To evaluate the performance of stainless steel fiber in concrete

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***Abstract*—**This paper deals with stainless steel fiber reinforced concrete mechanical static behavior and with its classification with respect to fibers content and mix-design variations. A number of experimental tests were conducted to investigate uniaxial compressive strength and tensile strength. Different mixtures were prepared varying both mix-design and fiber length. Fibers content in volume was of 0.5% and 1%. Mechanical characterization was performed by means of uniaxial compression tests with the aim of deriving the ultimate compressive strength of fiber concrete. The tensile strength of stainless steel fiber reinforced concrete (SFRC) was obtained both from an experimental procedure and by using an analytical modeling. The experimental tests showed the different behavior of SFRC with respect of the different fiber content and length. Based on the experimental results, an analytical model, reported in literature and used for the theoretical determination of direct tensile strength, was applied with the aim of making a comparison with experimental results. The comparison showed good overall agreement.

***Keywords*— compressive strength, durability, flexural strength, high strength concrete, Spilt tensile, stainless steel fiber, , , ,**

I. *INTRODUCTION*

The use and definition of high-strength concrete Mix design is a fundamental aspect in stainless steel fiber reinforced concrete (SFRC) behavior, meaning that the correct proportion between different constitutive materials has to be properly designed. Physical and mechanical properties of the composite depend on the dosage and properties of the components (i.e. cementitious matrix and fibers). When steel fibers are added to a concrete mix, the final composite behavior changes, especially during the cracking phase. Choosing the optimum dosage and right mix components, and their benefits is essential for a good resulting SFRC.

First of all, aggregate properties are directly related to concrete mechanical behavior. If the course aggregate and the cementations matrix show similar elastic modulus, the mechanical behavior in the elastic phase isomer uniform and failure arises suddenly. On the contrary, if elastic modules are different, micro-cracking takes place and stress–strain curve clearly shows a softening behavior. Because the presence of steel fibers reduces the mixtures workability, an improvement of it can be obtained by increasing fine aggregate content or adding fluidifying admixures. Moreover, the minimum cement dosage depends on the maximum coarse aggregate size; consequently, water-to-cement ratio, which defines the mechanical strength of hardened concrete, depends on the cement proportioning. Finally, the addition of steel fibers to concrete, expressed as volume fractions, increases both strength and ductility properties, but reduces the workability. The present paper was developed to characterize concrete elements reinforced by steel fibers mixed in two different volume fractions and having different lengths, with the aim of giving a useful contribution to the ongoing research effort in the field of these composite materials. In particular, three different experimental tests were conducted on concrete specimens mixed with steel fiber volume fractions of 0.5% and 1%, respectively: Experimental results allowed the study of fiber influence in the mixtures, and showed that compressive strength is less affected by the presence of fibers, while post-cracking behavior considerably changesThe final section of the work is focused on split tensile strength of steel fiber reinforced concrete, both from an experimental and theoretical point of view. An analytical modeling of SFRC has been conducted adopting the theoretical model proposed in developed for the determination of upper and lower bounds for tensile stiffness and strength of SFRC by means of homogenization techniques and variation principles. On the basis of the model hypothesis both for materials constitutive relations and SFRC internal structure, and taking into account split tensile test results obtained from the proposed experimental procedure, a comparison was made between analytical and experimental results, showing good overall agreement.

II. *MATERIALS & THEIR PROPERTIES*

A). AGGREGATES

The aggregate properties that are most important with regard to high performance concrete are: Particle shape, particle size distribution, mechanical properties of the aggregate particles, and possible chemical reactions between the aggregate and the paste which may affect the bond. Unlike their use in ordinary concrete, where we rarely consider the strength of the aggregates, in high performance concrete the aggregates may well become the strength limiting factor. Also, since it is necessary to maintain a low w/c ratio to achieve high strength, the aggregate grading must be very tightly controlled.

1. Fine Aggregate (Sand):

Good quality river sand (sevaliya region) was used as a fine aggregate.Ref. Code : IS: 383 & 2386

Table 1: Results of tests on Fine Aggregate

Description	Results
Fineness Modules	3.09
Zone	II
Water Absorption	2.10
Specific Gravity	2.65

2. COARSE AGGREGATE

For high performance concrete, the coarse aggregate particles themselves must be strong. From both strength and rheological considerations, the coarse aggregate particles should be roughly equi-dimensional; either crushed rock or natural gravels, particularly if they are of glacial origin, are suitable. In addition, it is important to ensure that the aggregate is clean, since a layer of silt or clay will reduce the cement-aggregate bond strength, in addition to increasing the water demand.

Ref. Code: IS: 2386 & 383

Results of tests on Coarse Aggregate

Tests	Results
Coarse aggregate 20 mm	
Water Absorption	1.90
Specific Gravity	2.87
Impact Value	10.70
Crushing Value	13.90
Coarse Aggregate (Grit)	
Water Absorption	2.10
Specific Gravity	2.74
Impact Value	12.40
Crushing Value	14.20

3.SUPERPLASTISIZERS

In modern concrete practice, it is essentially impossible to make high performance concrete at adequate workability in the field without the use of super plasticizers. Cumacon-3755-SS (1.2% of cement) was used for the experimental work.

