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Experimental study on flexural behaviour of textile reinforced concrete

ABSTRACT

Alkali-Resistant (AR) glass mesh fiber reinforced concrete emerges as a promising alternative in modern construction, offering enhanced durability, flexibility, and structural integrity. This paper provides experimental investigation and benefits of AR glass mesh fiber reinforced concrete in construction. It explores the properties, and performance characteristics of AR glass mesh fibers, highlighting their alkali-resistant nature and compatibility with concrete matrices. This experimental work utilizes a 145 gsm (grams squared per meter) alkali-resistant (AR) glass fiber textile mesh. Flexural strength and compressive strength findings demonstrating the practical application and effectiveness of AR glass mesh fiber reinforced concrete in various construction projects are presented. Finally, future directions and opportunities for further research and development in this field are identified, aiming to promote the widespread adoption of textile reinforced concrete (TRC) as a sustainable and high-performance construction material. This paper aims to analyze the flexural behavior of concrete specimens reinforced with textile fiber, evaluating their structural performance, durability, and environmental impact. For flexural strength of TRC, it is found that 2 layers of AR glass mesh attains more strength compared to the single layer AR glass mesh fiber. The structural enhancements provided by AR glass mesh fiber reinforcement in concrete are discussed, including improved crack control, flexural strength, and durability in harsh environments.

Keywords: *Textile Reinforced Concrete, AR Glass fiber, Compressive Strength and Flexural strength*

1. INTRODUCTION

Textile reinforced concrete (TRC) has become a potential breakthrough in the search for cutting-edge building materials that combine strength, durability, and flexibility. Instead of using steel bars as reinforcement like regular reinforced concrete does, TRC incorporates high-performance textiles like aramid, glass, or carbon fibres into the concrete matrix. Because of its better tensile strength, less weight, and improved fracture resistance, this composite material is especially well-suited for complex geometries, thin-walled buildings, and architectural facades where traditional reinforcement techniques fall short [1].

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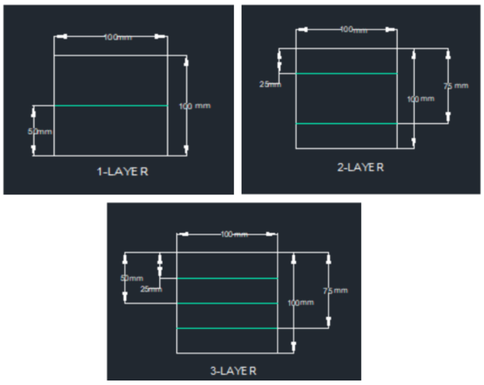
The necessity for materials that not only satisfy the structural requirements of contemporary design but also take sustainability issues into account is what is driving the development of TRC. With the focus on lowering the carbon footprint of construction methods growing, TRC presents potential benefits in the form of longer lifespans, more efficient materials, and less maintenance needs. Additionally, creative design possibilities made impossible with conventional concrete before are now possible thanks to the flexibility of textile reinforcements. TRC is a material that can be used in a variety of fields because of its special qualities, which include its high tensile strength, light weight, and capacity to construct intricate designs. TRC makes it possible to create intricate, light-weight, and thin geometries that are not possible with conventional reinforced concrete [2]. For cladding systems and architectural facades, this makes it perfect. Bridges, buildings, and historical monuments are among the structures that

TRC is used to strengthen and restore. Its thin layers provide it strength without adding a lot of weight or changing how the structure looks. Precast concrete panels and pieces are made using TRC and are lighter, simpler to transport, and easier to install than standard concrete components [3]. Architects are able to create free-form, organic forms with textile reinforcements, which would be challenging to accomplish with more conventional materials. This is very helpful for modern architecture.



a) Positioning of AR Glass fiber

b) AR Glass fiber reinforcement

c) TRC Prism

Figure 1. Casting of TRC

This study intends to investigate the mechanical characteristics, longevity, and possible uses of TRC, with an emphasis on comprehending how various textile materials and matrix compositions affect the composite's performance. By looking at these areas, the project hopes to help TRC become more widely used in the building sector and offer knowledge that might lead to the development of new guidelines for structural engineering and material science.

