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Optimization of Glass Fiber Percentage in Concrete for Enhanced Mechanical Performance

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Abstract - *Concrete is widely used in construction but can suffer from cracking under tensile stress, leading to repairs. This study investigates glass fiber reinforcement in concrete to improve performance. Tests evaluated strengths with 0-12% fiber volume, showing up to 19.6 MPa compressive and 4.5 MPa flexural gains at 12% fiber. GFRC offers durable alternatives for prestressed elements.*

Keywords- Glass fiber, Plaster reinforcement, Compressive strength, Flexural strength, Construction materials, Durability.

1 Introduction

In modern construction, concrete is the backbone of structural development, widely used for foundations, beams, slabs, and surface finishing. However, despite its compressive strength, conventional concrete often suffers from brittleness and low tensile capacity, leading to cracking under mechanical and environmental stresses. These failures increase repair frequency and overall maintenance costs. Glass fiber reinforcement has emerged as a promising method for enhancing concrete's tensile strength, flexibility, and durability. By incorporating glass fibers—renowned for their high tensile strength, flexibility, and corrosion resistance—concrete gains improved mechanical performance and robustness.

This project investigates the effects of varying glass fiber proportions in concrete, aiming to provide a more durable, low-maintenance alternative for construction applications. Controlled laboratory tests are conducted to evaluate compressive and flexural strengths, offering insights into practical construction uses.

Picture a world where our buildings are not only tall and impressive but also incredibly durable, withstanding the wear and tear of time with minimal maintenance. This vision is becoming a tangible reality through the innovative use of glass fiber in concrete. Traditional concrete, while effective in load-bearing applications, often falls short under tensile stress, leading to cracks and costly repairs. Enter glass fiber—a game-changing material that addresses these limitations by dramatically improving concrete's mechanical properties.

The history of concrete dates back to ancient civilizations, with the Romans pioneering lime-based mixtures and volcanic ash to build enduring structures like aqueducts and the Colosseum. Over centuries, concrete evolved with the introduction of Portland cement in the 19th century, revolutionizing modern construction. Yet, its inherent brittleness persisted, especially under seismic loads and high-rise demands. Studies show unreinforced concrete fails under tensile loads as low as 2–5 MPa, resulting in frequent structural repairs and billions in global maintenance costs.

This study investigates whether glass-fibre-reinforced concrete can offer a more robust and reliable solution. By exploring the enhanced tensile and compressive strength, flexibility, and durability of glass-fibre-reinforced concrete, this research aims to provide insights into its potential applications in construction. The scope includes preparation and testing of concrete mixes with varying fibre proportions under controlled laboratory conditions, seeking the optimal composition that maximizes performance without

compromising workability.

In an industry constantly seeking advancements, the potential of using glass fiber in concrete is highly promising. Offering significant improvements in strength, durability, and reduced maintenance costs, glass-fiber-reinforced concrete stands to revolutionize the way we build—ensuring structures that are not only robust but also sustainable. This report aims to shed light on this innovative material, its benefits, and its future in the construction industry.

2 Literature Review

2.1 Historical Development of GFRC

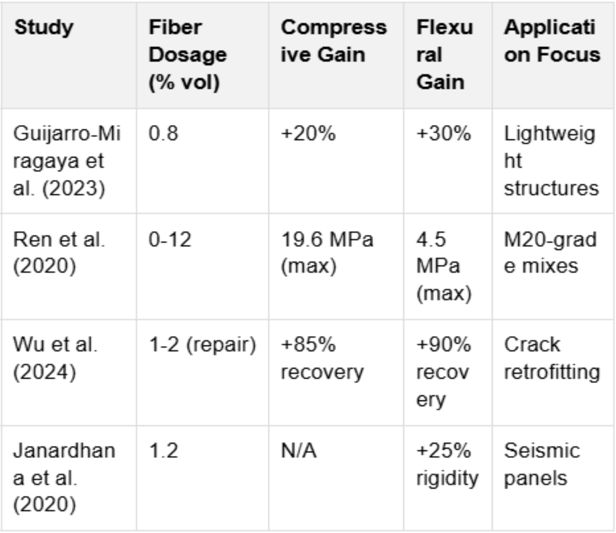
Research on glass fibre-reinforced concrete (GFRC) traces back to the 1970s, evolving from initial cement matrix modifications to advanced structural composites. Lankard (1979) first demonstrated fibre-crack bridging, doubling flexural strength in plain concrete and addressing inherent tensile brittleness (failure at 3-5 MPa).

