Enhancing Concrete Performance: Mechanical Properties with Glass Fiber Reinforcement

Yashpal Kumar[1], Rishabh Bajpai[2]

[1]*Research Scholar, Department of Civil Engineering, Guru Kashi University, Talwandi Sabo, Bathinda, Punjab, India*
[2]*Assistant Professor, Department of Civil Engineering, Guru Kashi University, Talwandi Sabo, Bathinda, Punjab, India*

Abstract

Concrete is a material used for construction purpose, but its mechanical properties can be further enhanced through fiber reinforcement techniques. This study investigates the impact of glass fiber reinforcement on different properties of concrete. The research aims to evaluate the effectiveness of glass fibers in improving concrete performance over different curing periods. Experimental results shows the inclusion of glass fibers significantly enhances the characteristics strength of concrete. Compressive strength tests indicate a notable increase in strength, with glass fiber-reinforced concrete (A2) outperforming the control sample (A1) at all curing ages. The improvements were most pronounced at 7 days (20% increase), 28 days (16.6% increase), and 90 days (18.8% increase), highlighting the positive contribution of glass fibers to matrix integrity and strength development over time. Split tensile strength results further confirm the beneficial impact of glass fibers, with A2 samples exhibiting a 14.6% increase at 7 days, followed by 7% and 7.2% improvements at 28 and 90 days, respectively. These findings suggest that glass fibers effectively bridge microcracks, enhancing the material's tensile resistance and overall durability. Flexural strength testing reveals similar positive trends, with A2 demonstrating an 8.3% increase in 7 days, 3.6% in 28 days, and 4.7% in 90 days. These enhancements indicate that glass fiber reinforcement contributes to the ductility and capacity of load-bearing in concrete. Overall, the study confirms that glass fiber reinforcement significantly improves concrete's mechanical properties. Observed enhancements suggest that glass fibers contribute is more durable.

Keywords: Concrete, Glass Fibre, Glass Fibre Reinforcement, Compressive Strength

Introduction

Concrete is one of the world's most used construction materials due to its high compressive strength, durability, and ease of manufacture.[1] However, despite its numerous advantages, traditional concrete suffers from inherent weaknesses such as brittleness, low tensile strength, and susceptibility to cracking under tension and impact loads. These limitations necessitate the exploration of reinforcement techniques to improve the mechanical properties of concrete and extend its service life.[2] One of the emerging solutions in this field is the incorporation of glass fiber reinforcement, which has shown promising potential in enhancing the performance of concrete structures. Glass fibers, as a reinforcement material, have been extensively studied and implemented due to their favorable properties, including high tensile strength, lightweight nature, and corrosion resistance. Unlike conventional steel reinforcement, glass fibers provide an alternative that not only improves mechanical performance but also reduces the overall weight of the structure.[3] This makes glass fiber-reinforced concrete (GFRC) an attractive option for applications where weight reduction is a critical factor, such as in high-rise buildings, bridges, and prefabricated structural elements. The use of glass fibers in concrete improves mechanical qualities such as tensile strength, flexural strength, impact resistance, and toughness.[4] These improvements are mostly due to the fibers' ability to bridge cracks, reduce crack propagation, and increase the material's energy absorption capacity. As a result, GFRC is gaining attention as a viable material for infrastructure projects that demand high durability and resilience.[5] The performance of glass fiber-reinforced concrete is influenced by various factors, i.e type & dosage of glass fibers, fiber length & aspect ratio, matrix composition, and curing conditions. Understanding the interaction between these variables is essential for optimizing GFRC properties and ensuring its effective application in construction.[6] Extensive study has been undertaken to assess the impact of these parameters on the mechanical behavior of GFRC, with findings indicating that a well-balanced combination of fiber content and concrete mix design can lead to superior material performance. In addition to its mechanical benefits, GFRC also presents environmental and economic advantages.[7] The use of glass fibers can contribute to sustainable construction practices by reducing the dependence on steel reinforcement, which is associated with high energy consumption and carbon emissions during production. Moreover, glass fibers can be sourced from recycled materials, further enhancing their sustainability profile. Cost-effectiveness is another important aspect, as the lightweight nature of GFRC reduces transportation and labor costs, making it a financially viable option for large-scale construction projects. Despite its numerous advantages, Researchers are actively investigating solutions to mitigate this issue, such as the use of coated or modified glass fibers with enhanced chemical resistance. Additionally, the workability of GFRC may be affected by the introduction of fibers, requiring adjustments in mix proportions and admixtures to maintain desirable fresh concrete properties.[8] The growing interest in GFRC has led to ongoing advancements in materials science, manufacturing techniques, and testing methodologies aimed at further optimizing its performance. Innovations such as hybrid fiber reinforcement, nano-modifications, and tailored fiber-matrix interfaces are being explored to push the boundaries of GFRC applications.[9] With continuous research and development, the adoption of GFRC is expected to increase across various construction sectors, contributing to more resilient and sustainable infrastructure solutions. By reviewing recent studies and experimental findings, this research seeks to provide a comprehensive understanding of GFRC's role in modern construction and its potential to revolutionize conventional concrete practices. The insights gained from this study will contribute to the knowledge base on fiber-reinforced concrete and guide future developments in enhancing concrete performance through glass fiber reinforcement.