2. LITERATURE REVIEW

This study investigated the mechanical behavior of sandwich panels constructed with aerated concrete cores and reinforced with textile layers, under both static and low-velocity dynamic loading. The core material was made from two variants of aerated concrete, while the outer skin comprised a cement-based binder reinforced with two layers of Alkali Resistant Glass (ARG) textiles. The research evaluated the flexural stiffness, strength, and energy absorption capacity of two types of composites: one with a ductile skin and brittle core (TRC–AAC), and another with a ductile skin and core (TRC–FRAC). The mechanical properties of the lightweight, low-strength aerated concrete core significantly improved due to the textile reinforcement, with dynamic flexural strength reaching up to four times the static flexural strength. Crack propagation mechanisms were analyzed using digital image correlation (DIC) and high-speed photography [4].

The flexural behaviour and microstructure of carbon woven textiles applied to fine aggregate concretes were examined in this work [5]. The specimens were examined using scanning electron microscopy and four-point bending tests. The findings indicated that a reduction in textile mesh size from 20 to 2 mm resulted in an increase in flexural load and toughness of nearly 380% and 820%, respectively. However, because there was less cement matrix penetration in the samples with zero mesh size, they performed worse. The study discovered that the flexural behaviour of the reinforced concrete (TRCs) was not primarily influenced by the mesh size, but rather by the volume content. The flexural strength of the samples was modelled using artificial neural networks (ANN), demonstrating the efficacy of ANN as a method for forecasting the flexural strength of TRCs.

Particularly in thin wall concrete constructions, carbon fibre textile (CT) is frequently employed as a strengthening and retrofitting material for reinforced concrete structures [6]. Its application is, however, restricted in developing nations. An inexpensive and more resilient option to CT for reinforcing thin concrete buildings is galvanised iron textile (GIT). A study was done on textile-reinforced concrete (TRC) that has GIT and CT in it. Two kinds of specimens were cast to test impact and flexural behaviour. The flexural load capacity of CT panels increased dramatically with an increase in GIT layer, whereas that of GIT panels did not. Specimens reinforced with a double layer of CT exhibited a greater load-bearing capacity compared to control specimens with a higher reinforcement ratio. When comparing CT-reinforced samples to those reinforced with GIT, using both circular and conical impactors, the CT-reinforced specimens endured up to 37 times more impacts before failure. Additionally, CT-reinforced specimens with thicknesses of 50 mm and 75 mm demonstrated impact energy absorption that was nearly twenty times and seventeen times higher, respectively, than their GIT-reinforced counterparts. This study examines the measurement variability of thin 15 section cement composites' constitutive properties through tensile and flexural tests [7]. It demonstrates that the variability can reach 200–300% when subjected to a straightforward linear analysis. The findings of experiments conducted on laminated Textile Reinforced Concrete (TRC) composites with different textile fabrics in tension and flexural testing are reported. A parametric model for flexural behaviour simulation is used to investigate the correlation of material attributes. A back-calculation method is used to determine the flexural load carrying capacity of TRC composites, and closed form equations are used to determine the parameters of a strain hardening material model [8]. The study also analyses the discrepancies in experimental and back-calculated tensile characteristics and proposes that the average moment-curvature relationship obtained from the data can be applied to cement composite structural analysis and design[6].

This study investigates the behaviour of TRC beams [9] that have been treated with epoxy and have a high yarn count. The study looks into how surface finish plain or sand-coated and the geometry of textile fibre strands affect TRC cracking behaviour in relation to the concrete cover. According to the findings, transverse fracture breadth can be reduced by one-third in sand-coating treatment compared to plain textile specimens [10]. The manner of textile manufacture also affects the geometry of plain fibre strands, which results in notable variations in recorded fracture widths. Splitting (longitudinal) cracks in the textile reinforcing layer, which were seen in concrete covers thicker than 15 mm regardless of surface treatment, had a substantial impact on the overall cracking behaviour. Splitting fractures in textiles treated with sand began as soon as the first crack appeared and spread throughout the material, reducing the tension stiffening effect [11]. The concrete cover of the plain textile samples experienced severe spalling due to the fissures. The study offers a more thorough understanding of TRC cracking behaviour using epoxy-impregnated textiles and a large database for future research, laying the groundwork for uniform laws pertaining to the limit states of TRC structures[12].

