International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
Volume 1 Issue 8 (September 2014) www.ijirae.com

FIBER ADDITION AND ITS EFFECT ON CONCRETE STRENGTH

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Abstract— Fibers are generally used as resistance of cracking and strengthening of concrete. In this project, I am going to carry out test on steel fiber reinforced concrete to check the influence of fibers on strength of concrete. According to various research papers, it has been found that steel fibers give the maximum strength in comparison to glass and polypropylene fibers. Hence, in this project I was interested in finding the effect of steel fibers in concrete. An experimental investigation on the behavior of concrete specimens reinforced with steel fibers and subjected to compressive and flexural loading is presented. Tests were conducted on specimens with three different fiber volume fractions. It was observed that SFRC specimens showed enhanced properties compared to that of normal specimens.

Keywords: Concrete, Slump, Compressive strength, Flexural strength, Split tensile strength

I. INTRODUCTION

Concrete is characterized by quasi-brittle failure, the nearly complete loss of loading capacity, once failure is initiated. Concrete can be modified to perform in a more ductile manner by the addition of randomly distributed discrete fibers in the concrete matrix, which prevent and control initiation, propagation and coalescence of cracks.

A variety of materials such as polypropylene, nylon, polyester, glass, carbon, basalt and steel fibers can be used in fiber reinforced concrete. The characteristics of FRC depend upon many factors such as size, type, elastic properties, aspect ratio and volume fraction of fibers. For each application it needs to be determined which type of fiber is optimal in satisfying the purpose. The fibers are able to prevent surface cracking through bridging action leading to an increased impact resistance of the concrete. The addition of steel fibers to concrete considerably improves its properties of concrete in the hardened stage such as flexural strength, impact strength, tensile strength, ductility and flexural toughness. These fibers have already been used in many large projects involving the construction of industrial floors, pavements, highway-overlays, etc. in India.

II. FIBRE REINFORCED CONCRETE (FRC)

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 a 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 fibers to conventional plain or reinforced and prestressed 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 fibers, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete.

2.1 Mechanism

The composite will carry increasing loads after the first cracking of the matrix if the pull-out resistance of the fibers at the first crack is greater than the load at first cracking. At the cracked section, the matrix does not resist any tension and the fibers carry the entire load taken by the composite. With an increasing load on the composite, the fibers will tend to transfer the additional stress to the matrix through bond stresses. This process of multiple cracking will continue until either fibers fail or the accumulated local debonding will lead to fiber pull-out.

The randomly-oriented fibers assist in controlling the propagation of micro-cracks present in the matrix, first by improving the overall cracking resistance of matrix itself, and later by bridging across even smaller cracks formed after the application of load on the member, thereby preventing their widening into major cracks (Fig. 1).

2.2 Characteristics

In comparison to conventional reinforcement, the characteristics of fiber reinforcement are that:

1. The fibers are generally distributed throughout a cross-section, whereas steel bars are only placed where needed.
2. The fibers are relatively short and closely spaced, whereas the steel bars are continuous and not as closely placed.
3. It is generally not possible to achieve the same area of reinforcement with fibers as with steel bars.
4. It is much tougher and more resistant to impact than plain concrete.

Fig. 1 Failure mechanism and the effect of fibers

The fibers are not added to improve the strength, though modest increases in strength may occur. Rather, their main role is to control the cracking of FRC, and to alter the behavior of the material once the matrix has cracked, by bridging across these cracks and so providing some post-cracking ductility.

III. EXPERIMENTAL PROGRAM

3.1 Materials and Properties

The materials selected for this experimental study includes normal natural coarse aggregate, manufactured sand as fine aggregate, cement, superplasticizer, both end hooked steel fiber and portable drinking water. The physical and chemical properties of each ingredient has considerable role in the desirable properties of concrete like strength and workability.

3.1.1 *Cement:* The cement used for this project work is Portland slag cement. It gives low heat of hydration.

Table I : Physical Properties of Cement

Brand of cement	PPC
Standard consistency	34%
Initial setting time (in mins)	147
Final setting time (in mins)	325
Specific gravity	2.91

3.1.2 *Fine aggregates* **:** It should be passed through IS Sieve 4.75 mm. It should have finess modulus 2.50-3.50 and silt contents should not be more than 4%. Manufacturer's sand has been used for the present investigation; it is also called M sand. Manufactured sand has been regularly used to make quality concrete for decades in India and abroad. M-sand is crushed aggregates produced from hard granite stone which is cubically shaped with grounded edges, washed and graded with consistency to be used as a substitute of river sand. . It confirms to IS 383-1970 which comes under Zone II.

Table II : Physical Properties of fine aggregates

Specific Gravity	2.54
Water absorption	11%

3.1.3 *Coarse aggregates:* It should be hard, strong, dense, durable and clean. It must be free from vein, adherent coatings and injurious amount of disintegrated pieces, alkalis, vegetable matters and other deleterious substances. It should be roughly cubical in shape. Flaky pieces should be avoided. It should confirm to IS 2838(I). Coarse Aggregate used are of two sizes 20 mm maximum size and 12.5 mm maximum size.

