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EVALUATION OF SPLIT TENSILE STRENGTH OF HIGH STRENGTH FIBER REINFORCED CONCRETE

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Abstract-- **This paper deals with the results of an experimental investigation of the split tensile strength with steel fiber blended with the high strength concrete (M60). The fiber content varied from 0.5 to 5 % by weight of cement at the interval of 0.5 %. Beams of 150mm x 150mm x 700 mm were tested for the flexural strength which was failed and broken in between middle third. The smaller broken piece was taken and tested for the split tensile test. A circulat bar of 6mm diameter was placed at a distance 150mm from the finished end and loaded till the failure and the tensile strength was found. Results and expressions by regression analysis are obtained. A significant improvement in the split tensile strengths is observed due to inclusion of steel fibers in the concrete.**

Key Words -**High strength concrete, Steel Fiber, Volume fraction of fibers, SFRC, Split.**

I. INTRODUCTION

"High Strength Concrete" (HSC) is generally used for concrete with compressive strength higher than 42MPa (6000psi) which leads to the design of smaller sections. This in turn reduces the dead weight, allowing longer spans and more usable area of buildings.

The increase in concrete strength reduces its ductility. The higher the strength of concrete, the lower is its ductility. This inverse relation between strength and ductility is a serious drawback for the use of high strength concrete and a compromise between these two characteristics of concrete can be obtained by adding discontinuous fibers. Also high-strength concrete is known to manifest a more brittle behaviour than normal strength concrete. When concrete cracks, the randomly oriented fibers arrest a micro-cracking mechanism and limit crack propagation, thus improving strength and ductility.

Development of such type of concrete that has to meet special requirements and performance cannot be always achieved by using only conventional materials and procedure. The requirements may be the enhancement of characteristics such as placement and compaction without segregation, mechanical properties, toughness, durability and serviceability in severe environments. To improve properties of concrete, a new type of concrete known as fiber reinforced concrete is introduced. Fiber Reinforced Concrete (FRC) is a relative new composite material in which fibers are introduced in the matrix as micro reinforcement, so as to improve the tensile, cracking and other properties of concrete.

II. LITERATURE REVIEW

Balendran, Zhou, Nadeem and Leung [1] investigated the effectiveness of fiber inclusion in the improvement of mechanical performance of concrete with regard to concrete type and specimen size. Lightweight aggregate concrete, the limestone aggregate concrete with and without steel fibers were used in the study. The compressive strength of the concrete mixes varied between 90 and 115 MPa and the fiber content was 1% by volume. The increase in spitting tensile strength, flexural strength and toughness index for lightweight concrete seems much higher than that of normal aggregate concrete.

Barros and Figueiras [2] established flexural behavior of SFRC with fiber content of the concrete ranged from 0 to 60 kg/m3.

Ghugal [3] studied effect of steel fibers on various strength of concrete. Author takes various percentage of steel fiber with four grades of mixes. For each mix cube, cylinder, beams and shear specimens are casted.

Giuseppe Campione [4] he reported that an analytical model was proposed that is able to determine the flexural response of supported beams under four point bending tests. A simplified analytical model is presented that is able to calculate the load deflection curves and the maximum and ultimate deflections occurring in the case of shear or flexure failure.

Lok and Xiao [5] demonstrated that how the first crack flexural strength Fcr and the ultimate flexural strength Fult can be derived from a constitutive stress- strain mode. The model is described in a separate study both strength Fcr and Fult are dependent on material and composite properties. Further stories are then conducted to derive a simplified form to asses the ultimate flexural strength of SFRC.

Parviz Soroushian and Ziad Bayasi, [6] investigated the flexural behavior of reinforced concrete beams containing steel fibers. They indicated that the ductility and the ultimate resistance are remarkably enhanced due to the addition of steel fibers. The design implication of fiber-reinforced concrete beams is also discussed & method for incorporating fiber effects in the flexural analysis of singly reinforced concrete beams.

Sawant, Khan, Aher and Bundele [7] did comprehensive study of high strength fiber reinforced concrete under pullout strength and reported considerable improvement in the pullout strength.

Sawant, Khan, Khan and Waykar [8] studied the behaviour of high strength fiber reinforced concrete under shear and observed that the inclusion of fiber has comparatively increased the shear strength of the concete.

III. METHODOLOGY

1. Materials used in experimental work.

The ingredients of concrete i.e. cement, fine aggregate and coarse aggregate are tested before put them in the work. The various tests have been conducted according to relevant Indian standard code of practice.

