Bending Behaviour of Textile Reinforced Mortar (TRM) Plate

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Abstract

This research examined how several textile layers and fibre kinds, including AR-glass and basalt fibres, performed as reinforcement with mortar used to create plate specimens (TRM). TRM blends inorganic matrices, such as cement-based mortars, with sophisticated fibres in the form of textiles (open-mesh configurations). With two, four, and six textile reinforcement layers, a total of 14 specimens were cast. On a 100 kN MTS machine, three point bending tests were performed with a deformation rate of 1 mm/min, and four point bending tests were performed with a loading frame capacity of 5 tonnes. In comparison to AR-glass textile fibres, the basalt TRM specimen with six-layer textile fibres shown superior bending strength. While BTRM composite has demonstrated better ductility, the bending failure of AR-glass TRM specimens shows a brittle fracture.

Keywords: AR-glass, Basalt, Rectangular Plate, Flexural behaviour.

1.Introduction

Due to ageing, environmental damage, lack of maintenance, or the necessity to adhere to current design specifications for the length of their service lives, existing reinforced concrete (RC) structures need to be structurally retrofitted. Over the past two decades, engineers have increasingly used externally bonded composite materials, such as fiber-reinforced polymers (FRPs), as a retrofitting strategy. However, there are several limitations with the usage of FRPs that are typically associated with the use of epoxy resin, such as high cost, incapability to put on wet surfaces or at low ambient temperatures, low permeability to water vapour, and poor performance at high temperatures. Later, the structural engineering community gradually becomes interested in TRM. TRM is a low-cost, fire-resistant, and suitable substance for masonry and concrete substrates that can be used on wet surfaces or in colder temperatures. Due to all of these factors, employing TRM rather be the more often utilised fiber-reinforced polymers will become increasingly more appealing for strengthening existing concrete and masonry structures (FRPs).

Testing procedure for the uniaxial tensile characterization of FRCM [1] Advanced cement-based materials called Fabric Reinforced Cementitious Matrix (FRCM) composites are comprised of dry-fiber fabric embedded in an inorganic matrix and are intended to be retrofitted into masonry or concrete buildings. Two test setups were examined in order to determine the tensile behaviour features of this composite under various boundary circumstances. To get design parameters, a clevis grasp (pin action) was employed to replicate field boundary conditions from a typical installation. By causing a tensile failure in each of the constituent materials, a clamping grip was employed to characterise the composite completely. For the experiment, several FRCM systems made of various materials were employed, including polyparaphenylene benzobisoxazole (PBO), carbon, and glass, as well as carbon and glass that had been coated with an unique barrier. A type of reinforced concrete called textile-reinforced concrete (TRC) substitutes textiles or fibres for traditional reinforcement. The strong textile threads produce flexible and strong concrete structures. The literature has only covered TRC uses for nonstructural and retrofitting purposes. In order to clarify the evolving research direction on the use of TRC as a structural member, this article aims to: [2]. Test methods of textile reinforced mortar system. Tensile and bond behaviour of TRM were defined in [3]. In cementitious composite material called Textile Reinforced Concrete (TRC), a carbon or glass fabric is included as reinforcement. Because there are no corrosion issues, using TRC enables the construction of structures that are light and thin with decreased concrete covers and increased longevity. In this article, an experimental and theoretical inquiry is used to review the behaviour of TRC elements that have been subjected to tension. Compared to bare textile, the composite's failure load might be lower [4]. This study uses uniaxial tensile tests to look at the effects of the reinforcement ratio, steel fibre volume percentage, and prestressing on the uniaxial tensile behaviour of carbon textile reinforced mortar (CTRM). The findings indicate that while the reinforcement ratio increases the tensile strength of CTRM specimens, the textile-matrix bond strength weakens and debonding is possible. Short steel fibres can strengthen the textile-matrix bond and increase the mechanical characteristics of the entire CTRM composite, resulting in finer cracks with narrower spacing and smaller crack diameters [5]. The anchorage method, which was recently developed to enhance the tensile behaviour of the composite, served as the main parameter of the test specimens. This method involved spreading the ends of the fibre filaments, using steel rebars or glass fibre reinforced polymer tabs to reinforce the ends of the filaments, and coating the ends of the filaments with aluminium oxide powder. The majority of TRM specimens using developed anchorage methods showed ductile behaviour, according to the test results. Additionally, employing the established anchorage techniques could boost the composite specimens' peak strength and cracking strength to 66.1 and 97.9%, respectively [6]. State of the art review [7]. Flexural Behaviors ofConcrete/EPS-Foam/Glass-Fiber Composite Sandwich Panel [8]. In this study, the flexural behav- ior of TRM-strengthened beams was determined considering intermediate crack debonding occurred [9]. Flexural behaviour of TRC strengthened using carbon and glass fibres [10]. Recommendation of RILEM TC 232-TDT: test methods and design of textile reinforced concrete [11]. Tenile behaviour of basalt textile reinforced mortar (BTRM) [12]. Self-stressing concrete and textile were combined to create textile-reinforced self-stressing concrete, which increases concrete's crack resistance. Self-stresses can be established in the concrete matrix due to the confinement action of textile, greatly enhancing crack resistance [13]. Numerical modelling of RC beams repaired by TRC composites [14]. Textile reinforced mineral matrix composite beams' mechanical bending behaviour is examined. Unidirectional rovings and chopped strand mat are two types of E-glass fiber-based textile reinforcement that are taken into consideration (CSM). The mineral matrix has the benefit of not being alkaline and is an inorganic phosphate cement (IPC) [15]. TRC is especially suitable for quasi-static loading-subjected constructions that need reinforcement. Structures under impact can be strengthened most effectively with SHCC. High endurance of RC structures can be ensured by repair or reinforcing layers made of TRC or SHCC. Multiple tiny fissures and their ability to repair are crucial for the flow of liquids and gases into and through TRC and SHCC. The significant potential of TRC and SHCC for the rehabilitation of concrete structures is demonstrated by practical applications [16]. Non-linear analytical model of composites based on basalt textile reinforced mortar under uniaxial tension [17],[18]. Textile reinforced concrete multiscale mechanical modelling: Application to TRC sandwich panels [19]. The TRC efficiency ratios for rigidity are larger than those for strength under tension. To characterise TRCs, a new in-plane shear test was created. Compared to glass, TRC with aramid fibres exhibited significantly improved in-plane shear behaviour [20]. Tensile behaviour of BTRM [21] and effect of short dispersed glass and carbon fibres of TRC [22]. Bond between TRM and concrete [23].

