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Behavior of Steel Fiber Reinforced Concrete with M40 Grade Mix Design

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Abstract
Concrete is the world’s most versatile, durable and very reliable material. Concrete is probably the most extensively used construction material in the world. Plain, unreinforced concrete is a brittle material, with low tensile strength and a low strain capacity. Fibre reinforced concrete (FRC) is a composite material made with Portland cement, aggregate and incorporating more or less randomly distributed discrete discontinuous fibres. . Round fibres are the most common type and their diameter ranges from 0.25 to 0.75 mm. Rectangular steel fibres are usually 0.25mm thick, although 0.3 to 0.5mm wires have been used in India. Deformed fibres in the form of a bundle are also used. The main advantage of deformed fibres is their ability to distribute uniformly within the matrix. The experimental program consists of casting and testing of 20 cubes of each for M40, in which 12 cubes would be cast with steel fibre and the remaining eight without steel fibres. The cubes proposed for tests would be of size 0.15m x 0.15m x 0.15m (length x width x depth). The fibre reinforced concrete cubes would contain steel fibres with a volume fraction (Vf) of 0.1%, 0.25%, 0.35%, and 0.45% of the volume of the cubes. The results would be statically analyzed and interpretation of the results would be carried out to arrive at the optimum quantity of steel fibres required to achieve the maximum flexural strength for M40 grade concrete.

Keywords: *Steel fibre increases Compressive, Flexural and Split Tensile Strength of Concrete, UTM, CTM.*

I. Introduction:

Fibre reinforced concrete (FRC) is a composite material made with Portland cement, aggregate and incorporating more or less randomly distributed discrete discontinuous fibres. In FRC thousands of small fibres are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties in all directions. Lot of research has been done to understand the contribution of fibre to the behavior of concrete. It has been established that the randomly distributed discontinuous fibre bridge across the cracks that develop in concrete and provide post cracking “ductility”. Ductility is a measure of the post crack strength. When the fibres are sufficiently strong and sufficiently bonded to material, they permit friction carry significant stresses over a relatively large strain capacity in the post cracking phase. The fibre tends to increase the strain at peak load, and provide a great deal of energy absorption in post peak portion of the load vs. deflection curve. The real contribution of the fibres is to increase the toughness of concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibres produced greater impact, abrasion and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete and so cannot replace moment resisting structural steel reinforcement. When the fibre reinforcement is in the form of short discrete fibres, they act as rigid inclusions in the concrete matrix. Physically, they have thus the same degree of importance as aggregates; steel fibre reinforcement cannot therefore be regarded as a degree replacement of longitudinal direction reinforcement in reinforced and pre-stressed structural members. However, because of the inherent material properties of fibres concrete, the presence of fibres in the body of concrete or provision of tensile skin of fibres concrete can be expected to improve the resistance of conventionally reinforced structural member to cracking, deflection and other serviceability conditions.

II. What is F. R. C?

The presence of micro-cracks at the mortar aggregate interface is responsible for the inherent weakness of plain concrete. The weakness can be removed by in inclusion of fibers in the mix. The fiber helps to transfer the loads at the internal micro-cracks. Such a concrete is called as Fiber Reinforced Concrete. Thus the fiber reinforced concrete is a composite material essentially consisting of conventional concrete or mortar reinforced by random dispersal of short, discontinuous and discrete fine fibers of specific geometry. The fibers can be imagined as an aggregate with an extreme deviation in shape from the rounded smooth aggregate. The fibers interlock and entangle around aggregate particles and considerably reduce the workability while the mix becomes more cohesive and less prone to segregation. [1]

In contract to reinforcing bars in reinforced concrete which are continuous and carefully placed in the structure to optimize their performance, the fibers are discontinuous and are generally randomly distributed throughout the concrete matrix. As the result, the reinforcing performance of steel fibers, for example, is inferior to that of reinforcing bar. In addition, the fibers are likely to be considerably more expensive than the convectional steel rods. Thus fibers reinforced concrete is not likely to replace conventional reinforced concrete. [2]

However the addition of fibers to the brittle cement and concrete materials can offers a convenient, particle and economical method of overcoming their inherent deficiencies of poor tensile and impact strengths and enhances many of the structural properties of the basic materials such as fracture toughness, flexural strength and resistance to fatigue impact, thermal shock or spalling.

