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Mechanical behavior of hybrid glass Fiber-Jute reinforced with polymer composite for the wall of the Acehnese boat ‘Jalo Kayoh’

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Abstract. Hybrid fiber composites are widely used composites in engineering applications, especially for the frame and wall structure of Acehnese traditional boat *Jalo Kayoh*. The purpose of this study is to obtain a hybrid material which is a blend of natural jute fiber reinforced with the synthetic fibers E-glass and polyester as a matrix. The materials potential to become a material for the structure and walls in the traditional Acehnese boat *Jalo Kayoh*. The fabrication of the hybrid composites is carried out manually using an engineered press at a pressure of 25 kg/cm² for 24 hours. The ratio of jute fiber and E-glass in the composites at each layer are (1:0), (1:1) and (2:1). Tensile testing of the hybrid composites refers to ASTM D 3039 - 00. The results show that the tensile strength of the hybrid composites tends to increase with the increase in the volume of the fiber, with the maximum tensile strength of 4.8 MPa. The increasing number of layers in the jute and E-glass is adding strength to the composites. This will be good to use in the initial material of the structure and walls in the traditional Acehnese boat *Jalo Kayoh*.

1. Introduction

The Acehnese traditional fishing boat, known as Jalo Kayoh [1], is a mean of transportation used by the fishing community to work and perform activities on the water, be it in a river, a lake, the sea, or a fishing pond. Jalo Kayoh is traditionally built using wood as the main material. The scarcity of wood is pushing the production of Jalo Kayoh to switch to low-quality wood materials. This makes the structure and walls of the boat more vulnerable to damage and decay. In this study, the model plan of the Jalo Kayoh has the specification with a length of 4 meters, a width of 0.96 meters and a height of 0.40 meters. Its main function is to help fisherman in their water activities such as short distance transportation, catching fish, crabs, shrimp, and pond rehabilitation.

The durability of the wood used as the main component for the boat can range from 2 to 3 years [2]. It makes wood a less ideal material to use in the long term, so efforts must be made to use synthetic

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materials to replace wood. As technology advances, researchers have produced breakthroughs in the fields of renewable and environmentally friendly material science (green technology material science). In reducing the use of various petroleum-based products, many developed countries view natural fiber-reinforced composite materials as having excellent potential in replacing petroleum-based products [3]. The use of natural fiber is now categorized as environmentally friendly fiber, easily cultivated, low in price, and has high mechanical strength [4].

A mechanical property of E-glass fibers reinforced with epoxy resin in tensile and bending tests has an increase in strength accompanied by an increase in the weight fraction of fibers [5]. This is followed by an increase in brittleness depending on the increase in the weight percentage, which is accompanied by a decrease in collision energy [6]. Glass fibers can increase mechanical stress concentration when combined with epoxy, polyester, vinyl ester resins thus increasing the threat of brittle fracture [7]. This can be eliminated or reduced through chemical optimization on the composite to avoid damage caused by cracks [8]. Tensile properties can be improved through the use of Kevlar fiber or glass fiber - Hybrid Epoxy for composites, as long as the fiber direction is higher in strength along the fiber direction [9]. It is necessary to develop reinforced natural and artificial fibers hybrid composite material that has the best properties to replace synthetic fibers, so jute fiber and glass woven fibers are used to strengthen matrix material [10].

Various natural fibers have been studied through mixing with polymeric materials, such as kenaf fiber, hemp, flax, hemp, sisal, coir, jute, straw, wood fiber, palm, rice husk, wheat, barley, oats, sugar cane, empty bunches, water pennywort, kapok, banana fiber, pineapple leaf fibers, paper-mulberry, raffia, papyrus, and grass reeds have been used very commonly for research activities [11]. Production with the use of natural fibers, which are cheap and environmentally friendly, can be measured as a source of synthetic fiber substitutes. Application of jute and banana fiber use has been discussed in detail. [12]. Jute fiber is obtained easily and has good mechanical properties, but through the treatment of mechanical properties of alkali medium, it can be increased again [13]. The use of polyester-reinforced straw with a 40% volume fraction produces a high tensile strength of 104 MPa [14].