2. Materials

2.1. Mortar

The mortar used was a ready-mix polymer mortar [9] with a w/p ratio of 0.24 to fulfill the plastic consistency of TRM. The compressive and tensile strength of the mortar were found using a cube and cylinder size of 70.6x70.6x70.6mm and 100x200mm respectively. The average Compressive strength of the mortar at 28 days was 45 N/mm^2 and average tensile strength was 4.5 N/mm^2.

Table 1 Mechanical properties of mortar.

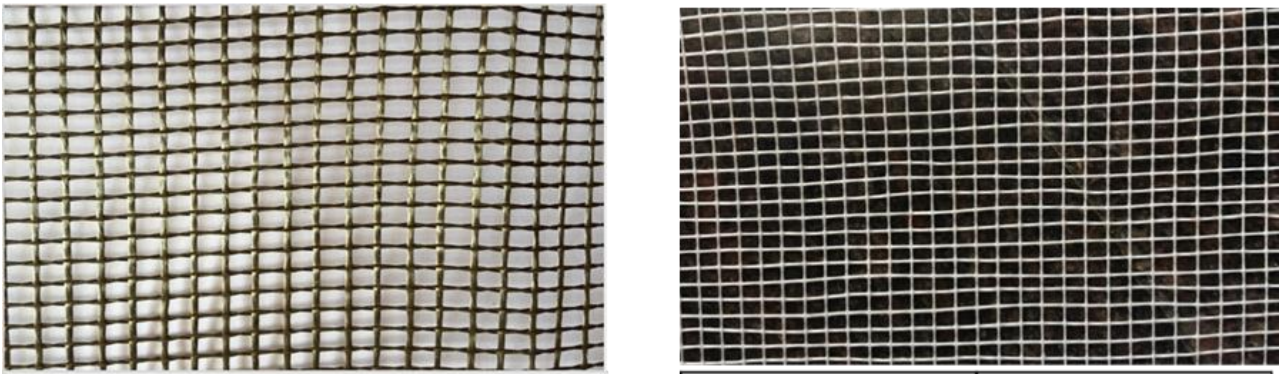
Compressive strength @ 28 days	45 N/mm^2
Tensile strength @ 28 days	4.5 N/mm^2
Flexure strength @ 28 days	8 N/mm^2
Bond strength @ 28 days	11 N/mm^2

Figure 1 Failure of (a) mortar cubes, (b) mortar cylinder.

