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The Application of Glass Fibers as A Substitute for Steel Reinforcment in Concrete

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Abstract: *Concrete as the most commonly used material in construction it is always under review to be produced with properties which satisfies specified mechanical, stiffness, and workability specifications. This could be done by evaluating the properties of concrete and its components under a variety of conditions and mixtures. Fiber reinforced concrete is a type of concrete, in which will be dispersed uniformly with fibers in order to obtain the required properties in the specification. Originally steel fibers have traditionally been the preferred option, due to his material properties such as their strength and toughness. However, their sensitivity to corrosion, added weight, and higher cost have encouraged interest in alternative materials. So the application of these fibers into concrete will have a significant effect of it's compressive strength, tensile strength, flexural strength by increasing all of them and as a result will impact concrete strength. Glass fibre reinforced concrete is a product of a cementatious matrix composed of cement, sand, water and admixtures, in which short length glass fibres are dispersed.*

Keywords: *Compressive Strength,Fiber Reinforced Concrete, Glass Fibers, Tensile Strength, Steel Fibers*

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I. INTRODUCTION

Engineers seek materials that improve durability, crack resistance, and structural performance. Concrete performance can be significantly improved by incorporating different types of fibers, which help control cracking, enhance durability. Fiberglass fibers present a potential substitute, offering advantages such as resistance to rusting, lower density, and simpler installation. Just like steel, which is an alloy with iron and carbon components, fiberglass is a material composed of several elements, like SiO2,Al2 O3, MgO, B_2O_3 etc. This is the category of fibers that enables good performance against the large forces of the structure. Today, fiberglass products make up more than 95% of the fiber reinforcements used in the composites industry. Exploring the application of fiberglass as a replacement for steel fibers in concrete provides valuable insight into how these materials influence mechanical behavior and a long-term performance in structures.

This research paper will be based on secondary data collection. In order to have solid arguments behind our conclusions, a vary tests of steel fibers and glass fibers are required such as their material properties including mechanical properties and physical properties. Tensile and compressive strenght test results will be taken into account in this study.

II. METHODOLOGY

We have provided information from experimental results from previous studies, in which we can detect cleary the difference between the glass fibers (GFRC) vs the steel fibers(SFRC) from the given figures. Both steel and glass fibres enhance the mechanical properties of concrete compared with conventional plain concrete. However, the level of improvement varies according to the type of strength being evaluated and the amount of fibre incorporated into the mix.

Tensile Strength Performance

Fibre %	28 days average Tensile strength N/mm² Normal	28 days average Tensile strength N/mm² SFRC	28 days average Tensile strength N/mm² GFRC
0.5		3.02	2.79
1	2.18	3.18	2.31
1.5		2.39	2.11

Fig .1. Source: a comparative study of tensile strength of concrete mixed with steel and glass fibers (s.bohora)

Tensile strength is key factor in determination a material's ability to withstand loads without braking. This experiment evaluated how adding steel and glass fibers influences the split tensile strength of M20 grade concrete. The fibers were added at volumes of 0.5%, 1%, and 1.5%.

Based on the tensile strength results, the inclusion of fibres leads to a notable improvement compared with plain concrete. Concrete reinforced with steel fibres consistently exhibits greater tensile strength than that reinforced with glass fibres across all fibre dosages. The maximum tensile strength is achieved at approximately 1% fibre content, where steel fibre reinforced concrete attains a value of 3.18 N/mm², while glass fibre reinforced concrete shows a comparatively smaller increase of 2.31 N/mm². These findings indicate that steel fibres are more effective in enhancing tensile behaviour, as their higher stiffness and stronger bond with the cement matrix enable better crack control and resistance to tensile stresses.

