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UNI-AXIAL TENSILE BEHAVIOUR OF TEXTILE REINFORCED MORTAR (TRM)

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Abstract

Objectives: This study based on the performance of textile fibres as reinforcement in variations of textile layers and fibre types such as AR-glass and basalt fibres on the uni-axial tensile behaviour of plate specimens using textile reinforced mortar (TRM). TRM combines advanced fibres in the form of textiles (open-mesh configurations) with inorganic matrices, such as cement-based mortars. **Methods:** To test their capabilities, plate specimens with textile reinforcement layers were made. A total of 14 specimens were cast with reinforcement layers of two, four, and six textile layers. The tests were carried out on a 100 kN MTS machine with a deformation rate of 1 mm/min**. Findings:** The volume percentage of the fibres and the number of textile layers, specifically, have a significant impact on the uniaxial tensile behaviour. The TRM specimen with basalt six-layer textile fibres showed better strain-hardening behaviour than AR-glass textile fibers. When compared to unreinforced mortar, the capacity gain in GT6 was 200%; in BT6, it was treble that (450%). **Novelty:** TRM is a modern building and strengthening material for retrofitting structural elements. TRMs, a new class of composite materials, are used because they have excellent tensile strength properties.

Keywords: AR-glass, Basalt, Rectangular Plate, Tensile behaviour, TRM.

1 Introduction

Existing reinforced concrete (RC) structures require structural retrofitting due to deterioration caused by ageing, environmental degradation, and a lack of maintenance, or the need to meet current design requirements for the duration of their service lives. Over the last two decades, the use of externally bonded composite materials such as fiber-reinforced polymers (FRPs) has become a common retrofitting technique usually employed by engineers. However, some drawbacks have been observed with the use of FRPs, which are generally related to the use of epoxy resin, including high cost, inability to apply on wet surfaces or at low ambient temperatures, low permeability to water vapor, and poor behaviour at high temperatures. Later, TRM progressively attracts the interest of the structural engineering community. TRM combines advanced fibres in the form of textiles (open-mesh configurations) with inorganic matrices, such as cement-based mortars. TRM is a low-cost, fire-resistant, and compatible material for concrete and masonry substrates that can be applied on wet surfaces or at low temperatures. For all these reasons, using TRM will progressively become more attractive for the strengthening of existing concrete and masonry structures than the widely used fiber-reinforced polymers (FRPs).

The research gap is that, despite the fact that diverse tensile responses showed that TRM strengthening thickness was not at a minimal level, this study only took a 10mm thick plate with two distinct fibres into account.

1.1 REVIEW OF LITERATURE

This section presents the thorough analysis of the literature pertinent to the ongoing research. Tensile, bond and the use of TRM for flexure, shear, confinement and seismic retrofitting of concrete structures (1). The TRM beams showed sufficient efficiency in the service load and yield stages (2). The polymer modified cementitious mortar with glass fibres enhanced strength and ductility than other types of mortar. Coating of textiles with epoxy improved ultimate load by 25% than uncoated specimens (3). The tensile response of textile reinforced concrete is performed by two types of fibres are carbon and glass fibre as embedded as reinforcement (4). The effects of the reinforcement ratio, volume fraction of steel fibers, and prestressing on the uniaxial tensile behavior of carbon textile reinforced mortar (CTRM) through uniaxial tensile tests (5). This study aims to investigate the behaviour of textile fibres by conducting a uniaxial tensile and flexural test and type of fibre used were AR-glass and basalt fibre as reinforcement in the plate specimen with variation in textile layers. When fabrics or fibres are used in place of conventional reinforcement. The strong textile fibres produce flexible and strong concrete structures. (6).

2 Methodology

2.1 Mortar

To meet the plastic consistency of TRM, a ready-mix polymer mortar with a w/p ratio of 0.24 was used as the mortar. The mortar's compressive and tensile strengths were measured using cubes and cylinders with respective dimensions of 70.6x70.6x70.6mm and 100x200mm. The mechanical properties of the mortar as in

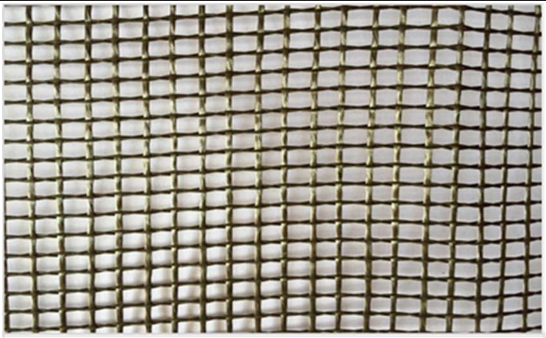
Table 1. The failure of the specimens in Figure 1.

