

Experimental study on mechanical properties of Textile Reinforced Concrete(TRC)

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Abstract. Textile-reinforced concrete (TRC) is a variant of reinforced concrete in which textiles are used in place of steel reinforcing bars. Reinforcing the concrete with steel means increasing its tensile strength, but steel also corrodes and wears out over time. The TRC is a novel idea that has the potential to overcome these drawbacks. TRC is a composite reinforcing material that is made from cement and has the benefits of being resistant to corrosion, having a high bearing capacity, and performing well in terms of its fracture limit. The principal function of TRC in buildings has been as reinforcement and as a means of enhancing the ductility and performance of concrete. This experimental work utilizes a 145 gsm (grams squared per meter) alkali-resistant (AR) glass fiber textile mesh. Specimens were cast with and without fibers, and the number of layers was increased from 1 to 3 at 25 mm spacing. In this experimental work, the mechanical behavior of TRC was investigated by conducting tests on its impact, compressive, and flexural strengths. From these results, the TRC specimen exhibits more flexibility than the control specimen. The TRC specimen bends under force and returns to a new position when the load is removed, indicating a good energy absorption capability. As a result, it infers that the specimen with fibre has the capacity to withstand a higher maximum load than conventional specimens. TRC has a greater fracture control system compared to conventional steel-reinforced concrete.

Keywords: *Textile reinforced concrete, compressive, flexural, and impact strength.*

1 Introduction

New building materials and technologies have made it more important to study long-lasting engineering structures that use fewer materials, are lighter, and have better economic benefits. The new method of embedding reinforcing fabrics into inorganic

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matrices makes it possible to make thin, strong structural parts. Textile-Reinforced Concrete (TRC) has recently emerged as a viable solution for reducing concrete usage and overall building weight by substituting glass fiber or an alkali matrix for steel. The most effective building material during the last century has been Reinforced Concrete (RC). Assembling concrete using steel reinforcement bars results in a nearly perfect composite. As a result of its superior performance, it has found widespread application in the building and bridge industries. However, RC is limited in requiring minimum in terms of requirements. Protecting steel bar reinforcing from corrosion requires a concrete cover of 20–70 mm per layer. Yet, TRC constructions are shown to be lighter, more elegant, and more efficient than RC structures. In the same way that RC has its benefits, TRC does as well, but it also provides some additional possibilities [1]. The optimal sizing and arrangement of fibre in concrete elements are achieved using a textile processing technique applied to various structures. With the use of TRC, we can make thin concrete that can withstand tremendous pressure. This method is a fantastic alternative for fixing concrete buildings. Fibre-reinforced concrete that has been reinforced with glass, carbon, or aramid textiles forms the binding matrix of textile-reinforced concrete. TRC is a multifaceted material with the following desirable characteristics: low weight, high tensile strength, great resistance to corrosion, and the ability to provide further corrosion protection for mostly concrete reinforcement with minimal layer thickness. TRC strength, which includes a reinforced fibre grid, can enhance performance in areas like binding or flexural strength, strength characteristics, torsion, rigidity, and axial twisting forces [3].

Because of its malleability, TRC can be formed into complex geometries using curves, including shells, columns, and others similar shapes. A very thin reinforcing layer can be manufactured as TRC does not require a concrete overlay. In comparison to the smaller surface area of steel reinforcing bars, the Glass fibre textile employed as reinforcement has a much larger surface area. As a result, glass fibre with extremely strong bond forces can be included in concrete; this fibre provides two indicators of its workability: first, a relatively short anchoring length, and second, a relatively dense fracture pattern. The glass fabric used to make TRC has a direct tensile strength that exceeds that of the conventional steel bars used in such structures. TRC can be used to resolve issues if its ultimate load is raised. The concrete's cracking can be mitigated by adding a TRC strength layer to an existing RC framework. Glass textile fiber mesh of 145 gsm is used as reinforcement for the steel replacement in this project. Flexural strength specimens were cast with and without fibers in the range of increasing the layers at various levels, as shown in the Fig 1.

