TENSILE STRENGTH OF TEXTILE WASTE COMPOSITE

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Abstract- The increasing numbers of textile waste in Malaysia are alarming when in 2018 approximately 195300 tonnes of textile waste were dumped and occupied about 6.3% of the landfills. Textiles made of synthetic fibers such as nylon, lycra, polyvinyl chloride, polyurethane, and spandex could be detrimental to the environment and take up to 200 years to decompose in landfills. The tensile strength of the textile could achieve up to 800 MPa and potentially be used as retrofitting materials. This study aims to utilize textile waste as one of the structural retrofitting materials with specific objective to determine the tensile strength of two types of textile waste (cotton and nylon) layered with epoxy namely textile waste composite (TWC). The tensile strength of TWC of with different layers (1 layer, 2 layers, and 3 layers) was determined by conducting a tensile test. The TWC of nylon textile showed better strength than cotton textile with tensile stress value up to 17.9 MPa. This material is possible for low-cost concrete retrofitting materials options in improving or restoring the capacity of structures.

Keywords- Cotton, nylon, sustainability, textile waste composite, tensile strength.

1 Introduction

In 2018, Malaysia recorded 195,300 tonnes of textile waste that constituted about 6.3% of the total waste in landfills [1]. Over 60% of the dumped textile was composed of synthetic materials which take decades up to 200 years to decompose. Synthetic textiles like polyester, nylon, and acrylic are derived from petrochemicals and are known for their durability and resistance to wrinkles and moisture. However, the non-biodegradable nature of the synthetic textiles poses environmental challenges due to difficulty to breaking down the fibers [2]. On the other hand, the hydrophobic feature of synthetic fibers and could achieve up to 830 MPa of tensile strength makes this material a promising candidate to be incorporated into building construction materials [3].

Utilization of textile waste in engineering field has been explored and showed promising outcomes [4], [5], [6], [7]. Combination of cotton, polyester mixed waste and natural rubber successfully developed sustainable sound insulation material where the acoustic performance was comparable to commercially sound insulation panels [4]. It was reported that the addition of waste woven polypropylene fiber and textile mesh in the production of gypsum board showed post-peak behavior improvement and lead to a more ductile material which can be used for sustainable finishes in construction [5]. Kamble and Behera [6] employed cotton fibres to produce hybrid composite with significant improvement of tensile, flexural and impact strength which can be replaced the low and medium-cost timber in building materials.

A common building material for most infrastructure and building construction is concrete. Concrete is a strong and durable, yet long service might cause concrete deterioration that can affect the ultimate capacity of the concrete elements. Thus, concrete retrofitting is necessary to at least restore the structural capacity. Concrete retrofitting refers to the process of enhancing or upgrading existing concrete structures to improve their performance, durability, safety, or functionality using various techniques such as fiber reinforcement, external post tensioning, and base isolation. Typical structural retrofitting work is using steel due to its high tensile strength. However, the drawback of steel is the risk of rust when exposed to water. This could lead to poor strength and appearance. Fiber reinforced polymers are other options due to excellent performance and easy installation for the retrofitting work, yet the cost has become a concern [8].

Thus, this study was carried out by utilizing textile waste and epoxy as retrofitting materials which were later known as textile waste composite (TWC). This paper presents a part of the study that provides information on tensile strength of two types of textiles.

2 Research Methodology

2.1 Sample preparation and testing

Two types of textiles were used to prepare the samples, i.e., cotton (T) and nylon (N) for tensile testing. A total number of 24 samples consisting of control sample (C), one layer (1-L), two layers (2-L) and three layers (3-L). For the 1-L, 2-L and 3-L samples, the textiles were layered with epoxy. Figure 1 shows the arrangement of the TWC samples. All the sample were cut into dog-bone shape (see Figure 2) as recommended by ASTM E8 [9]. The TWC samples were air cured up to 72 hours prior to the testing. The tensile test was conducted according to the ASTM E8 [9] using universal testing machine (UTM). The displacement of the samples was measured using linear variable displacement transducer (LVDT).

