

Investigations of the mechanical properties of bi-layer and tri-layer fiber reinforced composites

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Abstract. Natural fibers are renewable raw materials with an environmental-friendly properties and they are recyclable. The mechanical properties of bi-layer and tri-layer thermoset polymer composites have been analyzed. The bi-layer composite consists of basalt and jute mats, while the tri-layer composite consists of basalt fiber, jute fiber and glass fiber mats. In both cases, the epoxy resin was used as the matrix and PTFE as a filler in the composites. The developed tri-layer natural fiber composite can be used in various industrial applications such as automobile parts, construction and manufacturing. Furthermore, it also can be adopted in aircraft interior decoration and designed body parts. Flexural, impact, tensile, compression, shear and hardness tests, together with density measurement, were conducted to study the mechanical properties of both bi-layer and tri-layer composites. From the comparison, the tri-layer composite was found to perform in a better way in all tests.

1. Introduction

In the past few years, contemporary researchers who are working on finding sustainable solutions have focused their attention to the natural fiber-reinforced polymer composites. This situation is due to the attractive features of the natural fiber-reinforced polymer composites including light weight, low cost, moderate strength, high specific modulus, lack of health hazards, renewable and also environmentally friendly. Composite materials are defined as the structural materials that are created synthetically or artificially by combining two or more materials having dissimilar characteristics at macroscopic level [1]. Natural fiber-based composites have diverse and varied applications in aircraft, spacecraft, ships, submarines, trucks, rail vehicles, automobiles, civil engineering structures, packaging and also storage devices among others [2]. Though many studies have been conducted in which several widely used conventional materials were substituted in engineering applications with natural fiber components, there is still only a few studies done on mechanical properties of tri-layer epoxy filled composites [3-5]. Therefore, this present work has been undertaken to develop reinforced matrix composites using basalt, jute and glass fibers with epoxy resin as the matrix and to study their mechanical properties such as the tensile strength, flexural and impact strength in comparison to the bi-layer fiber reinforced composites.



2. Methodology

The methodology that was adopted in investigating the mechanical properties of bi-layer and tri-layer fiber reinforced composites is depicted in Figure 1. Fabrication and testing of the composite materials for mechanical properties in manufacturing had been selected as the main goal of this research work. A brief literature survey was conducted to investigate the research studies carried out with the focus on the mechanical properties of the composite materials. The lack of information in the previous research works in this domain were identified and used to define the research problem. The thrust activities in development of composite materials were identified for the study and subsequently, experiments were conducted. The results obtained were then analyzed to draw the conclusions.