3. METHODOLOGY

Cement

The cement used in this investigation was regular Portland cement, grade 53, compliant with IS 12269:1987. It serves as a binding agent and helps produce the hydration products in concrete [19].

Fine Aggregate

The fine aggregate in the mix was M-sand, and water was added to increase the mix's strength and hydration [13]. Aggregates, which make up 60–80% of the total quantity of concrete, have a major impact on the qualities of concrete both when it's new and when it's hardened. Fine aggregate makes up a negligible portion of the aggregate composition overall, making up between 15 and 30 percent of the aggregate volume. The concept of employing artificial sands in place of natural sand has become more appealing due to its declining availability.

Coarse Aggregate

A vital component in concrete mixtures, coarse aggregate is essential to the overall strength, durability, and characteristics of the concrete. The binding between the aggregate and the cement paste is influenced by the aggregate's surface texture [14]. The largest size for coarse aggregate is 20 mm, yet it can be as small as 10 or 12 mm provided the structure contains densely spaced reinforcing steel. Graded round or cubical aggregates are recommended for best outcomes. The fine aggregates usually have a size of less than 0.125 mm and can be created naturally or artificially.

AR Glass Fiber

Figure 2 presents the three-layer structure of a commercially available AR Glass textile mat, which was used consistently throughout the experimental study. Alkali-Resistant Glass (AR Glass) is a glass material resistant to alkaline substances, created from non-metallic organic raw materials. These materials are melted at temperatures ranging from 1250°C to 1350°C to form molten glass, which is then processed using a wet-spinning method. The figure demonstrates the formation of AR-Glass Fibres using a glass composition containing an optimal amount of zirconium ($ZrO2$), ideal for use in concrete[15]. This alkali-resistant glass fibre mesh, with a density of 145 grams per square meter (GSM), benefits from a higher zirconium content, increasing its resistance to alkaline corrosion. The inclusion of fibres significantly enhances the tensile and mechanical strength of concrete, making it more durable and flexible compared to traditional concrete [16]. Glass fibre products exhibit high strength and longevity, withstanding repeated stress without cracking or deforming, and reducing concrete shrinkage to manageable levels. For the M25 concrete mix, a slump of 25–50 mm and a water-to-cement ratio (w/c) of 0.45 was achieved using the BIS-10262(2019) method. Table 1 displays the concrete mix proportions for M-25. Figure 1 illustrates the study's findings on the concrete's flexural behavior, and compressive strength, which were analyzed by incorporating AR glass fibres as reinforcement in multiple layers of steel [17].