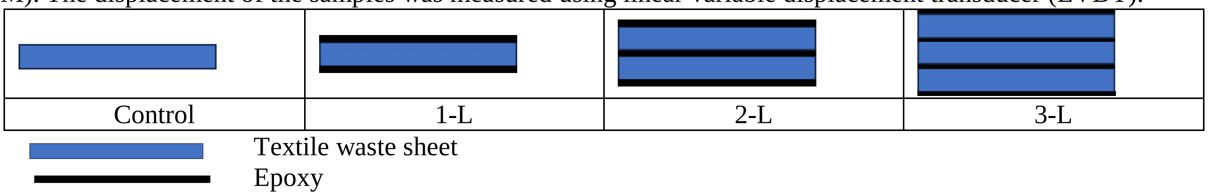

Figure 1: TWC sample arrangement

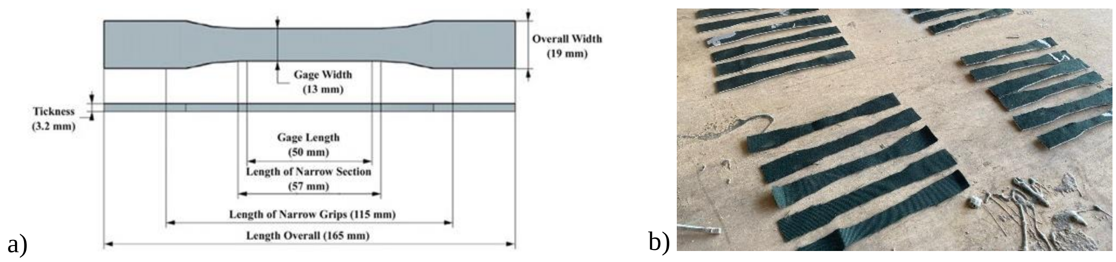

Figure 2: Dog-bone shape, a. dimension, and b. TWC sample

3 Results

3.1 Mode of failure of TWC samples

From the observation, the samples showed three different failure mode which can be classified as textile failure (TXF), epoxy failure (EXF) or total failure (AF) (see Figure 3). The TXF failure occurred on TWC sample when the textile tears into two parts due to gradual loss of load carrying capacity. The control sample for both types of textiles (CT and CN) and 2-LT sample exhibit the TXF failure. The EXF failure was observed on 1-LT sample when the layer of epoxy failed first. The remaining samples for both cotton and nylon (coated and uncoated) showed AF failure when both textile and epoxy break together.

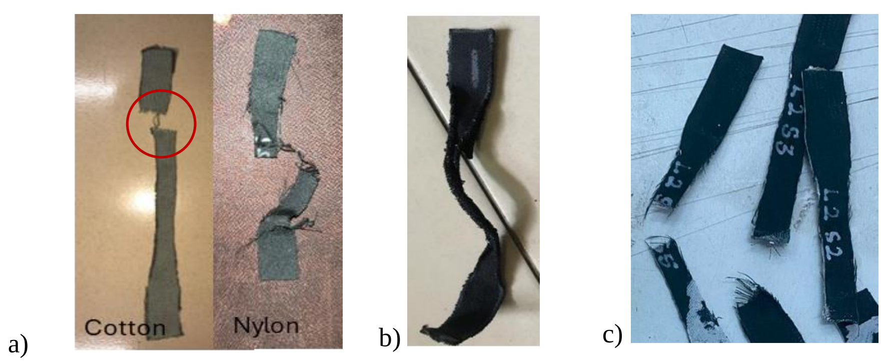

Figure 3: Mode of failure of TWC samples, a. textile failure (TXF), b. epoxy failure (EXF), c. total failure (AF)

3.2 Load-displacement curve

Figure 4 shows load-displacement curve of TWC samples. In general, all the TWC samples show ductility pattern with elongation before failure. The strength of TWC samples increased with increment of textile layer for both cotton and nylon samples. It can be observed that uncoated nylon has higher tensile strength with maximum loading of 240.7 N while uncoated cotton sample only achieved about 54.6 N. All the nylon samples show higher maximum load when compared to the cotton samples with the highest maximum tensile load of approximately 1100 N for the 3-LN sample. This suggest that the 3-LN sample has better ductility and might be used for application that requires high strength and flexibility. All the cotton samples experienced large elongation more than 60 mm when compared to the nylon samples.