Compressive Strength Performance

Sample	Average Compressive Strength (N/mm²)		
Glass Fibre	7 days	14 days	28 days
0.5%	20.68	22.12	24.39
1%	19.53	21.49	23.45
1.5%	17.23	19.23	20.95
Steel Fibre			
0.5%	21.51	23.36	24.49
1%	22.61	24.34	25.41
1.5%	20.01	22.04	23.64
Normal	17.36	21.11	22.24

Fig .2. Source : {[a comparative study of compressive strength of concrete mixed with steel and glass fibers (s.bohora)]

Compressive strength is a fundamental material property that measures the maximum axial load a material can withstand before failing or crushing under compression.The compressive strength results show that both glass fibre reinforced concrete (GFRC) and steel fibre reinforced concrete (SFRC) achieve higher strength values than conventional concrete at all curing periods of 7, 14, and 28 days. In general, SFRC exhibits superior compressive strength compared with GFRC across most fibre dosages and testing ages. The highest compressive strength, 25.41 N/mm², is recorded for concrete containing 1% steel fibres at 28 days. In the case of glass fibres, the optimum performance occurs at a lower fibre content of 0.5%, with a maximum value of 24.39 N/mm², after which further increases in fibre content result in a reduction in strength. This trend suggests that steel fibres are more effective in improving compressive performance, while excessive fibre addition—particularly with glass fibres—reduces workability and leads to poor fibre distribution, ultimately diminishing strength.
An optimal fiber content exists for each material: 0.5% for glass fiber and 1% for steel fiber. Exceeding these percentages reduces compressive strength, with the effect being more detrimental for glass fibers.