2.2 Mechanical Performance Studies

Controlled experiments establish dosage-performance relationships:Economic and Sustainability Perspectives

- **Bhatia et al. (2017)** modeled GFRG panels in high-rise buildings, reporting **28% material savings** and **22% lower embodied CO_2** compared to RCC frames. Lifecycle analysis projected **25% cost reduction** over 50 years, underscoring the economic viability of fiber-reinforced composites.
- **Chandramouli et al. (2023)** studied 50 South Indian projects, identifying **40%-time savings** and **30% labor reduction** with GFRG panels. Challenges included fiber dispersion and workmanship, highlighting the importance of optimized mixing techniques.

Comparative Table of Key Studies



Study	Fiber Dosage (% vol)	Compressive Gain	Flexural Gain	Application Focus
Guijarro-Miragaya et al. (2023)	0.8	+20%	+30%	Lightweight structures
Ren et al. (2020)	0-12	19.6 MPa (max)	4.5 MPa (max)	M20-grade mixes
Wu et al. (2024)	1-2 (repair)	+85% recovery	+90% recovery	Crack retrofitting
Janardhana et al. (2020)	1.2	N/A	+25% rigidity	Seismic panels

Optimal dosages (0.8-1.5%) maximize gains without workability loss; higher levels (9-12%) demand superplasticizers to mitigate fibre balling.

2.3 Structural and Prestressed Applications

Maganti Janardhana et al. (2020) reported GFRP panels sustaining 564 kN axial loads—25% superior to masonry—validating seismic suitability for regions like Madhya Pradesh. Taerwe (1992) confirmed glass-fibre prestressed beams resist corrosion-induced creep, outperforming steel in aggressive environments.

2.4 Durability and Optimization

Wu et al. (2024) achieved 90% strength recovery in damaged concrete via GFRC slurries. Fibers extend service life 2-3x by arresting crack growth, with alkali-resistant E-glass ensuring long-term matrix compatibility.

2.5 Economic and Sustainability Benefits

Bhatia et al. (2017) quantified high-rise savings: 28% material reduction, 22% lower embodied CO_2, and 25% lifecycle cost cuts versus steel-reinforced concrete. Chandramouli et al. (2023) documented 40% faster construction and 30% labour savings in Indian projects.

2.6 Research Gaps and Contribution

Literature favors low-dosage gypsum composites; high-volume (9-12%) aggregate concretes for prestressing remain underexplored, particularly M20 mixes scalable to field prestressed elements. This study bridges this void through systematic 0-12% dosage testing, informing corrosion-free structural design.

2.7 Future Research Directions

- Creep-rupture modelling in prestressed GFRC.
- Recycled fibre integration for sustainability.
- Full-scale prestressed beam prototypes.

3 Methodologies

The mixing process ensured uniform distribution of all components. First, the cement, sand, and coarse aggregates were thoroughly mixed. Next, the glass fibers were added slowly, making sure they spread out evenly instead of clumping. Water was then poured in gradually while mixing, forming a workable concrete mixture. Once the mix was ready, it was poured into molds to create test specimens—cubes for compressive strength tests and beams for flexural strength tests. These molds were filled carefully, layer by layer, to remove air bubbles and ensure uniform density. After 24 hours, the hardened samples were taken out of the molds and submerged in water for 28 days to allow them to fully strengthen.

After curing, the specimens were tested for their mechanical properties. To measure compressive strength, cube-shaped samples were placed in a Compressive Testing Machine (CTM), where an increasing force was applied until they broke. The maximum force they could withstand was recorded. For flexural strength, beam-shaped samples were tested using a three-point bending test, where force was applied at the center while supporting the ends. As the force increased, measurements were taken to see how much the material could bend before cracking or breaking. These tests helped determine how the added glass fibers influenced the strength of the concrete.

The collected results were carefully analyzed by comparing the performance of different fiber concentrations. Graphs were created to visualize the trends, making it easier to see how glass fiber reinforcement improved the material's overall strength. These findings were then compared with previous studies to understand how they fit into existing knowledge about fiber-reinforced concrete.

