EXAMINING THE MECHANICAL AND DURABILITY ASPECTS OF GEOPOLYMER CONCRETE

***SHAIK ASHRAF ALI, ** RASHMI KHAMBENOUR,**

***** SREENIVASULU DANDAGALA**

*Assistant Professor, Department of Civil Engineering, Annamacharya Institute of Technology and Sciences, Rajampet, Andhra Pradesh, India.

** Assistant Professor, Department of Civil Engineering, Annamacharya Institute of Technology and Sciences, Rajampet, Andhra Pradesh, India.

*** Associate Professor, Department of Civil Engineering, Annamacharya Institute of Technology and Sciences, Rajampet, Andhra Pradesh, India.

*shehnaazali1311@gmail.com ** risingrashmi09@gmail.com ***sreenu.nitk@gmail.com

Abstract— *Glass-fiber reinforced concrete (GRC) is a material consisting of a distributed cementitious matrix containing small glass fibers, which is formed of cement, sand, water, and admixtures. It has been extensively utilized in the building sector for non-structural components like as channels, pipelines, and façade panels. GRC has a lot of benefits, including strength, fire resistance, low weight, and attractive look. Using cubes of various sizes, trial tests for concrete with and without glass fiber are carried out in this study to show the variations in compressive strength and flexural strength. The study's numerous GFRC uses, the outcomes of experimental testing, a techno-economic comparison with other kinds, and the financial estimates provided all point to the material's enormous potential as a substitute for traditional building materials.*

Keywords – GRC, Construction , compressive strength and flexural strength

I. INTRODUCTION

GFRC or GRC is a fiber-reinforced concrete primarily utilized in exterior building façade panels and architectural precast concrete. This material excels in shaping building exteriors and boasts a lower density compared to steel. Comprised of fine sand, cement, polymer (typically acrylic), water, other admixtures, and alkali-resistant glass fibers, GFRC offers versatility in design. Numerous mix designs, available online, share similar ingredient proportions. Glass fiber reinforced cementitious composites, containing approximately 5% fiber content, are predominantly used for thin sheet components. Alternate applications include reinforcing bars made of continuous glass fibers joined and impregnated with plastics, or short, rigid units impregnated with epoxy for dispersion in concrete mixes. Glass fibers are manufactured by drawing molten glass into filaments, typically 204 strands coated with sizing to protect against weather and abrasion while binding them together.

II. FINDING FROM LITERATURE REVIEW

1. Glass fibers experience a reduction in strength when exposed to Portland cement, with alkali-resistant (AR) fibers outperforming others, retaining tensile strengths of 1000-1200 N/mm2 in a cement environment.

2. Assessing fiber content, matrix strength, fiber distribution, orientation, and bonding effectiveness is crucial. Additionally, manufacturing or material faults can be diagnosed. Moreover, tests indicate higher MOR and LOP in drying conditions compared to wet conditions, with a difference of around (1-5) MN/m2.

3. Dewatered GRC differs from non-dewatered GRC mainly in density, leading to higher fiber volume fraction and strengths in dewatered boards due to better compaction and reduced porosity.

4. Glass fiber-reinforced cement allows for thinner precast elements (typically 10 mm) compared to traditional steel-reinforced concrete (30mm or more), owing to low water-cement ratio, lack of coarse aggregate, and low permeability, resulting in panels of equal strength with less weight.

5. Adding polymer latex can mitigate the effects of poor or non-uniform water curing in AR-GRC, potentially replacing the need for traditional curing practices.

6. GFRC exhibits good fire resistance in laboratory tests, crucial for its architectural applications.

7. Contact between cement-based materials and window glass can cause etching due to alkali attack on silicates, but glass fiber stock, containing zirconia, offers better alkali resistance.

8. GRC, when used in telecommunication towers with carbon fiber and/or stainless steel bars, demonstrates structural viability, reduced weight, and good durability properties, with average properties including compression strength: 41 MPa, tension strength: 3.7 MPa, and initial Young modulus: 16.5 GPa.

9. Optimum composite properties are achieved with 1.5% volume of fibers, resulting in significant improvements in compressive, split tensile, and flexural strengths compared to reference concrete.

III. OBJECTIVES OF THE STUDY

The research aims to achieve the following goals:

i) Look into the GRC's mix design components.

ii) Acquire knowledge of diverse GRC applications.

iii) Compare GRC to substitute materials including granite, marble, steel, aluminum, wood, glass, and stone.

iv) Use glass fibers in concrete pours to conduct laboratory testing for compressive, tensile, and flexural strength.

METHODOLOGY OF THE STUDY

To achieve the set objectives, data was gathered from field practices observed in building construction and from GRC manufacturing facilities. Information was collected from various project sites and locations, focusing on experimental work conducted in laboratory settings. Research on concrete with glass fibers was compiled to discern differences based on varying fiber ratios.

The tests were conducted on cube specimens measuring 150x150x150mm and 100x100x100mm, using cast iron molds with leak-proof metal base plates. Mold sections were thinly coated with mold oil to prevent concrete adhesion. Prior to adding glass fibers, all materials were thoroughly mixed for 2-3 minutes, followed by an additional minute of mixing after fiber incorporation before casting the cubes.