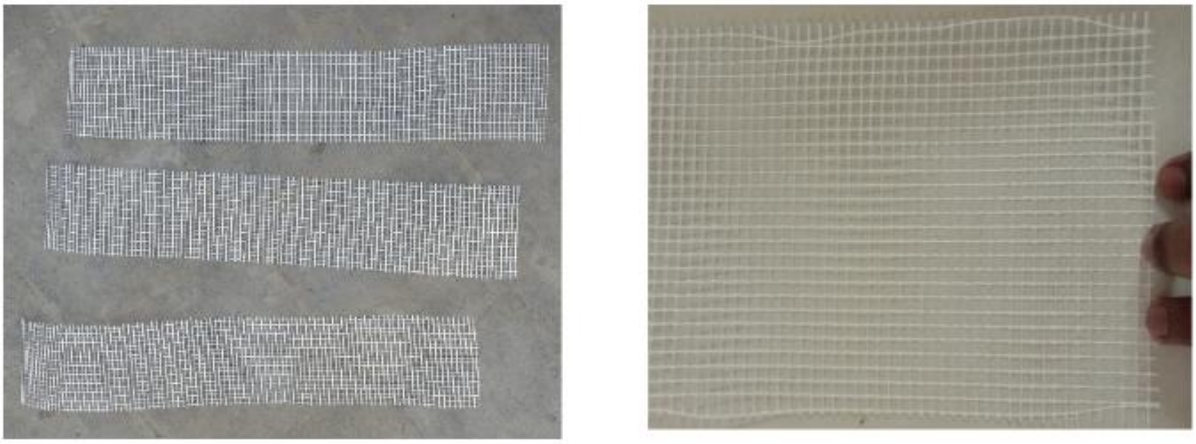


Figure 2. AR- Glass fibre mesh

Table 1. Concrete Mix Proportion

Description	Kg/m^3
Cement	412
Fine aggregate	649
Coarse aggregate	1122
Water	186
W/C ratio	0.45

4. MECHANICAL PROPERTIES

4.1. Compressive Strength

In order to create 15 cm x 15 cm x 15 cm concrete cubes (Fig. 3), either with or without AR-glass fibre layers [18], representative concrete samples must be collected in accordance with the code standards outlined in IS:516-1959 for determining the compressive strength of concrete [19]. Layers of concrete around 25 cm deep must be poured into the moulds. It would be uniformly dispersed and crushed using either manual tamping or vibration. Additionally, each layer of AG-glass fibre is positioned so that it is perpendicular to the loading condition point. Once the top layer has been compacted, the concrete surface needs to be levelled with a trowel to match the top of the mould, and to stop evaporation, it needs to be covered with plastic [20]. Following that, the samples must be demolded in a day and kept in clean water at 27+20C for the next 28 days as they cure. After testing the specimen in a compression testing machine, Figure 4 illustrates the failure load that was detected. Table 2 lists the compressive strengths of the ARGFRC specimen with various layers and the Control Specimen (CS).

Figure 3. Casting of Cube

Figure 4. Test Set up for Compressive Strength

Table 2. Compressive Strength

AR Glass Fiber	Days	Compressive Strength (N/mm^2)
Conventional	7	20.45
	14	23.25
	28	26.50
Single layer	7	22.25
	14	25.88
	28	30.72
Two layer	7	22.75
	14	27.4
	28	32.18

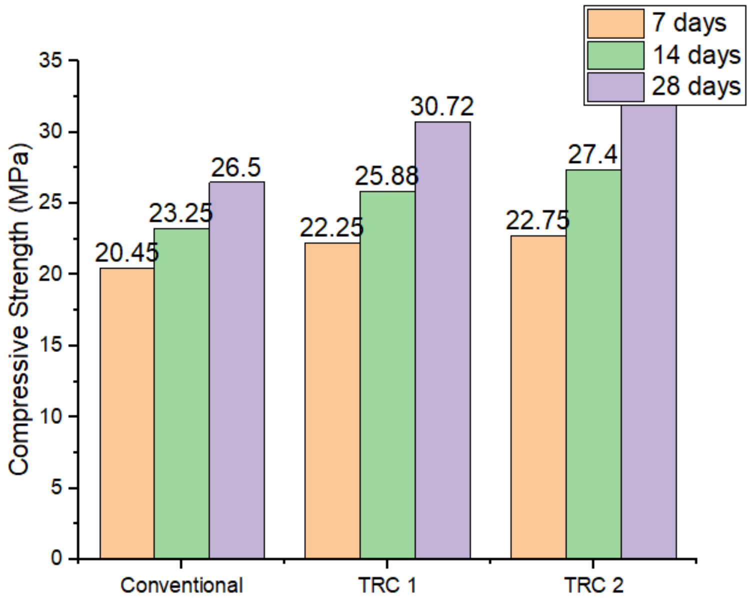


Figure 5. Compressive Strength

4.2. Flexural Strength

Figure 4 displays the flexural testing apparatus and the 500 mm x 100 mm x 100 mm prism that were employed in the investigation [21]. A reinforcement that can effectively modify the failure mechanism of the composite and is both stiffer and tougher than the matrix is necessary to increase the strength of the matrix [22]. This implies that the composite should have little to no ductility and be as brittle as feasible. In Table 2, flexural strength is shown. The graphical depiction of compression and flexural strength was shown in Fig. 5 and Fig. 7. The load vs. deflection and the fibre hardening stage are both concurrently displayed in Fig. 6 (Universal Testing Machine).

