AN EXPERIMENTAL STUDY OF THE MECHANICAL PROPERTIES OF GLASS FIBER REINFORCED HIGH STRENGTH CONCRETE PARTIALLY REPLACING CEMENT WITH NANO SILICA

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Abstract - *Concrete is an extensively used construction material for its various advantages such as low cost, ease of production etc. But it cannot be used alone everywhere because of its low tensile strength. So, fibers both natural as well as artificial are used as resistance strengthening of concrete especially against cracking. Researchers all over the world are attempting to develop high strength concretes by using fibers and other admixtures in concrete up to certain proportions. Most of the developments across the work have been supported by continuous improvement of these admixtures. Hence variety of admixtures such as fly ash, rice husk ash, stone dust and silica fume has been used so far. In the view of the global sustainable developments, it is imperative that fibers like glass, carbon, polypropylene and aramid fibers provide improvements in tensile strength, fatigue characteristics, durability, shrinkage characteristics, impact, cavitations, erosion resistance and serviceability of concrete. Fibers impart energy absorption, toughness and impact resistance properties to fibre reinforced concrete material and these characteristics in turn improve the fracture and fatigue properties of fiber reinforced concrete research in glass fiber reinforced concrete resulted in the development of an s glass fiber high dispersion that improved long term durability.*

This study has been conducted for understanding the mechanical behavior of S glass fiber reinforced concrete replacing 2% cement with nano silica. Studies were conducted on the compressive, flexural and tensile strengths of concrete by varying the fiber percentage from 0 to 1% by weight of concrete, at constant 2% Nano silica in cement. The obtained results where then compared with M40 conventional concrete. It was observed that the compressive, flexure and tensile strengths increased with the increase in fiber content up to 0.5-0.75% thereby indicating that 0.75% is the optimal fiber content. An increase of 17%, 42% and 54% over M40 conventional concrete were registered for compressive, flexure and split tensile strengths respectively.

Key Words: **S glass fiber, Nano silica and High strength concrete**

1. INTRODUCTION

Concrete is highly resistant against compression. It has low flexibility. Therefore, this results in low flexural and torsion strengths. However this problem was overcome by steel reinforcement in beams and slabs. But the steel in the concrete may get affected by corrosion. This leads to the failure of the structure on transverse loading. Utilization of glass fiber lessens the stiffness similar to steel reinforcement.

It has also been proposed to use highly alkali-resistant glass fibers and s glass fibers of spheres. This procedure does not completely eliminate the corrosion of the glass caused by the cement but merely delays this process. Moreover, it also has the disadvantage of resulting in poor adhesion to a cementitious matrix.

1.2 Fiber Reinforced Concrete

Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers. Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes discontinuous fibers is to bridge across the cracks that develop provides some post- cracking "ductility". If the fibers are sufficiently strong, sufficiently bonded to material, and permit the FRC to carry significant stresses over a relatively large strain capacity in the post-cracking stage.

1.3 Classification of Fibers

Various materials are used to produce fibers for use in concrete. Currently the main distinctly different categories are steel fibers, synthetic fibers, glass fibers and organic- or natural fibers. Manufacturers produce fibers in different geometrical forms to improve the bond characteristics between fiber and the concrete matrix while trying to prevent fiber bundling from occurring during the mixing process.

1.4 Fibre Mechanism

Fibers work with concrete utilizing two mechanisms: the spacing mechanism and the crack bridging mechanism. The spacing mechanism requires a large number of fibers well distributed within the concrete matrix to arrest any existing micro-crack that could potentially expand and create a sound crack. For typical volume fractions of fibers, utilizing small diameter fibers or micro fibers can ensure the required number of fiber for micro crack arrest.

1.5 Steel Fiber Reinforced Concrete

Steel-Fiber Reinforced Concrete is constructed by adding short fibers of small cross-sectional size to the fresh concrete. These fibers reinforce the concrete in all directions, as they are randomly oriented. The improved mechanical properties of concrete include ductility, impact-resistance, compressive, tensile and flexural strength and abrasion-resistance. These unique properties of the fiber-reinforcement can be exploited to great advantage in concrete structural members containing both conventional bar-reinforcement and steel fibers. The improvements in mechanical properties of cementitious materials resulting from steel-fiber reinforcement depend on the type, geometry, volume fraction and material-properties of fibers, the matrix mix proportions and the fiber-matrix interfacial bond characteristics.

