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TECHNOLOGY | INNOVATION | INDUSTRY

International Journal of
Advanced Structures and Geotechnical Engineering
ISSN 2319-5347, Vol. 03, No. 04, October 2014

Effect of Steel Fibers on Compressive and Tensile Strength of Concrete

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Abstract: Concrete is currently one of the most widely used construction material. The reason for such wide use is because it is easily available, can effortlessly be molded into any shape, is cheap and has a high compressive strength. However, it is widely known to have a low tensile strength and does not perform well in aggressive situations, an extremely objectionable quality in any construction material. To counter these shortcomings, concrete is ordinarily assorted with steel reinforcement. The tensile reinforcement compensates for the lack of tensile ability, increased brittleness and decreased strain capacity. Though the steel reinforcement helps the concrete to gain advantage, it still makes the construction cost quite high. With the advancement in nearly all the fields of science, it is the need of time to redefine concrete with such additional materials that will help to improve its properties, one such component is steel fiber. Much work is being carried out currently in this field and most of the codes have incorporated this material specifying the method of its use. In this research, steel binding wires were used as steel fibers which are locally available at very cheap cost. Steel fibers were added in different percentage i.e. 0.1 %, 0.5 % and 1 % along with control samples (0% Fibers). Concrete mix of 1:1.5:3 was used to accommodate for the high anchorage ability (absent in case when property enhancing material e.g. silica fume are not used).Compressive and Tensile strength calculation of all those samples and their comparison was the basic theme of the research. For this purpose cylinders and short beams were casted and checked under Universal Testing Machine for compressive and tensile strength. The research showed that there was slight increase in the compressive strength while increase in tensile strength was on higher side due to addition of steel fibers. Result data obtained had been analyzed and compared with the control sample. The important element in the testing procedure was that instead of using highly priced version of the steel fibers, ordinary binding wire cut into small pieces of size 2inch was used in the preparation of all specimens.

Keywords: *Steel Fibers, Concrete, Compressive Strength, Tensile Strength*

1. Introduction:

Concrete is a composite material consisting of coarse, fine aggregate, cement & water. Concrete is extensively used as a construction material in the world. It also replaces old construction materials such as brick and stone masonry. [1] Strength of concrete can be enhanced by changing the mix proportions. Concrete is stronger in dealing with compressive stresses in comparison to the Tensile strength. Tensile strength of concrete is 3 to 5 $\sqrt{fc'}$, whereas Modulus of rupture is 8 to $12\sqrt{fc'}$

With the evolution of the concept of admixtures and foreign material in the concrete for enhancing concrete properties to the level that it can replace steel, several achievements have been made in this field. Among these achievements fiber reinforcement is far ahead than any other substitutes in modifying concrete basic properties. Series of experiments were conducted to investigate the effectiveness of fiber inclusion in the improvement of mechanical performance of concrete with regard to concrete type and specimen size [2]

Fibers play an important role in reaching a definite load bearing capacity after the matrix fracture, depending on allocation, orientation and embedded length. [3]

Steel fiber reinforced concrete have the enhanced properties; more ductile, improved durability, structural strength, requirements for steel reinforcement reduces, improvement in the impact & Abrasion resistance.

Fiber reinforcement addresses the shortcoming of the normal concrete e.g. Low tensile strength, Brittleness, low post cracking capacity. Fibers make the concrete bonding stronger by increasing the interlocking strength.

2. Materials:

The materials used during the experimental program of this research were coarse aggregate (crush), Fine aggregate (sand), cement, water and steel fibers.

Locally available coarse and fine aggregates were used. Coarse aggregate used was ¾ inch down, with the fineness modulus of 2.77, Fine aggregate (sand) having fineness modulus 2.68

Along with the Ordinary Portland cement were the main ingredients of both mixes (with and without steel Fibers).The most important element to be incorporated in the mix i.e. the steel fibers were obtained by cutting the locally available

Steel binding wires; binding wires are generally used to bind the steel reinforcement. The main deviation from other researches was the use of locally available binding wire material as steel fibers, which were used by cutting them into small pieces of 50 mm (2 inches) having dia 0.498 mm. Aspect ratio of steel Fibers (steel binding wires) was 100.