All cement, sand, coarse aggregate (20mm), and coarse aggregate (10mm) measured with digital balance. The water is measured with measuring cylinder of capacity 1 liter and measuring jar of capacity 1000ml, 200ml. The Crimped Steel fiber is measured with digital balance of accuracy 1mg.

1.1Cement

Ordinary Portland Cement of 53 grade. All the properties of cement are tested according to IS 12269-1987 [9] specifications having 7 days compressive strength of 45.20Mpa

1.2. Potable water

Water available in the laboratory is used for mixing and curing of concrete.

1.3. Natural Sand

Source from local Godavari river is used confirming to IS 383-1970 [10].

1.4. Aggregate

Crushed black trap basalt rock of aggregate size 20mm down and 10mm down were used confirming to IS 383-1970 [10]. The fineness modulus of sand was 2.803 and those of 10mm and 20mm coarse aggregates were 7.52

The physical properties of fine and course aggregate are given in table 1.

Table 1 Physical Properties of Aggregates

S.No.	**Particulars**	**Coarse Aggregate**	**Fine Aggregate**
1	Density (compacted) in Kg/Cum	1730	1918.09
2	Fineness Modulus	7.52	2.803
3	Specific Gravity	2.78	2.6
4	Water Absorption (%)	1.6	1.21

1.5. Steel fibers

Conforming to ASTM A 820 type-I [11] are used for experimental work. Physical and mechanical properties of steel fibers are given in Table 2.

Table2. Physical and Mechanical Properties of Steel Fibers

Sr. NO	Property	Value
1	Length of fiber	50.0 mm (Flat)
2	Appearance	Bright in clean
3	Average aspect ratio	50
4	Deformation	Continuously deformed circular segment
5	Fiber tensile strength	1000 MPa
6	Modulus of Elasticity	200 GPa
7	Specific Gravity	7.8

Dosages used: 0.5 % to 5.0% with the increment of 0.5% by weight of cement

1.6. Super-plasticizer

An admixture conforming to IS 9103:1999 [12] was used to impart high workability at decreased water content. (Conplast 430)

2. Mix Design and proportioning of Concrete ingredients

Mix design of M-60 grade is carried out using IS method I.S. 10262-1982[13] The M-60 grade of concrete having mix proportions 1: 0.75: 2.52 (20mm-1.51+ 10 mm-1.01) i.e. Cement: Fine aggregate: Coarse aggregate (10mm and 20mm) with w/c ratio of 0.3 was used throughout the experimental investigation. The quantities of various ingredients in Kg/m^3 are given in table 3.

Table 3. Quality of Material per cubic meter of Concrete

Material	Proportion by weight	Weight in Kg/m^3
Cement	1	430
F.A.	0.75	309.6
CA I (20mm) (60%)	1.51	649.3
CA II (10mm) (40%)	1.01	434.3
Water/cement ratio	0.3	129

The tensile splitting strength was determined using broken half of a prism (beam) after it has been tested for flexural strength. The flexural beam brakes in between the middle third. The smaller piece of the broken specimen is taken and a 6mm mild steel bar is placed at a distance of 150mm from a finished end and loaded on the compression testing machine till the failure. The tests were conducted according to standard procedures. In this test, compressive line loads are applied along a vertical symmetrical plane setting up tensile stresses normal to plane, which causes splitting of specimen. The formula derived using theory of elasticity has been used to calculate the tensile strength of the time of splitting.

The split tensile is well known indirect test used to determine the tensile strength of concrete.

The indirect split tensile strength is calculated by the following formula.

For Prism split tensile

$$f_t = \frac{2P}{\pi \ D L_c} \quad (1)$$

where

f_t = Tensile Strength

P = Load at failure in N

D = Diameter of Cylender or side of the cube

L_c = length of the specimen

At 28 days mathematical regression analysis equation for the split tensile strength is given as

$$ft = -0.119Vf^2 + 0.610\ Vf + 4.117 \quad (2)$$

IV RESULT

Experimental results and results of regression analysis by Eq. (1) and Eq. (2) at 28 days along with the percentage variation in split tensile strength are presented in Table 4 and Table 5.