Use of Super plasticizer: Cumacon-3755-SS KUNAK chemicals

Properties:

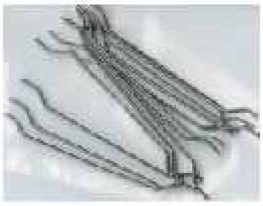
Specific gravity - 1.220 to 1.225 at 300C

Chloride content- Nil to IS: 456

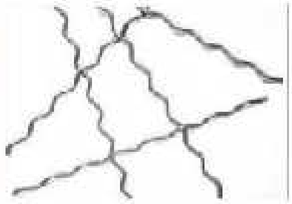
Air entrainment - Approx. 1% additional air is entrained.

4). STAINLESS STEEL FIBER

steel fibers are available in various shapes and sizes. however the common ones are 1)the hooked end fibers, 2) the crimped and round fibers and 3) corrugated fibers



Hooked End Steel Fibers



Round Crimped Steel Fibers

Area of application

Steel Fiber Technology is widely recommended in Concreting of Tunnels, Slope Stabilization, Mine Roof Support, and Pre Cast for Tunnel Linings, Foundation Slabs, Roads, Bridges, Runways, Taxiways, Factory Flooring, Pre Cast walls, Concrete Pipes, Manhole Covers, and various other concrete applications.

ADVANTAGES

- Steel Fibers result in more homogenous mix in concrete
- Flexural strain capacity is enhanced
- Adds ductility to concrete
- Controls cracks
- Joint stability
- Narrow joint width
- Shear load transfer
- Fatigue and impact resistance
- Post crack ductility
- Reduces material consumption and saves cost
- Longer service life

III. *MIXTURE PROPORTIONING*

The mixture proportioning was done according the Indian Standard Recommended Method IS 10262-2009.The target mean strength was 50 MPA for the PPC control mixture, the total binder content was 400 kg/m^3 ,fine aggregate is taken 628.52 kg/m^3 and coarse aggregate is taken 919.20 kg/m^3 the water to cement ratio was kept constant as 0.35, the Super plasticizer content was varied to maintain a slump of (50-80 mm) for all mixtures. The total mixing time was 5 minutes, the samples were then casted and left for 24 hrs before demoulding They were then placed in the curing tank until the day of testing Cement, sand, Basalt fiber and fine and coarse aggregate were properly mixed together in accordance with IS code in the ratio 1:1.57:2.29 by weight before water was added and was properly mixed together to achieve homogenous material. Water absorption capacity and moisture content were taken into consideration and appropriately subtracted from the water/cement ratio used for mixing. Hence, The stainless steel fibers was added in percentages of 0.5% and 1% of the concrete volume, Beam and Cylinder moulds were used for casting. Compaction of concrete in three layers with 25 strokes of 16 mm rod was carried out for each layer. The concrete was left in the mould and allowed to set for 24 hours before the cubes were de moulded and placed in curing tank. The concrete cubes were cured in the tank for 7, 14 days.

IV. *TESTING METHODS*

Experimental investigation of fresh mix Properties of stainless steel fiber concrete were conducted using a slump cone. Compressive and Flexural strength of each specimen was determined using IS: 516 - 1959 and splitting tensile strength of each specimen was determined using IS: 5816 - 1959.Length change was measured according to IS: 516 - 1959. Compressive strength were measured 7, 14, days and flexural tensile strengths were measured 7 days of testing. Splitting tensile strengths were measured at 7 days. Specimens were cube with a 150 mm side for compressive strength, prism with dimensions of 150x150x700 mm for flexural tensile strength, cylinder with 150 mm diameter and 300 mm height for splitting tensile strength.

V. SPECIMENS

Specimens have been prepared using metallic moulds properly designed as per standards.

i.e. For compression test-

cubic specimens having dimensions 150x150x150 mm^3. Mixtures and specimens preparation followed the current codes, both during the mixing and moulds filling phases and during the compaction phase occurred by means of a vibrating board. The slump of fresh reinforced concrete was also measured by means of Abrams cone method (Slump Test) to define its consistency class and designation. Twenty-four hours after the mixtures preparation, the specimens were taken out of the moulds and cured in standard conditions, covering them with damp sand in a closed room at 20 C Temperature and relative humidity of 90%. Specimens were taken out of the curing room 48 h before tests started. 3. Experimental equipment and test procedures experimental tests were carried out at the official Materials and Structures.