3. Experimental Program:

Two basic tests were performed, Compressive strength test and Tensile strength test. Concrete mix of 1:1.5:3 and water-cement ratio of 0.46 was used. These two tests were conducted for four different categories of concrete which were;

1) Normal Concrete (control sample) (with zero percent steel fibers)
2) Fiber reinforced concrete with 0.1% steel fibers.
3) Fiber reinforced concrete with 0.5% steel fibers.
4) Fiber reinforced concrete with 1% steel fibers.

Steel fibers were used in percentage with the weight of cement used. Concrete mix ratio was kept same for all the types of concrete, only difference was the percentage of steel fibers added.

3.1. Compressive strength test:

The specimen cylinders for each type of concrete were casted in the standard molds. Dimensions of specimen cylinders were 150mm (6 inches) in diameter with the height of 300mm (12 inches); cross-sectional area of cylinder is 28.26 in². Steel fibers were added according to their percentage during the mixing of concrete in concrete mixture machine. It was made ensured that the steel fibers were properly and thoroughly mixed. The molds were filled with the four different types of concrete and properly compacted. The top surface was leveled and finished by trowel.

For each type of concrete 5 samples were prepared. The specimen samples were demolded after providing initial curing for 48 hours under standard temperature and then placed in water tank for final curing. The curing period was 28 days. After curing the samples for each category of concrete were tested using universal testing machine (UTM).

The top surface of every cylinder was coated with the gypsum so that the surface can be leveled. The compressive load was applied through UTM. The ultimate load was noted for every sample of each type of concrete and the ultimate strength calculated. The ultimate load from UTM was noted in tons which later converted to MPa (Mega Pascal).

3.2. Tensile Strength Test:

Five specimen beams for each type of concrete were casted. The dimensions of beam were 750mm×150mm×150mm (30inch ×6inch ×6inch). Proper mixing of steel fibers in mixture machine was ensured. The molds were filled with concrete, properly vibrated and surface was leveled. Molds were removed after 48 hours. The samples were placed in water tank for final curing. Samples were then removed from water tank and tested under UTM after 28 days.

The specimens were tested under third point loading arrangement. Ultimate loads were noted for each specimen of every category of concrete. Load was then applied (recorded in tons). The formula used for calculation of tensile strength is:

$$\text{Tensile Strength} = \frac{\text{Ultimate load} \times \text{Length}}{\text{Width} \times \text{Height}^2}$$

Total Length of beam = 750 mm, Width = 150 mm Height = 150mm,

Figure 1: Cylinder in UTM under Compressive Loading

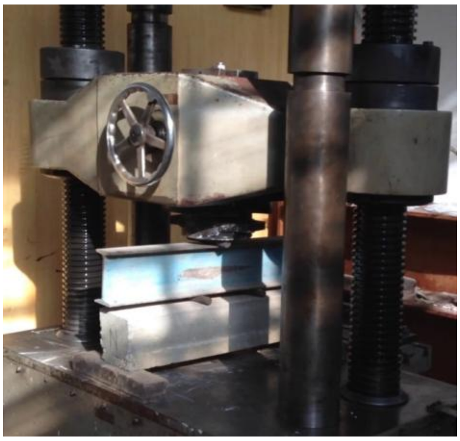

Figure 2: Beam in UTM under Tensile Loading

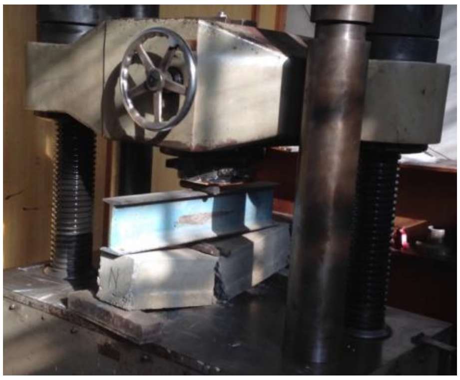

Figure 3: Control sample after attaining ultimate load

4. Experimental Results and Discussion:

4.1 Compressive Strength:

Table 1a: Normal/ Control Sample (0% Steel Fibe

S.No	Compressive Strength (MPa)	Average Compressive Strength (MPa)	Coefficient of Variance (%)
1	31.05		
2	30.70		
3	32.81	32.25	3.54
4	33.19		
5	33.48		

Table 1b: Normal/ Control Sample (0% Steel Fiber)