2.2. Basalt and AR-glass textile fibers

Textile made of roving fibres in the warp and weft directions with a mesh size of 5x5mm made of glass and basalt. The textile fibre mesh inside the plate specimen serves as interior reinforcement. The manufacturing process's disclosure of the mechanical properties of textile fibre in the form of a product data sheet in

Figure **2**.



Material	Coated basalt fibre
Mesh size(mm)	5mmx5mm
Thickness	0.6mm
Weight	220 g/m^2

Material	AR-glass fibre
Mesh size(mm)	5mmx5mm
Thickness	0.3mm
Weight	145 g/m^2

Figure 2 Textile used in this study; (a) coated basalt fibre, (b) AR-Glass fibre.

3. Preparation of specimen and Test method

3.1 Preparation of specimen

The TRM plate has a thickness of 10 mm, and the samples with 2, 4, and 6 textile layers serve as an internal reinforcement while the samples without textile layers have the same thickness. Two separate fabrics, basalt and AR-glass textile fibres, used as internal reinforcement. TRM plate has two textile layers; the mortar between the top and bottom layers is 3.5 mm thick, and the layers in between are 3 mm thick. TRM plate is reinforced with four textile layers, and the top, bottom, and middle mortar layers are all 2 mm thick. The mortar thickness in TRM with six textile layers is 1 mm between layers and 2.5 mm on top and bottom.

The process for preparing TRM plates began with the application of a mortar layer of the proper thickness, followed by the placement of the textile layers on top of the mortar layer and gentle hand pressing to ensure mortar impregnation (Figure 3). Apply a second mortar coat after that. The identical process was carried out once more using multiple textile layers. The final layer of fabric was smoothed and covered with a final coating of mortar of the proper thickness before being left in the mould for 24 hours. Then, after a total of 28 days of curing, all of the plates were taken out.

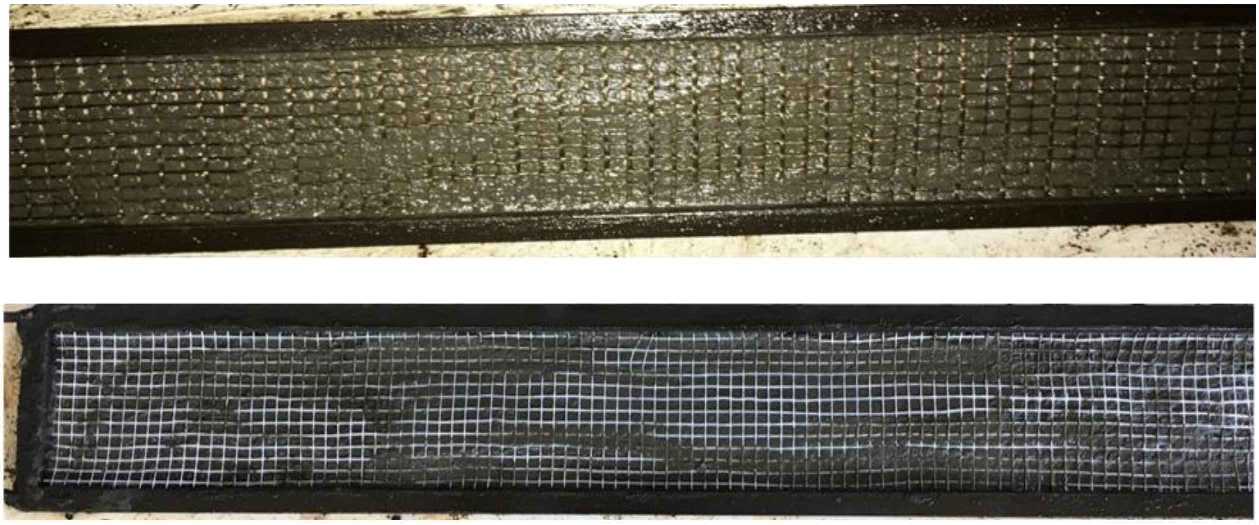


Figure 3. Specimen preparation

The impact of various textile layers (two, four, and six) and various textile materials (basalt and AR-glass) on the tensile and flexural behaviour of TRM plates were among the study's parameters Figure 4. To determine uniaxial tensile strength TRM plates were 500mm (length) x 60mm (width) x 10mm (thickness) (recommendation of RHILEM standards) [11] and the results are tabulated in