Essentially, fiber act as crack arrestor restricting the development of cracks and thus transforming an inherently brittle matrix i.e. Portland cement.

Types of fibers

There are mainly two types of fibers which are used in concrete.

Low Modulus High Elongation Fibers:

These types of fibers have capacity to absorb large amount of energy, but do not lead to strength improvement; however they impart toughness, and resistance to impact and explosive loading For e.g. Nylon, Polyethylene etc.

High Modulus High Elongation Fibers:

These fibers produces strong composite primarily they impart characteristics of strength and stiffness to the composites, and also dynamic properties to varying degrees. For e.g. steel, asbestos and carbon

III. Introduction to steel fibers

A number of steel fiber types are available as reinforcement. But generally round steel fibers are commonly used. These fibers found extensive engineering application. Most of the steel fibers are obtained by cutting drawn wires and fibers with different types of crimps, indentations and shapes to increase mechanical bond are also being produced steel fibers with low tensile strength (7141kg/cm2) are also produced from low carbon flat rolled steel coils. Generally the steel fibers used in concrete as reinforcement of diameter lying inbetween5-500mm specific gravity 7.8, modulus of elasticity 200 GPA,

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Failure3-4% and Tensile strength 1 to 3 GPA. However tests show that the tensile strength has little influence on the first crack flexural strength although it may have significant effect on the ultimate flexural strength, if the composite failure occurs by fiber failure rather than fiber pull out. The method of fiber production may however influence the cost of the fiber and significant improvement in the first crack. Flexural strength and ultimate flexural strength have been obtained through the use of short (6.4to63.5 mm) and small diameter (0.15 to 0.91mm) steel fibers. However the property improvement can only be obtained by ensuring uniform distribution of fibers and consolidation of the matrix around the fibers.

In the present state of fiber development, composite failure occurs by fiber pull out rather than fiber yielding so fiber matrix bond is the significant phase of composite.

A number of practical applications of steel fiber reinforced concrete have achieved to date. The superior structural properties of steel fiber reinforced concrete have found it an material for over lays and over slab for roads pavements, airfields and bridge decks and industrials well as other flooring, particular subjected to were and tear and chemical attack. Gunniting have also been successfully applied by using steel fibers of all the fibers, steel fibers are probably the best suited for structural applications.

IV. Experimental procedure

The main aim is to study the effect of steel fibers on flexural & compressive strength of concrete. An experimental program includes two phases. The first consists of high strength concrete mix design for grade of M40 by using IS 10206-1982,[5] whereas the second phase consists of casting and testing of 15 concrete beam specimens with different percentage of steel fibers (1%,2.5%,3.5%,4.5% by volume of concrete) for flexural strength of concrete and it also consists of casting and testing of 15 concrete cubes with different percentage of steel fibers 1%,2.5%,3.5%,4.5% by volume of concrete) for compressive strength of concrete. For each percentage of steel fiber three beams and three cubes were casted.

The properties of materials used for casting the concrete beam & cube specimens were observed by performing the necessary tests. The materials were categorized in two groups i.e, concrete and steel

Cement- 53 grade Ordinary Portland cement was used for casting the beams. It was tested in the laboratory and results are as follows.

1. Initial setting time = 190 min.
2. Final setting time = 240 min.
3. Compressive strength-
   - 3 days = 29.33 Mpa.
   - 7 days = 35.11 Mpa.
   - 28 days = 46.81 Mpa.

Sand- The sand used for concrete was from penna river. The properties are as follows.