The implications of this research are exciting. Glass-fiber-reinforced concrete (GFRC) can make construction materials stronger, tougher, and more durable, especially in places with high environmental stress, such as coastal areas or earthquake-prone regions.

It could also be useful for prefabricated building components, allowing for lighter yet stronger structures that require less material but maintain high performance.

Because GFRC reduces cracking, it could help extend the lifespan of buildings, making repairs less frequent and lowering maintenance costs. Looking ahead, more studies could explore long-term durability, impact resistance, and ways to make GFRC more eco-friendly, such as using recycled glass fibers to reduce waste and promote sustainable construction practices.

This study helps lay the foundation for future improvements in building materials, leading to stronger, greener, and more innovative structures.

Problem: Conventional concrete fails prematurely under service loads, imposing high life-cycle costs and compromising structural integrity, particularly in seismic-prone Madhya Pradesh.

In the dynamic world of construction, traditional concrete materials often fall short under mechanical stress, leading to cracks, deterioration, and frequent, costly repairs.

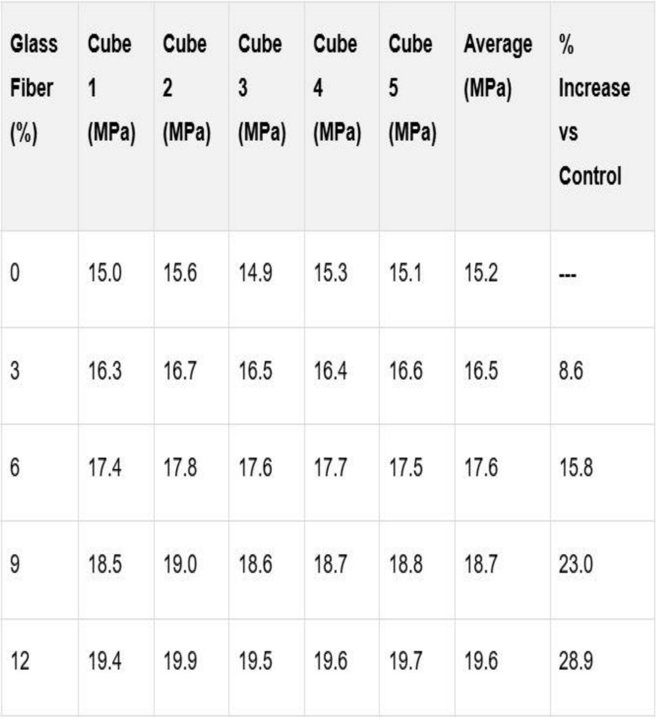
These issues compromise the durability and longevity of buildings, resulting in higher maintenance costs and inconvenience. There is an urgent need for a more robust and reliable solution that enhances structural integrity and reduces the maintenance demands of construction materials.