Materials

Cement

Concrete mixes were made with ordinary Portland Cement (OPC) of grade 53, as specified in IS: 12269-2013. The cement was tested for specific gravity, consistency, and setting time to ensure that it met specifications.[10]

Fine Aggregates

River sand with a particle size of less than 4.75 mm, as defined by IS 383-2016, was utilized. The sand was analyzed using sieves, specific gravity, and fineness modulus.

Coarse Aggregates

Course aggregates of 10 & 20 mm sizes, conforming to IS: 383-2016, were used in a specific proportion. The aggregates were tested for gradation, crushing strength, impact strength, and abrasion resistance.

Water

Potable water, free from impurities and conforming to IS: 456-2000, was used for mixing and curing.

Glass Fibers

The fibers were added to compare the normal Concrete with the concrete having glass fibre (e.g., 0.5%, by weight of cement) to assess their impact on mechanical properties.

Results

Sieve Analysis Test:

Sieve analysis is an important test for determining the particle size distribution in fine and CA used in concrete. For concrete (M20), which has a mix proportion of 1:1.5:3 (Cement: FA: CA), sieve analysis helps ensure that the aggregates conform to the required grading specifications.

Table 1: Sieve Analysis Test Results

Sr. No	Sieve Size	Cumulative % Passing	Limits as per IS
1	20 mm	96	95-100
2	12.5 mm	79	-
3	10 mm	64	-
4	4.75 mm	39	30-50
5	2.36 mm	36	-
6	1.18 mm	32	-
7	600 microns	19	10-35
8	300 microns	6	12-40
9	150 microns	0	0-10

20 mm Sieve: The cumulative percentage passing is 96%, which falls within the specified limit range of 95-100%. This indicates that the largest particles are adequately controlled. **4.75 mm Sieve:** The cumulative percentage passing is 39%, aligning with the IS standard range of 30-50%, which suggests suitable grading at this intermediate level. **600 microns Sieve:** The test result shows 19% passing, which fits within the range of 10-35%, meeting the grading requirements for finer particles. **300 microns Sieve:** The 6% passing is below the IS standard range of 12-40%, indicating a potential deficiency in finer material. **150 microns Sieve:** The result is 0%, which complies with the standard limit of 0-10%, ensuring there are minimal very fine particles.

Crushing Test:

The Crushing Value Test is a measure used to determine the strength of coarse aggregate and its ability to resist crushing under compressive load applied gradually. This is an important characteristic, particularly in concrete mix designs, as it affects the durability and stability of the concrete structure. For M20 grade concrete, the acceptable limit for the aggregate crushing value is generally less than 30%. If the result exceeds this limit, it indicates that the aggregate is not suitable for use in high-strength concrete applications.

Abrasion Test:

The Abrasion Value Test is used to determine the resistance of aggregates to wear and tear, particularly under abrasive forces. This test is significant as it provides an insight into the aggregate’s durability and suitability for use in various concrete applications, including pavements, industrial floors, and other surfaces that are subjected to heavy traffic or mechanical wear.

