IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

GLASS FIBER REINFORCED CONCRETE (GFRC): The impact of Alkali-Resistant {AR} glass fiber in concrete…..

Salman Sikander Lone, Awais Ahmed, Rahila Banoo, Reeya Kumari.

Under the guidance of Mr Kamal kumar.

Meerut Institute Of Engineering and Technology , Department of civil engineering (year 2025).

Abstract

During the 1940s, the potential of glass as a construction material was recognized, leading to continuous advancements. By the 1960s, the incorporation of zirconium dioxide enhanced its resistance to harsh alkaline conditions. To further improve durability, new generations of glass fibers were developed, paving the way for the production of glass fiber reinforced concrete (GFRC) to meet diverse industry needs. Research and testing have demonstrated that the physical and mechanical properties of GFRC vary based on material quality and manufacturing precision. This versatile material is valued for its lightweight nature, strength, fire and weather resistance, aesthetic appeal, and impermeability. With ongoing technological progress, constructing entire buildings and intricate freeform structures at lower costs is becoming a possibility. Recently, studies have explored the role of glass fibers in hybrid mixtures, contributing to the development of high-performance concrete (HPC), a cutting-edge innovation gaining traction in the construction sector. In our project, we have used the same material to test them and know its effect, how it will affect our building.

In this project, we have studied the change in strength of cement by replacing it with Glass Fiber. We prepared concrete cubes and concrete filled with glass fibers by replacing cement with Glass Fibre at 0%, 2%, 4% and 6% and calculated their 28 days compressive strength.

KEYWORDS: Fiber-reinforced concrete, glass fiber, compressive strength , alkali-resistant(AR) glass fiber.

Introduction to Fiber Reinforced Concrete (FRC):

Fiber Reinforced Concrete (FRC) is a composite material consisting of cement, aggregates, and discrete, uniformly dispersed fibers. These fibers can be made from steel, glass, synthetic materials (such as polypropylene or nylon), or natural fibers. The addition of fibers to concrete enhances its structural integrity by improving tensile strength, toughness, ductility, impact resistance, and crack control.

The key role of fibers in concrete is to bridge cracks that develop due to shrinkage, loading, or environmental factors. Unlike conventional concrete, which is brittle and weak in tension, FRC resists crack propagation and performs better under flexural and tensile stresses.

History of Glass Fiber Reinforced Concrete

The development of Glass Fiber Reinforced (GFR) materials dates back to the early 20th century when researchers began experimenting with fiber reinforcements to improve the strength and durability of traditional materials.

Early Beginnings (1930s - 1950s)

The concept of using glass fibers in composites emerged in the 1930s, driven by advancements in glass production and polymer technology.

During World War II, fiberglass became widely used in military applications, particularly in aircraft and naval components, due to its lightweight and corrosion-resistant properties.

By the 1950s, industries began incorporating glass fibers into plastics and concrete to enhance structural strength.

Expansion into Construction (1960s - 1980s)

The 1960s saw the first major introduction of Glass Fiber Reinforced Concrete (GFRC), which was developed to improve the durability and flexibility of traditional concrete.

In 1967, researchers introduced zirconium dioxide into glass fibers, making them more resistant to the alkaline conditions in concrete, greatly enhancing GFRC's lifespan.

By the 1970s and 1980s, GFRC became a preferred material in architectural cladding, precast elements, and decorative structures due to its lightweight and high strength.

Technological Advancements (1990s - 2010s)

In the 1990s, improvements in fiber composition and manufacturing techniques led to higher-performance GFRC with better impact resistance and design flexibility.

The 2000s saw the emergence of high-performance concrete (HPC), where glass fibers were combined with other reinforcements for superior strength and reduced cracking.

Innovations in 3D printing and prefabrication further expanded the use of GFR materials, making construction more efficient and cost-effective.

Modern Developments (2020s - Present)

Today, GFR materials are used in high-tech infrastructure, aerospace, automotive, and sustainable building solutions.

Research is now focused on nano-enhanced fibers, self-healing GFRC, and eco-friendly formulations to improve durability, sustainability, and adaptability.

The rise of smart construction technologies has enabled the monitoring of GFRC structures in real time, ensuring long-term performance and reduced maintenance.

From its early experimental stages to its widespread adoption in modern engineering and construction, GFR has transformed the way materials are used in lightweight, durable, and high-performance applications. Its continuous evolution promises even greater advancements in the years to come.

