983.

[14]. IS 516 (Reaffirmed 1999), "*Method of Test for Strength of Concrete*." BIS New Delhi, 1959, pp. 1-25.