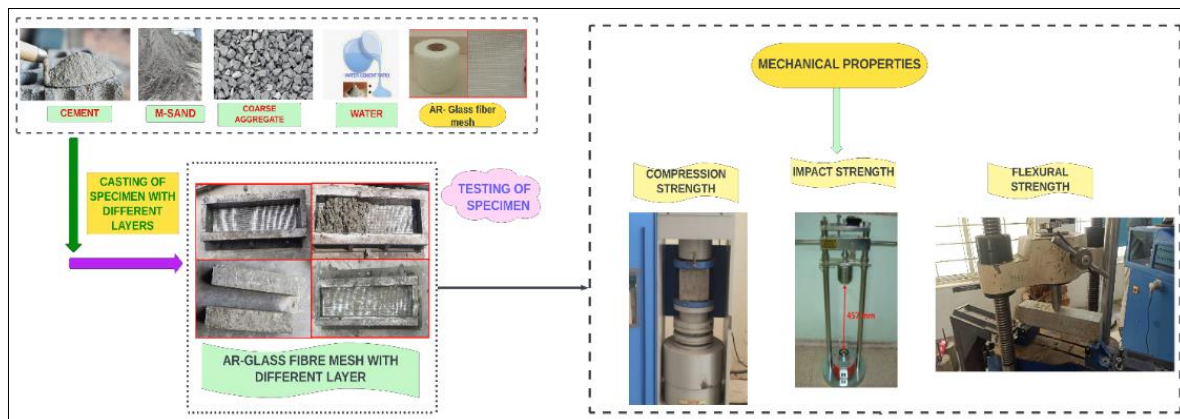


Fig. 1. Overview of TRC with AR-Glass fibre

Advantages of textile fiber:

- Structural reinforcement that is resistant to corrosion
- They are thin and light, and the surfaces are made of high-quality, fine-grained concrete that can be changed in color and texture.
- able to be removed when force is applied and is close to the surface of the component.
- Plastic shrinkage and drying shrinkage can be controlled, and the material is easy to make and can be designed in a lot of different ways.

So, the goal of this study is to try to find ways to use waste textile yarns as building materials in the construction industry and its overview of our work is shown in Figure 1. One possible use is fibre-reinforced composites in cement and concrete members, which is one of the things that this study will look at. Improves how well a structure performs under shock loads; offers real hope for resolving the waste disposal crisis.

2 Literature Review

In this study Portland cement (PC) substitution with metakaolin affects the mechanical performance of flax textile fibre-reinforced cementitious matrices. X-ray diffract and thermogravimetric analysis determined cementitious matrices as well as flax fibre composition, while three-point bending testing and Finite Element Analysis (FEA) examined textile reinforcing efficiency and its mechanical behaviour. High PC replacement with metakaolin created CH (Calcium Hydroxide) free atmosphere that prevented natural fibre deterioration and embrittlement and increased the cement-based composite material's ductility [2]. This work examined how short alkali-resistant glass fibres affect fine-grained concrete matrix mechanical characteristics. Four-point bending tests were also performed to assess carbon fibre textile-reinforced concrete sheet flexural performance. This study investigated 19 serial specimens, considering carbon fibre fabrics' short fibre lengths, content, and reinforcing ratio. The test findings showed that the small concrete composite had greater mechanical characteristics as fibre lengths and quantity increased. This study also found that carbon textile fibre content and reinforcing ratio improved CTCR bending strength and deformability. Short fibres improved CTCR sheet cracking load by 80.35%. The ultimate bending force increased more than six times compared to specimens without carbon fibre fabrics and short fibres [4]. Uses 145 GSM AR-Glass fibre mesh and the specimens were cast with and without fibres at 3, 4, and 5 fibre levels. Flexural beam strength was tested using 500mm×100mm×100mm beam mould cast beam specimens. Three fibre mesh beams and one PCC beam were cast. Three-point beam loading was used for testing. The Cementitious Matrix-Textile fibre mesh interaction was determined. TRC and conventional concrete are compared. The Modulus of Rupture for PCC is 7.75 N/mm², for AR-Glass Fibre 3 layer Mesh integrated in Cementitious Matrix it is 10.5 N/mm², for AR-Glass Fibre 4 layer Mesh embedded in Cementitious Matrix it is 13.25 N/mm², and for AR-Glass Fibre 5 layer Mesh embedded in Cementitious Matrix it is 11.5 N/mm². The beam reinforced with 4 layers of AR-Glass Fibre Mesh has a 70.6 percent higher flexural strength than conventional concrete [9].