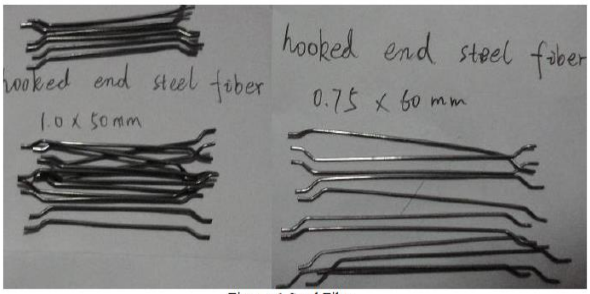


Figure -1 Steel Fiber

Figure Error! No text of specified style in document.**:** Steel Fibers

1.6 Glass Fiber Reinforced Concrete

Glass fiber reinforced concrete is (GFRC) basically a concrete composition which is composed of material like cement, sand, water, and admixtures, in which short length discrete glass fibers are dispersed. Inclusion of these fibers in these composite results in improved tensile strength and impact strength of the material. GFRC has been used for a period of 30 years in several construction elements but at that time it was not so popular, mainly in non-structural ones, like facing panels (about 80% of the GRC production), used in piping for sanitation network systems, decorative on-recoverable formwork, and other products.

Figure 1: Glass Fibers

1.9 Nano Silica

Nano silica having a low cost budget, high compressive & tensile strength, high surface area, ability to prevent silicosis, reducing percentage of CO2, nanosilica also helps in checking solid waste pollution when mixed with recycled concrete aggregates. It can also be added to concrete to stabilize fillers like fly-ash, to a coating material resulting in a very strong matrix, or used as fire retardant agent. Typical applications are UHPC (Ultra High Performance Concrete), scratch resistant coatings and fire resistant glass.

Figure 3: Nano silica

2. LITERATURE REVIEW

J Bothma of the Institute of Structural Engineering compiled a literature review of the various fibers used in concrete presently and brought together empirical relationships between the fiber contents used and mechanical properties of concrete. Tests that were conducted led to the conclusion that fibers contribute to an increase, albeit a slight one, in the compressive strength. This essentially takes place due to active participation of micro fibers in post cracking mechanism. The main contribution of fibers, however, is their significant increase in the flexural rigidity, impact resistance and toughness than ordinary concrete. Studies conducted by Mindess, S. & Vondran, 1988 found that by using 0.5% fibers by volume, the compressive strength could be increased by as much as 25%. The addition of supplementary materials such as silica fume or slag in combination with the use of fibers could yield some improvement in compressive resistance of concrete.

3. METHODOLOGY

- The quantities of cement, micro silica, size of aggregate and water for each batch were determined by weight, to an accuracy of 0.1 percent of the total weight of the batch.

- Mix design confirming to M30 was followed and batches were mixed according to the table in the following chapter. A total of 3 cubes, beams and cylinders were produced for every batch of trial.

- Fibers were added to concrete during the mixing stage manually, by dispersing them uniformly and randomly throughout the mix.
- S glass fibers were added at 0, 0.25, 0.5, 0.75 and 1% by weight of concrete during mixing.

Figure 4: Flexural strength of beams

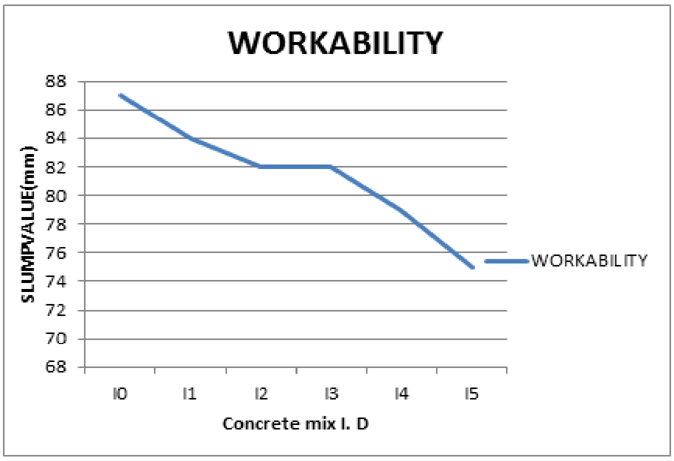
4. TESTS RESULTS AND DISCUSSION

The experimental investigations are conducted on M_{40} grade of concrete with percentages addition of s glass fiber by 0%, 0.25%, 0.5%, 0.75%, 1.0%, and Nano silica by 2% in cement by weight and concrete have been designed and tested. In the present work, to study the compressive strength, split tensile strength and flexural strength of s glass fiber and nano silica is considered and the results of the tested specimens are presented in this chapter. Results were compared and checked for compressive strength, split tensile strength and flexural strength of concrete.