Table 1 ***Mechanical properties of mortar***

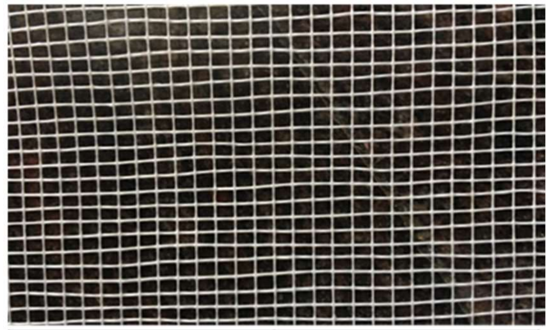
Compressive strength @ 28 days	45 N/mm^2
Tensile strength @ 28 days	4.5 N/mm^2

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

2.2 Basalt and AR-glass textile fibers



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***

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.

2.3 Preparation of specimen and Test method

2.3.1 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.

Application of a mortar layer of the proper thickness, placement of the textile layers, and gentle hand pressing to ensure proper mortar impregnation were the first steps in the preparation of TRM plates. 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 levelled 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).

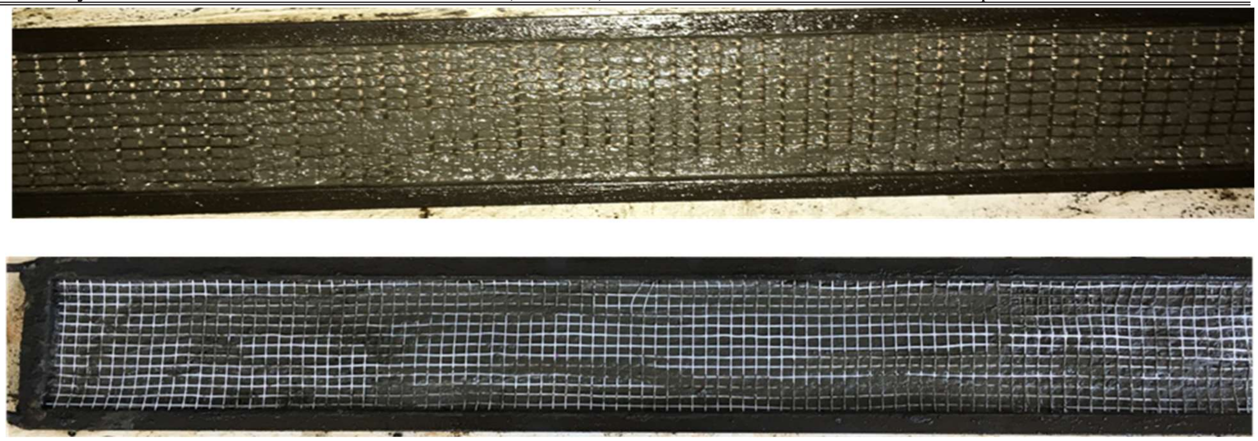


Figure 3. Specimen preparation

The considered parameters of this study comprise the effects of different textile layers (two, four, and six) and different textile materials (basalt and AR-glass) on the tensile behaviour of TRM plates Figure 4. TRM plates were 500mm (length) x 60mm (width) x 10mm (thickness) to determine uniaxial tensile strength (recommendation of RHILEM standards) (7). A total of 14 specimens, for each configuration two specimens were prepared and average of test results were used for calculations.

The configuration of TRM plate specimens is as follows: Plain mortar, BT2, BT4, BT6, GT2, GT4, and GT6. B-basalt, G-glass, T indicates tensile test; 2, 4, and 6 were numbers of internal reinforcement textile layers.

