Experimental Investigation on Steel Fiber Reinforced Concrete

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Abstract: **The present experimental investigation for M-25 grade of concrete having mix proportion 1:1.58:2.41 with water cement ratio 0.43 to study the compressive strength, flexural strength, Split tensile strength of steel fiber reinforced concrete (SFRC) containing fibers of 0%, 0.6%,1.2% and 1.8% volume fraction of hook tain. Steel fibers of 50, 60 and 67 aspect ratio were used. A result data obtained has been analyzed and compared with a control specimen (0% fiber). A relationship between aspect ratio vs. Compressive strength, aspect ratio vs. Split tensile strength represented graphically. Result data clearly shows percentage of steel fiber increases automatically strength of concrete increase in both 7 and 28 days Compressive strength and Split Tensile strength for M-25 Grade of Concrete.**

***KEYWORDS*-steel fiber reinforced concrete (SFRC), compressive strength and split tensile strength of concrete.**

I. INTRODUCTION

Concrete is the most widely used structural material in the world with an annual production of over seven billion tons. For a variety of reasons, much of this concrete is cracked. The reason for concrete to suffer cracking may be attributed to structural, environmental or economic factors, but most of the cracks are formed due to the inherent weakness of the material to resist tensile forces. Again, concrete shrinks and will again crack, when it is restrained. It is now well established that steel fiber reinforcement offers solution to the problem of cracking by making concrete tougher and more ductile. It has also been proved by extensive research and field trials carried out over the past three decades, that addition of steel fibers to conventional plain or reinforced and pre stressed concrete members at the time of mixing/production imparts improvements to several properties of concrete, particularly those related to strength, performance and durability. The weak matrix in concrete, when reinforced with steel fibers, uniformly distributed across its entire mass, gets strengthened enormously, there by rendering the matrix to behave as a composite material with properties significantly different from conventional concrete. The randomly-oriented steel fibers assist in controlling the propagation of micro-cracks present in the matrix, first by improving the overall cracking resistance of matrix it self, and later by bridging across even smaller cracks formed after the application of load on the memb.er, thereby preventing their widening into major cracks In general, SFRC is very ductile and particularly well suited for structures which are Required to exhibit:

- Resistance to impact, blast and shock loads and high fatigue
- Shrinkage control of concrete
- Very high flexural, shear and tensile strength
- Resistance to splitting, erosion and abrasion
- High thermal/ temperature resistance
- Resistance to seismic hazards.

II.HISTORY OF STEEL FIBER REINFORCED CONCRETE

Steel fiber reinforced concrete (SFRC) was introduced commercially into the European market in the second half of the 1970's. No standards or recommendations were available at that time which was a major obstacle for the acceptance of this new technology. Initially steel fibers were mostly used as a substitute or for crack control in less critical parts of the construction. Today steel fibers are widely used as the main and unique reinforcing for industrial floor slabs, short Crete and prefabricated concrete products. They are also considered for structural purposes in reinforcement of slabs on piles, full replacement of the standard reinforcing age for tunnel, concrete cellars, foundation slabs and shear reinforcement in pre stressed elements.

III. TECHNOLOGY FOR PRODUCING SFRC

SFRC can, in general, be produced using conventional concrete practice, though there are obviously some important differences. The basic problem is to introduce a sufficient volume of uniformly dispersed to achieve the desired improvements in mechanical behaviour, while retaining sufficient workability in the fresh mix to permit proper mixing, placing and finishing. The performance of the hardened concrete is enhanced more by fibers with a higher aspect ratio, since this improves the fiber-matrix bond. On the other hand, a high aspect ratio adversely affects the workability of the fresh mix. In general, the problems of both workability and uniform distribution increase with increasing fiber length and volume. One of the chief difficulties in obtaining a uniform fiber distribution is the tendency for steel fibers to ball or clump together.

Clumping may be caused by a number of factors:
- The fibers may already be clumped together before they are added to the mix; normal mixing action will not break down these clumps.
- Fibers may be added too quickly to allow them to disperse in the mixer.
- Too high a volume of fibers may be added.
- The mixer itself may be too worn or inefficient to disperse the fibers.
- Introducing the fibers to the mixer before the other concrete ingredients will cause them to clump together.