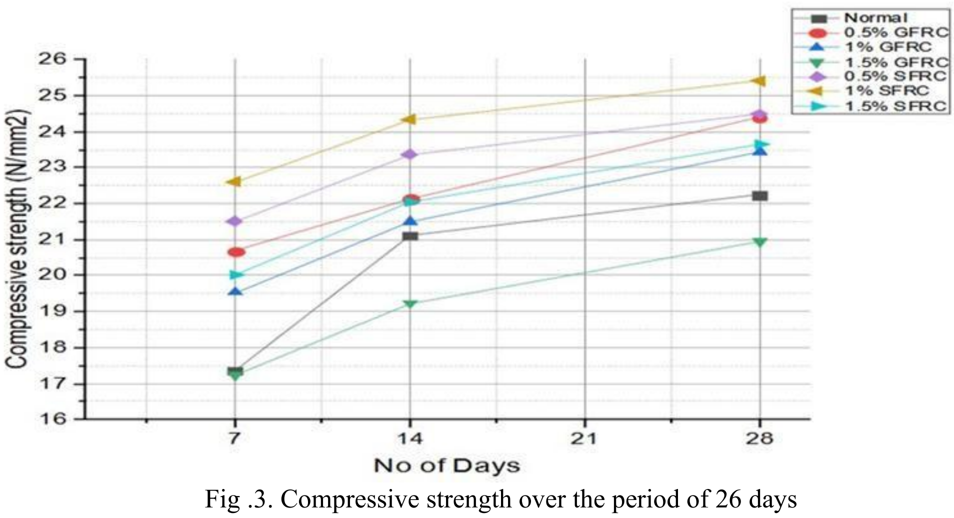

Fig .3. Compressive strength over the period of 26 days

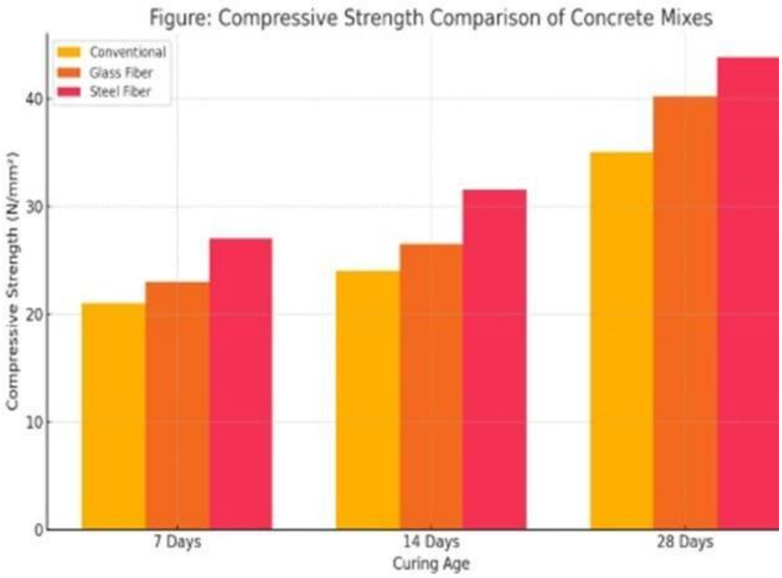

Figure .4. Compressive strength of GFRC, SFRC and Normal

The figure presents a comparison of compressive strength development for conventional concrete, glass fibre reinforced concrete, and steel fibre reinforced concrete at curing ages of 7, 14, and 28 days. For all mixes, compressive strength increases steadily with curing time, indicating normal hydration and strength gain. At each age, both fibre-reinforced concretes exhibit higher strength than the conventional mix, confirming the beneficial effect of fibre inclusion on compressive performance. Among the reinforced mixes, steel fibre concrete consistently achieves the highest strength values, particularly at 28 days, where it shows a marked improvement compared with both glass fibre and plain concrete. Glass fibre concrete also demonstrates enhanced strength relative to the control mix, although the increase is smaller than that observed with steel fibres. Overall, the results suggest that while both fibre types improve compressive strength, steel fibres provide a more significant contribution to long-term strength development.

III. FIRE RESISTANCE PERFORMANCE OF STEEL AND GLASS FIBERS IN CONCRETE

Fire resistance is a critical requirement for fibre-reinforced concrete, particularly in structures that may be subjected to high temperatures, such as tunnels, industrial facilities, and tall buildings. The behaviour of concrete reinforced with steel fibres and glass fibres under fire conditions differs considerably because of the distinct thermal and mechanical properties of these materials.

Behaviour of Steel Fibre Reinforced Concrete (SFRC)

Steel fibres possess a very high melting temperature, typically in the range of 1300–1500°C, which allows them to remain stable under most fire exposures encountered in buildings. At elevated temperatures, the presence of steel fibres helps preserve the integrity of the concrete by limiting crack widening and preventing excessive crack growth. They contribute to higher residual strength, improved ductility, and enhanced toughness after heating. In addition, SFRC demonstrates reduced spalling and is able to retain its load-bearing capacity for a longer duration when compared with plain concrete. Consequently, steel fibre reinforced concrete is well suited for structural elements where a high level of fire performance is required.

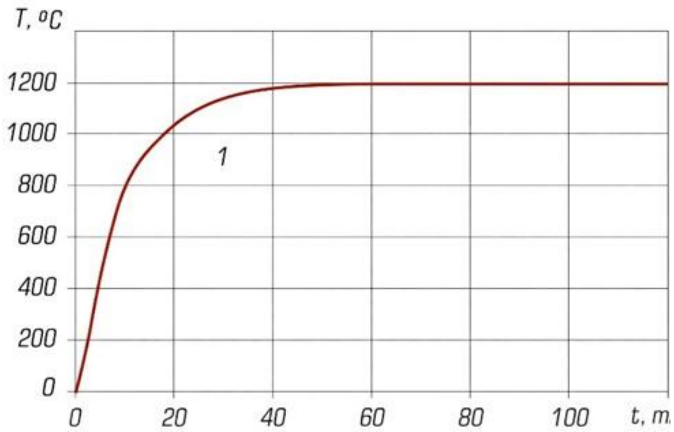

Fig .5.Fire-Time Steel

Behaviour of Glass Fibre Reinforced Concrete (GFRC)

Glass fibres, including alkali-resistant types, have a lower softening temperature, generally between 600 and 800°C, which affects their performance at elevated temperatures. During fire exposure, these fibres may soften or lose strength, leading to a decline in their reinforcing effectiveness. At moderate temperatures, glass fibres can still assist in limiting micro-crack formation and preserving surface quality. However, at higher temperatures their contribution to mechanical resistance is significantly reduced. As a result, glass fibre reinforced concrete offers limited fire resistance, mainly enhancing crack control and surface stability rather than providing sustained structural strength.

