

A Study On The Behavior Of Fibre Reinforced Concrete Using Steel, Glass, And Glass Textiles

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ABSTRACT

While concrete has been the constituting element in construction, it suffers from brittle and low tensile features. The only problem for protection against steel-induced corrosion remains to be tackled. This work considers the use of Alkali-Resistant (AR) Glass Textile as an addition to SFRC and GFRC processes so that structural performance and durability can be improved across the board. A M30 concrete mix was cast using steel and glass fiber percentages of 0.5, 1, and 1.5%. Compressive strength tests carried out during the wet curing period of 7, 14, and 28 days established 0.5% fiber content as the best fiber dosage. After 28 days, beam specimens containing 0.5% fiber content with AR glass textile were tested for flexural strength. The study presents a comparative account of GFRC and SFRC systems with AR glass textile to assess their efficiencies for enhancing crack resistance and mechanical properties. The performance indeed improved and pointed the way to the best composite for high-performance use.

KEYWORDS: *High-Performance Concrete, Steel Fiber Reinforced Concrete (SFRC), Glass Fiber Reinforced Concrete (GFRC), Alkali-Resistant (AR) Glass Textile, Structural Performance.*

1. INTRODUCTION

Concrete is the most used construction material in the world due to its versatility, availability, and cost-effectiveness. But its inherent brittleness and poor tensile strength limit its performance in flexural and tensile loading conditions [1]. Moreover, though reinforced concrete structures are good from the strength point of view, cracking can occur due to numerous reasons. Cracking of concrete causes faster ingress of moisture, chlorides, and carbon dioxide-corrosion of steel reinforcement, and reduction of service life [2]. Because of these reasons, more research is being conducted on fiber-reinforced concrete (FRC), which improves the mechanical properties and durability of plain concrete with enhanced resistance to cracking [3].

Compared with the many fiber types, steel fibers have been widely used to improve the post-crack behavior, ductility, and toughness of concrete [4].

Glass fibers, in particular alkali resistant (AR) ones, have also drawn considerable attention due to their high tensile strength, corrosion resistance, and compatibility with cementitious matrices [5]. Textile reinforced concrete (TRC) with AR glass textiles has also appeared as a promising substitute to steel reinforcement, providing enhanced crack control and structural performance [6]. Hybrid systems integrating steel and glass fibers or textile layers inside fiber-reinforced concrete have been proven to display synergistic action in improving both mechanical and durability characteristics [7]. Such systems can support crack bridging on multiple scales, thus controlling crack width and carrying loads in the process of being cracked [8]. Optimization of fiber dosages and combinations for maximum performance has also been studied extensively. For instance, investigations of steel fiber-reinforced concrete revealed that low dosages (0.5–2% by volume) are capable of enhancing compressive, flexural, and tensile strengths [9]. Similarly, glass fiber-reinforced concrete showed improved flexural behavior and impact resistance, especially with AR fibers [10].

Incorporating layers of textiles in the concrete composites further improves the resistance to cracks and energy absorption capabilities. TRC systems have enjoyed wide application in various forms of thin-walled structures and retrofitting works owing to their lightweight and high-performance characteristics [11]. The combination of textile reinforcement with discrete fibers such as steel or glass may provide a balanced option for structural elements that require both strength and durability in time [12]. Durability is another key aspect of concrete performance under aggressive environments. Fibers reduce permeability and limit adverse substance invasion, meanwhile delaying corrosion from setting into the traditional steel reinforcements [13]. Studies show that fiber addition helps in resisting chloride ion penetration, freeze-thaw, and sulfate attacks [14].

2. This study is aimed at assessing the mechanical properties of M30 grade HPC with steel fibers, glass fibers, and AR-glass textile fabric. Dosages of the fibers single-handedly were 0.5%, 1%, and 1.5% by cement weight; compressive strength tests followed at 7, 14, and 28 days of curing. In

line with the outcome from compressive strength, 0.5% of fiber content was selected for flexural testing on beam specimens incorporating AR glass textile. The intention is to evaluate and compare the efficiency of SFRC and GFRC systems with textile reinforcement for the enhancement of mechanical properties and crack resistance, to draw conclusions regarding the best composite for high-performance structural applications.

