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EXPERIMENTAL ASSESSMENT OF TRC CYLINDRICAL TUBE-SHAPED UNITS

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The purpose of this study is to investigate the behavior of tube-shaped TRC ductility experimentally via monotonic loading. Ar-Glass and PVA as textile materials are used in the production of composite tube parts. These parts were tested in four and six layers and in different thicknesses. As a result of the mortar thickness, textile layers play the major role in ductility and strength. As the tube thickness increases, the strength increases, but the ductility decreases. However, ductility increases as the tube thickness decreases and the energy absorption increase by making the parts more flexible. This paper analyzes how much ductile the 10 cm long tube can be under pressure and tensile forces. The use of different textile materials, different thicknesses, and different numbers of textile layers has been examined. According to the test results, it is concluded that cylindrical tube shaped units produced by using PVA fabric material is more ductile than units produced by using Ar-Glass fabric material. Also, with the wall or slab elements or pipeline obtained by using these units, the structure system can be strengthened against earthquake loads.

Keywords: TRC composite, Ductile, Flexural behavior, Tube/pipe-shaped system, Fabric, Strength.

1 INTRODUCTION

The development of high strength and ductile composite materials in seismic areas has become a major research subject in recent years. These types of materials have experienced high strength and displacement capacity under compression and tension loadings. One of the most widely used composite materials is textile-reinforced concrete (TRC), which consists of a fine-grained concrete matrix and high-strength textile fabric reinforcement made of alkali-resistant glass fibers or polyvinyl alcohol (PVA) fibers. TRC can be used as a structural element in addition to being used generally as structural strengthening material such as fiber reinforced polymer (FRP). The combination of fabrics and fine-grained concrete, which in fact resembles more a mortar than a concrete, allows architects and engineers to design thin and lightweight structures, characterized by a high load-bearing capacity. The main advantages of this material are related to its durability and strength performance since no cover against corrosion is required, while it is also possible to align fibres with the load direction (Colombo *et al.* 2013, Mobasher 2012). Structural elements made of TRC material show much more ductile behavior because of the high form flexibility of the textile reinforcement (Pakravan *et al.* 2016). In order to increase ductility and flexibility, cylindrical tube form was chosen, and experimental studies have been associated with it. Understanding the link between the basic damage effects in the material structure (matrix cracks, debonding, etc.) and the corresponding shape of the load-deflection curve is essential for the targeted design of the composite material structure (Chudoba *et al.* 2016). This paper investigates the behavior of ductility under the compression and tensile forces of the structural components of the cement-based textile composite tube-shaped units with different thicknesses and layers. The behavior of large-scale shell structures can be predicted with the investigated TRC members (Sharei *et al.* 2017).

2 EXPERIMENTAL STUDIES

2.1 Specimen Production

One-meter-long cylindrical tube specimens are produced using a PPR (Pull Pour Roll) method, a new method similar to the winding method (Figure 1). The production is carried out by this method, which has less production effort than the "hand laying method". The samples are obtained by pulling and wrapping the fabric material according to the desired strength without applying any heat treatment for the molding process (Daskiran 2018).

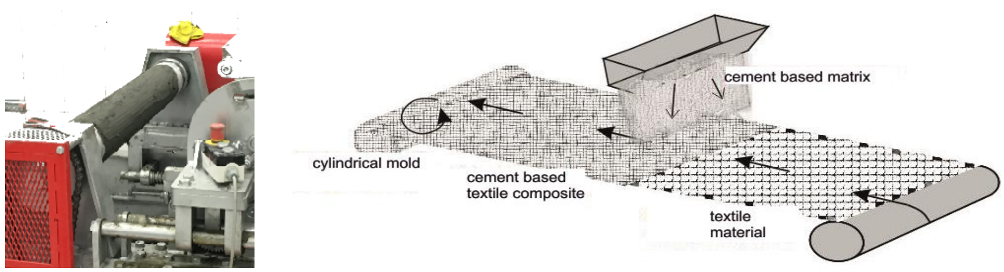

Figure 1. Production setup - PPR method.

Ar-Glass and PVA, as textile materials, are chosen in the production of composite tube parts. These parts were produced in 4 and 6 layers, with various thicknesses. As a result of that, the textile layers and the thickness of mortar plays the major role on ductility and strength. These parts were cut into 10 cm pieces. Thus, the cylindrical tube-shaped test specimens are obtained (Figure 2).

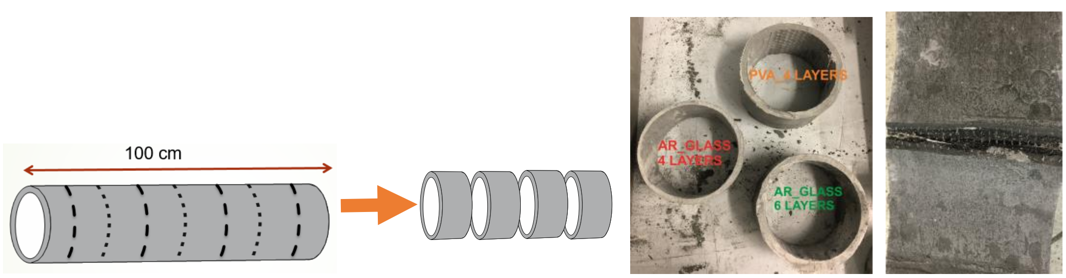

Figure 2. Cement based textile composite tube-shaped units.