Glass Fiber Reinforced Concrete (GFRC)

Glass Fiber Reinforced Concrete (GFRC) is a type of fiber-reinforced concrete where alkali-resistant glass fibers are used as the primary reinforcement. GFRC is known for its high tensile strength, lightweight properties, and excellent resistance to weathering and cracking. It is widely used in architectural and decorative applications.

Properties of GFRC

Glass Fiber Reinforced (GFR) materials have unique properties that make them highly valuable across different industries. Here are some of their key characteristics:

1. Exceptional Strength with Low Weight

GFR offers high tensile and compressive strength while remaining much lighter than conventional materials.

This makes it an excellent choice for structural applications where weight reduction is crucial.

2. Long-Lasting Durability

Highly resistant to wear, impact, and external environmental factors, ensuring longevity.

Does not deteriorate easily, even under harsh weather conditions.

3. Resistance to Corrosion and Chemicals

Unlike metals, GFR does not rust, corrode, or degrade when exposed to moisture or chemicals.

Ideal for marine environments, chemical plants, and industrial applications where resistance to aggressive substances is needed.

4. Fire and Heat Resistance

Offers excellent fire-retardant properties, making it suitable for fireproof structures and safety applications.

Can withstand high temperatures without significant loss of strength or integrity.

5. Flexible and Versatile Design

Can be shaped into intricate forms, allowing for innovative and customized designs.

Used in architectural facades, decorative elements, and complex engineering structures.

6. Insulation and Energy Efficiency

Low thermal conductivity, making it an excellent insulator in buildings and industrial settings.

Helps maintain stable indoor temperatures, reducing energy costs.

7. Non-Conductive & Safe for Electrical Use

GFR is an excellent electrical insulator, reducing risks in power plants, electrical panels, and transmission systems.

8. Lightweight and Easy to Install

Significantly lighter than traditional concrete and metals, reducing transportation and labor costs.

Makes construction faster and more efficient.

9. Water & Moisture Resistance

Does not absorb moisture, preventing mold growth and structural degradation.

Ideal for marine, coastal, and humid environments.

10. Impact and Stress Resistance

Can withstand sudden mechanical shocks without cracking or breaking. Used in vehicle manufacturing, aerospace, and industrial reinforcement applications.

With these properties, GFR continues to be a preferred material in construction, transportation, aerospace, and industrial applications, offering a perfect balance of strength, durability, and design flexibility.

Applications of GFRC

Glass Fiber Reinforced Concrete (GFRC) is a versatile material widely used in construction and design due to its strength, lightweight properties, and adaptability. Some of its key applications include:

1. ***Architectural Cladding & Facades***

GFRC panels are commonly used for building exteriors, offering both durability and an aesthetically appealing finish.

Frequently applied in high-rise structures where reducing weight is essential.

Allows for customized decorative facades that can replicate stone, wood, or other materials.

2. Precast Elements & Decorative Features

Used for window trims, columns, cornices, and moldings, providing a lighter alternative to traditional concrete.

Ideal for restoration projects, as it can replicate intricate historical details.

3. Interior Design & Aesthetic Applications

Popular for fireplace surrounds, wall panels, countertops, and furniture, adding both function and style.

Custom finishes and textures make it suitable for modern and luxury interiors.

4. Infrastructure & Public Projects

Commonly used in bridges, noise barriers, and retaining walls, offering durability and weather resistance.

Applied in tunnel linings and railway stations, benefiting from its fire-resistant properties.

5. Landscaping & Outdoor Installations

Found in benches, fountains, planters, and sculptures, providing durability with a lightweight structure

Used for pedestrian walkways and decorative paving in urban environments.

6. Prefabricated & Modular Construction

Enables lightweight prefabricated structures, reducing transportation costs and installation time.

Used in temporary or mobile buildings due to its easy handling and flexibility.

7. Marine & Coastal Engineering

Resistant to saltwater and corrosion, making it ideal for sea walls, docks, and marine structures.

Common in water parks and swimming pools for aesthetic and functional elements.

8. Advanced Architectural Forms & 3D Printing

GFRC is increasingly used in 3D-printed buildings and intricate designs, allowing for creative and cost-effective structures.

9. High-Performance & Hybrid Concrete Mixes

Frequently incorporated into advanced concrete formulations to enhance strength and durability for demanding applications.

10. Fire-Resistant & Protective Structures

Thanks to its fireproof properties, GFRC is used in fire-rated walls, enclosures, and security barriers for added safety.