The purpose of this study was to obtain preliminary data from a combination of glass fiber and jute layer as the basic material for traditional boat making in Aceh Jalo Kayoh. Literature study shows that composite materials are very important to be used for a variety of needs for the manufacture of diverse products, both for car, aerospace, structure, and products used in the marine field. To support the creation of high-performance composites through the use of natural and artificial fibers followed by studying the mechanical properties of composite properties reinforced by natural and artificial fibers (E-glass and jute). Both fibers will be reinforced by polyester resin. The composite will be tested for tensile strength to find out the ideal strength for the initial use of the structure and walls of the traditional Acehnese boat *Jalo Kayoh*.

2. Experimental Details

Jute fiber and glass fiber in this research were prepared for fillers on composites. Fiber-reinforced composites are formed based on different layers. While the test specimens are prepared using the hand layup method, fiber is required weight percentages were added to the resin and mixed properly.

2.1. Materials and fabrication

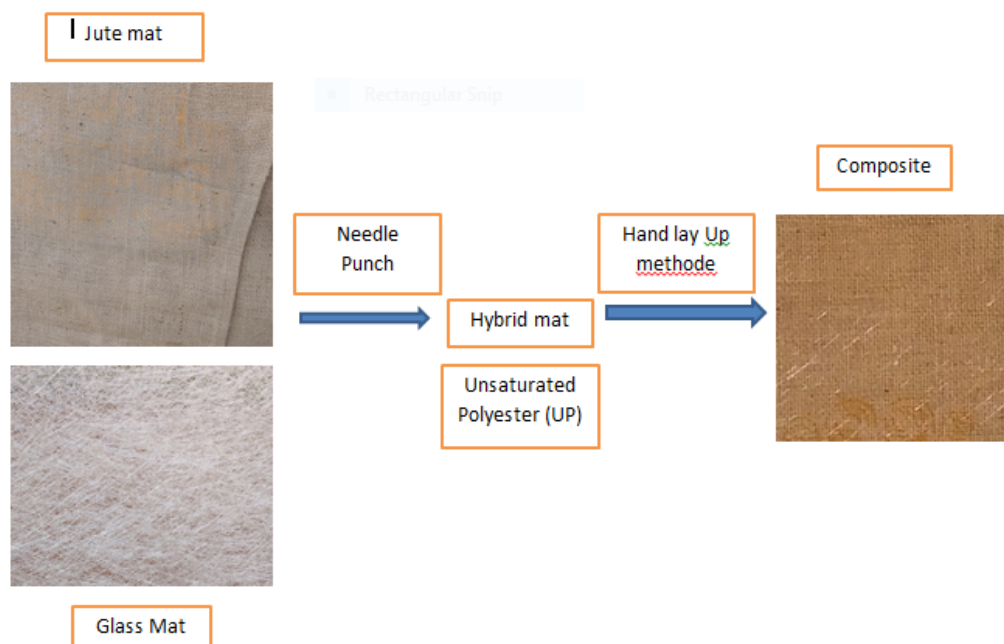
Jute fiber and E-glass fiber are used as reinforcement. Jute fiber has an area weight of 420 g/m². Chopped strand mat type E-glass fiber has an area weight of 300 g/m². Unsaturated polyester resin is used as a matrix. The properties of jute fiber, E-glass, and unsaturated polyester resin can be seen in Table 1. On this side, the composite is made according to the flowchart shown in Figure 1. This figure shows the E-glass fiber and jute fiber are made single and layered. The ratio of the jute layer and E-glass is set to 1:0, 1:1, and 2:1. These specimens are made using the hand lay-up method, where the polymer is mixed with Mepoxe Peroxide hardener in a ratio of 100:1.0; then the ingredients are pressed and left for 24 hours at room temperature. The appearance of the lay-up process for different composites is shown in Figure 2. The volume fraction of fiber (V_f) of jute fiber and E-glass fiber is shown in Table 2.