4.1 Workability

Table 1: Slump Value for Different Concrete Mix

S.No.	Mix ID	Slump (mm)
1	I_0 conventional	87
2	I_1	84
3	I_2	82
4	I_3	82
5	I_4	79
6	I_5	75



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4.2 Compressive Strength

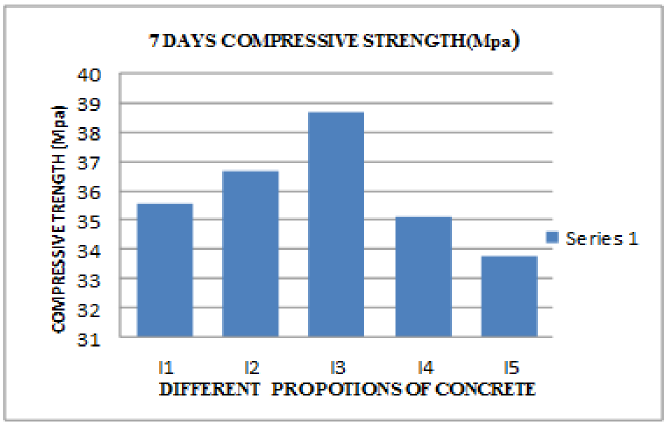

Figure 6: 7 Days Compressive Strength for Different Concrete Mix

- At 0% addition of S Glass Fiber by weight and 2%nano silica, the Average Compressive Strength of Cubes at 7 days is 35.55 MPa
- At 0.25% addition of S Glass Fiber by weight and 2%nano silica, the Average Compressive Strength of Cubes at 7 days is 36.66MPa
- At 0.5% addition of S Glass Fiber by weight and 2%nano silica, the Average Compressive Strength of Cubes at 7 days is 38.66MPa
- At 0.75% addition of S Glass Fibers by weight and 2%nano silica, the Average Compressive Strength of Cubes at 7 days is 35.11MPa
- At 1.0% addition of S Glass Fiber by weight and 2%nano silica, the Average Compressive Strength of Cubes at 7 days is 33.77 MPa

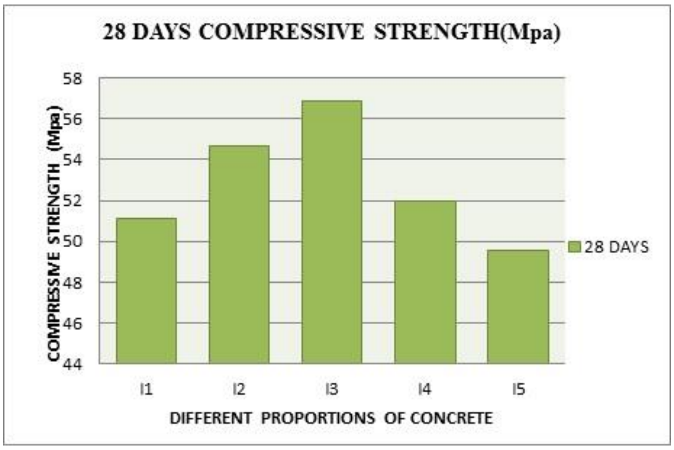

Figure 7: 28 Days Compressive Strength for Different Concrete Mix

- At 0% addition of S Glass Fiber by weight and 2%nano silica, the Average Compressive Strength of Cubes at 28 days is 51.11 MPa
- At 0.25% addition of S Glass Fiber by weight and 2%nano silica, the Average Compressive Strength of Cubes at 28 days is 54.66 MPa
- At 0.5% addition of S Glass Fiber by weight and 2%nano silica, the Average Compressive Strength of Cubes at 28 days is 56.88 MPa
- At 0.75% addition of S Glass Fibers by weight and 2%nano silica, the Average Compressive Strength of Cubes at 28 days is 52 MPa
- At 1.0% addition of S Glass Fiber by weight and 2%nano silica, the Average Compressive Strength of Cubes at 28 days is 49.95 MPa.

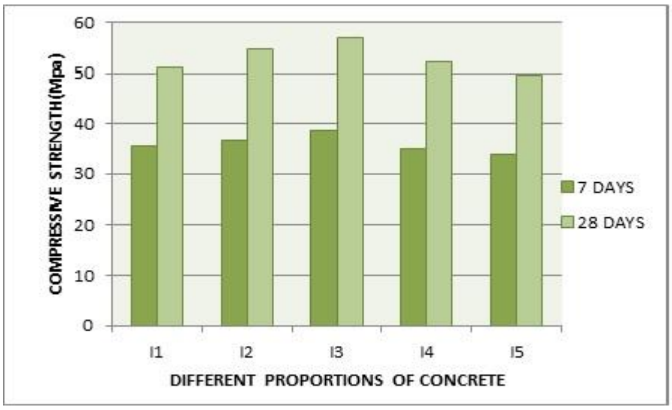

Figure 8: Comparison of 7 & 28 Days Compressive Strength of Different Concrete Mix