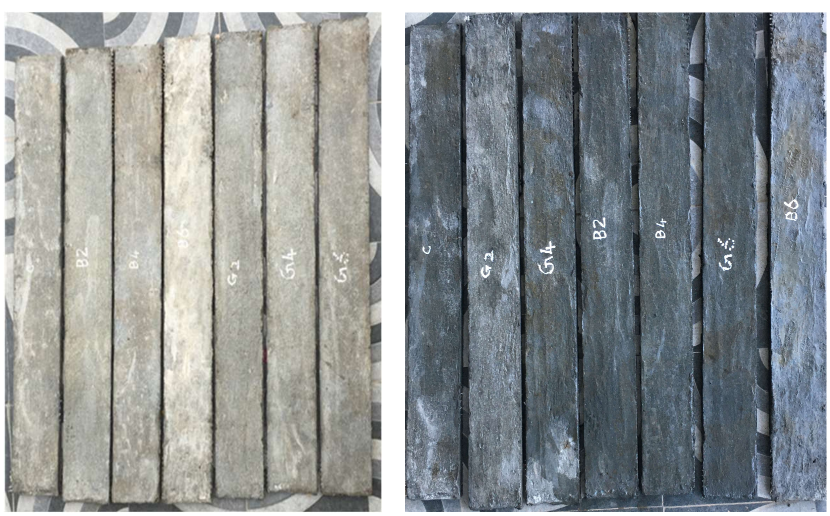


Figure 4. ***TRM Tensile specimens***

2.3.2 Test Method

Uniaxial test on TRM plate:

Using an MTS machine with a loading capacity of 100 kN and a controlled deformation rate of 1 mm/min, uniaxial tensile tests on TRM plates were performed. The gripping length on both sides was 125 mm, and the gauge length was 200 mm.

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 The RILEM Standard 2016 (7) governs the test and specimen size

Figure 5. ***Uniaxial tensile test set-up.***

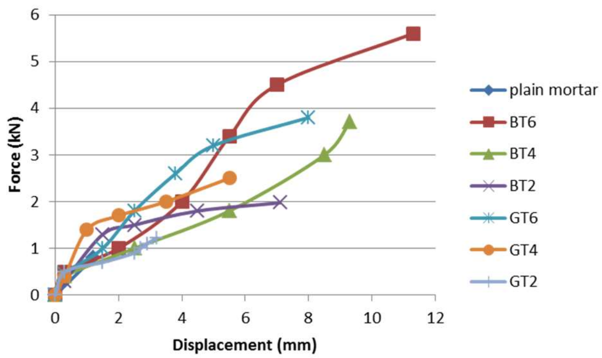
3 Results and discussion

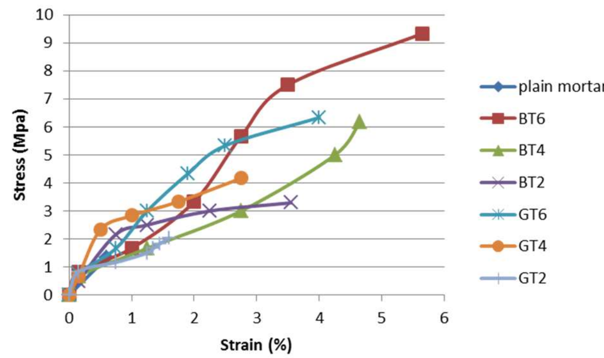
3.1 Uniaxial Tensile test

3.1.1 Influence of textile layers

The uniaxial tensile results (average) for TRM specimens are shown in

Table 2. Ultimate tensile stress was calculated by ultimate load with cross sectional area (width x depth) specimen. The stress-strain curve of tensile specimen as shown in





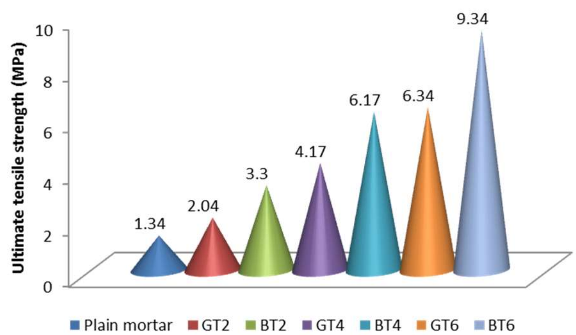


Figure 6. Load, displacement, elongation value from the graph of the test results and elongation % was calculated using gauge length (200 mm) of the specimen. It shows the tensile strength of TRM depends on the number of textile layers. In a plain mortar (unreinforced) specimen, the curves are linear up to the ultimate stress, after which sudden brittle failure occurs. The failure of the TRM specimens shows three stages

Figure 7 Figure 8.