In view of this, care must be taken in the mixing procedures. Most commonly, when using a transit mix truck or revolving drum mixer, the fibers should be added last to the wet concrete. The concrete alone, typically, should have a slump of 50-75 mm greater than the desired slump of the SFRC. Of course, the fibers should be added free of clumps, usually by first passing them through an appropriate screen. Once the fibers are all in the mixer, about 30-40 revolutions at mixing speed should properly disperse the fibers. Alternatively, the fibers may be added to the fine aggregate on a conveyor belt during the addition of aggregate to the concrete mix. The use of collated fibers held together by a water-soluble sizing which dissolves during mixing largely eliminates the problem of clumping. SFRC can be placed adequately using normal concrete equipment. It appears to be very stiff because the fibers tend to inhibit flow; however when vibrated, the material will flow readily into the forms. It should be noted that water should be added to SFRC mixes to improve the workability only with great care, since above a w/c ratio of about 0.43, additional water may increase the slump of the SFRC without increasing its workability and place ability under vibration. The finishing operations with SFRC are essentially the same as for ordinary concrete, thought perhaps more care must be taken regarding workmanship.

IV.PROPERTIES OF CONCRETE IMPROVED BY STEEL FIBERS

- **Flexural Strength:** Flexural bending strength can be increased of up to 3 times more compared to conventional concrete
- **Fatigue Resistance:** Almost 1 1/2 times increase in fatigue strength.
- **Impact Resistance:** Greater resistance to damage in case of a heavy impact.
- **Permeability:** The material is less porous.
- **Abrasion Resistance:** More effective composition against abrasion and spalling.
- **Shrinkage:** Shrinkage cracks can be eliminated.
- **Corrosion:** Corrosion may affect the material but it will be limited in certain areas.

V.SOME APPLICATIONS OF SFRC IN INDIA

Fiber reinforced concrete is in use since many years in India, but the structural applications are very much limited. However, its application is picking up in the recent days. Following are some of the major projects where large quantities of steel fibers are used.
- More than 400 tonnes of Shakhty man Steel Fibers have been used recently in the construction of a road overlay for a project at Mathura (UP).
- They have also been successfully used at the end anchorage zones of pre stressed concrete girders for resisting bursting and sapling forces in bridge projects in Bangalore and Ahmadabad executed by one of the reputed construction companies.
- The fibers have also been used for heavy-duty industrial floors.
- Other projects include Samsonity Factory-Nasik, BIPL Plant-Pane, KRCLMSRDC tunnels, NathaJakri Hydro Electric Plant, Kohl HEP, BagliharHEP,Chamera HEP, Sala HEP, Ranganadi HEP, Sirsisilam project, TehriDamproject, Uri Dam Project, etc.
- Used in many tunnelling projects and for slope stabilisation in India.

VI.EXPERIMENTAL PROGRAMME

A. Material used

The material used for this experimental work are cement, sand, water and steel fibers.

Cement: Ordinary Portland cement of 53 grade was used in this experimentation conforming to I.S. – 12269- 1987. Sand: Locally available sand zone II with specific gravity 2.65, water absorption 2% and fineness modulus 2.92, conforming to I.S. – 383-1970.

Coarse aggregate: Crushed granite stones of 20 mm down size having specific gravity of 2.70, fineness modulus of 2.73, conforming to IS 383-1970

Water: Potable water was used for the experimentation.

Fibers: Steel Fibers: - In this experimentation Hook tain Steel fibers were used. length35,30 and 30mm with diameter 0.70, 0.50 and 0.40 resp.

*B. **Experimental methodology***

Compressive strength test:
For compressive strength test, cube specimens of dimensions 150 x 150 x 150 mm were cast for M40 grade of concrete. The moulds were filled with 0%, 0.6% 1.2% and 1.8% fibers. Vibration was given to the moulds using table vibrator. The top surface of the specimen was levelled and finished. After 24 hours the specimens were demoulded and were transferred to curing tank where in they were allowed to cure for7 and 28 days. After 7 and 28 days curing, these cubes were tested on digital compression testing machine as per I.S. 516-1959. The failure load was noted. In each category three cubes were tested and their average value is reported. The compressive strength was calculated as follows.
Compressive strength (MPa) = Failure load / cross sectional area.