3. MATERIALS AND METHOD

2.1 MATERIALS

a) Cement

We used OPC with Grade 53

Table1: Properties of cement

S. No	Description	Values
1	Normal Consistency of cement	30%
2	Specific Gravity	3.27
3	Fineness	6%
4	Initial Setting Time	30 min
5	Final Setting Time	250 min

Cement is a binding material and chemical substance used for construction it helps to set, hardens, and adheres the other materials to bind them together. Many types of Cement are available now depending on the requirement the type of cement is decided. Generally, In Construction we use OPC(Ordinary Portland Cement) and PPC(Portland Pozzoloan Cement).PPC tends to develop strength over time and often matches or exceeds OPC's strength in the longer term. While OPC provides good strength, its durability might be slightly lower in certain certain conditions. PPC is used in hydraulic structures, dykes, marine, sewage pipe works etc., and OPC used in Building, Bridges, large Structures etc.,



Fig. 1 Cement

b) Coarse Aggregate (C.A)

Coarse aggregate is a material which retained through an IS sieve 4.75mm to 80mm sieve. Coarse aggregate shall consist of naturally occurring materials (Silica, Quartz,etc.,) such as gravel or resulting from the crushing of parent rock, to include natural rock, slag, expanded clays and shales, and other approved inert materials with similar characteristics, having hard, strong, durable particles, conforming to the specific requirements of this Materials. It is in angular shape should not possess high flakiness dues to flakiness the aggregate may break easy and the strength decreases. It is available in the ocean and river bed. Mainly granite, marble and beasalt stones are used in coarse aggregate.

Table 2:Properties of Coarse Aggregate

S. No	Description	Values
1	Specific Gravity of CoarseAggregates	2.61
2	Water Absorption of CoarseAggregates	0.4%
3	Impact Test	23.48%
4	Los Angeles Test	32.42%
5	Aggregate Crushing test	28.62%
6	Flakiness index	22%
7	Elongation index	17%



Fig. 2 Coarse Aggregate

c) Fine Aggregate (F.A)

Fine aggregate is a material which passes through an IS sieve 4.75mm. The river sand is used Fine aggregate cubical or rounded shape with a smooth surface texture. Being cubical, rounded, and smooth texture, it gives good workability. The Fine aggregate also helps the cement paste to hold the Coarse aggregate.

Table 3: Properties of Fine Aggregate

S.No	Description	Values
1	Specific Gravity	2.69
2	Sieve Analysis of sand	ZONE -II
3	Bulking of Sand	7.45
4	Water Absorption	3.36%



Fig. 3 Fine Aggregate

Water plays a crucial role in concrete mix design by ensuring proper cement hydration and optimizing strength development. In this study, local tap water was used for all mixes. The water-cement ratio was maintained between 0.42 and 0.45.

d) Steel Fiber

Steel fiber Crimped steel fibers improve concrete by raising the interacting bond strength, crack resistance, and flexural performance. A deformed shape strengthens the concrete's resilience by increasing toughness and energy absorption against impact and fatigue loadings.

Table 4: Properties of Steel fiber

Properties	Value
Length (L)	50mm
Diameter (d)	0.2mm
Aspect Ratio(L/d)	25
Specific gravity	7.85



Fig. 4 Steel Fiber

e) Glass fiber & Glass Textile

Glass fibers are short strands of chopped fibers generally in lengths varying from a few millimeters to a couple of centimeters. They have extensive use in composite materials to increase strength, toughness, and crack resistance. These fibers could be added to concrete, polymer, or resin to improve mechanical properties such as tensile strength, flexural strength, and impact resistance. Glass textile is any woven or non-woven fabric made of glass fibers and applied mainly for reinforcing construction, composites, insulation, and protective applications. It confers high strength, durability, and resistance to heat, chemicals, and electrical conductivity.

Table 5: Properties of glass textile

Property	Values
Tensile strength	2000-4000 MPa
Melting Point	1200 to 1500 0c
Density	2.7 g/cm ³
Youngs Modulus	70-80MPa
Fabric diameter	5-30 microns
Fabric GSM	200



Fig. 5 Glass fiber



Fig. 6 Glass textile

Admixture The study utilized the superplasticizer SNP (Sulphonated Naphthalene Polymers) of specific gravity 1.20, having a brand name of TEC® MIX 550 which has enhanced water reduction properties, to improve workability and reduce water demand in the concrete mix.