Textile reinforcement like carbon strands is being used more in concrete components to improve their performance. Textile-reinforced concrete (TRC) is generally utilised for primary reinforcement. TRC member structural performance has not been studied. Hence, a large-scale experimental study was done to understand better TRC beam behaviour under bending force. TRC beams have similar tension, load-deflection, moment-curvature values to Steel Reinforced Concrete (SRC) beams. This study tested

four-point bending and tension strength. According to the findings, in contrast to the stress-strain behaviour seen in steel, the textile reinforcement does not exhibit any signs of yielding strain. TRC beams have different postcracking flexural behaviour than SRC beams. TRC beams have 56% higher moment capacity and 7 times higher tension stiffening than SRC beams. Given these observations, TRC beams behave differently from SRC beams [11]. Due to its mechanical properties, light weight, energy absorption, and extremely high strength under impact loads, TRF concrete is being used in many sectors. This study examined impact energy and initial strength of concrete using Forta, Basalt, and Barchip fibres under penetration impact loading. 16 single and hybrid specimens were tested to determine how fibre fraction affects impact attributes. The fracture surface and fiber-reinforced concrete adhesion with deterioration modes were assessed. Hybrid-fiber reinforced concrete had 45.3 and 49.7% higher overall strength and energy absorption than single-fiber concrete. The specimens' fracture surfaces showed that the Basalt and Forta fibres' adherence to the foundation concrete is good. The large spacing between Barchip fibres and concrete lowers their reinforcing efficacy [13].

3 Material Study

Cement: The cement that was utilised in this study was an ordinary Portland cement of grade 53 that was in accordance with IS 12269:1987. It is used in concrete to form the hydration products and also acts as a binding material.

Fine aggregate: M-sand was used as the fine aggregate, and water was added to improve the mix's hydration and strength. A significant influence on both the fresh and hardened properties of concrete can be attributed to the presence of aggregates, which account for 60–80 percent of the total concrete quantity. Fine aggregate constitutes approximately 15–30% of the total volume of aggregate, making up a small percentage of the overall aggregate composition. The diminishing availability of natural sand has opened the door to the idea of using artificial sands instead.

Coarse aggregate: The workability of the concrete mixture is significantly impacted by the coarse aggregates, namely the shape, proportion, and hardness of the coarse aggregate, as well as the quantity of fines present in the coarse aggregate. As a coarse aggregate, crushed stone with fractions of 2/6 millimetres is utilised.

AR-Glass fibre: The entire experimental investigation utilized a three-layer setup of a commercially available AR Glass textile mat is shown in Figure 1. Glasses that are resistant to alkalis are called Alkali-Resistant glass (AR Glass) and are made from non-metallic organic raw ingredients. The raw components are then melted at a temperature between 1250°C to 1350°C to create molten glass, which is then fabricated using a wet-spinning method [8]. Figure 1 shows that the AR-Glass Fibers, an alkali-resistant glass fibre mesh with a GSM (Grams per Square Meter) of 145, are produced using a glass composition with an optimal quantity of zirconium (ZrO_2) for usage in concrete. If the fibre has a higher zirconium concentration, it will be more resistant to alkaline corrosion. Stronger and more adaptable than traditional concrete, the inclusion of fibres results in exceptional tensile and mechanical strength. Glass-fiber products are strong and durable, able to withstand heavy usage without breaking or bending. Concrete shrinkage is minimized as a result, and it is really feasible. The BIS-10262(2019) method was adopted for obtaining M25- concrete mix proportion having slump of 25–50 mm with $w/c=0.45$. The water content for the reference

mix was found to be 186 kg/m³. Table 1 indicated the concrete mix proportion for M-25. In this study AR glass fibre incorporated for steel reinforcement with different layers and calculate the compression strength, split tensile strength and flexural behavior of concrete is represented in Fig 2.

