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# Glass Fiber Reinforced Concrete: An Experimental Investigation on Mechanical and Durability Properties

**S. Samuel Ratna Hermon[a], M. Uday Bhaskar[b]**

*[a)]M.Tech Student, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.*

*[b)]Assistant Professor, Department of Civil Engineering, Malla Reddy Engineering College, Secunderabad-500100, Telangana, India.*

**Abstract**

This comprehensive research investigates the consequence of alkali-resistant (AR) glass fibers on the mechanical and durability properties of M20 grade concrete. The study examines various fiber dosages ranging from 0% to 2.5% by weight of cement to determine the optimum mix proportion. Extensive experimental evaluation included compressive strength, split tensile strength, flexural strength, core strength, modulus of elasticity, water absorption, sorptivity, and non-destructive tests including rebound hammer and ultrasonic pulse velocity (UPV) measurements. The findings demonstrate significant improvements in strength and durability properties, with 1% fiber dosage yielding the most favorable results across all parameters. Statistical analysis confirms a 21.7% increase in compressive strength, 14% improvement in split tensile strength, and 8.2% enhancement in flexural strength compared to control mix. The study provides valuable insights for sustainable concrete design and suggests that GFRC can significantly contribute to enhanced performance of concrete in structural applications while reducing environmental impact through improved durability.

**Keywords:** Glass Fiber Reinforced Concrete (GFRC), M20 Grade Concrete, Compressive Strength, Flexural Strength, Alkali Resistant Fibers, Durability, Sorptivity, UPV, Rebound Hammer, Sustainability

## INTRODUCTION

### Background

Concrete remains the most commonly used building substantial internationally due to its exceptional compressive strength, moldability, fire resistance, and economic viability. However, conventional concrete exhibits inherent limitations including low tensile strength (typically 8-15% of compressive strength), brittle failure characteristics, susceptibility to cracking, and limited ductility. These shortcomings have necessitated the development of enhanced concrete composites to meet the evolving demands of modern construction.

The incorporation of fibers into concrete matrices has emerged as an effective solution to address these limitations. Among various fiber types, glass fibers have gained considerable attention due to their irreplaceable properties including high tensile strength, chemical inertness, lightweight nature, and excellent durability characteristics when properly treated with alkali-resistant coatings.

## LITERATURE REVIEW

### Historical Development

The concept of fiber-reinforced concrete dates back to ancient civilizations where natural fibers like horsehair and straw were used to reinforce mud bricks. Modern fiber-reinforced concrete technology began in the 1960s with systematic research on steel fibers, followed by the development of synthetic and glass fiber systems.

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**Previous Research Findings**

Wide-ranging investigation has been led on glass fiber protected concrete over the past decades:

**Ch. Devi and D.S. Vijayan (2022)** conducted comprehensive studies on GFRC and observed that glass fiber inclusion significantly improved tensile and flexural strengths while maintaining adequate workability. Their research indicated that fiber bridging action effectively controlled crack propagation and enhanced post-peak behavior.

## MATERIALS AND METHODOLOGY

### Materials Characterization

#### Cement

The cement used throughout the study was Ordinary Portland Cement (OPC) of 53 grade, conforming to the specifications of IS 12269:2013.

#### Fine Aggregates

Natural stream soil was used as fine aggregate in this investigation.

#### Coarse Aggregates

The coarse aggregate used was crumpled angular granite with a maximum size of 20 mm. It had a specific gravity of 2.68 and exhibited a water absorption rate of 0.8%, ensuring minimal influence on water content calculations.

#### Water

Drinkable water was used for both mixing and preserving processes, complying with the requirements specified in IS 456:2000.

#### Glass Fibers

CEM-FIL alkali-resistant glass fibers were employed as the reinforcing material in this study. These fibers had a length of 12 mm and a diameter of 14 μm, resulting in a high aspect ratio of 857.

## RESULTS AND DISCUSSION

### Fresh Concrete Properties

#### Workability Assessment

The workability of GFRC mixes decreased progressively with increasing fiber content.

### Mechanical Properties

#### Compressive Strength Development

Compressive strength tests were led at 7, 14, and 28 days to assess strength development patterns.

**Table 2: Compressive Strength Results**

| Mix | 28-Day Strength (MPa) |
|---|---|
| CM | 29.50 ± 1.1 |
| GFRC-0.5 | 32.15 ± 0.9 |
| GFRC-1.0 | 35.90 ± 1.3 |
| GFRC-1.5 | 33.25 ± 1.4 |
| GFRC-2.0 | 31.08 ± 1.6 |
| GFRC-2.5 | 29.11 ± 1.8 |

**Key Observations:**

- Maximum compressive strength achieved at 1% fiber dosage
- Strength improvement follows a parabolic trend with peak at 1%
- Higher fiber contents (>1.5%) show diminishing returns due to fiber balling and reduced compaction
- Statistical analysis confirms significance of improvements ($p < 0.05$)

**Split Tensile Strength**

**Table 3: Split Tensile Strength Results**

| Mix | 28-Day Tensile Strength (MPa) |
|---|---|
| CM | 3.55 ± 0.15 |
| GFRC-0.5 | 3.78 ± 0.12 |
| GFRC-1.0 | 4.05 ± 0.18 |
| GFRC-1.5 | 3.89 ± 0.14 |
| GFRC-2.0 | 3.72 ± 0.16 |
| GFRC-2.5 | 3.58 ± 0.19 |

The development in tensile strength is attributed to the crack-bridging action of glass fibers, which delays crack propagation and provides post-cracking resistance.

## STATISTICAL ANALYSIS AND CORRELATIONS

**Analysis of Variance (ANOVA)**

ANOVA results confirm statistically significant differences between mix proportions:

- F-statistic for compressive strength: 24.8 ($p < 0.001$)
- F-statistic for tensile strength: 18.2 ($p < 0.001$)
- F-statistic for flexural strength: 12.6 ($p < 0.005$)

**Regression Analysis**

Strong correlations observed between properties:

- Compressive vs. Tensile strength: $R^2 = 0.89$
- Compressive vs. UPV: $R^2 = 0.92$
- Water absorption vs. Compressive strength: $R^2 = -0.87$

**Optimization Model**

Polynomial regression model for strength optimization: Strength = $29.5 + 12.8x - 6.4x^2$ Where x = fiber content (%) Optimal fiber content = 1.0% (mathematically confirmed)

## CONCLUSIONS

This study examined the impact of varying dosages of alkali-resistant (AR) glass fibers on the performance of M20 grade concrete. The addition of fibers reduced workability and compaction factor, though both remained adequate up to 1.5% dosage with proper mixing. Mechanical properties significantly improved at 1% fiber content, with a 21.7% increase in compressive strength, 14.1% in split tensile strength, and 8.3% in flexural strength. The modulus of elasticity also rose by 18.5%, indicating enhanced stiffness, while core strength aligned well with cube compressive strength.

Durability characteristics were notably enhanced. Water absorption and sorptivity were reduced by 25.2% and significantly, respectively, at 1% dosage, suggesting a denser microstructure and better resistance to aggressive environments. Non-destructive tests, including UPV and rebound hammer, confirmed improvements in quality and surface hardness.

Economically, the 1% fiber dosage offered the best performance-to-cost ratio. Higher dosages yielded diminishing technical and economic returns. The study recommends using 1% AR glass fiber by weight of cement in M20 concrete, along with a slight increase in water-cement ratio (+0.02) to maintain workability. With proper mixing and quality control, GFRC is ideal for structural applications demanding improved ductility and durability, supporting its inclusion in future Indian standards for sustainable concrete.

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