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Mechanical Properties of Steel Fiber Reinforced Concrete Composites

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Abstract:- Concrete is most widely used construction material in the world. Fiber reinforced concrete (FRC) is a concrete in which small and discontinuous fibers are dispersed uniformly. The fibers used in FRC may be of different materials like steel, G.I., carbon, glass, aramid, asbestos, polypropylene, jute etc. Hybrid fibre can provide reinforcement at all the range of strains. Combination of low and high modulus fibres can arrest cracks at micro level as well as macro level. Overcome disadvantage of lower workability caused due to use of only higher percentage of steel fibres. Potential advantage in improving concrete properties as well as reducing the overall cost of concrete production. FRC has found many applications in civil engineering field. Based on the laboratory experiment on fiber reinforced concrete (FRC), cube and cylinders specimens have been designed with steel fiber reinforced concrete (SFRC) containing fibers of 0% and 0.5% volume fraction of hook end Steel fibers of 53.85, 50 aspect ratio and alkali resistant glass fibers containing 0% and 0.25% by weight of cement of 12mm cut length were used without admixture. The results obtained show that the addition of steel fiber improves the modulus of elasticity of concrete. It was also analyzed that by increasing the fiber volume fraction from 0.5% to 1.5% and aspect ratio of fibers from 50 to 71 there was a healthy effect on modulus of elasticity of Steel Fiber Reinforced Concrete.

Keywords--- Compressive Strength, Fiber Reinforced Concrete, Glass Fibers, Split Tensile Strength.

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1. INTRODUCTION

Cement concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This characteristic, which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibers (steel, glass, synthetic and natural) and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, etc [1,4].The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cemetitious material, aggregate and water and by adding some special ingredients [5]. Hence concrete is very well suited for a wide range of applications. However concrete has some deficiencies as low tensile strength, low post cracking capacity, brittleness and low ductility, limited fatigue life, not capable of accommodating large deformations, low impact strength [3]. Steel Fiber Reinforced Concrete (SFRC) has an untapped potential application in building frames due to its high seismic energy absorption capability and relatively simple construction technique. To tap such potential, the existing body of knowledge on SFRC must be expanded to provide a proper basis for officials to add this method of construction to the provisions of the building code.

A.M Shende et al. [7] carried out the comparative study on steel fiber reinforced cum control concrete. Steel fibers of 50, 60 and 67 aspect ratio at volume fraction of 0%, 1%, 2% and 3% were used. It was observed that compressive strength, tensile strength and flexural strength from steel fibers were on higher side from 3% fibers as compared to that produced from 0%, 1% and 2% fibers. All the strength properties were observed to be on higher side for aspect ratio of 50 as compared to those for aspect ratio 60 and 67.

Through utilization of steel fibers the compressive strength increased from 11 to 28%, flexural strength increased from 18 to 58% and tensile strength from 9 to 29%. Fibers influence the mechanical properties of concrete and mortar in all failure modes [6], especially those that induce fatigue and tensile stress, e.g., direct tension, bending, impact, and shear. The strengthening mechanism of the fibers involves transfer of stress from the matrix to the fiber by interfacial shear or by interlock between the fiber and matrix if the fiber surface is deformed. Stress is thus shared by the fiber and matrix in tension until the matrix cracks, and then the total stress is progressively transferred to the fibers.

2. LITERATURE REVIEW

Concrete is one of the most versatile building materials. It can be cast to fit any structural shape from ordinary rectangular beam or column to a cylindrical water storage tank in a high-rise building. It is readily available in urban areas at relatively low cost. Concrete is strong under compression but weak under tension. As such, a form of reinforcement is needed. The most common type of concrete reinforcement is by steel bars. The advantages in using concrete include high compressive strength, good fire resistance, high water resistance, low maintenance, and long service life. The disadvantages in using concrete include poor tensile strength, and formwork requirement. Other disadvantages include relatively low strength per unit weight.

Presently, a number of laboratory experiments on mechanical properties of SFRC have been done. Shah Surendra and Rangan [07], in their investigations conducted uni-axial compression test on fiber reinforced concrete specimens. The results shown the increase in strength of 6% to 17% compressive strength, 18% to 47% split tensile strength, 22% to 63% flexural strength and 8% to 25% modulus of elasticity respectively.