2.2 METHODOLOGY

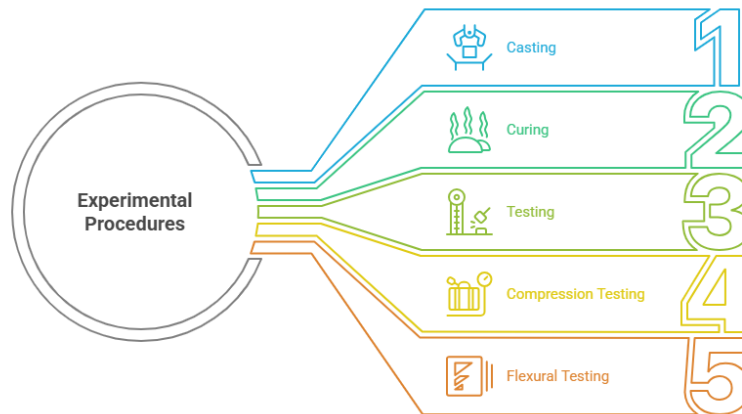


Fig. 7 Flow chart for Methodology

Experimental considerations for investigating the mechanical properties of fiber-reinforced concrete were applied systematically. Concrete specimens were cast with different fiber content, cured under specified conditions, and then subjected to compressive and flexural strength tests. Cubic specimens were used for compression tests, and beam specimens were used for the flexural tests. These results were helpful for evaluating how fibers contribute to strength, ductility, and crack resistance so that these materials would be feasible for use in the development of high-performance construction materials.

Mix Design

The study aimed to evaluate the performance of Steel fibre reinforced concrete (SFRC) and Glass fibre reinforced concrete (GFRC) the concrete makes us designed for M30 grade as per IS 10262:2009, ensuring a balance between workability, strength and durability while incorporating fibres in different proportions.

A control mixes plain cement concrete (PCC- M30) was prepared first. Then followed by fibre reinforced variants with different percentages of steel and glass fibres. The mix proportions for PCC are presented in that table.

Table 6: Mix proportion of M30 grade concrete

Component	Cement	Fine aggregate	Coarse aggregate	Water	W/C Ratio
Content (kg/m ³)	440.96	819.46	946.52	185.20	0.42

The mix proportions are 1:1.8:2.1

The fibre reinforced concrete mixes were modified based on the fibre dosage levels (0.5 %, 1.0%, 1.5 % by volume of concrete) requiring adjustments in the volume fractions of other materials to maintain mix consistency

Fiber incorporation and placement

1. Steel fibre reinforced concrete (SFRC)

Crimped steel fibres were added in 0.5%, 1%, 1.5% by volume of concrete. The fibres were uniformly

distributed throughout the mix to improve tensile strength toughness and crack resistance. The addition of fibers reduced workability leads to usage of superplasticizer.

2. Glass fibre reinforced concrete (GFRC)

Alkali resistant air glass fibres were introduced by 0.5%, 1.0%, and 1.5% in concrete. Glass fibres were distributed and enhance exhaust and impact resistance. Higher fibre content showed increased difficulty in mixing and placement due to reducing workability.

3. Textile reinforced concrete (TRC)

In the casting SFRC and GFRC beams, a glass textile sheet was strategically placed at the tension zone of the beam to act as an additional reinforcement layer. A proper compaction was performed using a vibrator to ensure adequate bonding between the textile sheet and the surrounding concrete.

3. SPECIMEN TESTING

This study evaluates the effect of steel fibres, glass fibres and glass textile reinforcement on the compressive and flexure strength of concrete. The compressive strength was accessed for SFRC and GFRC specimens after 7, 14 and 28 days of curing.

And flexural strength was analysed for textile reinforced SFRC and GFRC beams where the glass textile was placed in the texture zone. The findings will provide insights into the effectiveness of fibre and textile reinforcement in enhancing concrete performance for structural applications.