S.No	Compressive Strength (MPa)	Average Compressive Strength (MPa)	Coefficient of Variance (%)
1	30.27		
2	32.23		
3	33.63	32.33	3.55
4	32.40		
5	33.12		

Table 1c: Normal/ Control Sample (0% Steel Fiber)

S. No	Compressive Strength (MPa)	Average Compressive Strength (MPa)	Coefficient of Variance (%)
1	33.99		
2	32.15		
3	34.64	33.37	2.63
4	33.28		
5	32.77		

Table 1d: Fiber Reinforced Concrete
(1% Steel Fiber)

S. No	Compressive Strength (MPa)	Average Compressive Strength (MPa)	Coefficient of Variance (%)
1	35.41		
2	33.06		
3	34.79	34.17	2.45
4	33.63		
5	33.93		

Table 2: Average Compressive Strength

Average Compressive Strength (MPa)			
0%	**0.1%**	**0.5%**	**1%**
32.25	32.33	33.37	34.17

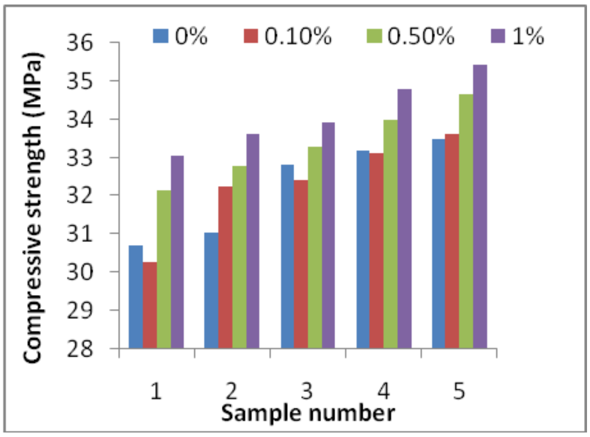

Figure 4: Combined Compressive Strength for Each Category of Concrete

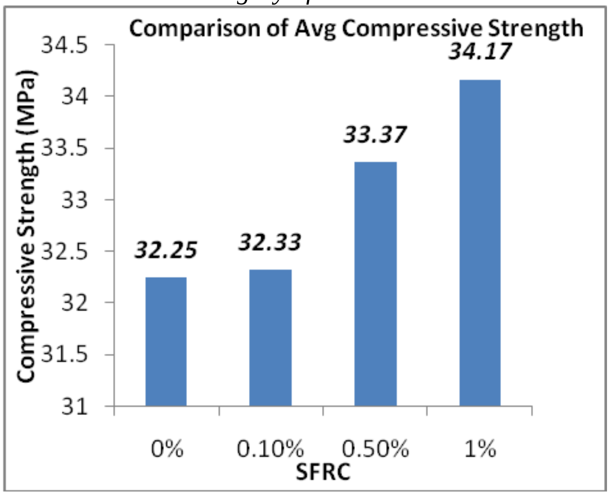

Figure 5: Average Compressive Strength

Graph is drawn between compressive strength (MPa) and number of samples using four different types of concrete mixes (using same proportion of concrete ingredients except steel fibers). 05 cylinder samples for each type of concrete mix were tested using universal testing machine under compressive loading. The graph shows increase in compressive strength while increasing percentage of steel fibers. When the samples of 0.1% fibers are compared with the samples with no steel fibers, it can be easily assessed that there is an increase in compressive strength, though the increase is not so prominent. When the fibers are increased from 0.1% to 0.5% and 1%, an increase in compressive strength is noted.

4.2 Tensile Strength:

Table 3a: Normal/ Control Sample (0% Steel Fiber)

S.No	Tensile Strength (MPa)	Average Tensile Strength (MPa)	Coefficient of Variance (%)
1	4.64		
2	4.66		
3	4.54	4.68	2.32
4	4.69		
5	4.88		

Table 3b: Fiber Reinforced Concrete (0.1% Steel Fiber)

S.No	Tensile Strength (MPa)	Average Tensile Strength (MPa)	Coefficient of Variance (%)
1	4.73	5.02	3.36
2	5.21		
3	5.14		
4	4.97		
5	5.07		

Table 3c: Fiber Reinforced Concrete (0.5% Steel Fiber)

S.No	Tensile Strength (MPa)	Average Tensile Strength (MPa)	Coefficient of Variance (%)
1	6.46	6.66	3.75
2	7.07		
3	6.59		
4	6.81		
5	6.39		

