A comparison of the structural strength between fiberglass and jute fiber in the Acehnese Traditional Boat Jalo Kayoh using finite element method

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Abstract. The Acehnese traditional boat, known as Jalo Kayoh, is a mean of transportation used by Acehnese fishermen. The main constituent of the boat is wood. However, due to the decline of high-quality wood supply and as a preventative measure of illegal logging, fiberglass and jute fiber are used instead of wood. This study compares the strength of the two materials using finite element method. The Jalo Kayoh model plan stands at 4m in length, 0.6 m in width, and 0.4 m in height. A 2500 N static load is applied to the surface, using a C3D10 quadratic tetrahedron 0.02 mesh. The result of the simulation to the fiberglass is a maximum displacement of $7.123 \times 10^{-5}$ m, while the jute fiber has a maximum displacement of $2.255 \times 10^{-4}$ m. The maximum stress stands at $1.612 \times 10^6$ Pa for the fiberglass and $1.523 \times 10^6$ Pa for the jute fiber. The maximum strain occurs at $1.654 \times 10^{-5}$ for the fiberglass and $4.581 \times 10^{-5}$ for the jute fiber. To conclude, fiber glass has more stress 1.05 % and less strain 2.76 % than jute fiber and both the materials can sustain the load given.

1. Introduction
The Acehnese traditional fishing boat, known as Jalo Kayoh, 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, or the sea. Jalo Kayoh is traditionally built using wood as the main material. The quality of wood that degrades over time makes Jalo Kayoh susceptible to degradation and decay. This cannot be prevented as the fishing community are dependent on wood in the construction and maintenance of the Jalo Kayoh.

In this study, the model plan of the Jalo Kayoh has the specification of the length of 4m, the width of 0.6 m, and height of 0.4m. Its main function is to help fishers in their water activities such as short distance transportation, catching fish, crabs, shrimp, and pond rehabilitation. Jalo Kayoh needs to have a good hydrodynamic design and a strong structural design. With the decrease of high-quality wood supply and as a preventative step to combat illegal logging. The durability of wood used as the main component of the boat lasts between two to three years [1], it makes wood a less ideal material to use in the long term.

Nowadays, people are starting to switch to synthetic materials such as fiberglass, using resin as the adhesive and fiberglass as the filling. The quality of the product made from synthetic fibers is comparatively good that the production has grown locally and globally. The previous study shows that
a fiberglass based composite (chopped strand mat and woven roving) using the adhesive 157 resin polyester as the base material in constructing the Acehnese traditional boat Jalo Kayoh has a very good physical and mechanical property [2].

Jute fiber (Corchorus olitorius) is fiber from a plant that can grow well in Indonesia. It can grow all year long with a big number of production. Jute fiber is used in the covering and packaging of harvested goods, commonly known as gunny sacks. Due to its elasticity, researchers are interested in developing jute fiber as a material in constructing the traditional Acehnese boat Jalo Kayoh.

2. Literature Review

2.1 Composite Material Jute Fiber
The application of composite material jute fiber is very efficient in enduring load and force. Because of that, the composite material jute fiber is very strong and firm when the load is applied in the same direction as the fiber, yet it is inadequate when the load is applied perpendicular to the fiber direction [3]. The modification of the jute fiber surface with alkali is very effective in increasing the adhesive bond between the fiber and the matrix in the composite polypropylene with a jute fiber strengthener. The application of the alkali can remove the wax and fat residue on the fiber, which makes it difficult to apply the resin. Based on the observation using SEM-micrograph, the jute fiber without alkali looks softer compared to the one treated with alkali, which looks tougher. [4]

2.2 Fiber Reinforced Plastic (FRP)
The laminate of Fiber Reinforced Plastic (FRP) composition has high stiffness. Moreover, it has strength, tolerance of fatigue damage, fatigue strength for weight ratio, low thermal expansion coefficient, low corrosion, high internal damping and low maintenance cost. [5]