3.1 Compressive strength

The compressive strength test was carried out to evaluate the load-carrying capacity of steel fiber reinforced concrete (SFRC) and glass fiber reinforced concrete (GFRC). Standard concrete cube specimens measuring 150 mm × 150 mm × 150 mm were cast for the test. These cubes were prepared using plain concrete as well as concrete mixed with different percentages of steel and glass fibers to study how the fiber content affects the compressive strength. After casting the specimens or demolded after 24 hours and cured in water for 7, 14 and 28 days. The compressive strength test was performed using a compression testing machine (CTM) with a 2000 kN capacity applying a uniform load until the specimen failed. The failure load was recorded and the compressive strength of the specimens was determined. The results were analyzed to access the influence of steel and glass fibers on the compressive strength of a concrete in compression to the control mix.



Fig. 8(a) Compression Testing Machine (CTM)



Fig. 8(b) Testing the cube

3.2 Flexural Strength

The flexural strength of the beam specimens was determined using a universal testing machine (UTM) with a 1000 kN capacity under a three-point loading setup. The test was conducted on 100mm x 100mm x 500mm prism specimens to evaluate the influence of the glass textile sheet incorporated in steel fiber and glass fiber reinforced concrete. The presence of steel textile sheet along with the glass fiber and steel fibers enhances the flexural performance by improving crack resistance, load distribution and overall toughness of the composite material. The flexural testing equipment used in the study is shown in figure 9(a) while the prism specimens are depicted in figure 9(b).

The addition of steel and glass fibers improves the concrete toughness load capacity and post causes cracking behavior by reducing brittleness and enhancing ductility. The flexural strength results are shown in table 9 with

variations illustrations in figures 11. The UTM load Vs deflection curve further highlights the fiber hardening effect.



Fig. 9(a) Testing of Prism



Fig. 9(b) Specimen after breaking

4. RESULTS AND DISCUSSIONS

The outcomes of this research work obtain from the test results performing various tests related to strength and durability. The tests involved in identifying the results are compressive strength, flexural resistance which termed to be mechanical tests. Later, acid test is termed to be durability tests and conducting thermal test. The following table 4.1 gives detail in compressive strength test results after 28 days curing.

4.1 Compression test

Table 7: compressive strength of Steel Fiber

S. No	Specimens	Compressive strength(N/mm ²)		
		7 days	14 days	28 days
1	Plain Concrete	36.4	40.04	50.5
2	Steel fiber (0.5%)	40.0	48.02	53.7
3	Steel fiber (1.0%)	37.2	44.25	49.4
4	Steel fiber (1.5%)	34.4	45.5	45.1

Table 8: compressive strength of glass fiber

S.No	Specimen	Compressive strength(N/mm ²)		
		7days	14days	28days
1	Concrete	36.4	40.04	50.5
2	Glass fiber (0.5%)	39.8	47.3	53.8
3	Glass fiber (1.0%)	35.4	45.9	49.36
4	Glass fiber (1.5%)	32.7	36.2	41.7