4. Experimental Results and Discussion

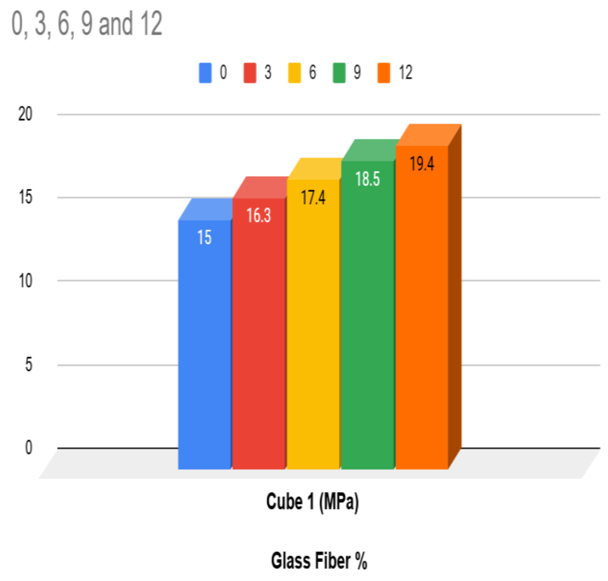
Fig 1 Compressive Strength testing

4.1 Compressive Strength Compressive Strength = Maximum load/ Cross section

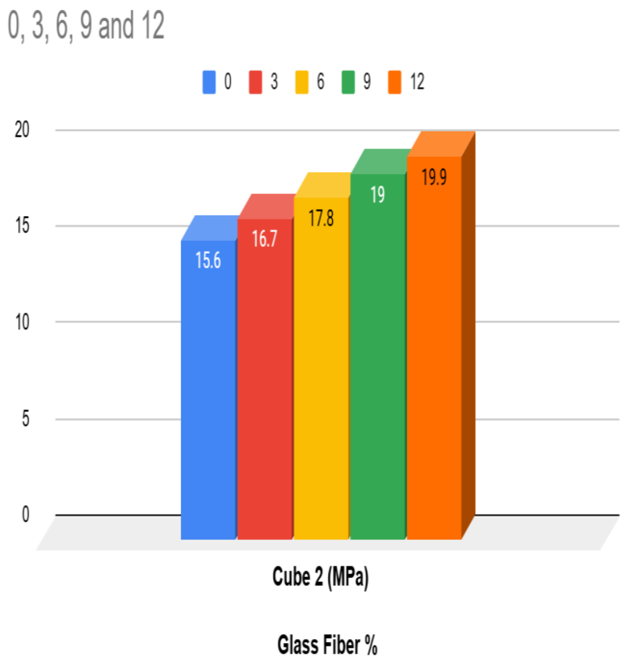
Compressive Strength Table



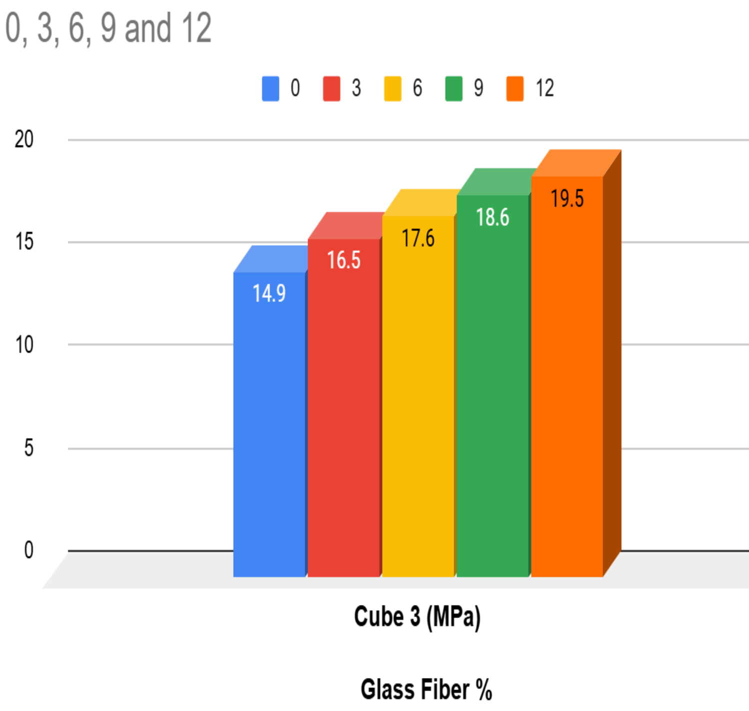
Glass Fiber (%)	Cube 1 (MPa)	Cube 2 (MPa)	Cube 3 (MPa)	Cube 4 (MPa)	Cube 5 (MPa)	Average (MPa)	% Increase vs Control
0	15.0	15.6	14.9	15.3	15.1	15.2	---
3	16.3	16.7	16.5	16.4	16.6	16.5	8.6
6	17.4	17.8	17.6	17.7	17.5	17.6	15.8
9	18.5	19.0	18.6	18.7	18.8	18.7	23.0
12	19.4	19.9	19.5	19.6	19.7	19.6	28.9