With its diverse applications, GFRC continues to be a crucial material in modern construction, combining practicality with innovative design possibilities

Latest Developments of glass fiber reinforced concrete

Glass Fiber Reinforced Concrete (GFRC) has seen remarkable advancements in recent years, improving its strength, durability, and sustainability. Some of the latest developments include:

1. ***Nano-Enhanced GFRC*** – Researchers have incorporated nanomaterials such as nano-silica and carbon nanotubes to improve GFRC's mechanical strength, reduce cracking, and enhance its resistance to chemicals and moisture.
2. ***Self-Healing Properties*** – Innovative formulations now include encapsulated polymers or bacteria that activate when cracks appear, allowing the material to repair itself and extend its lifespan.
3. ***Sustainable and Recycled GFRC*** – The push for eco-friendly construction has led to GFRC blends that incorporate recycled glass fibers and alternative binders, reducing environmental impact while maintaining structural integrity.
4. ***3D Printing Applications*** – The integration of GFRC with 3D printing technology has allowed for more intricate, lightweight, and cost-effective designs, paving the way for faster and more efficient construction methods.
5. ***High-Performance Additives*** – The use of advanced admixtures, including superplasticizers and shrinkage-reducing compounds, has improved GFRC's workability, strength, and durability.
6. ***Smart Monitoring Systems*** – GFRC structures are now being embedded with sensors to track their condition in real time, allowing for proactive maintenance and enhanced structural safety.
7. ***Improved Fiber Technology*** – Advances in glass fiber composition have led to stronger, more durable reinforcement, improving performance under stress and reducing the risk of degradation over time.
8. ***Advanced Formwork Techniques*** – The development of flexible, reusable molds has made it easier to create complex GFRC shapes, allowing for more customized and innovative architectural designs.

9. ***Lightweight and High-Strength Formulations*** – New mixes have been optimized to provide higher tensile strength while remaining lightweight, making GFRC an ideal choice for high-rise buildings, bridges, and prefabricated structures.
10. ***Enhanced Curing Methods*** – Steam curing and accelerated hydration techniques have led to faster production times and improved overall quality, ensuring consistent strength and durability.

Materials used and their properties:

Property	Value
Type of cement	OPC
Grade	43
Fineness	6.6
Consistency	31
Initial setting time	40 min.
Final setting time	540 min
Coarse aggregate	10-12.5mm
Fine aggregate	4.75mm

Alkali-resistant glass fiber:

Alkali-resistant (AR) glass fiber is a specialized reinforcement material used primarily in cementitious composites, such as Glass Fiber Reinforced Concrete (GFRC). These fibers are engineered to withstand high-alkaline environments, which are typical in cement-based products, preventing degradation over time.

Properties of AR Glass fiber:

Property	Value / Description
Composition	High zirconia (ZrO_2) content >=16%
Density	2.6 -2.7 g/cm^3
Fiber length	12mm
Diameter	10–20 µm
Tensile strength	1000–1700 MPa
Alkali resistance	Excellent due to high ZrO_2 content
Melting point	1050°C
Moisture Absorption	Low

Chemical composition of AR (Alkali-Resistant) Glass Fiber:

Chemical Component	Percentage (%)
Silica (SiO_2)	50-65%
Zirconium Dioxide (ZrO_2)	16-20%
Alumina (Al_2O_3)	4-6%

Calcium Oxide (CaO)	5-10%
Magnesium Oxide (MgO)	1-5%
Boron Oxide (B_2O_3)	0-5%
Sodium & Potassium Oxides ($Na_2O + K_2O$)	0-2%

Tests carried out during this project:

Fineness of cement: (IS: 269-1989 and IS: 4031-1988)

APPARATUS: IS-90-micron sieve conforming to IS: 460-1965, standard balance, weights, and brush.

Table of Observations:

S.NO.	W1 {Weight of sample} {g}	W2 {weight of residue(g) }	Fineness (%) (W2/W1) x 100
1	100	6.2	6.2
2	100	6.8	6.8
3	100	7	7

Normal consistency test:

(IS: 269 - 1989 and IS: 4031 - 1988 (Part 4))

Apparatus: Vicat apparatus (conforming to IS: 5513 - 1976) with plunger (10 mm in diameter) balance, weights, gauging trowel.