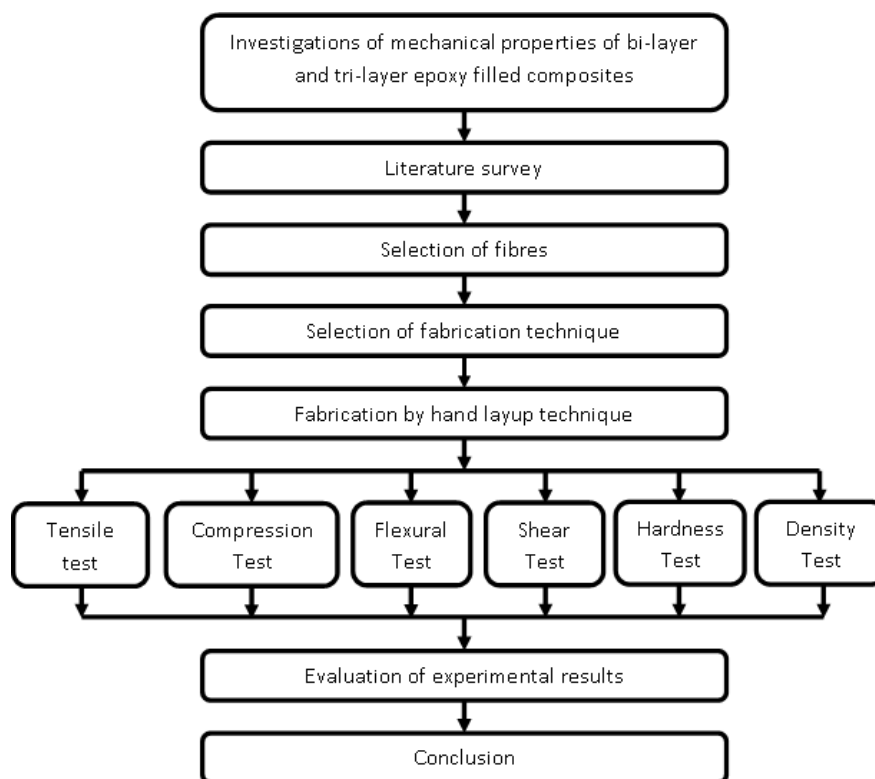


Figure 1. Methodology adopted

3. Raw materials used and their characteristics

Basalt and jute fiber mats were used as bi-layer materials. Basalt, jute and glass fiber mats, which were easily available and eco-friendly, were used as composite tri-layer materials. The epoxy resin (LY556) and industrial application hardener (HY951) were applied to fabricate the laminated sheets and hybrid combinations. LY556 epoxy resin has exceptional adhesion to different materials, high resistance to chemical and atmospheric conditions, high dimensional stability, free from internal stresses, excellent mechanical and electrical properties, and completely non-toxic with negligible shrinkage, plus it has been used as the matrix material in many composites [6]. Epoxy hardeners are not catalysts and they react with the epoxy resins, which greatly contributes to the properties of the cured epoxy resin system [7]. The performance of the epoxy hardeners in the epoxy resins system is dependent on the chemical characteristics of the latter [8].

4. Fabrication

The bi-layer and tri-layer composite plates were prepared with dimensions of $250 \times 250 \times 3$ mm. The composite plates were prepared by a simple manual hand layup procedure. Hand lay-up is the simplest and oldest open molding method for composite fabrication process. It is a low volume, labor intensive

method that is especially suited for large components [9]. The fibers were manually placed into a one-sided gel coated mould. A matrix of thermosetting resin was rolled onto the fiber using a hand roller, which also removed the entrapped air to complete the laminates structure. More layers were added and, after drying, the composite panel could be removed from the mould. For a high quality part surface, a releasing gel coat was first applied to the mold surface. After curing the composite, it was separated from the mould and the specimens were cut according to the ASTM and ISO standards using abrasive water jet cutting machine (see Figure 2). The sample specimens are shown in Figure 3.



Figure 2. Water jet cutting process of the specimen



Figure 3. Composite specimens

5. Material characterization

Tensile test was performed on a computer controlled universal testing machine according to guidelines of the ASTM D638 standard. Meanwhile, the flexural tests were performed using the 3-point bending method according to the ASTM D790 standard. The standard specimens were also prepared for both compression and shear tests, which were performed using a universal testing machine. Five sample specimens were tested in each test to determine mechanical properties with average values calculated.

5.1. Tensile test

For the tensile test, the specimens used were of 20 cm length, 3 cm width and also 0.3 cm thickness in dimension [10]. Figure 4 shows a comparison of the tensile strength obtained for bi-layer and tri-layer fiber reinforced composites tested. Less fiber pull out was observed in the fractured specimen. Based on the results in Figure 4, it becomes clear that the tri-layer epoxy filled composites exhibited a higher tensile strength (74.72 MPa) than the bi-layer fiber reinforced composites (73.09 MPa).

5.2. Flexural test

The flexural tests were performed using 3-point bending method according to ASTM D790 standard with specimen size of 24 cm × 3 cm × 0.3 cm. Figure 5 shows a comparison of the flexural load for bi-layer and tri-layer epoxy filled composites tested. The experimental results revealed that the tri-layer fiber reinforced composites were a better choice than the bi-layer fiber reinforced composites because they showed 13% increase in flexural property.

5.3. Impact test

Impact tests were performed using the Charpy izod impact method. Figure 6 shows comparison of the impact energy observed by the bi-layer and tri-layer fiber reinforced composites. Once again, the tri-layer fiber reinforced composites showed more superior impact properties. The average of 6% increase was shown in the impact strength of the tri-layer composites.