Curing procedures involved storing specimens on-site, free from vibration, under damp matting or similar covering for 24 hours post-water addition. Storage temperatures ranged between 22°C to 32°C. After the initial 24-hour period, cubes were marked and then submerged in clean potable water at temperatures ranging from 24°C to 30°C until transported to the testing laboratory.

In the flexural test, beam specimens were positioned in the testing machine such that the load was applied to the uppermost surface as cast in the mold. Beams underwent testing under two-point loading using a Universal testing machine with a capacity of 60 tons. Loading was applied at a rate specified for 10x10x50cm specimens, with load increment until specimen failure, and recording of failure load.

Flexural strength was calculated using the equation $Fb = PL/bd^2$ when 'a' is greater than 20cm, or $Fb = 3Pa/bd^2$ when 'a' is less than 20cm but greater than 17cm.

TABLE (1): GRC RAW MATERIAL COST

Aspect	GRC	Stone	Aluminum	Wood	Glass
Installation Cost (per sq.ft)	45 Rs.	40 Rs.	50 Rs.	50 Rs.	-
Material Cost (per sq.ft)	7 Rs.	7 Rs.	25 Rs.	25 Rs.	-
Routine Maintenance Cost (per sq.ft)	-	12 Rs.	12 Rs.	12 Rs.	-
Color	Uniform	Non-uniform	Uniform	Non-uniform	Uniform
Color Options	Wide range	Limited	Limited	No choice	Limited
Quality	Consistent	Inconsistent	Consistent	Inconsistent	Inconsistent
Thickness	Uniform	Non-uniform	Uniform	Non-uniform	Uniform
Shape	Any shape	Limited shapes	Limited shapes	Limited shapes	Limited shapes

Sizes	Any size	Limited size	Limited size	Limited size	Limited size
Dry Bulk Density	1.8 to 2.0 t/m3	2.2 to 2.5 t/m3	2.5 t/m3	0.4 to 0.7 t/m3	2.5 t/m3
Periodic Maintenance Cost (per sq.ft)	5 Rs.	5 Rs.	15 Rs.	15 Rs.	-
Total Cost	181 Rs.	141 Rs.	215 Rs.	245 Rs.	100 - 1000 Rs.

TABLE (2) THE DATA SHOWN WITH RESPECT TO YEAR 2010

S. No.	Materials	Unit Price
1	White Cement	Rs. 13.50 per Kg
2	Silica Sand	Rs. 3.50 per Kg
3	AR-Glass Fibre	Rs. 300 per Kg
4	Hardener 'A' (Cemplast)	Rs. 100 per litre
5	SBR (Styrene Butadiene Rubber)	Rs. 180 per Kg

PROPERTIES IN GRC WITH OTHER CLADDING MATERIALS

TABLE (3) THERE ARE DIFFERENCES TECHNICAL

Property	GRC	Stone	Aluminum	Glass	Wood
Manufacturing per sq.ft	120Rs.	65 Rs.	105 Rs.	135Rs.	-
Transportation per sq.ft	20Rs.	20 Rs.	15 Rs.	25Rs.	-

Type of casting: normal concrete mixed with AR- glass fibre.

Mix proportion ratio:

W/C- 0.15

Cement- 400 kg/m3

Micro silica (Silica fume) - 40 kg/m3 Standard sand- 1000 kg/m3

Glass fibre- 1% by weight of cement Coarse aggregate- Nil

Table (4) Trial no. 1 With Glass Fibre: 0.024% of total weight (0.11% of cementitious weight) Grade of Concrete: M60 (cubic 150X150X150 cm)

Trial	Percentage	Absorption (%)	Correction Mix Absorption (kg.)	Corrected Mix for 1 m3 (kg.)
W/C	0.26	-	-	-
Cement	400	-	-	400
Fly ash	100	-	-	100
Micro Silica	40	-	-	40
Glass	0.6	-	-	0.6
R. Sand	748	0.00	0.00	748
C. Sand	0	0.00	0.00	0
10 mm	448	0.00	1.30	446.70
20 mm	674	0.00	1.30	672.70
Net Weight	-	-	-	14.586
Water	140	-	-	155
Admixture	5.4	-	-	5.4
Total	2556	-	-	2556

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FIGURE (1) CASTING CONCRETE WITH GLASS FIBRE SURROUNDS PRESTRESS STRAND CABLE AT HOLAKAR BRIDGE

Table (5) Results of Compressive Strength Tests

Compressive Strength (7 days)

Sample No.	**% of Glass Fibre**	**Compressive Strength MPa (N/mm²)**
No. 1	0.11%	53.60
No. 2	0.11%	48.33
No. 3	0.11%	57.77
No. 1	1.5%	65.69
No. 2	1.5%	66.66
No. 3	1.5%	64.52
No. 1	2.0%	57.95
No. 2	2.0%	63.33
No. 3	2.0%	51.57