Table 4. Split Tensile Strength of Concrete, MPa

Sr.No	Fiber content (%)	Split Tensile Strength in N/mm^2 of Equivalent cubes Eqn.(1)	% Variation in slpit tensile strength
		28 Days	28Days
1	0.0	4.05	0.00
2	0.5	4.24	4.65
3	1.0	4.61	13.72
4	1.5	5.17	27.68
5	2.0	4.95	22.10
6	2.5	4.83	19.31
7	3.0	4.72	16.52
8	3.5	4.64	14.42
9	4.0	4.55	12.33
10	4.5	4.44	9.54
11	5.0	4.32	6.75

From Table 4, it is observed that, the 28 days spilt tensile strength increased continuously up to 1.5 % Fiber content. The increase in strain is more than 50% which is significant. Hence the Fibers are best suitable for improving the spilt tensile strength of structural concrete. The variation of 28 days, spilt tensile Strength with respect to Fiber content is presented in Figure. 1. The percentage variation of spilt tensile strength over controlled concrete with respect to fiber content at 28 days is presented in Figure. 2.

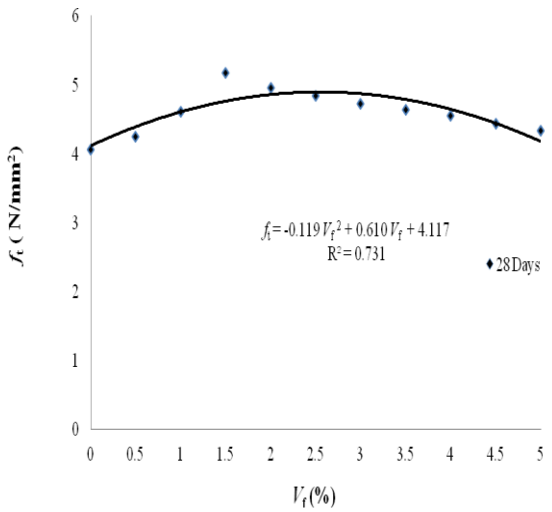

Figure 1: Variation of Split Tensile Strength (f t) With Respect to Fiber Content (V f %).

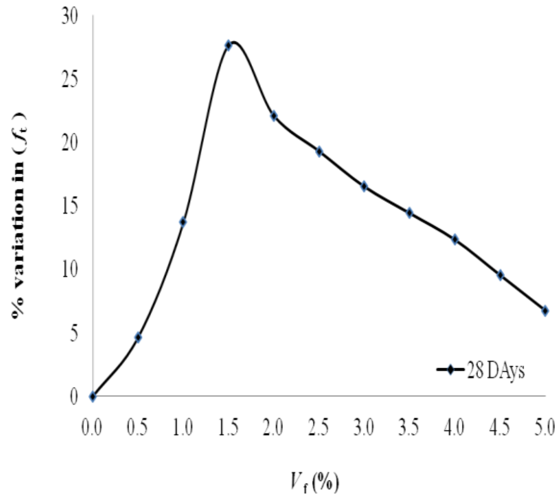

Figure 2: Variation of Split Tensile Strength (%) Over Controlled Concrete With Respect to Fiber Content (Vf %).

Table 5. Experimental and Regression Split Tensile Strength f_t (N/mm^2) on Equivalent cubes at 28 days

Sr.No.	Fiber content	Split Tensile Strength f_t (N/mm^2) on Equivalent cubes at 28 days	
		Experimental Value by Eq. (1)	Regression Value by Eq^n (2)
1	0.0	4.055	4.11
2	0.5	4.244	4.39
3	1.0	4.612	4.61
4	1.5	5.178	4.76
5	2.0	4.951	4.86
6	2.5	4.838	4.9
7	3.0	4.725	4.87
8	3.5	4.64	4.79
9	4.0	4.555	4.65
10	4.5	4.442	4.44
11	5.0	4.329	4.18

V CONCLUSION

Following conclusion are drawn based on the result discussed in the previous chapter.

1. The maximum percentage increase in split tensile strength, 27.68 %, with 1.5 % at 28 days of water curing
2. Empirical expressions have been established to predict the values of flexural strength for SFRC in terms fiber content.
3. After testing the cubes under split the specimen were further stressed and broken into two pieces. It was observed that about 40% of the fibers were slipped and 20 % were broken.
4. For all fiber content, mode of failure was changed from brittle to ductile failure when subjected to all types of strengths in this study.
5. In general, the significant improvement in various strengths is observed with the inclusion of steel fibers in the plain concrete. However, maximum gain in flexural strength of concrete is found to depend upon the amount of fiber content.
6. The optimum fiber content to impart maximum gain in strength varies with type of the strength.

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