Test Result: Abrasion Value

- Aggregate Abrasion Value**:** 14.38%

Impact Value Test:

The Impact Value Test result for M20 grade concrete aggregates is 5.74%, indicating that the aggregates have a high resistance to impact loads and possess excellent toughness. The impact value measures the ability of aggregates to resist sudden and repeated shocks, which is a crucial property for materials used in concrete subjected to dynamic or impact loads, such as road surfaces and foundations. For M20 grade concrete, a lower impact value is desirable as it signifies aggregates that can absorb and dissipate energy without significant degradation or fracturing. The result of 5.74% is well within the permissible limits (generally below 30% for most concrete applications), ensuring that the concrete mix will have good durability and structural integrity.

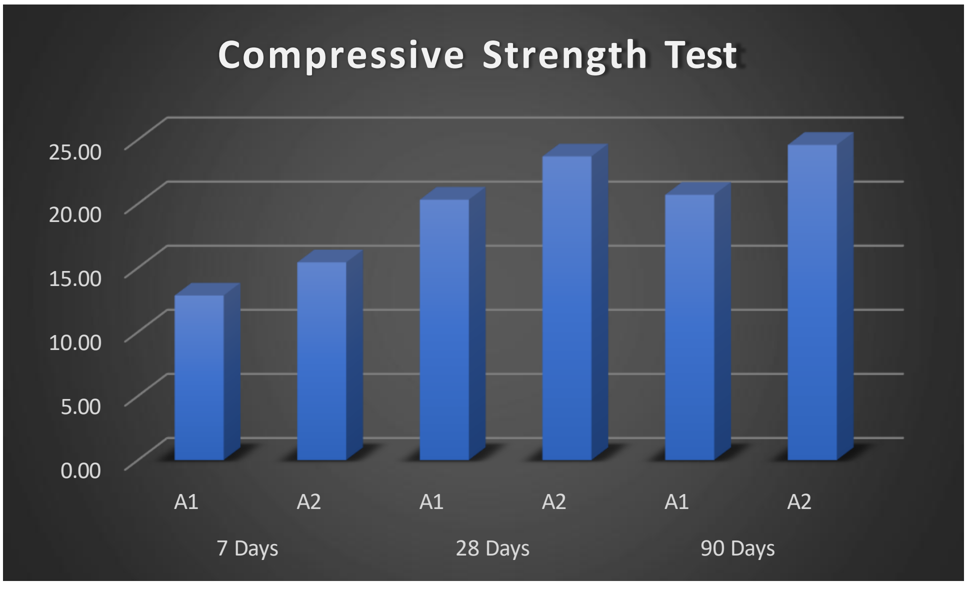
Compressive strength:

Fig: A1 Sample **Fig 2: A2 Sample**

Days	Sample No	Trial 1	Trial 2	Trial 3	Average
7	A1	12.83	12.74	12.98	**12.85**
	A2	15.6	14.8	15.89	**15.43**
28	A1	20.2	20.9	19.88	**20.33**
	A2	23.8	23.1	24.2	**23.70**
90	A1	21.03	20.87	20.22	**20.71**
	A2	24.9	23.6	25.3	**24.60**

Comparison between A1 and A2

Concrete of grade M20 is represented by sample A1 (Normal Sample), and nominal concrete with glass fibers in a proportion of 0.5% by cement weight is represented by sample A2{Addition of GF (0.50% by weight of cement). Nine samples from each mix were cast, and each sample's CS was measured. On comparing the average CS of the cubes cast from these mixes, it was determined that, addition of glass fibers increased the CS.