Table III : Physical Properties of coarse aggregates

Specific Gravity	2.778
Water absorption	0.25%

3.1.4 *Water:* Water should be free from acids, oils, alkalies, vegetables or other organic impurities. Soft waters also produce weaker concrete. Water has two functions in a concrete mx. Firstly, it reacts chemically with the cement to form the cement paste in which the inert aggregates are held in suspension until the cement paste has hardened. Secondly, it serves as a lubricant in the mixture of fine aggregates and cement.

International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163
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3.1.5 *Fiber*: Percentage volume fraction of fibres was varied from 0 to 0.38%. Hooked end Steel fibers of 0.75mm diameter with 60mm length is used and its aspect ratio is 80. Density of steel fiber is 7850Kg/m^3. The manufacturer is bekaert.

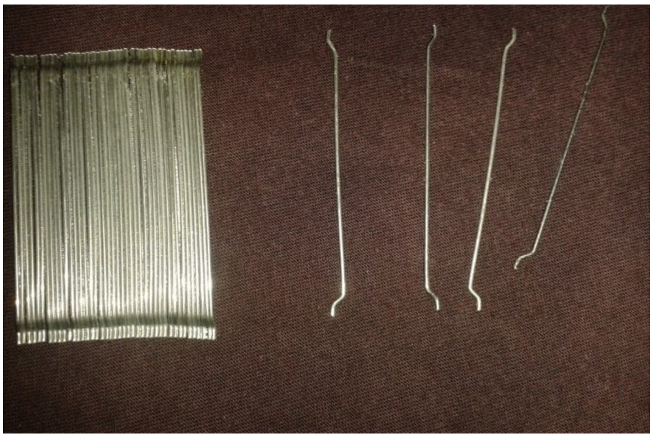


Fig. 1 Steel fiber

3.2 Experimental Work

The mix design is carried out as per IS 10262:2009.The proportioning is carried out to achieve strength at specified age, workability of fresh concrete and durability requirements. Relationship between strength and free water cement ratio should be preferably being established for the materials actually to be used. Mix designing is carried out to arrive at the quantities required for 1 m^3 of concrete as shown below table.

Table IV Quantities required for 1 m^3 of concrete

W/C	Steel Fiber kg/m^3	Water (kg)	Cement (kg)	F_A (kg)	C_A (kg)	Designation
0.45	0	189	420	828	1050	CM
	20					SM1
	25					SM2
	30					SM3

To study the effect of fiber, cubes of size 150mm x150mmx150mm, cylinders of diameter 150mm and height 300mm, beam of sizes 500x100x100mm were tested. Casting of the concrete specimens were done according to IS 516-1959 .

IV. RESULTS AND DISCUSSIONS

In the present investigation an attempt has been made to determine the effect of fiber by examining the slump, compressive strength, split tensile strength and flexural strength of the sample. For that cubes, cylinders and beams were casted using fibers. The mixing was done using a pan mixer. The compression test and splitting tension test were conducted by the same compression testing machine which has a capacity up to 200 Tones.

4.1 Effect on Workability

The rheology of FRC is significantly different than that of similar mixes without fibers, even when only small fiber dosages are used, especially due to the relatively high stiffness and the geometry of the fibers. Therefore, it is often not convenient to characterize its workability in terms of parameters used for plain concrete. Nevertheless, the most common measure of workability and consistency of concrete is the slump test. The slump test is carried out according to IS: 1199-1959.

Table 4 Details Of Mixes Corresponding To Slump

Mix designation	Water/cement ratio	Superplasticizer (% of cement)	Slump(mm)
CM	0.45	0.3	120
MS1	0.45	0.3	111
MS2	0.45	0.3	103
MS3	0.45	0.3	95

Here we can see that as fiber content increases slump decreases, which means workability decreases.

4.2 Compressive Strength

To study the 3, 7 and 28 days compressive strength of concrete mixes, three concrete cubes for each day were casted and tested in a set itself. The cube specimens were of size 150 mm x 150 mm x 150 mm and were prepared and tested according to IS: 516-1959. Crack pattern after testing of a particular cube specimen is shown in fig.2. The cube compressive strength obtained after testing is as given in table 5

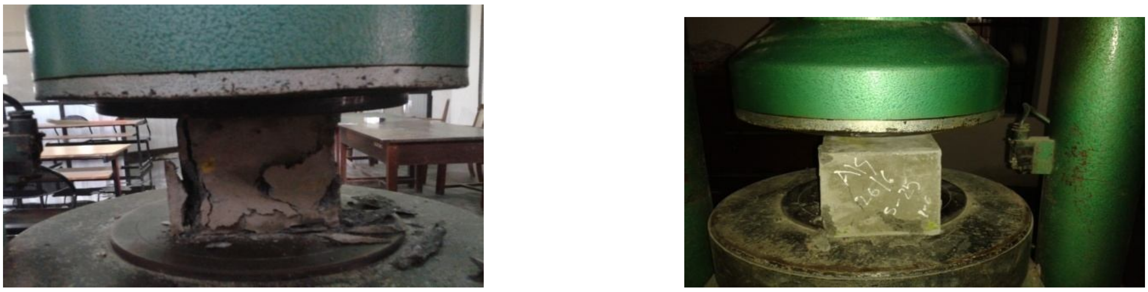


Fig. 2 Crack pattern in the Cube without and with steel fiber

4.3 Split Tensile Strength

Split tensile strength was found according to IS: 5816–1999 and the same three cylindrical specimens were casted and tested after 7 and 28 days of water curing. The cylindrical specimens were of diameter 150 mm and of height 300 mm. Crack pattern after testing of a particular cylinder specimen is shown in fig.3. The results of splitting tension test are given as in table 5.