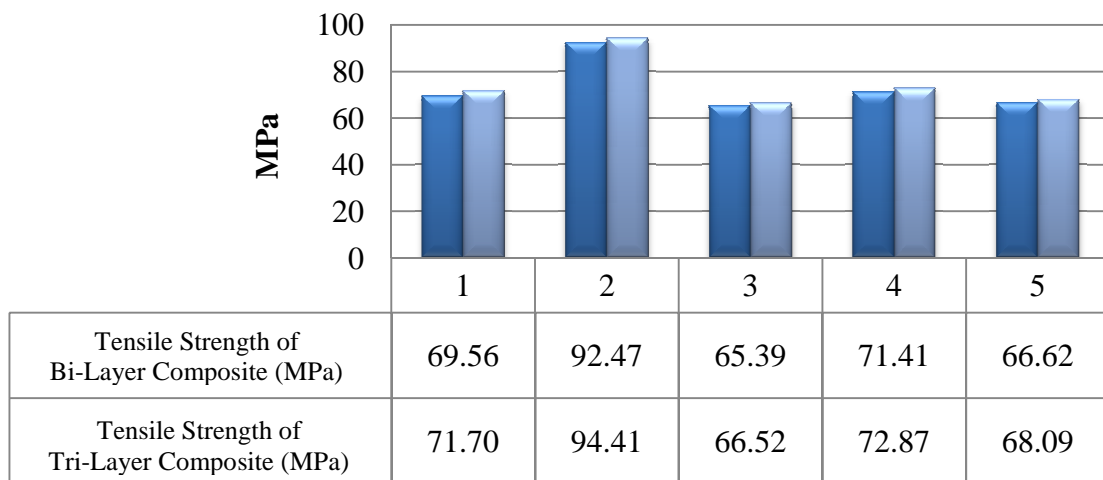


Figure 4. Comparison of tensile strength for bi-layer and tri-layer fibre reinforced composites

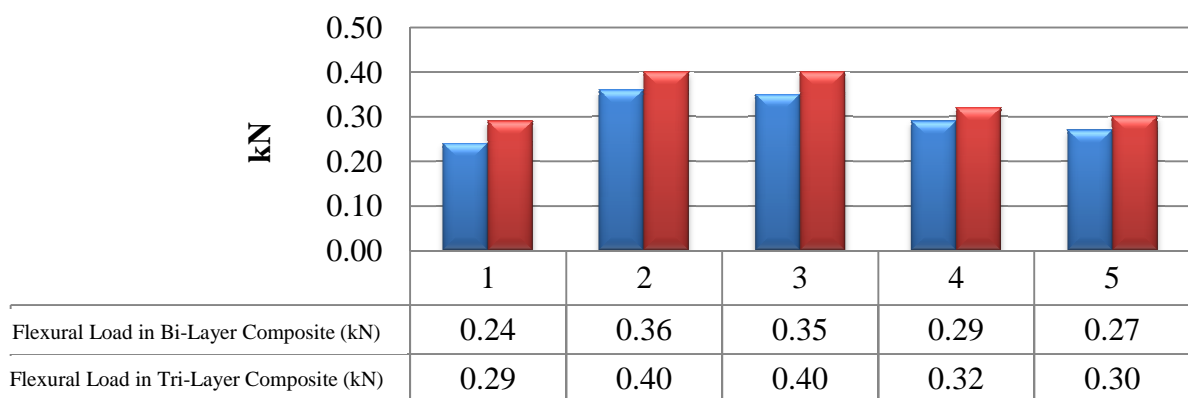


Figure 5. Comparison of flexural load for bi-layer and tri-layer fibre reinforced composites

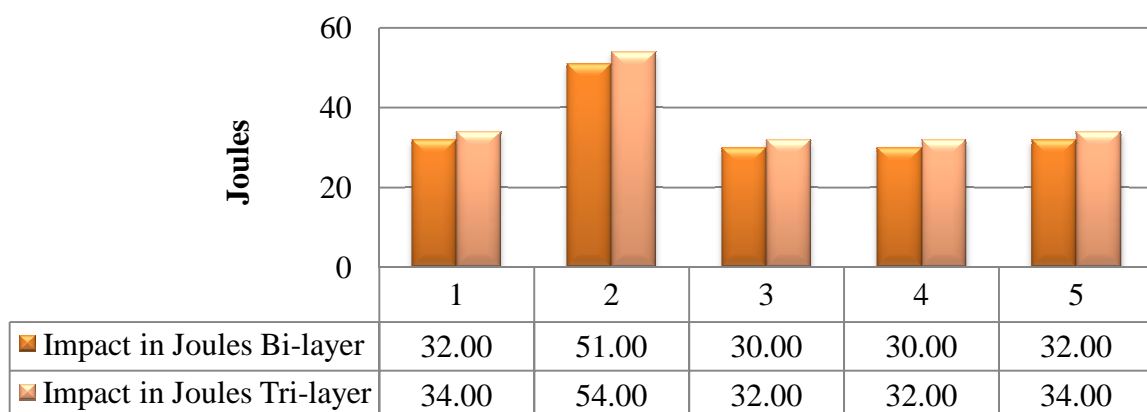


Figure 6. Comparison of impact load for bi-layer and tri-layer fibre reinforced composites

5.4. Density test

Density, ρ , or more precisely the volumetric mass density of a substance, is its mass per unit volume. Mathematically, density is defined as mass divided by volume. The dimension of the test specimen for density measurements was $10 \times 10 \times 3$ mm. Table 1 shows the density of bi-layer and tri-layer epoxy composite composites.