Table 2. Uniaxial tensile tests on TRM plates were conducted using a MTS machine with a loading capacity of 100 kN and a controlled deformation rate of 1 mm/min. The gauge length was 200 mm. The RILEM Standard 2016 [11] governs the test and specimen size. At both ends of the plate, additional strength in two layers was added to prevent crushing failure at the gripping region. Metallic clamps were used to apply the load, and forces versus displacement were measured. To measure the elongation, LVDTs were positioned. A graph of stress against strain was drawn; stress is determined as force divided by the cross-sectional area of the specimen (10 mm x 60 mm). The displacement in relation to the gauge length is known as strain.

Table 2 Test results of uniaxial tensile.

s.no	Specimens	Ultimate load N	Ultimate tensile stress (N/mm^2)
1	Plain mortar	800	1.34
2	GT2	1225	2.04
3	BT2	1975	3.3
4	GT4	2500	4.17
5	BT4	3700	6.17
6	GT6	3800	6.34
7	BT6	5600	9.34

To determine the flexural strength, three- and four-point bending tests were conducted. The dimensions were 600mm in length, 60mm in breadth, and 10mm (thickness). After three-point bending, the plate's length was 300 mm, making it ideal for machinery installations. There were 14 specimens in total. The TRM plate specimens are set up as follows: B3F2, B3F4, B3F6, G3F2, G3F4, G3F6, B4F2, B4F4, B4F6, G4F2, G4F4, G4F6 and plain mortar. B-basalt, G-glass, 3, 4, and 6 layers, as well as 3F-3 and 4F-4 Point Flexures.

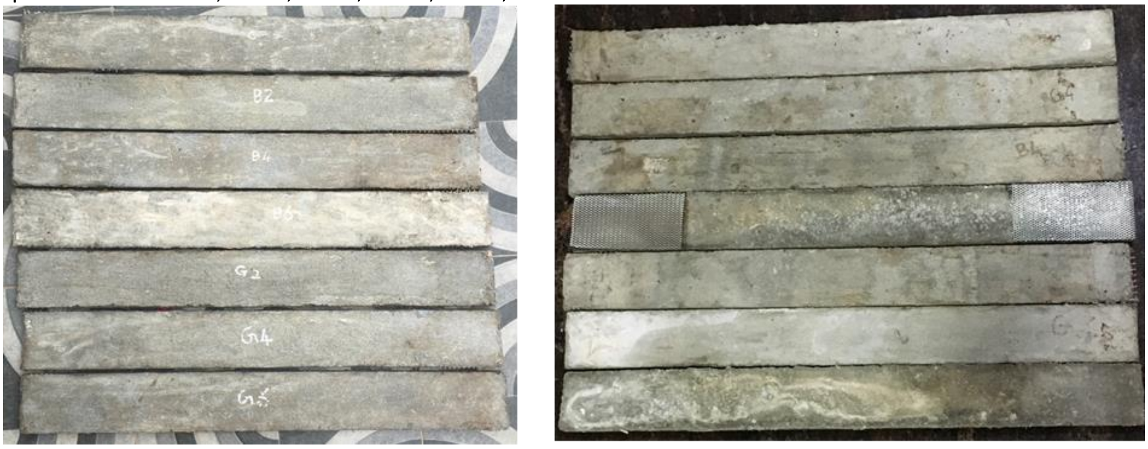


Figure 4. TRM Flexure specimen.

3.2 Test Method

Flexure test on TRM plate

Three-point bending was carried out using an MTS machine with a 100 kN loading capacity, a simply supported center-point load, and a 50 mm bearing. Using the loading frame, a four-point bending test was performed with simply supported two-point loads at a distance of length/3 and a bearing of 50 mm in Figure 5. The load was manually applied, and a dial gauge was used to measure the load and deflection.

Figure 5 Test set-up; (a) three point flexure, (b) four point flexure.