Table 3d: Fiber Reinforced Concrete (1% Steel Fiber)

S.No	Tensile strength (MPa)	Average Tensile Strength (MPa)	Coefficient of Variance (%)
1	6.80	7.00	3.16
2	7.37		
3	6.81		
4	7.13		
5	6.87		

Table 4: Average Tensile Strength

Average Tensile Strength (MPa)			
0%	**0.1%**	**0.5%**	**1%**
4.68	5.02	6.66	7.00

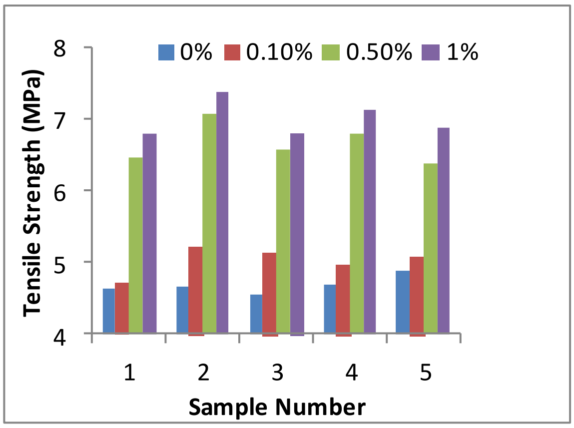

Figure 6: Combined Tensile Strength for Each Category of Concrete

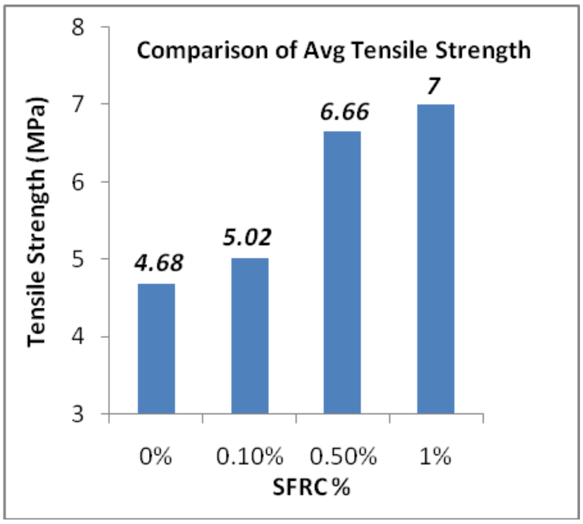

Figure 7: Average Tensile Strength

Comparative graph between Tensile strength (MPa) and number of samples (5 beams) using four different types of concrete mixes (using same proportion of concrete ingredients except steel fibers) mix were tested using universal testing machine. The graph shows increase in tensile strength while increasing Percentage of steel fibers. When the samples of 0.1% fibers are compared with the samples with no steel fibers it was observed that there is slight increase in Tensile strength. While increasing the percentage of fibers from 0.1% to 0.5% and 1%, significant increase in Tensile strength is observed.

Average compressive and tensile strength of cylinders and beams for each category of concrete are calculated along with coefficient of variance. While observing coefficient of variance it is clear that data is with in normal range and not too scattered. All results are of 28 days strength of concrete.

4. Conclusion and Recommendation:

Conclusions:

1. In case of fiber reinforced concrete cylinders the compressive strength was improved as compared to the normal concrete..
2. Compressive strength increase from 2% to 6% with the addition of Steel Fibers.
3. Tensile strength of concrete beams increase from 7% to 49% with the addition of Steel Fibers in the concrete mix from 0% to 1%.
4. A strong mechanical interlocking force in fiber reinforced concrete cylinders was observed because of steel fibers which held the matrix stronger and concrete remained intact even after failure loading, whereas the control sample without steel fibers after failure splitted into large concrete pieces.
5. Similar behavior was observed in case of Tensile strength, samples without fibers were splitted into two portions but beams having steel fibers remain intact due to strong

interlocking force between steel fibers and concrete matrix.

6. Steel binding wires showed enormous effect especially in tensile testing as Steel fibers and are also cost effective.

Recommendations:

1. More elaborative research is required to use steel binding wires as steel fibers
2. Proper investigation regarding change in quantity, size should be carried out to know all the relevant properties.
3. Utilization of other such cheap and common materials in the concrete to increase its tensile strength.

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