Fig. 3 Crack pattern in the cylinder without and with steel fiber

4.4 Flexural Test

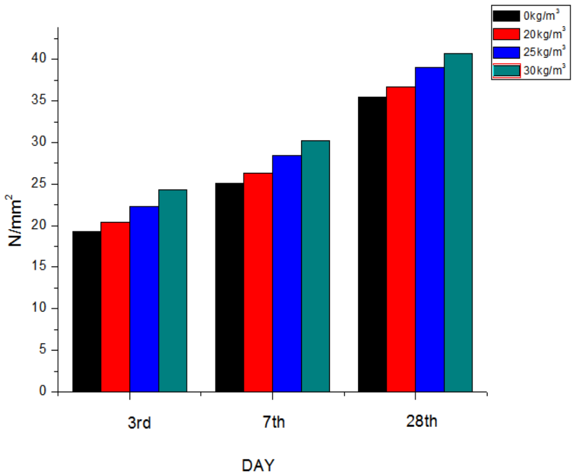
Flexural strength was found according to IS: 516-1959 and for the same three beam specimens were casted and tested after 7 and 28 days of water curing. The rectangular specimens were of dimensions 500x100x100mm. Crack pattern after testing of a particular beam specimen is shown in fig.4. The results of flexural test are given as in table 5.

Fig. 4 Crack pattern in the beam without and with steel fiber

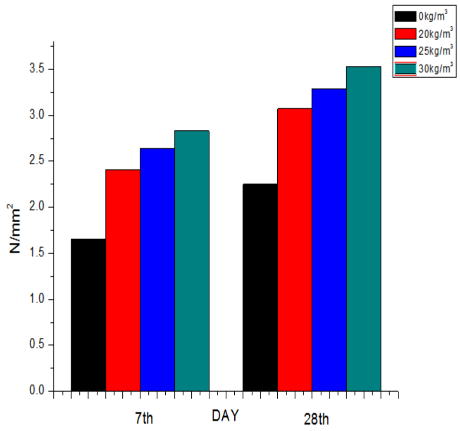
ISSN: 2349-2163
www.ijirae.com

Table 5 Test Results

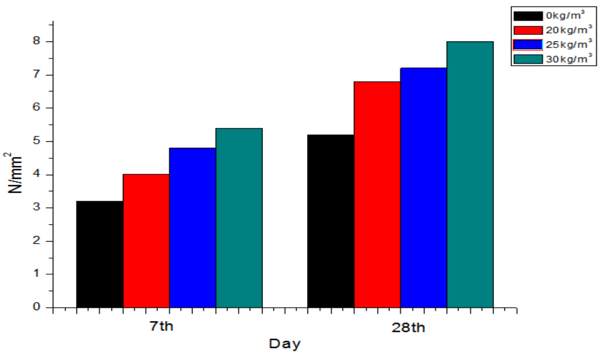
Designation	Fiber kg/m3	Average compressive strength (N/mm^2)			Average split tensile Strength (N/mm^2)		Average modulus of rupture (N/mm^2)	
		3rd	7th	28th	7th	28th	7th	28th
CM	0	19.3	25.1	35.4	1.65	2.25	3.2	5.2
MS1	20	20.4	26.3	36.7	2.41	3.07	4	6.8
MS2	25	22.3	28.4	39.0	2.64	3.29	4.8	7.2
MS3	30	24.3	30.2	40.7	2.83	3.53	5.4	8.0



(i) Compressive strength



(ii) Split tensile strength



(iii)Flexural strength

Fig.5 Graphs showing the variation of strength for different fiber content

From the test results of compressive strength, split tensile strength and flexural strength, it can be seen that, in the presence of steel fiber there is an increase in compressive strength, split tensile strength and flexural strength. The crack formation is also very small in fiber specimen compared to the non fiber specimens.

V. CONCLUSIONS

The findings of the above studies indicate that the addition of steel fibers to concrete improve not only the strength characteristics but also the ductility. Research over the years have shown that fiber reinforcement has sufficient strength and ductility to be used as a complete replacement to conventional steel bars in some types of structures; foundations, walls, slabs. The technology that is available today has made is possible to consider fiber reinforcement without the use of conventional steel bars in load carrying structures.

For this to be a reality, the fibers must be distributed and oriented as expected, which is difficult. If fibers can be used without the need of steel reinforcement bars, the reinforcement part of the construction work will be eliminated. Hence, the construction costs will be significantly reduced.

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