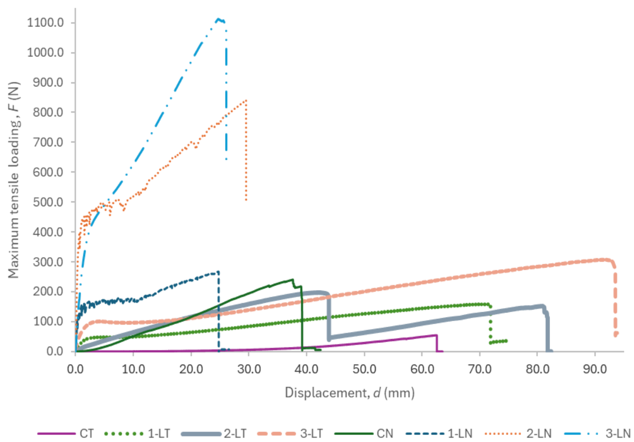

Figure 4: Load-displacement curve of TWC samples

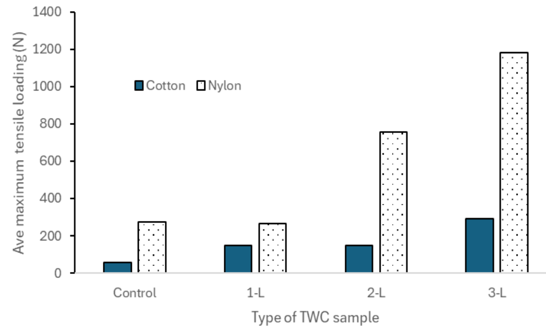

Figure 5: Maximum tensile loading of the TWC samples

3.3 Tensile strength of TWC samples

Tensile test results of the TWC samples are summarized in Table 1. All nylon textile samples showed higher tensile strength value when compared to cotton textile samples (see Figure 5). It was predicted since the nylon textile is categorized as synthetic fibre which has long strands and hydrogen bonds with strong intermolecular forces while cotton textile composed of cellulose which has a weaker bond [10]. For both cotton and nylon textile samples, 3-L samples exhibit the highest maximum tensile loading with value of 291.5 N and 1183.3 N, respectively. The presence of epoxy assists in strength and stress improvement of the TWC with a positive linear pattern can be observed for both types of TWC textile. For the cotton textile, the strength of 2-LT sample slightly reduces to 30% that might be resulted from inadequate bond intact between the textile and epoxy.

Table 1 Summary of tensile test of TWC samples

Sample	**Uncoated/ Coated**	**n**	**Types of failure**	**Average maximum tensile loading (N)**	**COV (%)**	**Average Tensile stress at break (MPa)**	**COV (%)**
CT	uncoated	3	TXF	55.9	15	0.5	20
1-LT	coated		EXF	148.8	10	6.4	9
2-LT			TXF	147.5	23	3.8	11
3-LT			AF	291.5	11	7.4	6
CN	uncoated		TXF	273.3	34	0.1	23
1-LN	coated		AF	263.3	13	0.2	30
2-LN			AF	756.7	10	12.4	10
3-LN			AF	1183.3	4	17.9	8

Note: **n** = number of tested samples; **COV** = Coefficient of variation

4 Application

The retrofitting procedure is performed on deteriorated structures with the aim of restoring the load-carrying capacity of the structural elements. Fibre-reinforced polymer is currently a favorable material to be used for retrofitting since it does not only restore the capacity but also improves the performance of the structures, yet the cost becomes a concern. This study was carried out as a pilot to utilize textile waste as a potential material for non-structural or/and structural retrofitting purposes. Further research on the application of the TWC is suggested on small scale beam or panel with various methods of retrofitting installation such as TWC wrapping or near surface mounted.

5 Conclusion

A pilot study was carried out to unleash the potential of textile waste to be utilized as structural retrofitting materials. Cotton and nylon textile waste were layered with epoxy resin to produce TWC retrofitting materials and undergo tensile strength tests. It can be inferred that:

1. The use of epoxy assists in tensile strength improvement for both cotton and nylon TWC samples.
2. TWC of nylon showed better performance when compared to cotton due to strong bond molecules formation of the nylon textile.
3. The highest tensile strength for both cotton and nylon textile were obtained from 3-L TWC samples with maximum load increments up to 400% compared to the control sample.

Further investigation on the development of the TWC material using different textiles and epoxy is required.

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