| Fiber   | Tensile Strength (MPa) | Young’s modulus (GPa) | Elongation at break (%) | Density (g/cm³) |
|---------|------------------------|-----------------------|-------------------------|-----------------|
| Abaca   | 400                    | 12                    | 3-10                    | 1.5             |
| Bagasse | 350                    | 22                    | 5.8                     | 0.89            |
| Bamboo  | 290                    | 17                    | -                       | 1.25            |
| Banana  | 529-914                | 27-32                 | 5.9                     | 1.35            |
| Coir    | 220                    | 6                     | 15-25                   | 1.25            |
| Cotton  | 400                    | 12                    | 3-10                    | 1.51            |
| Curaua  | 500-1150               | 11.8                  | 3.7-4.3                 | 1.4             |
| Flax    | 800-1500               | 60-80                 | 1.2-1.6                 | 1.4             |
| Hemp    | 550-900                | 70                    | 1.6                     | 1.48            |
| Jute    | 410-780                | 26.5                  | 1.9                     | 1.48            |
| Kenaf   | 930                    | 53                    | 1.6                     | -               |
| Pineapple | 413-1627            | 60-82                 | 14.5                    | 1.44            |
| Ramie   | 500                    | 44                    | 2                       | 1.5             |
| Sisal   | 610-720                | 9-24                  | 2-3                     | 1.34            |
| E-glass | 2400                   | 73                    | 3                       | 2.55            |

2.3 Finite Element Method (FEM) Analysis
Finite element method (FEM) is a method that is used to analyze a construction. This method is used in the construction of ships, on-shore, and off-shore buildings. The application of this method is not limited to the field of steel construction, but also fluidics. Structural analysis using finite element method allows the researcher to understand the spread of the stress on the construct that is being analyzed. The failure of construction can be shown by using this analysis. It also reveals the exact point of such failure. This will, in turn, allow planners to make modifications and fortifications on the
construction where the failure has been identified. The load applied to the Jalo Kayoh is 2500 N/m². The type of the load is body force.

2.4 Element and Structure Flexibility

An element’s flexibility is the ability of an element or a structured system to follow the shape change of the element or the structure due to an external load. It can be formulated that the relationship between the external element internal force (F), the element’s flexibility (d) and the displacement/deformation (Δ).

\[
\Delta = d \times F
\]

Where,

\[
d = \frac{1}{k}
\]

Flexibility (d) is the opposite of rigidity (K) [7].

3. Result of Simulation

From the simulation using the material fiber reinforced plastic, the result is a maximum displacement of 7.123 x 10⁻⁵ m at the node 1.8922. The displacement contours can be seen in Figure 2 below, and also Table 2 shows the maximum displacement value.

**Figure 1.** Load display and the boundary condition of the boat’s structure

**Figure 2.** Displacement contours in the material fiber reinforced plastic
From the simulation using the material jute fiber, the result is a maximum displacement of $2.255 \times 10^{-4}$ m at the node 1.8922. The displacement contours can be seen in figure 3 below.

![Displacement contours in the material jute fiber](image)

**Figure 3.** Displacement contours in the material jute fiber

| Force (N) | Fiber Glass (m) | Material Jute (m) |
|-----------|-----------------|-------------------|
| 0         | 0               | 0                 |
| 2.49      | 7.20E-06        | 2.26E+01          |
| 4.98      | 1.42E-05        | 4.51E+00          |
| 8.71      | 2.49E-05        | 7.89E+00          |
| 14.32     | 4.09E-05        | 12.96E-05         |
| 22.72     | 6.49E-05        | 20.57E-05         |
| 24.90     | 7.12E-05        | 22.55E-05         |

The Figure 4 below shows the comparison between the displacement that occurs in the fiberglass and the one that occurs in jute fiber, where it is known that natural fiber jute is stronger than the natural fiberglass.

![Comparing displacement between fiberglass and jute fiber](image)

**Figure 4.** Comparing displacement between fiberglass and jute fiber
From the simulation using the material fiberglass and jute fiber, the result is the maximum stress of $1.523 \times 10^6$ Pa and a maximum strain $4.581 \times 10^{-5}$. The contours for each number are shown in figure 5 and figure 6 below.

![Stress contours](image1)

**Figure 5.** Stress contours (von Mises) of the material fiber reinforced plastic and jute fiber

![Strain contours](image2)

**Figure 6.** Strain contours of the material fiberglass and jute fiber

The table 3. below shows the maximum of the stress and the strain between the material fiberglass and jute fiber.

| Material      | Stress   | Strain    |
|---------------|----------|-----------|
| Fiberglass    | $1.612 \times 10^6$ | $1.654 \times 10^{-5}$ |
| Jute fiber    | $1.523 \times 10^6$ | $4.581 \times 10^{-5}$ |

4. Conclusion
Some things that be concluded from the simulation are:
1. Fiber glass has more stress 1.05 % and less strain 2.76 % than jute fiber.
2. Both materials in Jalo Kayoh simulation can endure the load applied with 2500 N.

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