The energy absorption capacity is the main parameter for deciding the shape and used materials. Therefore, the cylindrical tube shape is chosen for the experimental investigation. PVA as a textile material is more ductile than Ar-Glass, but the strength of PVA is less than Ar-Glass. TRC specimens are produced by using both PVA and Ar-Glass and polymer-containing cement matrix. The properties of the units are shown in Table 1.

Table 1. Properties of the TRC cross-section.

Description	Length (mm)	Thickness (mm) (average)	Cross Section Diameter (mm)	Number of Textile Layers
Ar_Glass 4 Layer	100	8-10	150	4
Ar_Glass 6 Layer	100	18	150	6
PVA 4 Layer	100	15	150	4

2.2 Compression Test Setup

The load vs. displacement relationship of cylindrical tube-shaped specimens under monotonic loading is investigated by using a servo-hydraulic jack. MTS brand loading jack with 600 kN capacity, located in the ITU construction materials laboratory, is used for this purpose. The load is applied with a displacement-controlled setup. Loading rate for all the tests is 2 mm/min. A sample of compression loading test setup is shown in Figure 3.

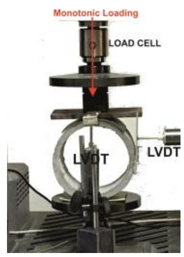

Figure 3. Compression test setup - MTS machine.

Three samples for each type of specimens are tested, which are Ar_Glass 4 Layer, Ar_Glass 6 Layer, and PVA 4 Layer. Two LVDTs for vertical and horizontal directions are used for measurements. It is intended to measure the displacement capacities in orthogonal directions.

2.3 Tensile Test Setup

Special head brackets for the tensile tests were prepared and the tensile test was applied to three specimens of each unit (Ar_Glass 4 Layer, Ar_Glass 6 Layer, and PVA 4 Layer).

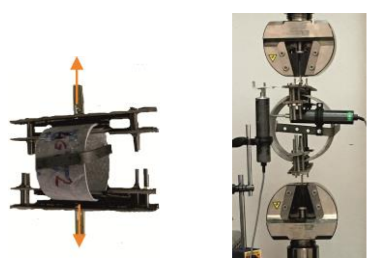

Figure 4. Tensile test setup - MTS machine.

Load-displacement relationships were investigated by applying monotonic tensile loading to specimens. It is expected that the load-displacement curves and maximum load capacities are similar to the load-displacement curves and load capacities obtained by the compression test. The test setup and LVDT placements for tensile loadings are shown in Figure 4.

3 COMPARISON OF TEST RESULTS

Three specimens of each unit (Ar_Glass 4 Layer, Ar_Glass 6 Layer, and PVA 4 Layer) were subjected to compression and tensile tests. Then the load-deflection curves and load bearing capacities are determined with the average of the results. In Figure 5, it can be deduced that TRC tube cracking pattern has a staggered shape in load vs displacement curves. The averages of three samples are shown in red in Figure 5. The testing materials with their experimental setups are shown on the graphs as well.