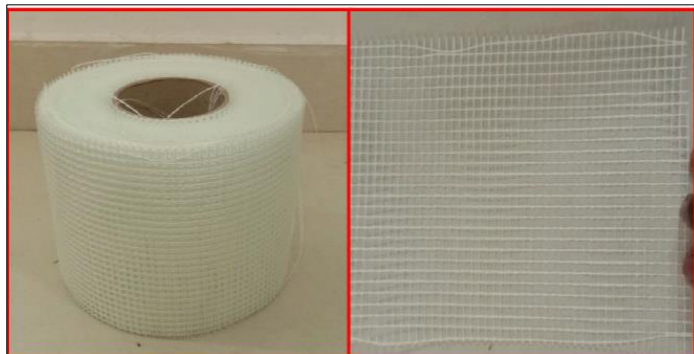


Fig 2: AR- Glass fibre mesh

Table 1: Concrete mix proportion

Component	Cement	Fine aggregate	Coarse aggregate	Water	w/c ratio
Content(kg/m ³)	413	657	1127	186	0.45

4 Mechanical properties

The purpose of this experiment was to investigate the effect that the presence of glass fibre reinforcement has on the compressive, impact, and flexural behaviours of concrete. The purpose of this study is to analyse the properties of AR-glass reinforced concrete (ARGFRC) after 7 and 28 days of curing in order to determine whether or not ARGFRC is suitable for use in the construction industry.

4.1 Compressive strength

As per codal provision (IS:516-1959-Compressive Strength of concrete) Representative samples of concrete shall be taken and used for casting cubes 15 cm x 15 cm x 15 cm with or without laying of AR-glass fibre in concrete. The concrete shall be filled into the moulds in layers approximate 25 cm deep. It would be distributed evenly and compacted either by vibration or by hand tamping. And each layer of AG-glass fibre is placed in the form of mat is perpendicular to the point of loading condition. After the top layer has been compacted, the surface of concrete shall be finished level with the top of the mould using a trowel; and covered with a plastic cover to prevent evaporation. After that, the samples shall be demoulded within 24 hours and stored in clean water at 27±2°C; until 28 days of curing. Finally the specimen tested in Compression Testing Machine and Failure load was observed is shown in Figure 3. Compressive strength of Control Specimen (CS) and ARGFRC specimen with different layers can be mentioned in Table 2.



Fig 3:Cube specimen for ARGFRC-layer 1.

4.2 Flexural Strength

The flexural strength of prisms was evaluated using a universal testing machine with a 1000 kN limit under three-point loading. Flexural testing equipment used in the study is shown in Figure 4, and the 500 mm x x 100 mm x 100 mm prism used for the study is shown in Figure 4. Enhancing the matrix's strength requires a reinforcement that is both tougher and stiffer compared to the matrix and susceptible of altering the composite's failure mechanism in an efficient manner. This means the composite should be as brittle as possible, with little or no ductility. Flexural strength is represented in Table 2. Fig 5 indicated the graphical representation of compression and flexural strength. Simultaneously Fibre hardening stage is clearly shown in Fig 6 as well as load vs deflection graph is taken from UTM(Universal Testing Machine).

$$\text{FlexuralStrength(N/mm}^2\text{)} = (3PL)/(2bd^2)$$

P-failureload(KN)

L-supportedlength(mm)

b-width of specimen(mm)

d-depth of specimen(mm)