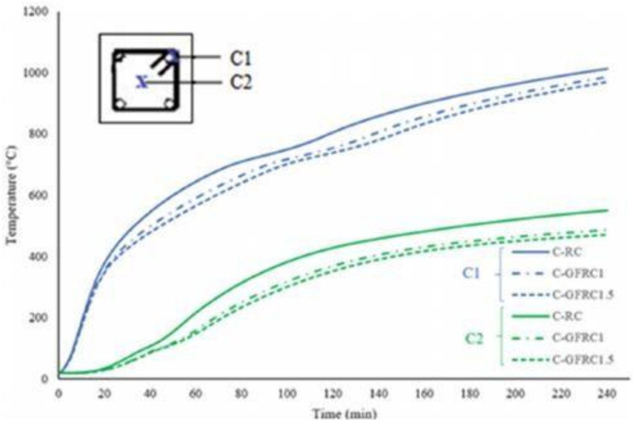

Fig.6. Temperature evolution as a function of time in the cross section of the columns

IV. APPLICATION DOMAINS OF SFRC AND GFRC

Steel fiber reinforced concrete is generally the more cost-efficient solution in structural and infrastructure applications where high mechanical performance, impact resistance, and construction speed are critical. One of the most economically advantageous uses of SFRC is in industrial floor slabs, where steel fibers can replace conventional welded wire mesh or secondary reinforcement. This substitution significantly reduces placement time and labor requirements, resulting in lower overall construction costs. Additionally, the superior resistance of SFRC to impact loading and fatigue makes it particularly suitable for heavy-duty industrial environments.

SFRC is also widely employed in pavements and overlay systems, including roadways, airport aprons, and parking facilities, where effective crack control and reduced joint spacing are required. In tunnel linings and shotcrete applications, steel fibers provide high toughness and energy absorption, making them ideal for sprayed concrete used in mining and underground civil engineering works. Furthermore, precast structural elements such as beams, piles, and sewer pipes benefit from the enhanced shear resistance and impact durability offered by SFRC, while also simplifying production by eliminating complex reinforcement cages.

Applications Favoring Glass Fiber Reinforced Concrete (GFRC)

Glass fiber reinforced concrete is generally more cost-effective in applications where weight reduction, architectural quality, and long-term durability are prioritized over maximum structural strength. Its most advantageous use is in architectural cladding and façade systems, where the unit cost per panel may exceed that of conventional precast concrete or SFRC, yet the total installed cost can be comparable or even lower. This economic benefit is primarily attributed to the substantially reduced self-weight of GFRC panels, which allows for thinner sections, lighter supporting structures, reduced foundation demands, and faster installation.

In addition to structural efficiency, GFRC offers exceptional design versatility, enabling the fabrication of complex geometries, intricate surface detailing, and sharp architectural features within single prefabricated elements. This capability reduces the need for multi-part assemblies and associated labor costs. The material also provides a high-quality surface finish, characterized by uniform texture, stain resistance, and compatibility with integral pigmentation or surface coatings.

GFRC is particularly well suited for decorative and non-structural components, including statues, cornices, trims, planters, and replicas of historic stonework, where precision and surface detail are critical. Moreover, thin-shell and lightweight structures, such as canopies, sunscreens, and landscape elements, benefit from the low density and formability of GFRC, making it the preferred choice where minimal self-weight is essential.