Flexural Strength (N/mm^2) = $(3PL)/(2bd^2)$

P-failure load(KN)

L-supported length(mm)

b-width of specimen(mm)

d-depth of specimen(mm)

Table 3. Flexural Strength

AR Glass Fiber	Days	Flexural Strength (N/mm^2)
Conventional	7	3.5
	14	4.8
	28	6.6
Single layer	7	4.72
	14	6.7
	28	10.39
Two layer	7	5.66
	14	6.99
	28	11.86

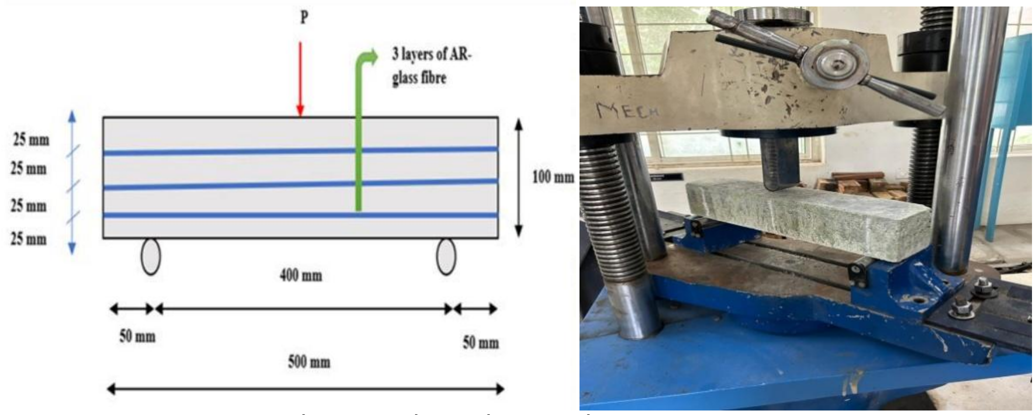


Figure 6. Flexural Strength Test Set up

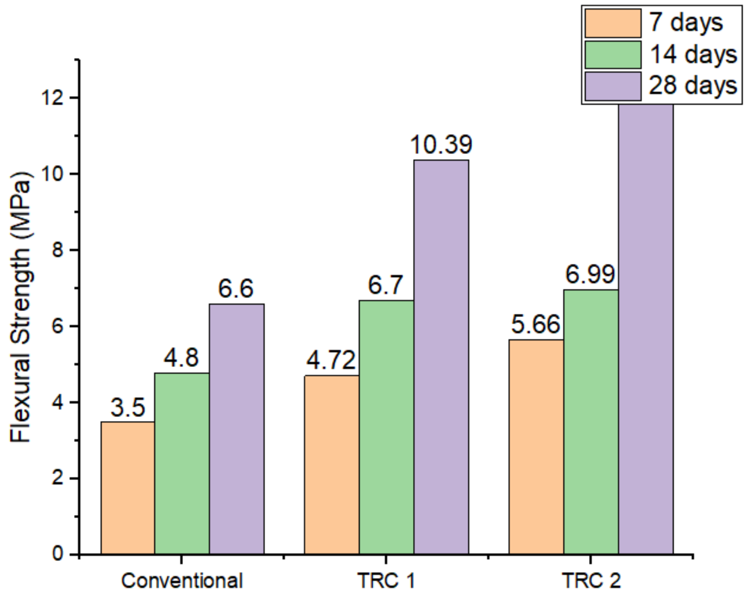


Figure 7. Flexural Strength

5. RESULTS DISCUSSION

This experimental study aimed to evaluate the performance of concrete incorporating materials such as M-sand and to reduce the risk of premature brittle failure through the inclusion of AR-glass fibres [23]. The connection between concrete particles led to a slight reduction in compressive strength and lower particle packing compared to traditional specimens. The study explores the potential of AR-glass fibre to prevent sudden brittle failure. Results showed that the compressive strength of the TRC specimens increased compared to the conventional ones. With the addition of two layers of AR-glass fibre, the compressive strength of the TRC 2 specimen rose to 32.18 N/mm².