Table 1. Mechanical properties of jute fiber, glass fiber, and unsaturated polyester resin

Properties	Jute fiber	Glass fiber	Unsaturated polymer
Density (g/cm ³)	1.15	2.4	1.24
Elongation at break (%)	1.4-1.7	0.4	2.1
Tensile strength (MPa)	393-773	2000-3500	42
Young's modulus (GPa)	25.6	67	3.0

Table 2. The fiber volume fraction of four types of composites

Composite	V _f (%)	V _g (%)	V (%)
Jute Fiber	12.5	-	12.5
Jute Fiber / Glass Fiber	16.5	4.2	20.7
Jute Fiber/Glass Fiber/Jute Fiber	19.4	2.5	21.8

**Figure 1.** Process flow chart used in the fabrication of different composites using hand lay-up method.

2.2. Measurements

Tensile testing is carried out using tensile tests according to standard D 3039-00. This test is carried out using the Universal Testing Machine (UTM). The final test specimen consists of three replications to be included in each test.

Each layer of jute has a thickness of 0.8 mm and each E-glass fiber has a thickness of 0.33 mm. So according to ASTM standards, lamination thickness varies depending on the number of layers. This combination places the glass fiber layer between the jute fibers in the 3-layer laminate.



Figure 2. Schematic representation of composite 1.

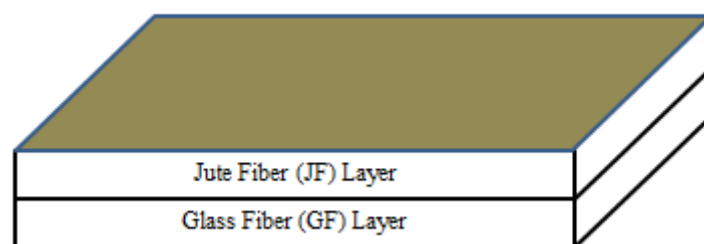


Figure 3. Schematic representation of composite 2.

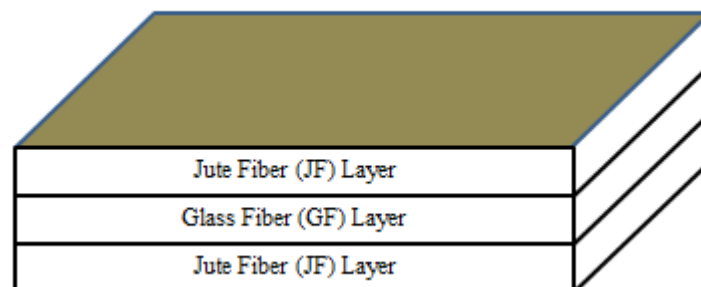


Figure 4. Schematic representation of composite 3.

3. Results and Discussion

Hybrid jute and E-glass fiber composite specimens will be subjected to tensile testing. The results obtained were analyzed, then compared to obtain conclusions from the hybrid composite to show better mechanical properties in the results of all tests. Jute fiber into biodegradable reveals excellent mechanical properties. This will be useful for preliminary data from the planned development of boat wall material replacing wood materials that will be used in general that can be developed towards mass production.

The mechanical properties of several different composite test specimens are shown in Figure. 5. Tensile stress increases linearly with a deflection in the initial stages until the slowing reaches the point of failure. In the case of Jute Fiber (JF), it was observed that the tensile strength reached a minimum value of 0.308 MPa with the lowest flexural deflection. Meanwhile, in the JF/GF-t (t: the jute layer is located on the surface) and JF/GF /JF-t, the two composites show the same maximum tensile strength. It can be observed that JF/GF/JF-t results in a maximum tensile strength lower than the maximum tensile strength of JF. Referring to hybrid composites b (b: jute layer on the top side), similar situations can be observed. In addition, the tensile strength of JF/GF/JF composites is higher than the JF/GF composite value.