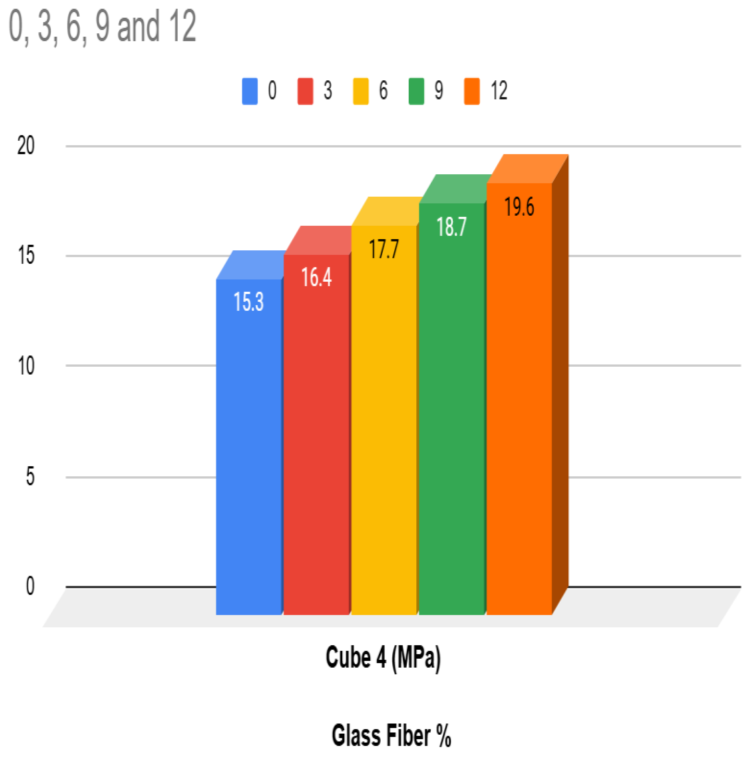
Graph 1
Compressive Strength Graph 1



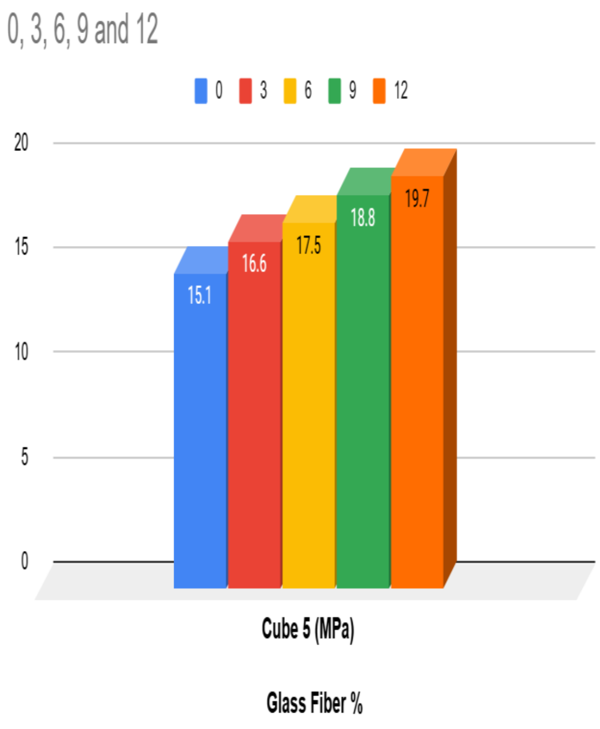
Graph 2
Compressive Strength Graph 2



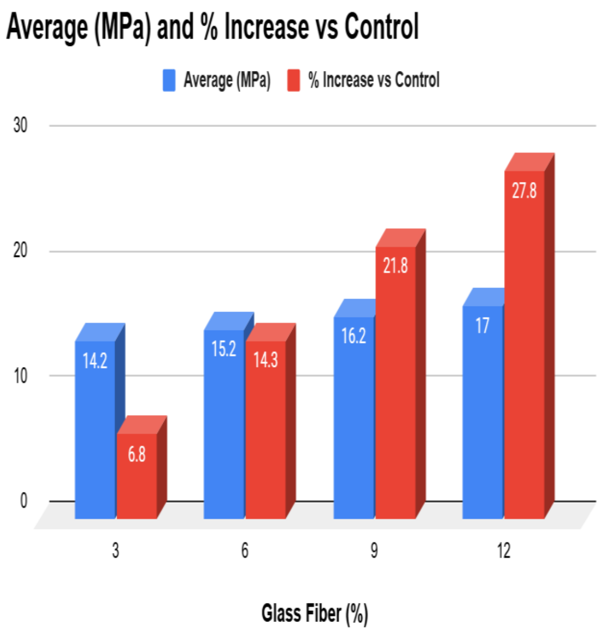
Graph 3
Compressive Strength Graph 3



Graph 4 Compressive Strength Graph