Reinforced bars (rebars), reinforcement grids, plates or fibres both organic and inorganic as well as composites have been incorporated to strengthen the concrete in tension. Steel fibre reinforced concrete (SFRC) comprises cement, aggregates and steel fibres. Steel fibre reinforcement cannot be regarded as a direct replacement of longitudinal reinforcement in reinforced and prestressed structural members. In tension, SFRC fails only after the steel fibre breaks or is pulled out of the cement matrix [2]. Properties of SFRC in both the freshly mixed and hardened state, including durability, are a consequence of its composite nature. The mechanics of fibre reinforcement which strengthens concrete or mortar is a continuing research topic. One approach to the mechanics of SFRC is to consider it as a composite material whose properties can be related to the fibre properties (volume percentage, strength, elastic modulus[8], and a fibre bonding parameter of the fibres), the concrete properties (strength and elastic modulus), and the properties of the interface between the fibre and the matrix.

Fibres are usually used in 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 produce greater impact, abrasion and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete, and so cannot replace structural steel reinforcement. If the modulus of elasticity of the fiber is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. However, fibres which are too long tend to "ball" in the mix and create workability problems.

3. EXPERIMENTAL INVESTIGATION

3.1 Test materials and mix proportions

Portland pozzolona cement with ISI mark was used for test on fresh and hardened concrete. The compressive strength was 23.77 MPa and 33.21 MPa at 7 days and at 28 days respectively. Local river sand with fineness modulus 3.17 was used. The coarse aggregate with basalt origin, maximum size 20mm used from local stone crusher. Portable water, with pH of 7.1, was used. The design mixed M30with proportion 1:1.54:3.31(Cement: Fine aggregate: Coarse Aggregate) for concrete on weight basis. The mix design was done as per IS 10262:2009. Water cement ratio of 0.5kept constant for concrete.

3.2 Specimen details

Cube moulds of 150x150 x150 mm and cylindrical moulds of 150 mm diameter and 300 mm long are used for casting the specimen for compressive strength and split tensile strength test respectively. For flexure test, specimen size of 150x150x700 mm is cast. Specimens were cured for 28 days. But out of 4 specimens 3 specimens of compressive strength test are cured for 7 days and 3 specimens were cured for 3 days to obtain the compressive strength after 7 days and 3 days respectively.

3.3 Testing

Flexural test were carried out on 18 beams, out of that each of 3 beams are tested for hybridization ratio 0-100%, 30-70%, 50-50%, 70-30%, 100-0% (Steel-Polypropylene)[14]. For all hybridization ratio fiber volume 0.5% by volume of concrete is kept constant.

Fig.1: Flexural test setup

The beams were kept on UTM as shown in fig.1 the beams were tested under gradually applied two point loading on UTM machine for flexural strength. Ultimate loads and modes of failure of beams were noted. Compressive strength and split tensile strength are carried out on cubes and cylinders respectively, tested under compression testing machine.

4. METHODOLOGY

The tests have been performed to determine the mechanical properties such as compressive strength and splitting tensile-strength of concrete mix with steel fibers 0%, 0.5% by volume of concrete and alkali resistance glass fibers, 0.25% by weight of cement.

4.1. Compressive Strength Test

The strength of concrete is usually defined and determined by the crushing strength of 150mm x 150mmx150mm, at an age of 7 and 28days. It is most common test conducted on hardened concrete as it is an easy test to perform and also most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. Steel mould made of cast iron dimension 150mm x 150mmx150mm used for casting of concrete cubes filled with steel fibers[9] 0%, 0. 5% by volume of concrete and alkali resistance glass fibers, 0% and 0.25% by weight of cement. The mould and its base rigidly damped together so as to reduce leakages during casting.