The mortar mostly bears the load during the first stage until it starts to break. The second stage begins with a multicracking method after this pre-cracking phase, when the stress is supported by mortar and fibre. In the third step, just the fibres support the weight; this property of textile fibres serves as a standard. As the number of layers increases, the response transitions from softening to trilinear to bilinear (5).

Specimens with basalt textile as reinforcement show greater strain-hardening behaviour. The GT2 specimen has multiple cracks but did not undergo more crack-widening than the BT2. BT4 and BT6 show an optimistic effect in stage III; thus, crack widening becomes larger and the strain-hardening effect shows better tensile characteristics with higher stiffness. The crack-widening in the BT2 specimen occurs simultaneously with increasing stress, rather than sequentially. GT4 and GT6 have higher tensile strengths than GT2, and the number of layers reduces first crack stress.

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Except plain mortar, all the TRM plates exhibit ductile response that means do not break the textile fibres when ultimate load achieved. BT4, BT6, GT6 specimen, the width of crack is more with greater ductility.

3.1.2 Effect on Type of Fiber

The TRM plate employed coated basalt fibre and AR-glass fibre for reinforcement. The property of textile reinforcement, which is primarily dependent on the number of layers and volume fraction of the textile, is clearly seen in stage III's strain-hardening zone. As a result, basalt fibre outperforms glass textiles in terms of tensile performance. Along with fibre type, coating and reinforcing ratio also have an impact on strength.

Table 2 ***Average test results of uniaxial tensile.***

s.no	Specimens	Ultimate load N	Max Disp mm	Strain (elongation) %	Ultimate tensile stress (N/mm^2)
1	Plain mortar	800	1.2	0.6	1.34
2	GT2	1225	3.2	1.6	2.04
3	BT2	1975	7.1	3.55	3.3
4	GT4	2500	5.5	2.75	4.17
5	BT4	3700	9.3	4.65	6.17
6	GT6	3800	8.0	4.0	6.34
7	BT6	5600	11.3	5.65	9.34

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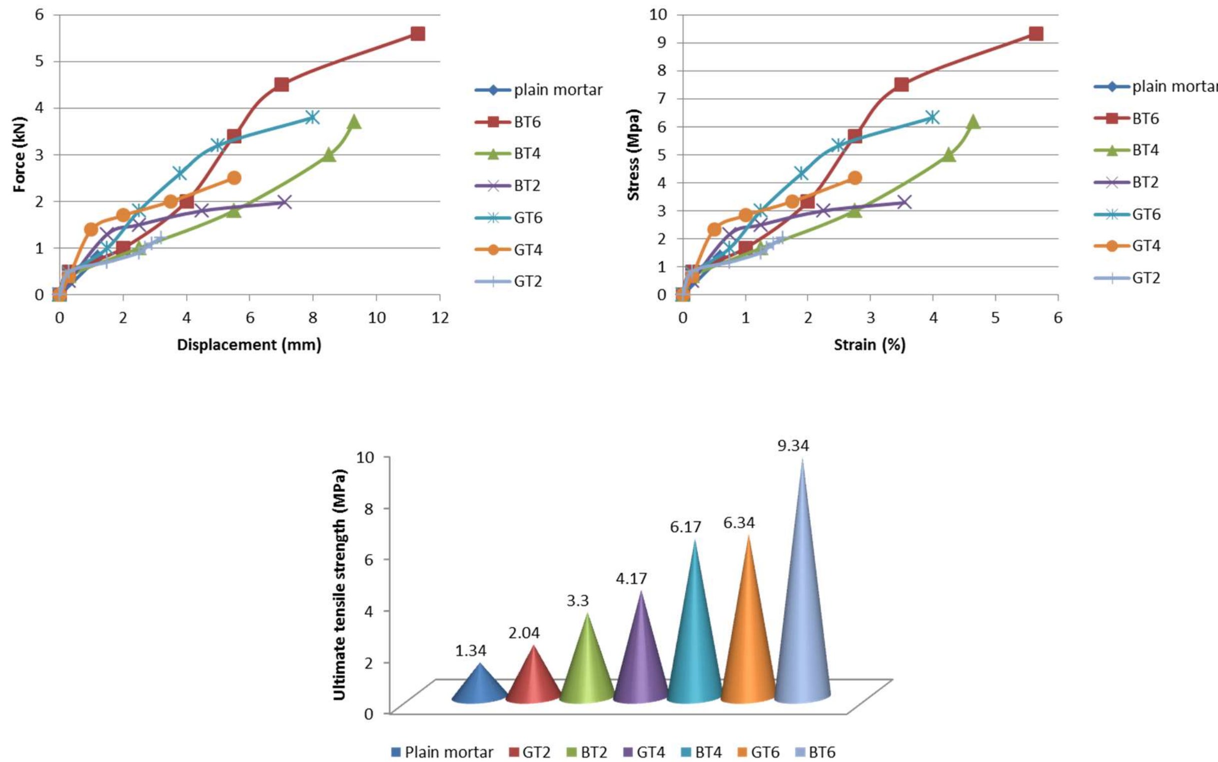