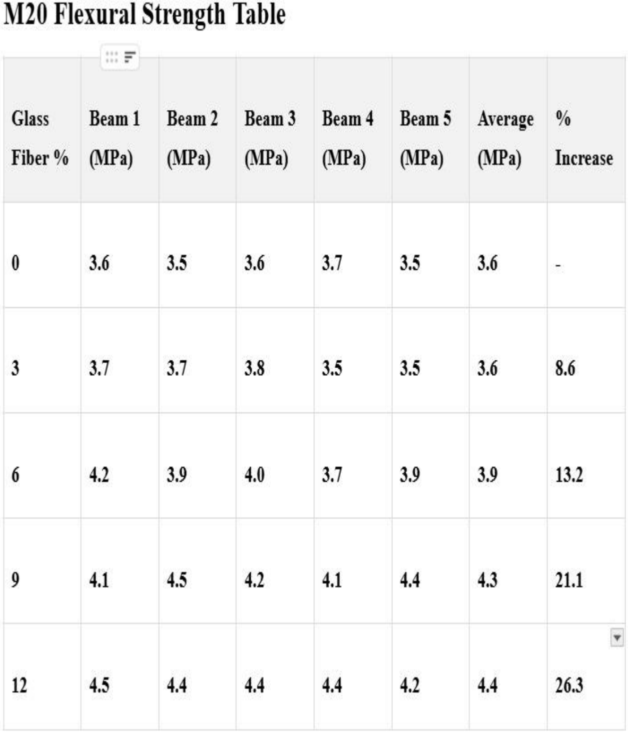
Graph 5
Compressive Strength Graph 5



Graph 6
Average Compressive Strength and % Increase vs Control Graph

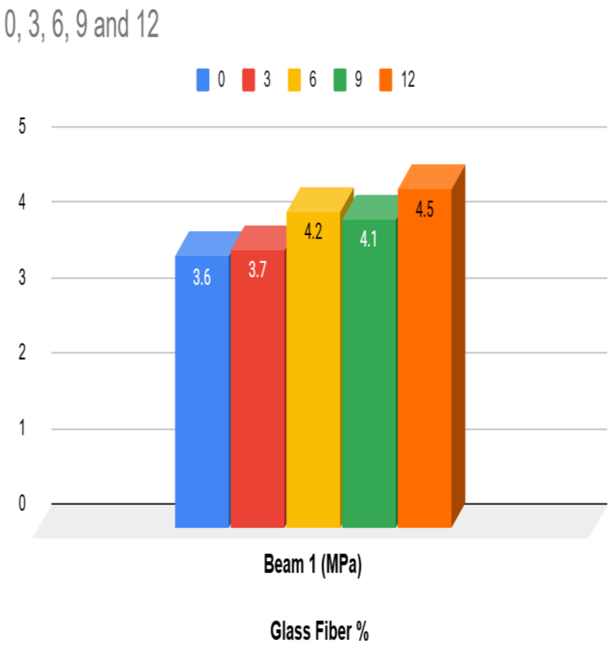
4.1 Flexural Strength

$$f = PL/bd^2$$

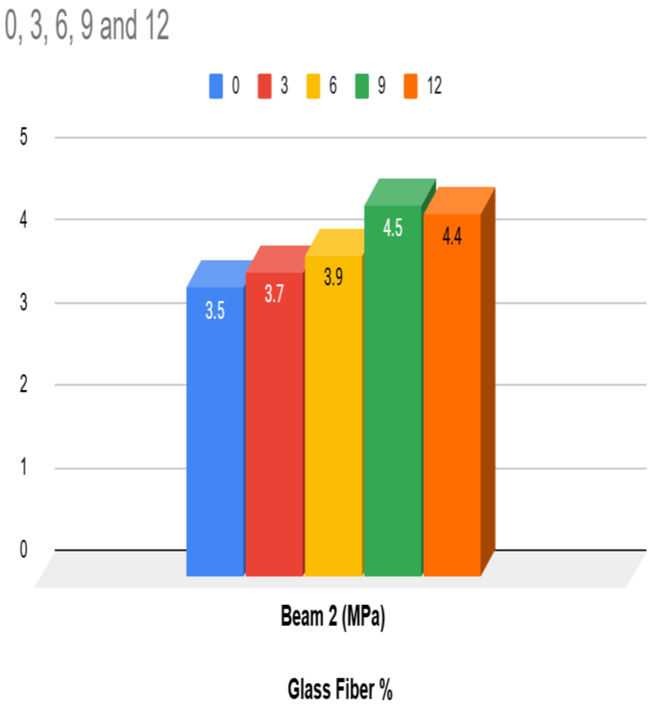


M20 Flexural Strength Table