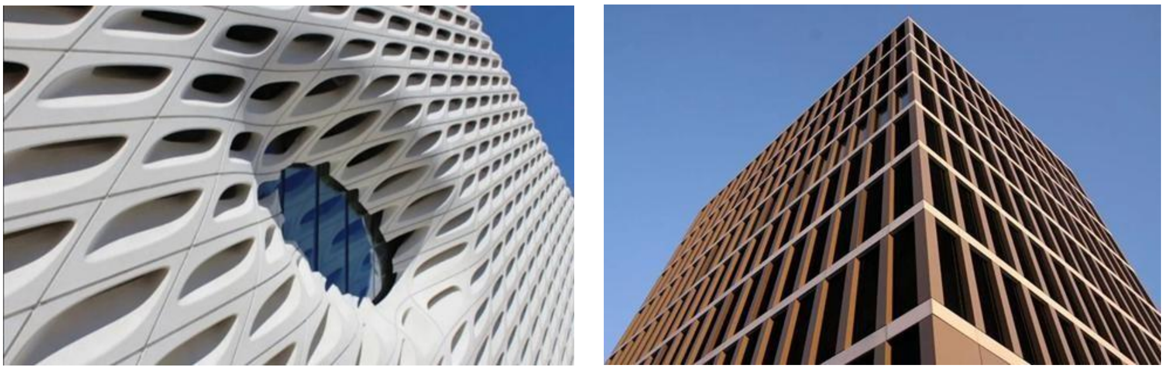

Fig.7.: Glass Fiber Reinforced Concrete in Contemporary Construction

V. CONCLUSIONS

The compressive and tensile behaviour of M20 grade concrete incorporating glass and steel fibres at proportions of 0.5%, 1%, and 1.5% by weight of cement was investigated using a nominal mix design. A total of 63 cube specimens measuring 150 mm × 150 mm × 150 mm were cast for compressive strength evaluation and tested after curing periods of 7, 14, and 28 days, with average values reported for each age. In addition, split tensile strength tests were carried out on 21 cylindrical specimens of 300 mm height and 150 mm diameter at 28 days. An economic assessment of the different fibre-reinforced mixes was also performed.

The results indicated that workability decreased as fibre content increased, suggesting that chemical admixtures may be necessary to maintain adequate consistency in fresh concrete. Improvements in compressive strength were observed only at optimum fibre dosages. The maximum increase in compressive strength, 14.25%, was obtained with 1% steel fibre, while glass fibre achieved its highest improvement of 10.11% at a lower content of 0.5%. Fibre contents above or below these optimum values resulted in reduced strength, in some cases falling below that of the control mix, highlighting the importance of selecting an appropriate fibre dosage.

A similar pattern was noted for split tensile strength. At 28 days, the addition of 1% steel fibre produced the greatest enhancement, with an increase of 45.87% compared with plain concrete, while 0.5% glass fibre resulted in a 27.98% improvement. For steel fibre contents of 0.5% and 1.5%, tensile strength increases of 38.53% and 9.63% were recorded, respectively. In contrast, glass fibre contents of 1% and 1.5% led to smaller gains of 5.96% and 3.21%. These results confirm that optimum fibre proportions are essential for achieving significant tensile performance.Strength development continued throughout the curing period, emphasizing the importance of a full 28-day curing regime for fibre-reinforced concrete to reach its maximum potential. From a structural perspective, steel fibre reinforced concrete is generally more economical and provides excellent performance as a partial replacement for conventional secondary reinforcement in mass concrete applications. Conversely, glass fibre reinforced concrete, although more expensive per unit volume, offers superior overall value for architectural panels, lightweight components, and intricate shapes, where durability, corrosion resistance, and surface quality are critical. Cost comparisons with conventional precast concrete should therefore consider the complete wall system, supporting framework, and installation requirements rather than material cost alone.

In conclusion, both steel and glass fibres enhance the safety and performance of concrete by modifying its failure behaviour from brittle to a more ductile response. Steel fibres are primarily selected for applications demanding high toughness, structural reliability, and resistance to sudden failure, whereas glass fibres are preferred in situations where crack control, durability, and corrosion resistance are of primary importance. The choice of fibre type and dosage should be based on structural demands, exposure conditions, and economic considerations, ensuring improved performance and long-term resilience of the constructed facility.

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