Table of Observations:

S. No	Weight of cement (a)	Weight of water (b)	%Age of water added to cement	Plunger penetration (mm)	Consistency of cement in %by { $\boldsymbol{b}/\ \boldsymbol{a}\ \boldsymbol{x}\ \mathbf{100}$}
1	400g	100g	0%	14	25%
2	400g	112g	3%	12	28%
3	400g	124g	3%	7	31%

Result:

Normal consistency for the given sample of cement is 28%

Initial and final setting time:

(IS: 269- 1989 and IS: 4031- 1988 part 5)

Apparatus: (conforming to IS: 5513-1976) with attachments, balance, weights, gauging trowel.

Observations

For intial setting time;

%age of water taken= (0.85 x 31 x 400)/ 100 = 105.4

The final setting time was recorded after 540 min from the time water was added to the paste.

Table of observations:

S.NO.	Cement	Water (g)	Time (min) for Initial setting time.	Reading(mm)
1	400g	105.4	5	0
2	400g	105.4	10	1
3	400g	105.4	25	3
4	400g	105.4	30	5
5	400g	105.4	35	7

Determination of compressive strength of cement. [IS 4031-1988 (Part-6)].

Apparatus: Vibration Machine, Poking Rod, Cube Mould of 70.6 mm size conforming to IS: 10080-1982, Balance, Gauging Trowel, Watch, Graduated Glass Cylinders, etc. Material: Ordinary Portland cement (43grade); Water; Grease, Standard sand (IS: 650-1966).

Ratio - 1:3

Dimension of cube- 7.0 x 7.0 x 7.0 cm

No. of cubes-3

S.NO.	Date	Load(KN)	Strength(N/mm2)
1	07-12-24	220	44.8
2	07-12-24	210	42.85
3	07-12-24	220	44.8

Coarse aggregate tests:

To determine fineness modulus and grade of fine and coarse aggregate.

Reference: IS: 383-1970.

Apparatus: Balance; Gauging Trowel; Watch, Set of sieves -80mm, 40mm, 20mm,10mm, 4.75mm, pan. Material: Coarse aggregates (3Kg).

S.NO.	Sieve size Weight (mm)	Weight retained (g) (C1)	%age retained (C2)	Cumulative %age retained (C3)	%age passed (100-C3)
1	25	0	0	0	100
2	20	200	4	4	96
3	16	700	14	18	82
4	12.5	2850	57	75	25
5	10	300	6	81	19
6	4.75	200	4	85	15
7	Pan	750	15	100	0

Mix Proportion = 1:1.6:2.7

According to IS Code 10262-2009, we have to prepare the mix design for M40 and after designing it we get.

Cement =413kg/m3

Fine aggregate=687kg/m3

Coarse aggregate=1143kg/m3

Water cement ratio {W/C} =0.4

In this project, we are using the size of Cube 150*150*150 mm .

We have made the cube of Natural Aggregate Concrete (Plain Concrete) and without fibers.

Cement = 4.1kg

Fine Aggregate = 10.3kg

Coarse Aggregate = 16.2 kg

Water = 1.8Lt.

Results:

S.NO.	Grade of Concrete	Curing period {days}	Area of cubes {mm2}	Applied load {KN}	Compressive strength{N/mm2}
1	M40	28	22500	1210	53.44
2	M40	28	22500	1295	55.95
3	M40	28	22500	1320	60.10

Casting of Cubes by replacing cement:

1. ***Cubes with 2% of glass fiber:***

Cement = 4kg

Fine Aggregate = 10.3kg

Coarse Aggregate = 16.2kg

Water = 1.8 Lt

Glass fiber = 100g

2. ***Cubes with 4% of glass fiber:***

Cement = 3.9kg

Fine Aggregate = 10.3kg

Coarse Aggregate = 16.2kg

Water = 1.8 Lt

Glass fiber = 200g

3. ***Cubes with 6% of glass fiber:***

Cement = 3.8kg

Fine Aggregate = 10.3kg

Coarse Aggregate = 16.2kg

Water = 1.8 Lt

Glass fiber = 300g

Compressive strength test results on the above cubes after 28 days:

S.NO.	% of fiber used	Area of cubes {mm2}	Applied load{KN}	Compressive strength {KN/mm2}	Durability performance
1	2 %	22500	615	39.75	Improved
2	4%	22500	622	40.85	Significant improvement
3	6%	22500	595	38.92	Slight reduction

Conclusion:

This study investigated the effect of replacing cement with **Alkaki-Resistant [AR] glass fiber** at varying percentages **(2%, 4%, and 6%)** on the properties of the composite material. The results indicate that the incorporation of glass fibers **significantly influenced** the **strength** and **durability** characteristics. At lower replacement levels **(2% and 4%),** improvements in compressive and flexural strength were observed, suggesting enhanced bonding and crack resistance. However, at **6%** replacement, a **slight reduction** in strength was noted, likely due to fiber **agglomeration** and reduced **cementitious** bonding.