1. Specific gravity = 2.65
2. Fineness modulus = 2.28

Aggregate- Locally available crushed stones aggregate with maximum size 20 mm were used The properties are as follows.

1. Specific gravity =
2.45 Fineness modulus
= 2.60

Steel fibers having 0.97mm dia. And lengths 70 mm (i.e. aspect ratio) were randomly distributed into the concrete mixes to obtain the fiber reinforced concrete. The fiber taken by volume of concrete and grade of concrete is kept constant.

The test cube specimens were of dimensions 150x150x150 mm. The cubes were reinforced with steel fibers of size 70 mm long and 0.97 mm diameter. Typical section of cube is as shown in figure:

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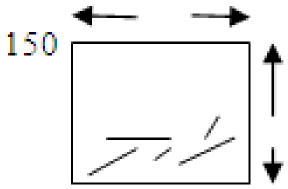

Figure 1: *Details of cube Speccimen*

The test cube specimens were of dimensions 150x150x150 mm. These were also reinforced with steel fibers of size 70 mm long and 0.97mm diameter

The second phase of experimental program consists of casting & testing of 15 concrete beams for flexural test and 15 cubes for compression test with varying percentage of steel fibers (1%, 2.5%, 3.5% &4.5% of volume of concrete. The ingredients of concrete viz. cement, sand and coarse aggregate, were weighted according to the mix proportion 1:0.81:2.52 by weight (say 515kg, 422kg and 1296kg respectively for 1 m3). The ingredients are thoroughly mixed in the dry state with respective fiber percentage (0%.0.25%, 0.50%, 0.75% & 1% by volume of concrete). To this, the calculated quantity of water with water cement ratio 0.35 (180 liters for $1m^3$) was added & thoroughly mixed. For beams 15cm x 15cm x 70cm beam moulds with inner faces oiled are taken &filled them in layers approximately 5cm deep. At the same time for cubes 15cm x 15cm x 15cm cubical moulds with inner faces oiled are taken &filled them in layers approximately 5cm deep. Each layer is compacted by a standard tamping rod (16mm diameter and 60cm long with bulleted end) &25 uniformly distributed strokes were given. Finally the surface is leveled with the help of a trowel. Three beams and three cubes for each percentage of steel fibers were casted. After 24 hours the beams and cubes were removed from the moulds and kept them for curing. The water in which the specimens are submerged was renewed after every seven days.

After 28 days of curing, the beams with different percentage of steel fibers (1%, 2.50%, 3.5% & 4.5% by volume of concrete) are tested under UTM(Universal Testing Machine) using three-point loading for flexural strength. Similarly, the cubes with different percentage of steel fibers (1%, 2.50%, 3.5% & 4.5% by volume of concrete) are tested under CTM (Compression Testing Machine) for compressive strength.

Flexural strength is calculated by equation (f) = PL/bd2
Where,

P = Failure load in Newton L = Effective span in mm. b = Breadth of beam
d = Depth of the beam

Similarly, Compressive strength is calculated by the equation

δc = Load/cross sectional area of cube

Where,

δc = Compressive strength of concrete

V. Test results:

6.1 Flexural Test Result:

The following table number 1 gives the test results of flexural test for beams with different percentage of steel fibers (0%, 1%, 2.5%, 3.5% and 4.5% by volume of concrete).

6.2. Compression test result:

The following table number 2 gives the test results of compressive test for cubes with different percentage of steel fibers (0%, 1%, 2.5%, 3.5% and 4.5% by volume of concrete).

Table 1: *Test result for flexural strength*

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Det ail s	Size of beam in (B x	Ave rage Fail	Ave rage Flex	% increas e
0 %	150x	25.	4	---
1%	150x	33.	5	27.
2.5 %	150x	36.	6	38.
3.5 %	150x	37.	6	43.
4.5 %	150x	34.	6	34.