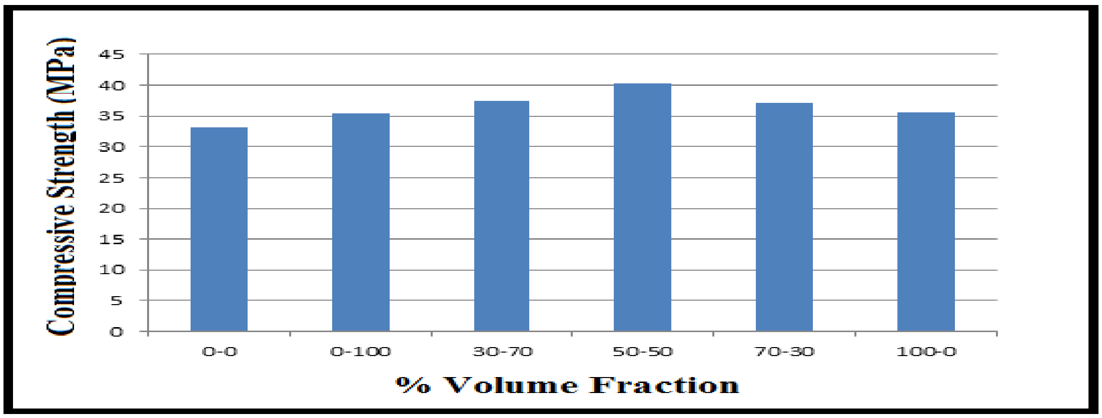
The sides of the mould and base plates were oiled before casting to prevent bonding between the mould and concrete. The cube was then stored for 24 hours undisturbed at temperature of l8°C to 22°C and a relative humidity of not less than 90% .It also stated in IS 516-1959 that the load was applied without shock and increased continuously at the rate of approximately 140 Kg/sq cm/ min until the resistance of specimen to the increasing loads breaks down and no greater load can be sustained. The maximum load applied to the specimen was then recorded as per IS: 516-1959. The testing of cube and cylinders under compression were shown in figure 1.

The compressive strength was calculated as follows:

Compressive strength (MPa) = Failure load / cross sectional area.

Fig 2: Compression Test on Cube and Cylinders

Fiber addition with equal percentage assures maximum availability of fiber in the fibrous matrix of concrete as regard to volume. Maximum availability of fibers are advantageous as under the axial load cracks occurs in microstructure of concrete, fiber reduces the crack formation and development.



Graph no.1: Compressive strength after 28 days

Concrete is very alkaline and as such it will corrode steel fiber very quickly so that non-metallic fibers (polypropylene) are used for effective reinforcement. Use of non-metallic fiber is to arrest only a micro cracks developed due to shrinkage. Modulus of elasticity of PP fiber is less than steel fiber hence PPFRC undergoes brittle failure after loading. Due to hybridization[10] of steel and polypropylene (50-50%) mix provide better response to arrest micro and macro cracks hence improve the compressive strength of concrete as compare to plain concrete and all other combination of hybridization ratio.

4.2. Split Tensile Strength Test

The test was conducted as per IS 5816:1999 [13]. For tensile strength test, cylindrical specimens of dimension 100 mm diameter and 200 mm length were cast.