4.3 Split Tensile Strength

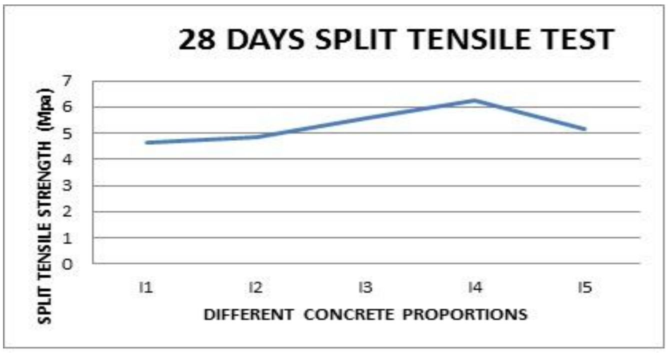

Figure 9: 28 Days Split Tensile Test for Different Concrete Mix

- At 0% addition of S Glass Fiber by weight and 2%nano silica, the Average split tensile Strength of cylinder at 28 days is 4.66 MPa
- At 0.25% addition of S Glass Fiber by weight and 2%nano silica, the Average split tensile Strength of cylinder at 28 days is 4.86 MPa
- At 0.5% addition of S Glass Fiber by weight and 2%nano silica, the Average split tensile Strength of Cylinder at 28 days is 5.56 MPa
- At 0.75% addition of S Glass Fibers by weight and 2%nano silica, the Average split tensile Strength of Cylinder at 28 days is 6.23 MPa
- At 1.0% addition of S Glass Fiber by weight and 2%nano silica, the Average split tensile Strength of Cylinder at 28 days is 5.136 MPa.
- By adding S glass fibers by weigh of cement by 0%, 0.25%, 0.5%, 0.75% & 1% and 2% nano silica the maximum optimum dosage of fiber in S glass fiber reinforced concrete by split tensile strength on cylinders is obtained at 0.75% S glass fiber and 2% nano silica.

4.4 Flexural Strength

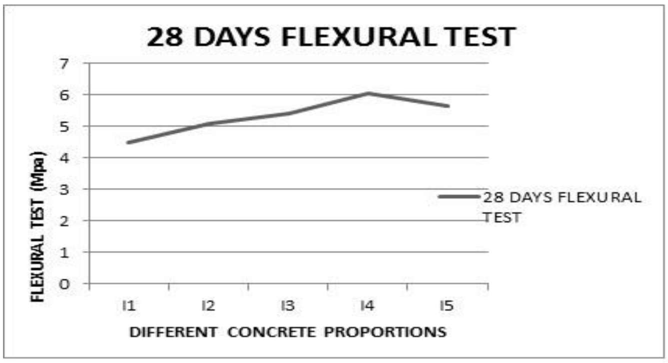

Figure 10: 28 Days Flexural Test for Different Concrete Mix

- At 0% addition of S Glass Fiber by weight and 2%nano silica, the Average flexural Strength of beams at 28 days is 4.503 MPa
- At 0.25% addition of S Glass Fiber by weight and 2%nano silica, the Average flexural Strength of beams at 28 days is 5.1 MPa
- At 0.5% addition of S Glass Fiber by weight and 2%nano silica, the Average flexural Strength of beams at 28 days is 5.39 MPa
- At 0.75% addition of S Glass Fibers by weight and 2%nano silica, the Average flexural Strength of beams at 28 days is 6.03 MPa
- At 1.0% addition of S Glass Fiber by weight and 2%nano silica, the Average flexural Strength of beams at 28 days is 5.66 MPa.
- By adding S glass fibers by weigh of cement by 0%, 0.25%, 0.5%, 0.75% & 1% and 2% nano silica the maximum optimum dosage of fiber in S glass fiber reinforced concrete by flexural strength on beams is obtained at 0.75% S glass fiber and 2% nano silica.

5. CONCLUSIONS

- The maximum optimum dosage of fiber in glass fiber reinforced concrete by compressive test on cube is obtained at 0.5% S glass fiber and 2% Nano silica. The average 7 days compressive strength is 38.66MPa and 28 days compressive strength is 56.88MPa.
- Up to 0.5% S glass fiber and 2% nano silica, there is a gradual increase in Strength at 28 days similar to the compressive strength of 7 days. And then there is a gradual decrease of compressive strength. This may be due to increase of fibrous material in concrete. From the test results it indicates that there is an increase of about 17% of compressive strength by utilization of 0.5% S glass fiber and 2% nano silica.
- The maximum optimum dosage of fiber in glass fiber reinforced concrete by split tensile test on cylinder is obtained at 0.75% S glass fiber and 2% Nano silica. The average 28 days split tensile strength is 6.23 MPa.
- From the test results it indicates that there is an increase of about 42% of tensile strength by utilization of 0.75% S glass fiber and 2% Nano silica.
- The maximum optimum dosage of fiber in glass fiber reinforced concrete by flexural test on beam is obtained at 0.75% S glass fiber and 2% Nano silica. The average 28 days split tensile strength is 6.03 MPa.
- From the test results it indicates that there is an increase of about 54% of flexural strength by utilization of 0.75% S glass fiber and 2% Nano silica.

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