Compressive Strength (28 days)

Sample No.	**% of Glass Fibre**	**Compressive Strength MPa (N/mm²)**
No. 4	0.11%	72.92
No. 5	0.11%	71.74
No. 6	0.11%	75.55
No. 4	1.5%	>80.00 unbroken
No. 5	1.5%	>80.00 unbroken
No. 6	1.5%	>80.00 unbroken
No. 4	2.0%	76.59
No. 5	2.0%	76.22
No. 6	2.0%	77.16

Table (6) Results of Flexural Strength Tests

Flexural Strength (7 days)

Sample No.	% of Glass Fibre	Flexural Strength MPa (N/mm²)
No. 1	1.5%	5.90
No. 2	1.5%	5.38
No. 3	1.5%	5.66
No. 1	2.0%	5.10
No. 2	2.0%	5.61
No. 3	2.0%	5.12

Flexural Strength (28 days)

Sample No.	% of Glass Fibre	Flexural Strength MPa (N/mm²)
No. 4	1.5%	5.56
No. 5	1.5%	5.47
No. 6	1.5%	5.72
No. 4	2.0%	5.59
No. 5	2.0%	6.25
No. 6	2.0%	6.70

- **Discussion**

Following points emerge from the test results:

1) The 7-day average compressive strength peaks when 1.5% of glass fibers are used, showing about 15% to 20% reduction in strength at lower or higher percentages. However, by 28 days, the reduction in strength decreases to 5% to 10%.
2) Increased glass fiber content in normal concrete negatively impacts the cohesion between concrete particles, leading to decreased compressive, flexural, and tensile strength.
3) In a (M60) mix, a 2% glass fiber content resulted in a flexural strength of 6.15 MPa, which is 10% higher than that achieved at 1.5%.
4) Glass fiber has minimal impact on high-performance concrete, particularly with a coarse concrete gradation, as it increases porosity and allows air movement between particles.
5) Care must be taken during glass fiber mixing with concrete, limiting it to not more than 1 minute to prevent breakage into tiny pieces, rendering it unusable.

GRC as a cladding material

- **High Tensile Strength**: GFRC is chosen as reinforcement for concrete due to its excellent resistance to tension. It finds extensive use in cladding buildings, lining, sewer pipes, and road shoulders.
- **Compatibility with Concrete:** Glass fiber's compatibility with concrete or mortar makes it easy to incorporate into daily projects, especially for building facades. AR-glass fiber, with its resistance to alkalinity in cement, is particularly suitable for such applications.
- **Control of Shrinkage Cracks:** AR-glass fiber can effectively control shrinkage cracks, especially in cladding and rendering applications, due to the low water-to-cement ratio in GRC (maximum 0.35) and the bonding provided by glass fibers.
- **Alternative to Natural Stone:** GFRC serves as an alternative to natural stone, especially in regions where stone is scarce or expensive. Despite the higher initial cost, the lower maintenance requirements provide long-term cost benefits.
- **Ease of Installation and Repair:** GRC panels are easy to install and replace compared to other cladding materials. Broken panels can be quickly repaired or replaced, unlike stone or tile, which is more challenging to replace.

- **Eco-Friendly**: GFRC is environmentally friendly as it consumes less energy during production, helping to reduce pollution and carbon dioxide emissions, contributing to a safer environment.
- **Growing Industry in India:** The GFRC industry is experiencing growth in India, with increasing customer awareness and more projects incorporating GFRC components.
- **Flexibility in Location:** GFRC manufacturing units can be established anywhere, as existing manufacturers do not necessarily need to be located in city industrial areas.
- **Emerging as Preferred Cladding Material:** GFRC cladding has become the main application due to several reasons:
  - ✓ Unsatisfactory performance of alternative materials like glass and aluminum in Indian climates.
  - ✓ Weight advantages over granite, marble, and PCC panels, reducing handling issues.
  - ✓ Minimum heat loss compared to aluminum and glass cladding, making it preferable for various structures.
  - ✓ Turnkey solutions provided by GFRC manufacturers from concept to installation, simplifying the process.
  - ✓ Suitability for earthquake-prone areas and the potential for 'Green' certification through suitable additives.

Result and conclusion of glass fibre use in normal concrete

Optimal Glass Fiber Content: Glass fiber enhances concrete's compressive strength up to a certain limit. Beyond this limit, increasing the percentage of glass fiber negatively impacts the bond between materials. The best results are achieved with 1.5% of the cementitious weight, surpassing other percentages tested.

Impact of Air Entrainment: Air entrainment influences the ft/fc (tensile strength to compressive strength) ratio. The presence of air reduces the compressive strength of concrete more than the tensile strength, especially in rich and strong mixes. This indicates the importance of managing air content to maintain desired strength properties.

Effect of Coarse Aggregate Size: Using 20 mm coarse aggregate leads to increased air entrainment in concrete. To address this issue and prevent reduced flexural strength, it is recommended to utilize only 10 mm coarse aggregate. This adjustment can help optimize the concrete mix for improved performance in terms of both strength and durability.

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