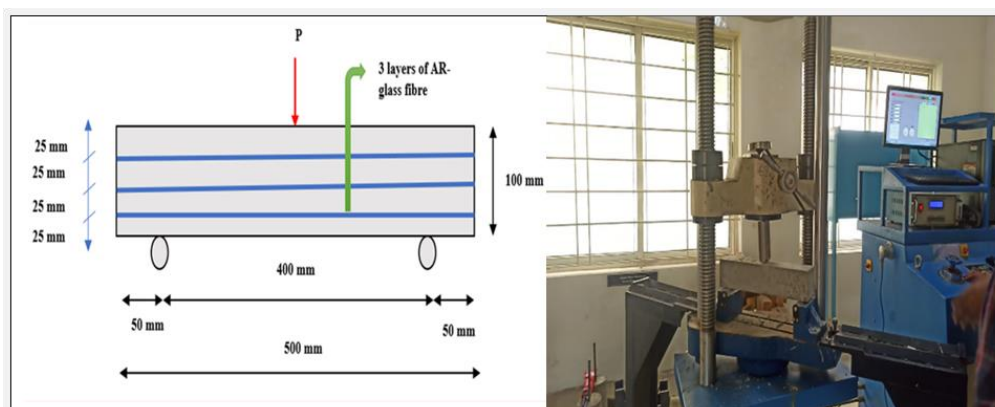


Fig4: Flexural testing for prism under three-point loading condition.

Table 2 : Compressive Strength and Flexural strength of CS and ARGFRC specimen

S.No	Specimen Name	28daysCompressive Strength(N/mm ²)	28days FlexuralStrength(N/mm ²)
1.	Control Specimen(CS)	24.5	24.5
2.	ARGFRC1-layer 1	23.32	23.32
3.	ARGFRC2-layer 2	22.98	22.98
4.	ARGFRC3-layer 3	21.17	21.17

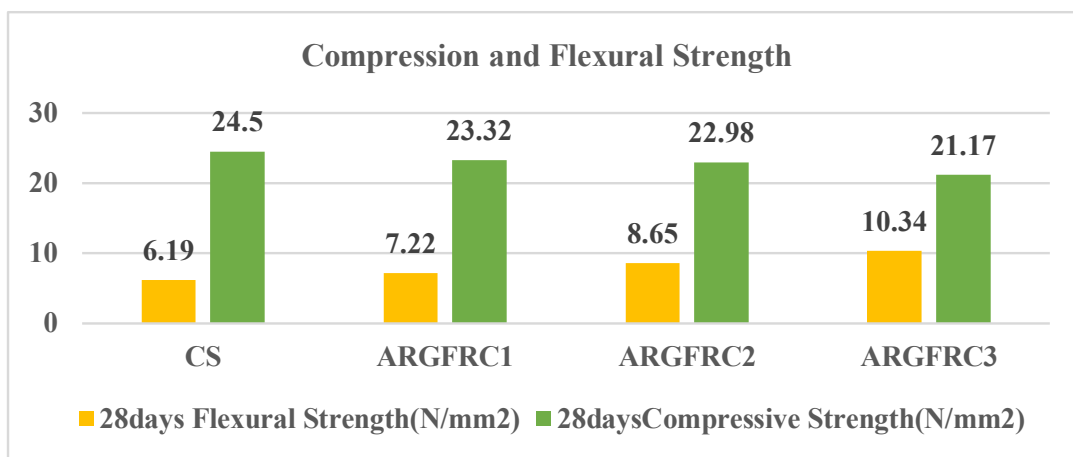


Fig 5: Graphical representation of Compression and Flexural strength test results