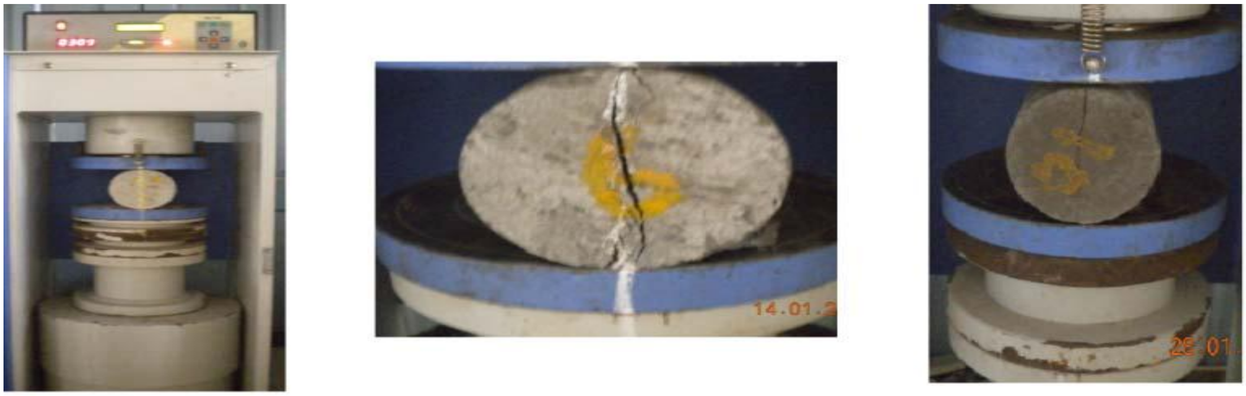


Fig 2: Cylinders under Split tension

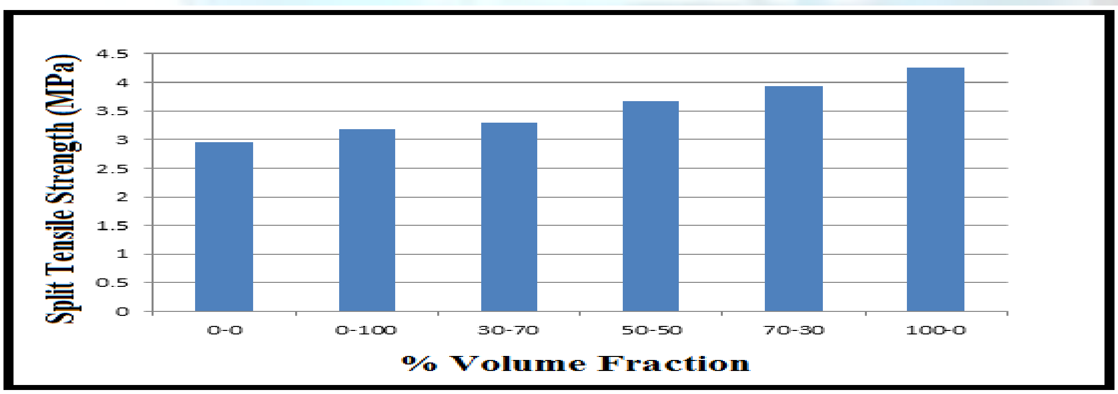
The specimens were demoulded after 24 hours of casting and were transferred to curing tank where in they were allowed to cure for 7 and 28 days. In each category, three cylinders were tested and their average value was reported [12]. The split tension test was conducted as shown in figure 2 using digital compression machine having 2000 kN capacity. Split tensile strength was calculated as follows:

Split Tensile strength (MPa) = $2P / \pi DL$

Where, P = Failure Load (kN)

D = Diameter of Specimen (100 mm)

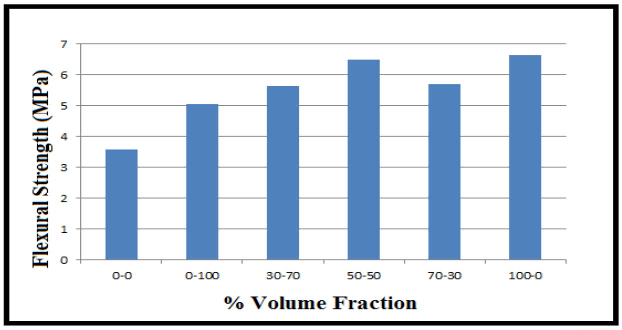
L = Length of Specimen (200 mm)



Graph no.2: Split Tensile Strength after 28 days

4.3 Flexural Strength

The results of flexural strength test at 28 days are given in table No.1. Flexural strength of concrete increases with increase in steel fiber percentage in specimen. It is also seen that the addition of polypropylene fibers increase the flexural strength. Flexural strength primary increase due to fiber intersecting the cracks in the tension half portion of the specimen. This fibers accommodate the crack face separation by process of stretching the fibers, thus providing additional energy absorbing capacity. It also provides stress relaxing mechanism at the tip of the cracks during micro cracks formation[15]. The modulus of rupture of steel fibers is more as compare to polypropylene fibers. Therefore steel fibers are effective to arrest the macro cracks and undergoes ductile failure while Polypropylene fibers are only effective to arrest the micro cracks and undergoes brittle failure.



Graph no.3: Flexural Strength after 28 days

5. CONCLUSION

The variation of direct compressive strength for concrete cubes was found to be inconsistent with the increase in percentage of fibers. The splitting tensile strength was increased by 20-22% for concrete cylinder samples with 0.5% fibre content in M20 and M30 Grade concrete mixes. Much research on readily available fibres was conducted with an additional input of cost for the purchase of fibres. But these tests were thus a true example of sustainable development as the recycling of scraps from lathe shops is done to improve the behavior of concrete and also the cement content was partially replaced by fly ash in higher grade concrete.

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