Mechanical properties of glass fiber reinforced polyester resin for use as the wall of the Acehnese boat ‘Thep-Thep’

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Abstract. Fiber composites are very commonly used for engineering applications nowadays. The product has begun to enter the field of boat and ship manufacturing. An Acehnese traditional boat known as thep-thep, which has a capacity of 3 GT, is a means of transportation used in Aceh waters. This study focuses on the mechanical properties of the material used for the structure and walls of the thep-thep. Specimens are made from materials with E-glass fiber reinforced polyester resin. The hand lay-up method is used in the process of making the specimens, applied with a pressure of 25 kg/cm² for 24 hours. This study aimed to obtain higher mechanical properties using composites of layers of chopped strand mat (CSM) fibers and woven roving mat (WRM) fibers with a ratio of 1:0, 1:1, and 2:1, respectively. Tensile testing is done using the ASTM D3039-00 standard. From the tensile test data obtained from several different composite ratios, the highest composite is found at around 49.2 MPa. An increase in the number of fiber layers makes the fiber composites more reliable to be the raw material in the making of the Acehnese boat thep-thep.

1. Introduction
The Acehnese traditional boat, known as the thep-thep, is an essential means in Acehnese fishing communities to do activities in the waters, especially in the ocean. Most of the Acehnese fishermen who live in the coastal area still use the Acehnese traditional boat known as Jalo Kayoh [1], but those who depend on their sustenance in the ocean prefer to use the boat thep-thep to catch fish, to travel between islands, and to transport, deliver, and pick up goods from large trawlers that are fishing in the middle of the sea to be delivered to the port. The many uses provided by the boat has made the thep-thep the most widely used boat in almost all Aceh waters. In this study, the thep-thep will be made measuring at 7 meters long, 1.4 meters wide and 1.0 meters high, with a carrying capacity of 3 Gross Tons (GT).

Based on the testing of the mechanical properties of E-glass fiber reinforced epoxy resin in tensile and flexural testing, it was found that the strength will increase with the increasing of fiber weight fraction [3]. This increase will be followed by an increase in the fragility value which corresponds to...

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the percentage increase in weight and a decrease in collision energy [4]. Then, the E-glass fiber will increase in mechanical strength when combined with polymer resins such as epoxy, polyester, vinyl ester to increase the threat value to brittle fracture [5]. However, this can be reduced by chemically optimizing some parts of the composite to avoid damage caused by cracks [6].

Fiber composites are widely used in structural construction, which ranges from low strength construction to high strength construction. The advantage of this material is that it is lighter, elastic, corrosion resistant, strong, and easily fabricated. This composite material consists of two parts, the strengthener or filler, and the matrix or binder. The quality of composite materials is strongly influenced by the orientation of fibers and matrices. This study only examined the mechanical properties of E-glass composite composites consisting of a base layer of chopped strand mat (CSM) single fiber composite, woven roving mat (WRM) and a combination of CSM and WRM. The test that is done is tensile testing. The specimens use the D3039-00 standard for the use of fiber orientations 0°, 90°, and 0°.

Based on a literature study, it was found that fiber composites are very effective to be used for a variety of diverse products in various fields, namely automotive, aerospace, and structures and products used in the marine field. To create high-capacity composite products that use artificial fibers, this research is done on the mechanical properties of composite properties 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 Acehnese traditional boat thep-thep. The purpose of this study is to obtain the basic data of the strength of mechanical properties as the basis of production of the thep-thep using synthetic materials.

2. Experimental Details
E-glass fiber in this study was prepared for as the filler reinforcement on the composites. Fiber reinforced composites are formed based on differences between layers. In the preparation of a specimen using the hand lay-up method, it requires fiber which is calculated based on the percentage of weight added to the resin and stirred evenly.

2.1. Materials and fabrication
E-glass fiber is used as a reinforcement of composites. Glass fiber in this study has two types of fiber, the chopped strand mat (CSM) type with a weight of 300 g/m² and the woven roving mat (WRM) type with a weight of 300 g/m². Meanwhile, the matrix used is an unsaturated polyester resin. The properties of both the E-glass fibers, CSM and WRM, and unsaturated polyester resin can be seen in Table 1. On the table, the composites displayed to follow the form as shown in the flowchart in Figure 1. In the picture, CSM fibers and WRM fibers are made single and layered. The ratio of the E-glass layer is set to 1:0, 1:1, and 2:1. The hand lay-up method is used for making test specimens. The resin is mixed with Mepoxe Peroxide hardener at a ratio of 100: 0.7, then the ingredients are pressed slowly and then left for 24 hours at room temperature. The mechanical properties of the fractions of Glass Fiber Reinforced Polymers (GFRP) can be seen in Table 1.

| Components     | Tensile Strength, MPa | Young’s Modulus, GPa | Elongation, % | Density, g/cm² | C/S Area of Single Yarn, mm² |
|----------------|------------------------|----------------------|---------------|----------------|----------------------------|
| Glass Fiber    | 919                    | 113                  | 15            | 2.54           | 0.473                      |
| Polyester resin| 42                     | 30                   | 2.1           | 1.24           | -                          |

Table 1. Mechanical properties of jute fiber, glass fiber, and unsaturated polyester resin
Figure 1. Process flow chart used in the fabrication of different composites using hand lay-up method.