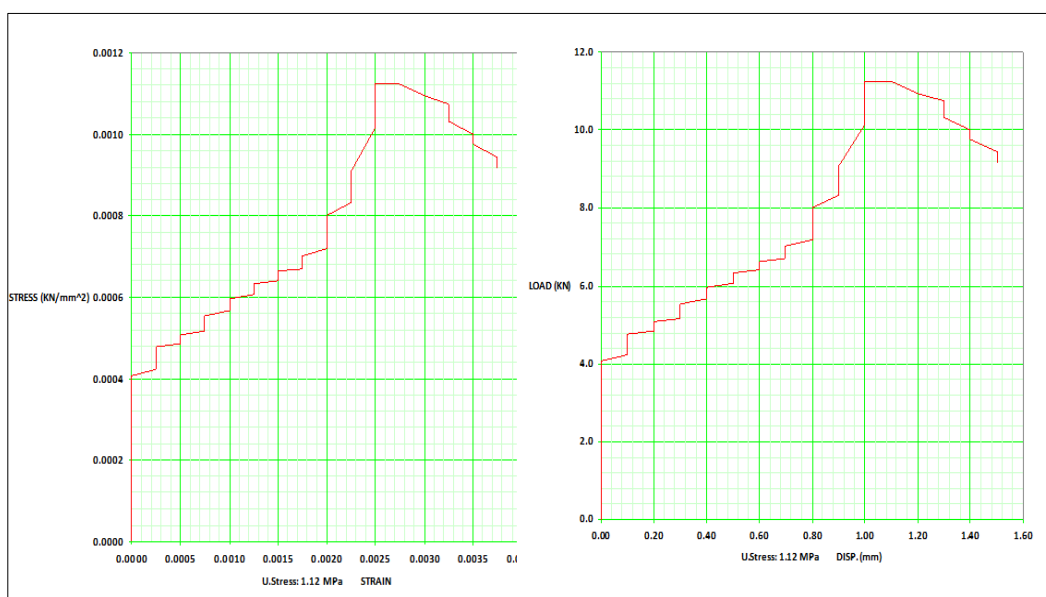


Fig 6: Flexural behaviour of Layer 3 -TRC(Stressvs Strain; Load vs Deflection)

4.3 Impact Strength

The concrete's ability to withstand impact was evaluated using a drop weight test. The impact study was carried out in accordance with the guidelines that were provided by ACI Committee 544. The test was performed by repeatedly hurling a hammer with a weight of 4.54 kilogrammes from a height of 500 millimetres onto a ball formed from hardened steel measuring 63.5 millimetres in diameter that was positioned on top of the mid of the cylinder disc. The impact energy generated by this apparatus is identical to that generated by the conventional drop weight testing apparatus. The first-crack impact force was measured by recording the number of blows that were required before a visible crack appeared on the disc (M1). After the initial crack has formed, the specimen is subjected to a series of hammer blows that are permitted to continue until the cracked disc is broken into pieces. Failure impact force was determined by recording the number of blows that were required to achieve the ultimate failure by contacting action (M2). Hence, the initial fracture impact resistance, denoted by M1, is contrasted with the failure impact resistance, denoted by M2, of concrete. The following equation determined the impact energy at initial crack and final failure as shown in Table 3.

- Wi - impact energy (Joule);
- Ni -number of strikes;
- m -weight of the steel hammer (4.5 kg),
- g - gravity (9.81 m/s²);
- h -falling height (500 mm); and
- i = 1, 2 represents the initial crack and final failure, respectively. (1 Joule=1 Newton metre(Nm)).

$$W_i = N_i m g h$$

Table 3: Impact Strength of CS and ARGFRC specimen

S.No	Specimen Name	Impact Strength(Joule)
1.	Control Specimen(CS)	22
2.	ARGFRC1-layer 1	24.78
3.	ARGFRC2-layer 2	25.87
4.	ARGFRC3-layer 3	27.11

5. Results and Conclusion

There are many types of textile fibre are present in the market The type of textile chosen as per our work, reinforcement and the composite materials, most of the textiles materials is AR-Glass fiber : It is used to making fibre concrete where contact are a make durable. In this only AR glass are used. This experimental investigation was aimed to lessen the risk of premature brittle fracture of concrete (by making use of AR-glass fibre), as well as to make use of materials like M-sand to evaluate the performance of concrete. Shows nearly insignificant decrease in compressive strength as a consequence of the existence of a connection between the concrete particles, which results in a reduced particle packing as compared to the CS specimen. This study looks at the effect of adding AR-Glass fibre to a

material to see if it may prevent it from breaking suddenly and brittlely. The volume of the concrete mix is then supplemented with alternating layers of AR-Glass fibre. Because of this, the flexural strength is significantly increased in comparison to the CS. Because of the bridging effect that fibre mat has when it is placed in 3 layers of prism in specimen ARGFRC3, the flexural strength of this material is 10.34 N/mm^2 . When placed in flexure, textile-reinforced concrete will be in a state where the crack widths are restricted, and typically high resistances can be attained. The drop mass hammer test is the final step in determining the impact strength of the specimen. This test involves counting the number of blows that are delivered to the specimen. The specimen ARGFRC3 has an impact strength of 27.11 J, which is the highest. Because it contains three layers of AR glass fibre, concrete will have a great capacity for absorbing and redistributing energy. As a result, one can draw the conclusion that encouraging the use of TRC concrete in mechanical applications is possible.

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