Furthermore, from the data shown in the graph in Figure 5, it can be summarized that the average value of tensile stress on the strain that occurs based on the difference in the composite produces a variety of different values. As seen in Figure 6, the tensile strength obtained for JF is around 4,308 MPa, this result is higher than the tensile strength value of JF/GF composite which is 3,771 and lower than JF/GF/JF which is 4,800 MPa.

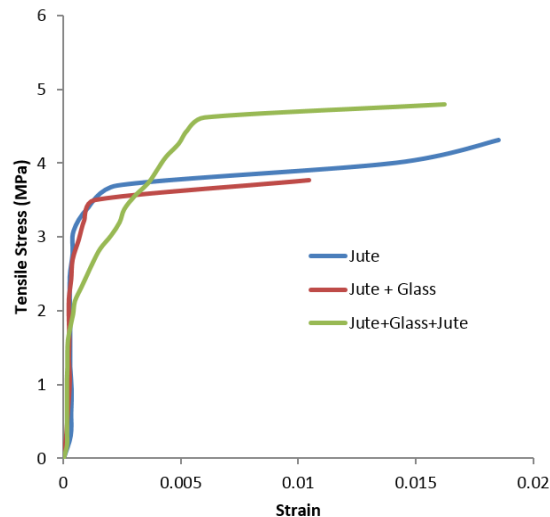


Figure 5. Typical tensile stress curves of different composites.

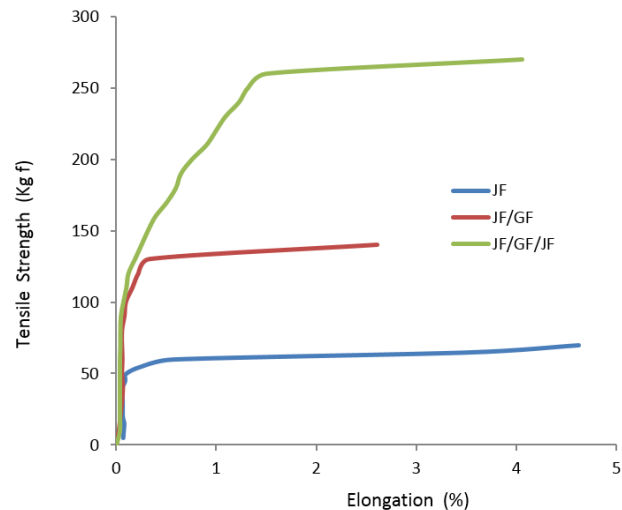


Figure 6. Typical Tensile Strength curves of different composites.

In short, JF showed a significantly higher increase in tensile stress value than the JF/GF sample but also showed a decrease in value compared to the JF/GF/JF sample consisting of two layers of jute fiber and one layer of glass fiber. This indicates that an increase in the fiber jute layer adds to the tensile strength value of the sample being tested.

Meanwhile, the result of the length increase value is a significant increase in the sample consisting of more layers. The JF sample produces a length addition value of 4,625 mm, higher than the JF/GF and JF/GF/JF samples which has a value of 2.61 mm and 4,055 mm.

The results of the observation show that the JF sample which is a sample consisting of single jute fibers has a higher increase in length, but when added with a layer of 300 gram chopped strand mat type glass fiber, the length addition value decreases and this is supported with the JF/GF/JF data samples which produce higher value after adding a jute fiber layer.

4. Conclusion

In this study, the incorporation of jute fibers into a pair of glass fiber reinforced composites results in a hybrid effect on the flexural properties of the composite to be used in the structure and walls of the Acehese boat Jalo Kayoh. The following points are taken from the experimental results:

1. The tensile stress of different composites shows little variation.
2. It should be noted that JF manifests the highest length increase among the samples tested from different composites, but also shows lower tensile stress than JF/GF/JF composite samples showing more brittle properties.
3. It appears that JF/GF/JF shows higher tensile stress and a better toughness value than the JF and JF/GF samples.
4. The addition of the GF layer to JF results in higher brittle properties; this is indicated by the reduction in length of the sample coated with GF.

5. Acknowledgments

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