Fig. 1 "Testing of compressive strength test specimen"

Split Tensile strength test:

For Split tensile strength test, cylinder specimens of dimension 150 mm diameter and 300 mm length were cast. The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 7 and 28 days. These specimens were tested under compression testing machine. In each category three cylinders were tested and their average value is reported. Split Tensile strength was calculated as follows as split tensile strength: Split Tensile strength (MPa) = 2P / π DL, Where, P = failure load, D = diameter of cylinder, L = length of cylinder

Fig. 2 "Testing of Split tensile strength test specimen"

C.Experimental results

Following graphs give compressive strength and Split Tensile strength result for M-25 grade of concrete with 0%, 0.6%, 1.2% and 1.8 % steel fibers.

Table 1 –Average Compressive Strength at 7 Days of SFRC with 0%. 0.6% ,1.2%and 1.8% fibers M25 grade

GRADE OF CONCRETE	% OF SFRC	AVERAGE COMPRESSIVE STRENGTH AT 7 DAYS (N/mm^2)
M_{25}	0%	28.4
M_{25}	0.6%	33.3
M_{25}	1.2%	35.8
M_{25}	1.8%	37.8

Table 2 –Average Compressive Strength at 28 Days of SFRC with 0%. 0.6% ,1.2%and 1.8% fibers M25 grade

GRADE OF CONCRETE	% OF SFRC	AVERAGECOMPRESSIVE STRENGTH TEST AT 28 DAYS(N/mm^2)
M_{25}	0%	33.3
M_{25}	0.6%	39.9
M_{25}	1.2%	47.2
M_{25}	1.8%	53.1

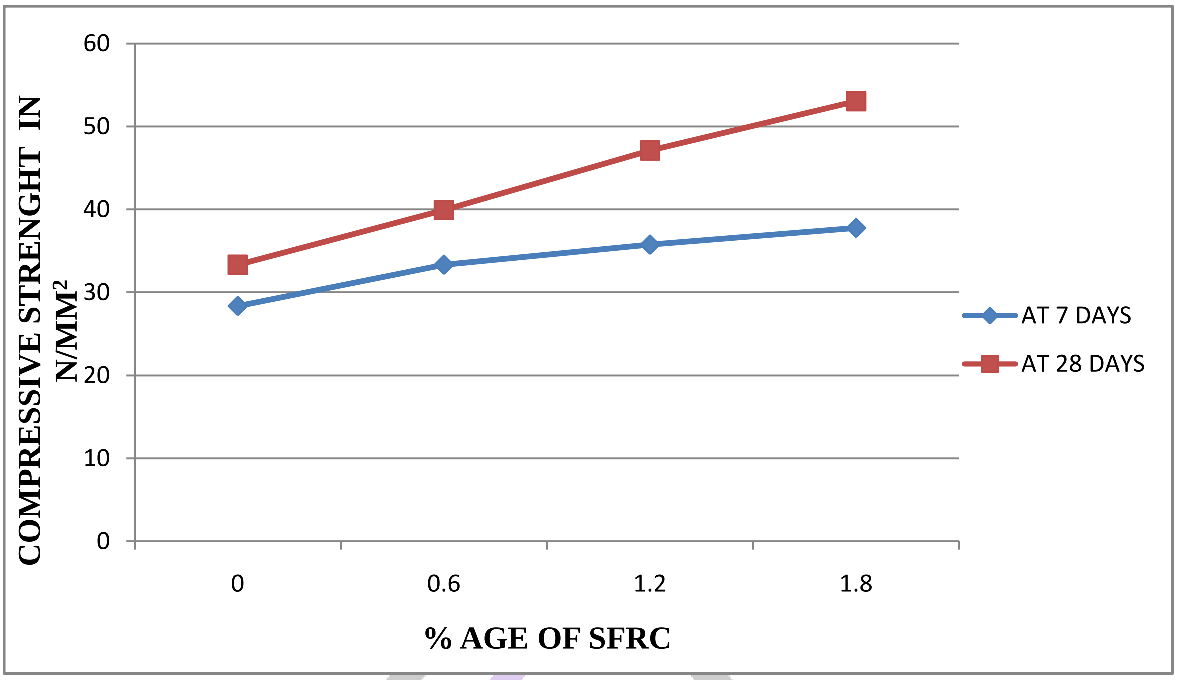

Figure 3: percentage increase in 7 and 28 days compressive strength for M-25 grade concrete