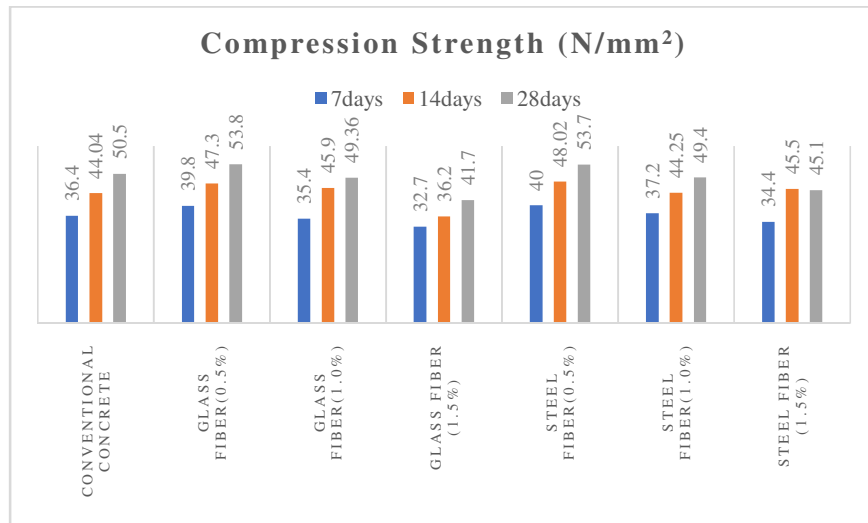


Fig. 10 Graphical representation of compressive strength values

The bar chart explains the compressive strength of different concrete mixes tested at 7, 14, and 28 days. It compares plain concrete with concrete reinforced with fibers of glass and steel at percentage levels of 0.5%, 1.0%, and 1.5%. Among the mixes, concrete with 0.5% glass fiber yielded the maximum 28-day compressive strength of 53.8 MPa, seconded by steel fibers with 0.5% at 53.7 MPa. Therefore, 0.5% fiber contents significantly make a difference in strength enhancement when compared to the 50.5 MPa achieved by conventional concrete at 28 days. Further increase of fiber content beyond 0.5% lowered the strength to some extent, probably due to less workability or the clumping of fibers in higher dosages. In essence, a fiber reinforcement of 0.5% seems to provide improvements in concrete strength, whereas too much fiber will do the opposite.

4.2 Flexural Strength

Table 9: Flexural Strength results

S. No	Specimen	Flexural strength(N/mm ²)
1	Conventional concrete	3.77
2	Glass fibre (GFRC)	4.81
3	Steel fibre (SFRC)	6.22

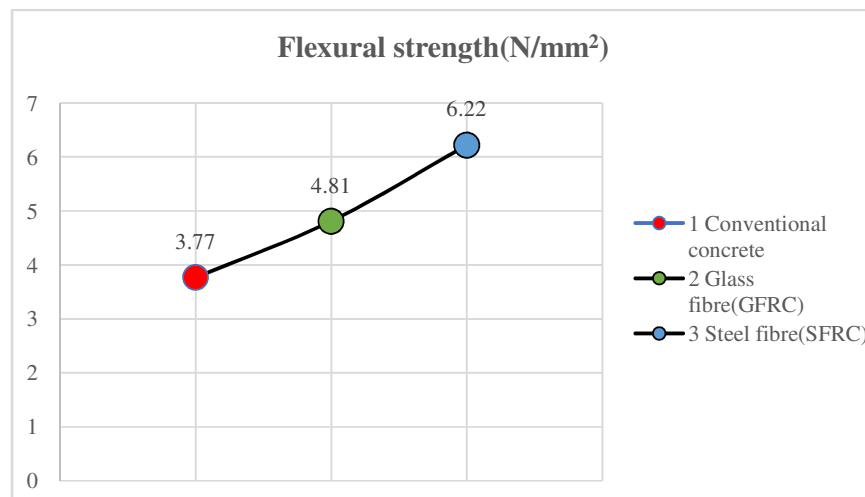


Fig. 11 Graphical representation of Flexural Strength values

The graph shows the enhancement in flexural strength of concrete with the addition of fibers. Conventional concrete has the lowest flexural strength of 3.77 N/mm². With the addition of glass fibers, the strength has increased to 4.81 N/mm², which is more than evident. The greatest strength is seen in steel fiber reinforced concrete of 6.22 N/mm². This shows that fiber addition and more especially steel fibers enhance greatly the concrete's resistance against bending and cracking.

5. CONCLUSION

The study clearly shows that adding a small number of fibers-especially at 0.5%-can significantly improve the compressive strength of concrete. Both glass and steel fibers performed better than conventional concrete at this percentage. However, when the fiber content was increased beyond 0.5%, the strength slightly decreased, which could be due to reduced workability or poor fiber distribution. This indicates that there is an ideal fiber dosage that gives the best results. For future research, it would be useful to explore how different types, lengths, and shapes of fibers affect concrete properties. Studies could also look into the long-term performance of fiber-reinforced concrete, such as how it handles cracking, shrinkage, and exposure to various environmental conditions. Investigating the use of mixed fiber types (like combining glass and steel) might also lead to improved performance. Additionally, future work could assess the cost-effectiveness and sustainability of using fiber reinforcement on a larger scale.

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