Figure 6. ***(a) Force Vs Displacement, (b) Stress Vs Strain, (c) Comparison of ultimate tensile strength.***

Figure 7. ***Failure of TRM tensile specimens.***

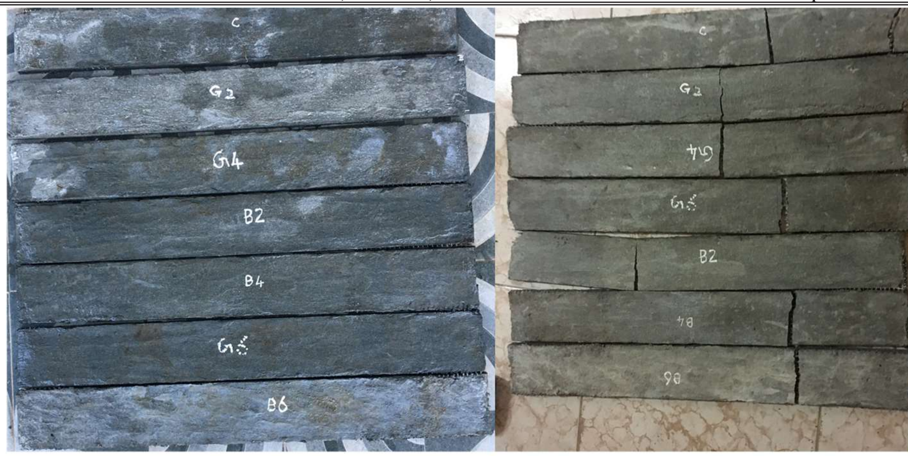

Figure 8. ***Specimen; (a) before test, (b) failure after test.***

4 Conclusions

TRM mixes inorganic cement-based mortars with advanced textile fibres. The mechanical properties of textile fibre and mortar must be established in order to reliably employ TRM as a novel construction and strengthening material for structural retrofitting of structural components. Plate specimens reinforced with textile layers were created to test their qualities. The results of the current investigation led to the following conclusions: The usage of textile-reinforced mortars (TRM), a new generation of composite materials, offers tensile strength characteristics like,

The uniaxial tensile behaviour primarily depends on the number of textile layers and type of fiber, particularly the volume fraction of the fibres. The textile fibre has warped and weft filament yarn, the vertical strands mentioned as warp, it majorly takes the tensile load while testing. The horizontal fibers, as weft, primarily take the flexure load.

Besides warp and weft volume fraction, the strength depends on the number of textile layers; BT2 and GT2 exhibit less efficiency than four and six layers. In GT6, the capacity increase was 200% compared to unreinforced mortar, and that increased by double (450% in BT6). BT6, GT6, and BT4 show better strain-hardening responses. BT6 demonstrates a higher elongation of 5.65%.

Novelty: This study shows the basalt textile reinforcement experiences greater ductility. TRM plate with two layers of textile shows less reinforcement efficiency.

Recommendation: The above-mentioned conclusion is based on a limited number of tests and two types of textile fibre materials. More research is required, including on different types of textile materials that would have the same volume fraction of fibers, to increase the level of confidence in the obtained results.

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