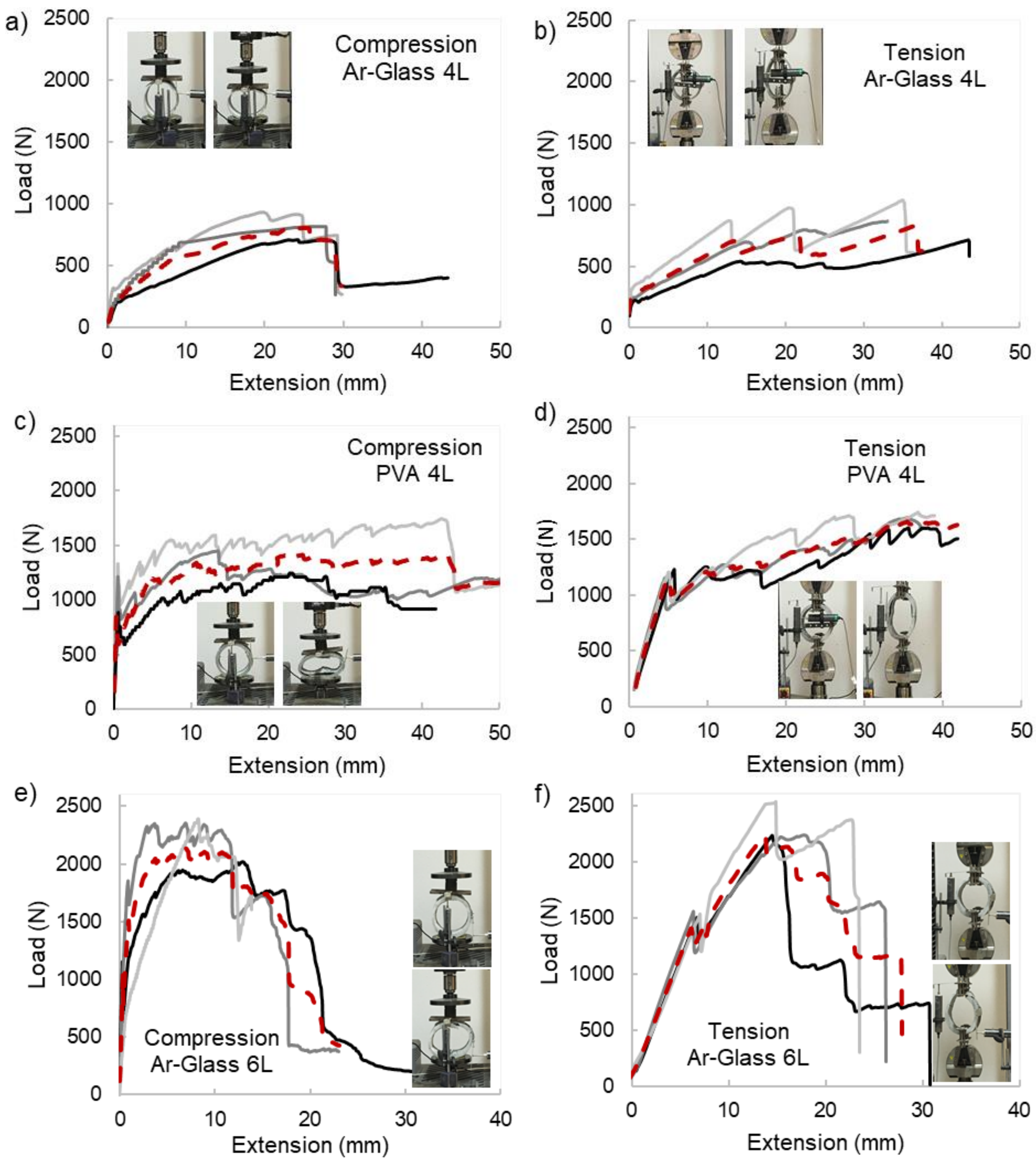

Figure 5. Compression and tensile load (N) –deflection (mm) curves.

The load-bearing capacity of 4 layered cement based PVA textile composites is measured as 1400N while the load bearing capacity of 4-layer Ar-glass textile composites is around 800 ~ 1000N. The strength of the cement-based 6-layer Ar-glass textile composite is about 2150N. When the number of cement-based Ar-glass textile composites increases from four to six, the load capacity doubles and the displacement decreases. The cement-based Ar-glass 6L cylindrical textile composite units have less ductility and consume less energy than Ar-glass 4L. The initial crack of PVA 4L cylindrical textile composite is exhibited at around 1000N load. Delamination of layers in the PVA reinforced TRC specimens is the main observed failure type. On the other hand, Ar-Glass 4L and 6L cylindrical textile composite specimens mainly exhibit transverse cracking. As the number of layers (or thickness) increases, the brittleness increases, and the displacement capacity drops sharply. The ultimate load and displacement forms are similar for compression and tension tests as expected. Table 2 shows the maximum loads and displacements under tension and compression experiments.

Table 2. Experimental results of the cylindrical tube shaped TRC units.

Description	**The Average Ultimate Compression Load (N)**	**The Average Ultimate Compression Deflection (mm)**	**The Average Ultimate Tensile Load (N)**	**The Average Ultimate Tensile Deflection (mm)**
Ar_Glass 4 Layer	800 ~ 1000	29	800 ~ 1000	35~40
Ar_Glass 6 Layer	2100~ 2300	20	2200~ 2500	28
PVA 4 Layer	1500	50	1800	45

4 CONCLUSIONS

In this paper, the experimental results of the textile reinforced concrete cylindrical tube-shaped specimens are presented. The load-bearing behavior of TRC is influenced by material, amount and orientation of the textile reinforcement and the fine concrete matrix. It has been observed that the strength of the Ar-Glass is high and that the 4-layer cement-based Ar-Glass textile composite behaves in sufficient ductility. The mesh spacing of Ar-Glass is higher than the PVA textiles. This feature provides great convenience during production. Moreover, the cement-based mortar of Ar-Glass TRC provides better adherence with the Ar-Glass textile than PVA material. Compression and tension tests result in textile-mortar delamination of TRC produced by using PVA textile material. In this content, TRC produced by using PVA textile material can absorb high strain energy. However, the ductility of TRC produced by using Ar-Glass textile material depends on layer number. If the number of layers increases, ductility, and deflection of TRC produced by using Ar-Glass textile material decreases. Moreover, the failure modes of the specimens change from delamination type to flexural failure with an increasing number of textile layers (Du *et al.* 2018).

In addition, the cylindrical tube-shaped form is effective in strengthening structural elements. In addition, this form provides system flexibility. By using tube-shaped TRC members, high energy absorbent slab or wall elements can be produced. Also, ductility and resistance of load-bearing structures against seismic loads can be increased.

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