Table 3 –Average Split tensile Strength at 7 Days of SFRC with 0%. 0.6% ,1.2% and 1.8% fibers M25 grade

GRADE OF CONCRETE	%OF SFRC	SPLIT TENSILESTRENGTH TEST AT 7 DAYS (N/mm^2)
M_{25}	0%	1.9
M_{25}	0.6%	2.9
M_{25}	1.2%	3.2
M_{25}	1.8%	3.3

Table 4 –Average Split tensile Strength at 28 Days of SFRC with 0%. 0.6% ,1.2% and 1.8% fibers M25 grade

GRADE OF CONCRETE	% OF SFRC	SPLIT TENSILE STRENGTH TEST AT 28 DAYS(N/mm^2)
M_{25}	0%	2.9
M_{25}	0.6%	3.8
M_{25}	1.2%	4.1
M_{25}	1.8%	4.6

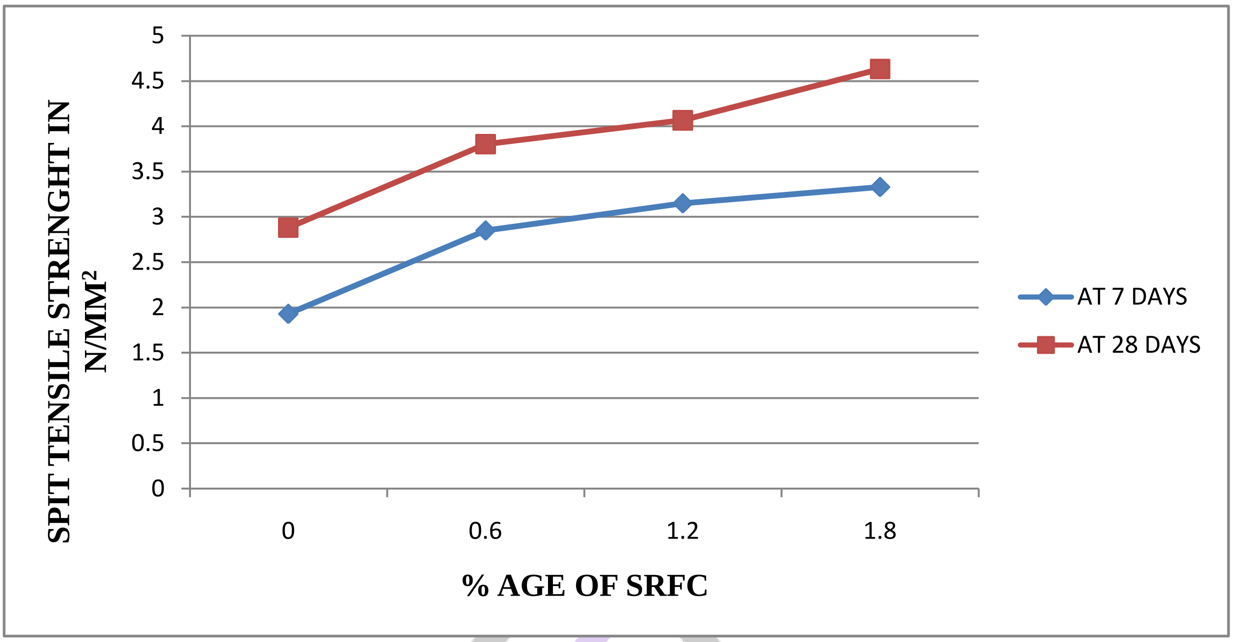

Figure 4: percentage increase in 7 and 28 days Split tensile strength for M-25 grade concrete

VII.CONCLUSIONS

The following conclusions could be drawn from the present investigation.

1. It is observed that compressive strength, split tensile strength and flexural strength are on higher side for 1.8% fibers as compared to that produced from 0%, 0.6% and 1.2% fibers.
2. It is observed that compressive strength increases from 19 to 60% with addition of steel fibers.
3. It is observed that split tensile strength increases from 31 to 58% with addition of steel fibers.
4. The addition of fibers significantly reduces the workability of concrete.

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