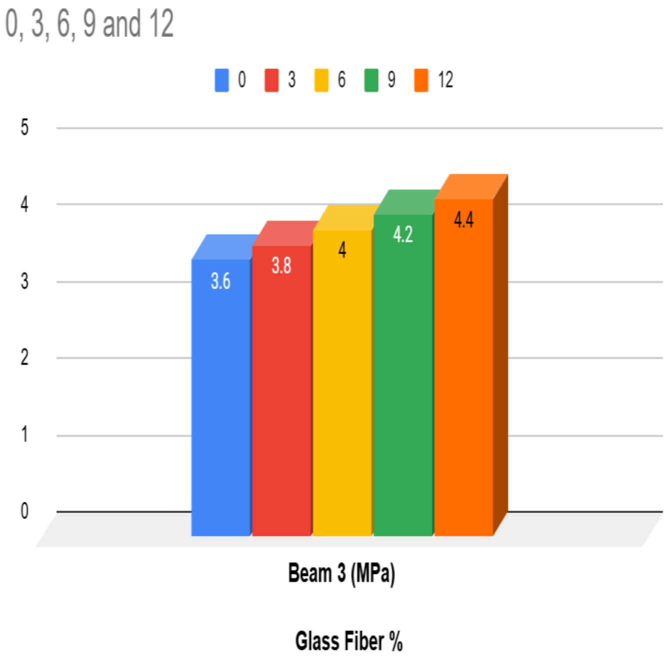
Glass Fiber %	Beam 1 (MPa)	Beam 2 (MPa)	Beam 3 (MPa)	Beam 4 (MPa)	Beam 5 (MPa)	Average (MPa)	% Increase
0	3.6	3.5	3.6	3.7	3.5	3.6	-
3	3.7	3.7	3.8	3.5	3.5	3.6	8.6
6	4.2	3.9	4.0	3.7	3.9	3.9	13.2
9	4.1	4.5	4.2	4.1	4.4	4.3	21.1
12	4.5	4.4	4.4	4.4	4.2	4.4	26.3