4. Results and discussion

Flexure test

To enable rotation, the loading and support points were pinned. M/Z calculated the three-point bending test's flexural strength. Simply supported with a center-point load has a WL/4 bending moment (Nmm) in Figure 7

Table 3; Where Z is the section modulus. The flexural strength in four-point bending was determined using Pl/bd2. P stands for the specimen's maximum load, l for its effective length, and b and d for the plate specimens' width and depth Table 4. After reaching ultimate stress, the glass TRM plate failed in pure bending with a brittle fracture, whereas the basalt TRM plate exhibits ductile behaviour without completely rupturing the textile reinforcement. Basalt cloth had a higher moment carrying capacity and bending stiffness. Additionally stronger is basalt reinforced with two layers of textile. Overall, the basalt reinforcement performs better in terms of bending strength Figure 9.

Table 3 Test results of three-point flexure test

Specimen	Ultimate Load N	Ultimate moment (M) Nmm	Flexural strength N/mm^2	Capacity increase %
Plain mortar	100	7500	7.5	-
G3F2	125	9375	9.375	25
B3F2	150	11250	11.25	50
G3F4	225	16875	16.875	125
B3F4	325	24375	24.375	225
G3F6	300	22500	22.50	200
B3F6	550	41250	41.25	450

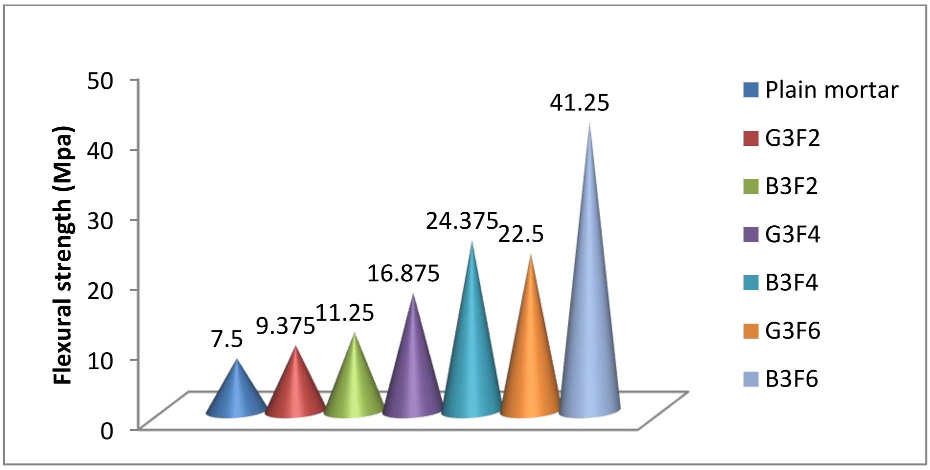
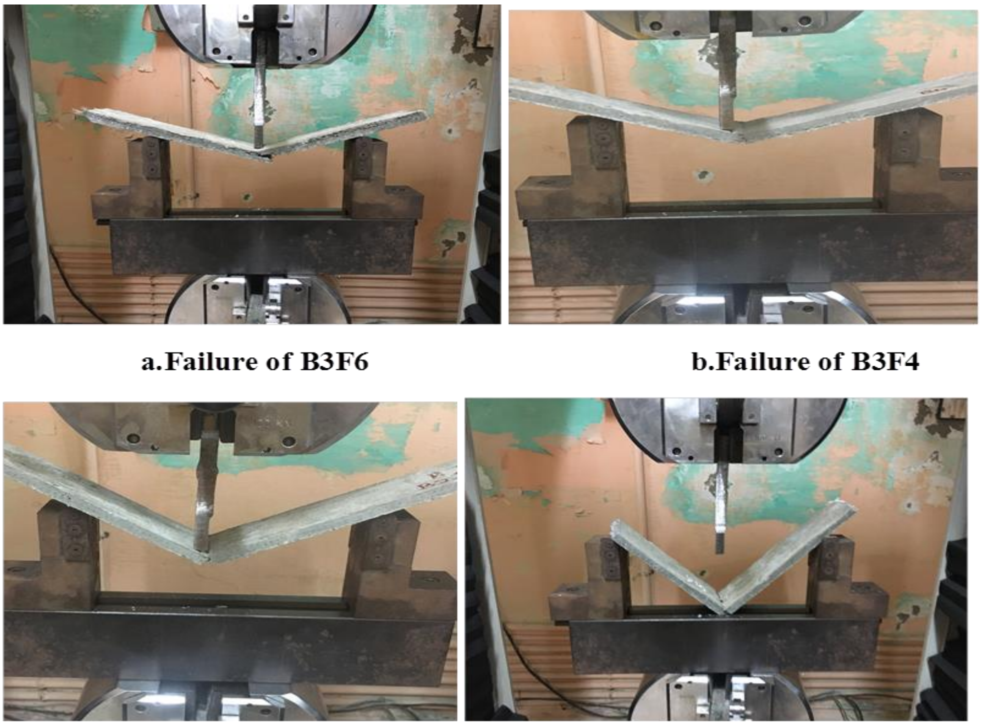


Figure 6 Comparison of test results (3-point bending)



a.Failure of B3F6 b.Failure of B3F4

c.Failure of B3F2 d.Failure of G3F6

Figure 7. Three point flexure test failure specimens.