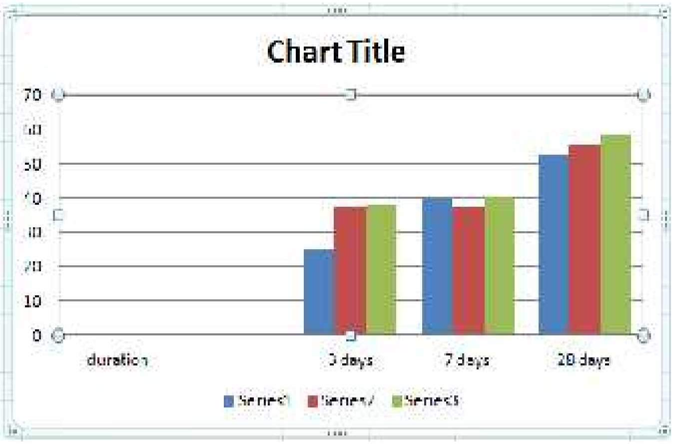
VI . EXPERIMENTAL RESULTS

Compression test

Compression test results allowed the mechanical characterization of the material and the evaluation of its compressive strength.. Table shows the compression test results. Experimental results showed that compressive strength of SFRC is less affected by the presence of fibers. However, failure mode considerably changes from fragile to ductile. Due to bridging effect of the fibers, the cubic specimens did not crush but held their Integrity up to the end of the test.

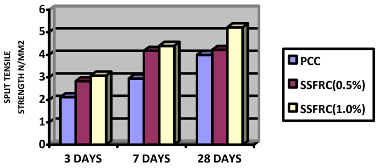
This section shows the experimental results for the three kind of test performed.

Duration	COMPRESSIVE STRENGTH IN N/mm^2		
	FIBER DOSAGE		
	0 %	0.5 %	**1.0 %**
3 days	25.03	37.27	38.04
7 days	39.59	37.29	40.05
28 days	52.36	55.38	58.35



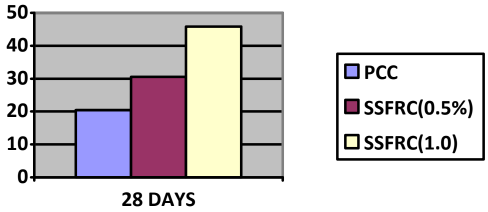
SPLIT TENSILE STRENGTH

SPECIMEN TYPE	AVERAGE TENSILE STRENGTH IN N/MM^2		
	3 DAYS	7 DAYS	28 DAYS
PCC	-	2.95	4.00
SSFRC (0.5%)	-	4.18	4.22
SSFRC (1.0 %)	-	4.40	5.22



FLEXURAL STRENGTH

SPECIMEN TYPE	FIRST CRACK LOAD IN KN	28 DAYS FLEXURAL IN N/MM2	AVERAGE FLEXURAL STRENGTH IN N/MM2
B-1	28.50	4.59	4.64
B-2	27.00	4.80	
B-3	25.50	4.53	
BSF-1	26.50	4.71	4.91
BSF-2	27.00	4.80	
BSF-3	29.00	5.16	
BSF-1	34.00	6.04	5.48
BSF-2	28.50	5.06	
BSF-3	30.00	5.33	



I. DISCUSSIONS :

COMPRESSIVE STRENGTH

The compressive strength of concrete mixed with steel fibers was found to vary marginally, the variation was about -1% to 1% at 28 days. The 3 days strength of ssfrc with volume fraction 0.5% and 1% was 8% and 27% greater than that of control concrete. 50% of the 28 days strength of ssfrc was obtained in 3 days. The compressive strength of ordinary concrete and fiber reinforced concrete are tabulated in table and bar chart is plotted in figure.

SPLIT TENSILE STRENGTH

The tensile strength was found to be increased as the percentage of fiber was increased. For the corrugated fiber with volume fraction of 0.5% and 1.0% the increase in tensile strength was 8 % and 32.4% respectively. The 28 days strength of 0.5% volume fraction of ssfrc was 7% greater than that of PCC of same volume fraction. In all the ssfrc cylinders, the specimen was not broken into two as that of control concrete. The comparison of tensile strength of ordinary concrete and fiber reinforced concrete and the results are tabulated in table and bar chart is plotted in figure.

FLEXURE STRENGTH

The strength was found to increase marginally. The failure was brittle in case of plain concrete and failure was ductile in case of steel fiber reinforced concrete. When the ultimate load was reached the concrete matrix failed, the first crack appeared on the beam. In all the sfrc beams the failure was only by pullout of fibers at the maximum deflection and not by tearing of fibers. In all the specimens (with and without steel fiber) the failure was between the mid-third points. The results are tabulated in table and bar chart is plotted in figure.

VI. CONCLUSION

The following results are inferred based on the experimental results discussed on the previous chapters.

1. Addition of steel fibers to concrete increases the compressive strength of concrete marginally.

2. The addition of steel fibers increases the tensile strength. The tensile strength was found to be maximum with volume fraction of 1%.

3. By the addition of steel fibers the flexure strength was found to decrease marginally.

4. The addition of fibers to concrete significantly increases its toughness and makes the concrete more ductile as observed by the modes of failure of specimens.

5. The stiffness of beams was studied and was found to be maximum for hooked end fiber with 1% volume fraction.

6. The empirical equations developed in this experiment can be used for calculating the toughness indices or percentage of fiber whichever is required.

IX. REFRENCES

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