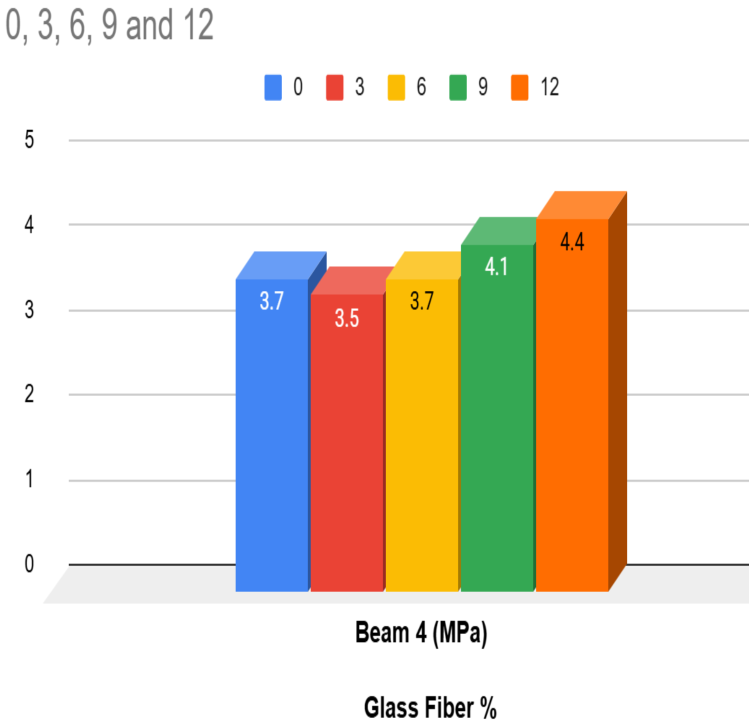
Graph 7
Flexural Strength Graph 1



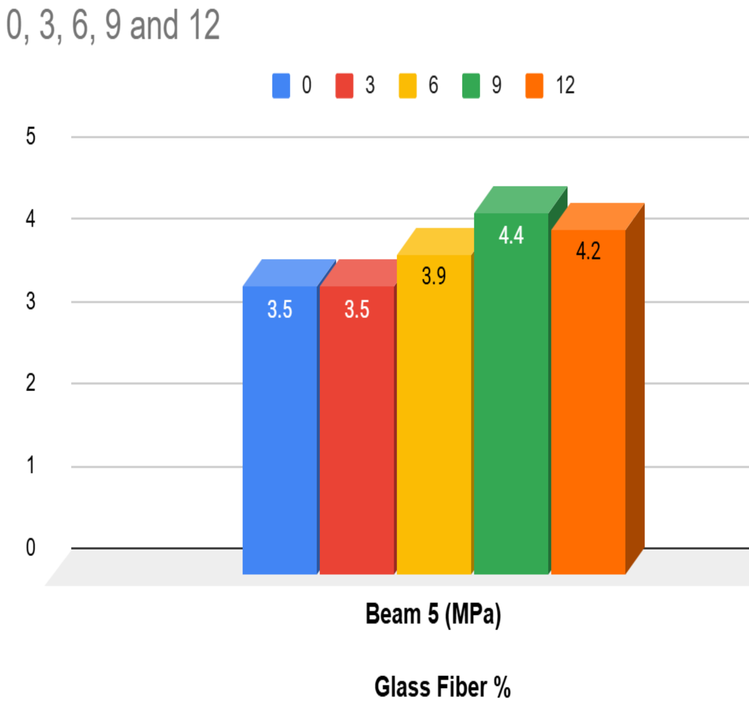
Graph 8
Flexural Strength Graph 2



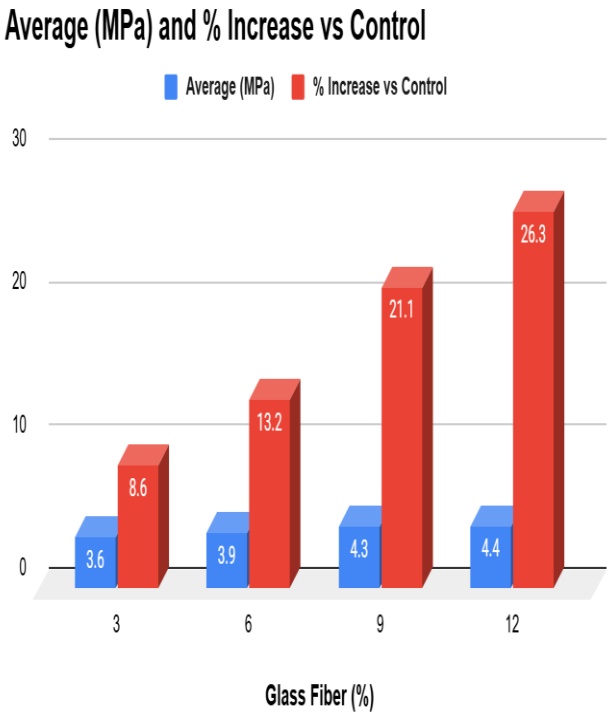
Graph 9
Flexural Strength Graph 3



Graph 10
Flexural Strength Graph 4



Graph 11
Flexural Strength Graph 5



Graph 12 Average Flexural Strength and % Increase vs Control Graph

5 Conclusion *and Future Work*

This study confirms that glass fiber reinforced concrete exhibits superior mechanical strength, flexibility, and durability compared to conventional concrete. Optimal glass fiber content is found between 10-12%, balancing strength gains and workability. These improvements support sustainable construction by reducing repair frequency and extending material lifespan.
Future studies should explore:

- Long-term durability under field conditions.
- Impact and fatigue resistance.
- Use of recycled glass fibers for environmental sustainability.
- Scale up to pilot construction projects.

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