5.4. Hardness test

Hardness test is used to determine the hardness of a material to deformation, which can be performed either on a macroscopic or microscopic scale. In this study, D shore hardness test was used for testing. The ASTM standard for the D shore hardness test is D2240/2240. Table 2 shows the hardness values for bi-layer and tri-layer epoxy composite composites.

5.5. Shear test

Shear test was carried out using universal testing machine for specimens with the dimension of 20 cm length, 3 cm width and 0.3 cm thickness. A comparison of the composites tested under shear test is represented in Figure 7. From Figure 7, the tri-layer epoxy filled composites exhibited a higher tensile strength of the bi-layer fiber reinforced composites tested.

Table 1. Comparison of density values for the bi-layer and tri-layer fibre reinforced composites

Density (g/cm ³)	
Bi-layer	Tri-layer
1.318	1.738

Table 2. Comparison of hardness values for the bi-layer and tri-layer fibre reinforced composites

Hardness HRL	
Bi-layer	Tri-layer
84.8	87.00

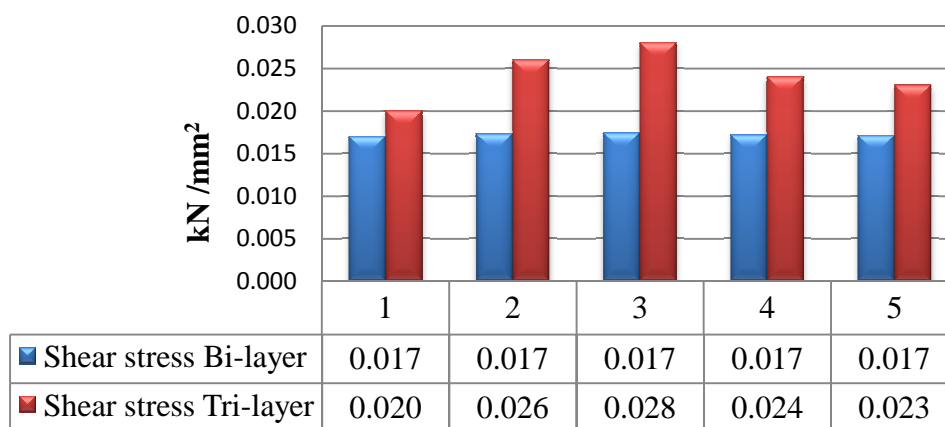


Figure 7. Comparison of shear stress for bi-layer and tri-layer fibre reinforced composites

6. Conclusion

The developed tri-layer fiber reinforced composites were environmentally-friendly materials and they were also recyclable. In this study, the tri-layer composite materials were reinforced with natural fibers such as jute fibers, together with basalt and glass fibers, in the epoxy resin (LY 556) matrix and with PTFE as filler. It showed better structural properties. The developed tri-layer epoxy composites could be used in various applications in the fields of aircraft, automobile construction and manufacturing. Flexural, impact, tensile, compression, shear, hardness and density tests were conducted to study the mechanical properties of bi-layer and tri-layer composites. The tri-layer fiber reinforced composites had shown higher values in all mechanical properties in comparison with the bi-layer fiber reinforced

composites. As an extension of this study, it is proposed to conduct tribological studies on the tri-layer fiber reinforced composites.

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References

- [1] Sreenivasan V S, Ravindran D, Manikandan V and Narayanasamy R 2011 *Materials and Design* **32** 2444-55
- [2] Lai C Y, Sapuan S M, Ahmad M, Yahya N and Dahlan K Z H M 2005 *Polymer-Plastics Tech. Eng.* **44** 619-32
- [3] Sapuan S M and Maleque M A 2005 *Materials and Design* **26** 65-71
- [4] Arib M N, Sapuan S M, Hamdan M, Paridah M T and Dahlan K Z H M 2006 *Materials and Design* **27** 391-6
- [5] Nimityongskul G 1987 *Journal of Ferrocement* **17** 321-8
- [6] Yousif B F 2012 *Materials and Design* **40** 378-85
- [7] Kumar M A 2011 *Journal of Metallurgy and Materials Science* **53** 85-95
- [8] Bagghi A K and Sharma B G 1981 *Indian J. Technol.* **19** 368-72
- [9] Hashim J, Looney L and Hashim M S J 1999 *Journal of Materials Processing Technology* **92-93** 1-7
- [10] ASTM International 2008 *Annual book of ASTM standards*
- [11] Amuthakkannan P, Manikandan V, Jappes J T W and Uthayakumar M 2013 *Science and Engineering of Composite Materials* **20** 343-50
- [12] Chairman C A and Kumaresh Babu S P 2013 *Journal of Applied Polymer Science* **130** 120-30
- [13] Subramanian K and Nagarajan R 2015 *Mechanical Engineering Letters* **12** 7-18