Table 4 Four- point flexure test results

Specimen	Ultimate Load N	Ultimate moment (M) N.mm	Flexural strength N/mm²	Capacity increase %
Plain mortar	98.10	490.5	8.175	-
G4F2	125	62500	10.41	27.33
B4F2	147.15	73575	12.26	49.96
G4F4	196.2	98100	16.35	100
B4F4	294.30	147150	24.52	199.9
G4F6	343.35	171675	28.62	250
B4F6	490.50	245250	40.875	400

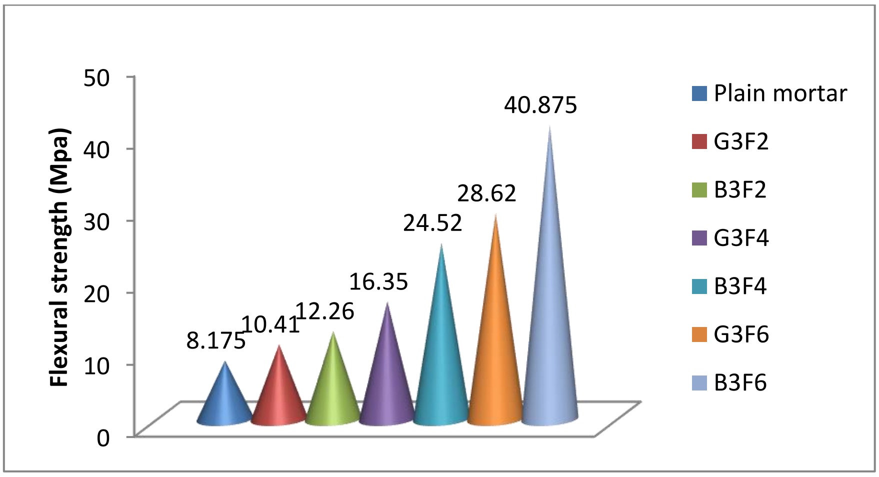


Figure 8 Comparison of test results (4-point bending)


Figure 9. Four point flexure test failure specimens.

5. Conclusion

TRM mixes modern textile fibre with mortars made of inorganic cement. It is necessary to ascertain the mechanical properties of textile fibre and mortar in order to employ TRM as a novel construction and strengthening material for structural retrofitting of structural components. Plate specimens reinforced with textile layers were developed in order to learn more about their characteristics. From the current investigation, the following conclusions were made: A new category of composite materials called textile-reinforced mortars (TRM) offer better flexure and tensile strength qualities including

The volume percent of the fibres, as well as the number of textile layers and kind of fibre, are the main determinants of TRM strength. The vertical strands known as the warp in the textile fiber's weft filament yarn are what bear the majority of the tensile load during testing. The flexure load is mostly supported by the weft of the horizontal strands. The strength is also influenced by the warp and weft volume fraction and the number of textile layers; B3F2 and G3F2 are less effective than four and six layers. In comparison to unreinforced mortar, the capacity gain in G3F6 was 200%, while in B3F6, it was doubled (450%). Glass with six layers exhibits better strain-hardening reactions and bending strength with more stiffness than basalt with six and four layers. TRM plate with two layers of textile shows a reduced amount of reinforcement effectiveness.

The flexure strength of both AR glass and Basalt textile showed better performance. The moment-carrying capacity of basalt is higher when compared with AR glass. When the ultimate load is reached, the failure of basalt textile exhibits a ductile response and that of glass exhibits a brittle failure. This demonstrates the use of TRM as an encouraging technique for constructing and strengthening structures.

The stated result is based on two different types of textile fibre materials and a small number of tests. To raise the level of trust in the results, additional research is needed, including on various types of textile fibres that would have the same volume fraction of fibres.

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