Compressive Strength Test Result (A1 VS A2) 7, 28 & 90 Days

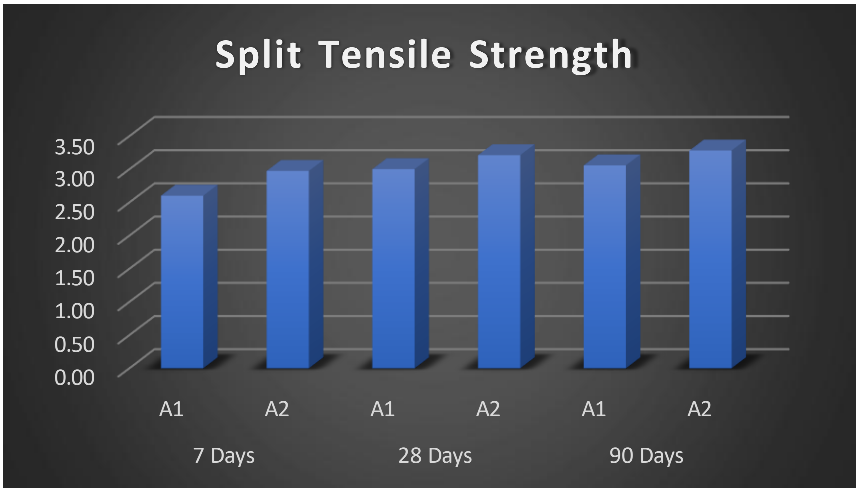
Split tensile strength:

Days	Sample No	Sample 1	Sample 2	Sample 3	Average
7	A1	2.45	2.79	2.57	**2.60**
	A2	2.92	3.06	2.95	**2.98**
28	A1	2.93	3.19	2.89	**3.00**
	A2	3.27	3.25	3.12	**3.21**

90	A1	2.76	3.35	3.07	**3.06**
	A2	3.05	3.46	3.34	**3.28**

A1 vs A2

Concrete of grade M20 is represented by sample A1, and sample A2 consists of nominal concrete with 0.5% of GF of the cement weight. Nine specimens were cast from each mix, and the ST strength of each sample was evaluated. The comparison indicated that incorporating Glass Fibers resulted in an enhancement of the ST strength.



Split Tensile Strength Test Result (A1 VS A2) 7, 28 & 90 Days

Flexural strength:

Days	Sample No	Trial 1	Trial 2	Trial 3	Average
7	A1	2.39	2.53	2.64	2.52
	A2	2.57	2.76	2.85	2.73
28	A1	2.89	3.03	3.14	3.02
	A2	2.97	3.16	3.25	3.13
90	A1	3.02	3.28	3.32	3.21
	A2	3.29	3.32	3.48	3.36

A1 vs A2

Sample A1 represents grade M20 concrete, while sample A2 is composed of nominal concrete with 0.5% GF of the cement weight. From each mixture, nine specimens were cast and the flexural strength of each sample was assessed. The analysis of the mean flexural strengths of the cylinders from these mixtures revealed that addition of glass Fibers led an improvement in flexural strength.

Conclusion:

This study examined how the use of GF reinforcement improved concrete performance, with an emphasis on mechanical qualities such as CS, ST strength, and FS. The results show that the use of glass fibers improves the overall strength qualities of concrete throughout various curing times. The CS results shows a significant improvement in GF-reinforced concrete (A2) compared to the Normal sample (A1). At 7 days, the CS of A2 was approximately 20% higher than A1, and this trend continued at 28 and 90 days, where A2 exhibited 16.6% and 18.8% higher strength, respectively. This suggests that glass fibers contribute to the development of CS over time by enhancing the integrity of the concrete matrix. Similarly, the split tensile strength results reveal an improvement in tensile properties with glass fiber reinforcement. At 7 days, A2 exhibited a 14.6% increase in tensile strength compared to A1. By 28 and 90 days, the increments were 7% and 7.2%, respectively. These findings indicate that the glass fibers effectively bridge microcracks, enhancing the material's tensile resistance. The flexural strength results further confirm the beneficial impact of glass fiber reinforcement. A2 samples consistently outperformed A1 samples across all curing ages. At 7 days, A2 demonstrated an 8.3% increase in FS, while at 28 & 90 days, the improvements were 3.6% and 4.7%, respectively. Overall, the findings confirm that glass fiber reinforcement significantly enhances concrete's mechanical properties. The improvements in compressive, tensile, and flexural strengths indicate that glass fibers contribute to a more durable and resilient concrete mix.

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