2.2. Measurements
Form specimens from tensile testing are formed by making molds; then the pressure is applied at 25 kg/cm² for 24 hours. The tensile test is carried out using the D 3039-00 standard. This test is done using the Universal Testing Machine (UTM) machine. The final test specimen consists of three replications to be used in each test.

Figure 2. Schematic representation of composite 1.

Figure 3. Schematic representation of composite 2.
A pure layer of woven roving mat (WRM) fiber has a thickness of 0.6 mm, while a layer 300 gram/m² chopped strand mat (CSM) 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 WRM layer between the CSM layers in the 3-layer laminate.

3. Results and Discussion

Fiber composites using E-glass fibers is the goal of the experiment in the form of tensile testing. The results of the test are analyzed, then compared with other results to get a conclusion on fiber composites that score better than the rest in all test results. This score will be useful for completing the data planned to develop wood replacement materials for the manufacturing of the structure and walls for the Acehnese traditional boat thep-thep.

Some mechanical properties displayed by different composite test specimens are shown in Figure 5. A linear increase in the tensile stress value against the deflection at the initial stage causes the voltage value to gradually slow down to the point of failure. In CSM fibers, it can be observed that the tensile strength can reach 7,385 MPa with lower bending deflection. With the presence of WRM fibers in WRM/CSM-t (t: the layer located on the surface) and CSM/WRM/CSM-t, the two composites show similar maximum tensile strengths. So, it can be concluded that CSM/WRM/CSM-t produces maximum tensile strength higher than the maximum tensile strength of CSM-t. When used as a reference for the fiber composite, a similar situation can be obtained through the results of tensile strength higher than CSM/WRM/CSM-t against WRM/CSM-t composites.

Furthermore, the data shown in the graph in Figure 5 illustrates the average value of tensile stress on the strain that occurs based on the difference in the composite resulting in different variations of values. As shown in Figure 5, the tensile strength obtained for CSM is around 7,385 MPa, this result is lower than the tensile strength value of WRM/CSM-t composite which is 34,462 MPa and even lower than CSM/WRM/CSM-t which is 49,231 MPa.

In short, CSM/WRM/CSM-t showed a significant increase in tensile stress value, higher than the WRM/CSM-t and CSM samples. This indicates that an increase in the fiber layer increases the tensile strength value of the sample being tested.

Figure 6 shows that a given load has a direct effect on the increase in the length of the specimen. The results of the increase in length can be observed significantly in the sample that consists of more layers. The CSM sample produced an increase in the length of 2.99 mm at 120 Kgf of the load. This was lower than the WRM/CSM sample, which experienced an increase in the length of 7.395 at a load of 560 Kgf and a CSM/WRM/CSM sample, which experienced an increase in the length of 8.41 mm at a load of 800 Kgf.

From all the data observed, an analysis was made that the specimen CSM, which was a specimen consisting of 300 gram/m² chopped strand mat single fiber, had the lowest length increase value. However, when woven roving mat fiber is added to the layer, the length increase value went up. This is supported by the WRM/CSM specimen data which resulted in higher tensile strength after the addition of another layer.
Figure 5. Typical tensile stress curves of different composites.

Figure 6. Typical Tensile Strength curves of different composites.

4. Conclusion
In this study, composite reinforced E-glass fibers chopped strand mat type and woven roving mat type produced a composite with a flexural effect that would be used for the manufacturing of frame structures and walls of the Acehnese boat *thep-thep*. There are also points of test results concluding:

1. The tensile strength of synthetic composites shows an increase based on the addition of layers.
2. CSM manifests the lowest length increase among the tested samples from different composites but also shows a tensile strength that is lower than CSM/WRM/CSM synthetic composite specimen.
3. CSM/WRM/CSM specimens show higher tensile stress and have better toughness values than CSM and WRM/CSM specimens.
4. The addition of one CSM layer to the WRM caused the sample to have a higher elasticity. This was followed by an increase in the length increase of the sample layered with CSM.

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6. References
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