Figure 1 *Flexural strength vs. Percentage steel fiber content*

Figure shows. The variation of flexural strength for different percentage of steel fibers(0%, 1%, 2.5%, 3.5% and 4.5%)

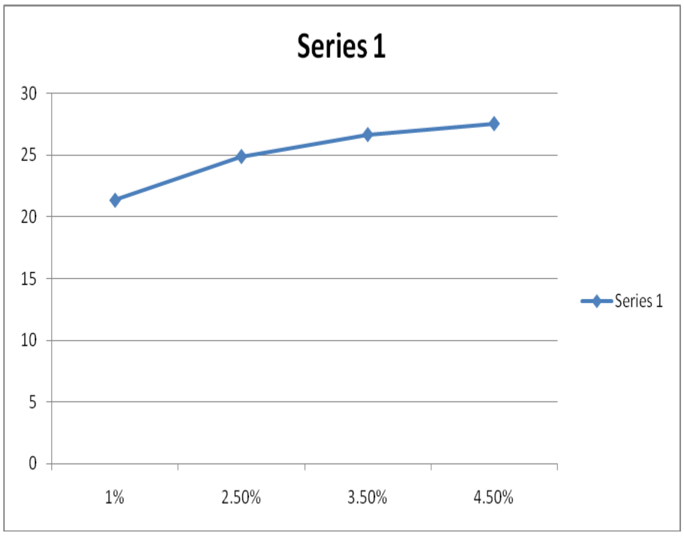

Figure shows. The variation of compressive strength for different percentage of steel fibers (0%, 1%, 2.5%, 3.5% and 4.5%)

VI. Observation and conclusion:

To study the effect of steel fibers on flexural and compressive strength of concrete, the experimentation is conducted in the laboratory. Based on the experimentation conducted, on the beams and cubes with different percentage of steel fibers the following observations were made and hence some conclusions.

Flexural strength-

It has been observed that the flexural strength of concrete for the beams with steel fibers 0%, 1%, 2.5%, 3.5% and 4.5% is more than that of beam without steel fibers. This may be due to the fact that the steel fibers will effectively hold the micro cracks in concrete mass.

The percentage increase in the flexural strength for the beams with steel fibers 0%, 1%, 2.5%, 3.5% and 4.5% compared to the beams without steel fibers are +27.92%, +38.33%, +43.29%, and +34.19% respectively.

It can be seen from the observations that the maximum percentage increase in flexural strength can be obtained for the beams with steel fibers 0.75% by volume of concrete (+30.21%). Thus it is recommended to use steel fibers 0.75% by volume of concrete to get the maximum benefit in improving flexural strength.

Compressive strength:

It has been observed that the compressive strength of concrete for the cubes with steel fibers 0%, 1%, 2.5%, 3.5% and 4.5% is more than that of cubes without steel fibers. This may be due to the fact that the steel fibers will effectively holds the micro cracks in concrete mass.

The percentage increase in the compressive strength for the cubes with steel fibers 0%, 1%, 2.5%, 3.5% and 4.5% compared to the cubes without steel fibers are 11.56%, 21.05%, 24.15% and 10.52% respectively.

It can be seen from the observations that the maximum percentage increase in compressive strength can be obtained for the cubes with steel fibers 0.75% by volume of concrete (+19.50%). Thus it is recommended to use

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steel fibers 0.75% by volume of concrete to get the maximum benefit in improving compressive strength.

Table 2: *Test result for compressive strength*

Details of beam	Size of beam in (B x D x L)mm	Average Failure Loa	Average Compres sive strengt	% Increase / decrease in
1% steel	150x150x150	480	21.33	-
2.5 %	150x150x150	560	24.88	14.26
3.5 %	150x150x150	600	26.66	6.67
4.5 % stee	150x150x150	620	27.55	3.23

VII. Conclusion:

In a nutshell it can be concluded that the use of steel fibers is an effective method to improve the flexural & compressive strength of concrete. To get the maximum benefit it is recommended to use steel fibers 0.75% by volume of concrete. More percentage of steel fibers will have the workability problem & also air cavities are left in the system.

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