Overall, the findings suggest that the **optimal replacement** percentage lies between **2% and 4%,** balancing strength gains and workability. The inclusion of glass fiber not only contributes to sustainability by reducing cement consumption but also enhances the mechanical performance of the material. Future research can focus on optimizing fiber dispersion and exploring long-term durability aspects to further validate these findings.

References

1. Cent karakurt and Ahmet Turap Arslan(2017):properties of concrete pavements produced with different types of fibers .Journal of Turkish Chemical Society,section B:Chemical engineering.2017;(sp.is.2):17-24.
2. Md Zoheb and Amaresh S Patil(2015): “Analytical study of steel fiber reinforced rigid pavements under static load” IJSRD-International Journal for scientific Research and Development (Vol.2,issue 09,2014) ISSN (online):2321-0613.
3. Mohammad Maaz Salman and Amaresh S Patil(2014): “Analytical study of steel fiber reinforced rigid pavements under moving load” IJSRD-International Journal for scientific Research and Development (Vol.2,issue 07,2014) ISSN (online):2321-0613.
4. Rakesh Kumar , Pankaj Goel and Renu Mathur(2014): “Suitability of concrete reinforced with synthetic fiber for construction of pavements” Rigid pavements division,Central Road Research Institute,Delhi-Mathura Road,New Delhi-110025,India. 5. RajarajeshwariB Vibhuti ,Radha Krishna(2013): “Mechanical properties of hybrid fiber reinforced concrete for pavement” in IJRET,2013
6. Jeffery Roesler et.al(2008) “Fracture behavior and properties of functionally graded fiber reinforced concrete” Deparment of Civil Engineering University of Illinious at Urbana-Champaign, 205 N.Mathews Ave,Urbana IL 61801.
7. Michal A Glinicki et.al(2000) “Mechanical properties of fiber reinforced concrete for thin repairs of concrete pavements” Published in Conference Paper; January 2000.
8. Samprati Mishra(2017) “glass fiber reinforced concrete” International Research Journal of Engineering and Technology(IRJET)(2017).
9. Ahmed Shalaby, Assistant Professor, and Scott Murison, Graduate Student “using fiber reinforced polymer load transfer devices in jointed concrete pavements”.
10. Faqi Chen et.al(2019) “Experimental Analysis on Flexural-tensile Performance of Polyester Fiber Asphalt Concrete” Annales de Chimie: Science des Materiaux Vol. 43, No. 2, April, 2019, pp. 81-88.
11. Manish kumar Bhardwaj et.al(2000) “ A Comparative Study between the Usages of Differently Sized Waste Rubber Obtained From Tires over the Strength Performance of Rigid Road Pavement” IOP Conf. Series: Earth and Environmental Science 889 (2021) 01- 2019.

12. Wang, W.-C., Wang, H.-Y., Chang, K.-H., Wang, S.-Y. "Effect of high temperature on the strength and thermal conductivity of glass f iber concrete", Construction and Building Materials, 245, 118387, 2020.
13. Rath, B., Deo, S., Ramtekkar, G. "Durable glass fiber reinforced concrete with supplimentary cementitious materials", International Journal of Engineering, 30(7), pp. 964–971, 2017.
14. Barluenga, G., Hernández-Olivares, F. "Cracking control of con cretes modified with short AR-glass fibers at early age. Experimental results on standard concrete and SCC", Cement and Concrete Research, 37, pp. 1624–1638, 2007.
15. Al-Ghaban, A., Jaber, H., Shaher, A. A. "Investigation of Addition Different Fibers on the Performance of Cement Mortar", Engineering and Technology Journal, 36(9A), pp. 957–65, 2018.
16. Paktiawal, A., Alam, M. "Alkali-resistant glass fiber high strength concrete and its durability parameters", Materials Today: Proceedings, 47, pp. 4758–4766, 2021.
17. Anandaraj, S., Rooby, J., Awoyera, P. O., Gobinath, R. "Structural distress in glass fibre-reinforced concrete under loading and exposure to aggressive environments", Construction and Building Materials, 197, pp. 862–870, 2019.
18. Abdi Moghadam, M., Izadifard, R. A. "Effects of steel and glass fibers on mechanical and durability properties of concrete exposed to high temperatures", Fire Safety Journal, 113, 102978, 2020.