AR-glass fibre [24] is incorporated into the concrete mix in alternating layers to enhance its volume. Consequently, both the flexural and compressive strengths significantly increase compared to the conventional sample. The TRC 2 specimen demonstrates a flexural strength of 11.86 N/mm², attributed to the fibre mat's bridging effect, which is applied in two layers within the prism. Textile-reinforced concrete enters a flexural state where crack widths are minimized, resulting in higher resistance. The two-layer AR-glass fibre composition of the concrete provides excellent flexural strength and energy dispersion. This suggests that TRC concrete could be effectively used in various mechanical applications.

6. CONCLUSIONS

This experimental study shows that concrete performs better mechanically when M-sand and AR-glass fibres are added. The addition of AR-glass fibres significantly increases both compressive and flexural strength, while lower particle packing causes a increase in compressive strength. Due to the bridging effect and energy dispersion of the fibre mat, the TRC 2 specimen, which has two layers of AR-glass fibres, demonstrated notable gains in compressive strength of 32.18 N/mm² and flexural strength of 11.86 N/mm². The flexural strength of the TRC specimens and their ability to absorb energy increased as the number of textile layers increased. According to these findings, textile-reinforced concrete (TRC) reinforced with AR-glass fibres shows promise for usage needing a greater resilience to brittle failure, which makes it appropriate for a range of mechanical and structural applications.

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IZVOD

EKSPERIMENTALNO ISTRAŽIVANJE SAVOJNOG PONAŠANJA TEKSTILNO ARMIRANOG BETONA

*Beton ojačan staklenim vlaknima otpornim na alkalije (AR) pojavljuje se kao obećavajuća alternativa u modernoj konstrukciji , nudeći povećanu izdržljivost , fleksibilnost i strukturalni integritet. Ovaj rad daje eksperimentalno istraživanje i prednosti betona armiranog staklenim vlaknima AR u građevinarstvu. Istražuje svojstva i karakteristike performansi AR staklenih mrežastih vlakana, naglašavajući njihovu prirodu otpornu na alkalije i kompatibilnost sa betonskim matricama. Ovaj eksperimentalni rad koristi tekstilnu mrežu od staklenih vlakana od 145 gsm (grama na kvadrat po metru) otpornu na alkalije (AR). Prikazani su rezultati čvrstoće na savijanje i tlačne čvrstoće koji pokazuju praktičnu primenu i efikasnost betona armiranog staklenim vlaknima AR u različitim građevinskim projektima. Konačno, identifikovani su budući pravci i mogućnosti za dalje istraživanje i razvoj u ovoj oblasti, sa ciljem da se promoviše široko usvajanje tekstilno armiranog betona (TRC) kao održivog građevinskog materijala visokih performansi. Ovaj rad ima za cilj da analizira savijanje betonskih uzoraka ojačanih tekstilnim vlaknima , procenjujući njihove strukturne performanse , trajnost i uticaj na životnu sredinu . Za čvrstoću na savijanje TRC -a, utvrđeno je da 2 sloja AR staklene mreže postižu veću čvrstoću u poređenju sa jednos lojnim AR staklenim vlaknom . Razmatraju se strukturna poboljšanja koja obezbeđuje armiranje staklenim vlaknima AR u betonu, uključujući poboljšanu kontrolu pukotin**a**, čvrstoću na savijanje i izdržljivost u teškim uslovima.*

Ključne reči: *tekstilni armirani beton, AR staklena vlakna, čvrstoća na pritisak , čvrstoća na savijanje*

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