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Technical Study of Natural Fibers from Banana Fronds as Boat Component Material in Inland Waterways

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KEYWORDS
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Experiment
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Banana frond
Boat

ABSTRACT – Many types of bananas are grown in Indonesia, indicating that it is one of the banana producing countries. Banana leaves are processed to make them stronger and more easily absorbed, so they are suitable as a composite mixture. Making banana stems as an alternative reinforcement for composite materials. Use ecologically safe substances and replace synthetic compounds. The aim of this research is to investigate the tensile strength and flexural strength of banana stem material as a composite fiber alloy in ship component materials in accordance with the review of the Indonesian Classification Bureau (BKI). The method used is experimental testing with a UTM machine according to ASTM D638-03 standards and ASTM D-790 standards. The results of the test experiments show that the tensile strength and flexural strength of banana stems as a composite and natural material are not yet suitable for use as boat component materials under water (hull skin construction), according to BKI's review, but can be used as an alternative composite material for boat component materials above the water line.

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INTRODUCTION

Banana trees also offer advantages from leaves to fruit and have qualities that suit growing conditions in Indonesia [1]. Banana leaves can be reprocessed to produce fibers with greater strength and absorbency, making them suitable for use as composite reinforcement materials [2]. Kepok Musa Paradisiaca banana fiber contains fibers with good mechanical properties. Density: 1.35 g/cm3, cellulose concentration: 63-64%, hemicellulose: 20%, and lignin content: 5% average tensile strength of 600 MPa, average tensile modulus of 17.85 MPa, and length increase of 3.36% [3]. Currently, non-renewable natural resource commodities such as glass, carbon and aramid are still used in several development projects in Indonesia. In the maritime sector, such as innovation in wooden ship construction [4] and fiberglass ship construction [5][6][7]. Because the effects of non-renewable materials have a negative impact, especially on the sustainability of shipping, this is not good enough in the long term. Studies and research related to renewable materials are needed to replace or innovate them. Much research has been carried out regarding the use of natural fibers because FRP materials can pollute the environment and are very difficult to decompose [8][9][10][11][12]. Natural fibers have been proven to degrade quickly.

To ensure the continued use of fiber composites in the maritime sector, banana stems are one of the natural fiber choices for component materials in the maritime sector. Extensive investigation and research must be carried out. Natural fibers have been proven to degrade quickly. By using natural fibers from banana stems as an alternative composite reinforcement material, a new option is offered, allowing the use of compounds that are safe for humans and the environment to replace synthetic ones [13]. It is hoped that the findings of this research can spur innovation in Indonesia, especially in the shipping sector, in the development of composite material technology using fiber mixtures in ship component materials.

In general, there are two categories of composite materials, namely matrix and reinforcement [14]. So composites are a number of multi-phase systems with combined properties, namely a combination of matrix materials or binders with reinforcements [15]. Due to the importance of alkali treatment in the manufacture of natural fiber composites, many studies have been carried out to determine the effect of alkali treatment on the resulting composites, which tend to greatly influence the properties of the material [16][17].

METHOD

In this research, testing specimens were modeled in accordance with the test standards of the American Society for Testing and Materials [18]. The preparation of test specimens is carried out based on these standards. Checking the dimensions of the test specimen is carried out visually and using measuring instruments. Next, tensile tests and bending tests were carried out using UTM. The following are the materials, tools and components needed to carry out experimental tests in the laboratory.

Universal Testing Machine (UTM)

UTM, or Universal Testing Machine, is a testing tool or machine. The function of this tool is to test durability and tensile strength and determine the structure of a material or the material of a product. It is not surprising that this tool is widely used in the industrial sector, starting with aircraft, oil drilling, construction, shipping, and others. Generally, the materials that are tested are rubber, metal, iron, and steel, either by tensile test or bending test. Such as the tensile test, bend test, hysteresis test, nick-break test, adhesion test, and pull-out test. The function of this tool itself is to provide a compressive or tensile force on the material to be tested. Even to carry out compression or tensile tests on certain substances or materials, you also need other test objects for comparison.

Figure 1. Tensile and bending test equipment [19]

Tensile Test and Bending Test

Tensile testing is a way to test the strength of a material by applying an axial force. The Universal Testing Machine uses the extensometer to measure changes in length, while the loadcell sensor measures the tensile force on the crosshead. After the test object has been stretched, a length measuring instrument or length meter on the test object must be used to measure the distance between the two objects see in Figure 2.

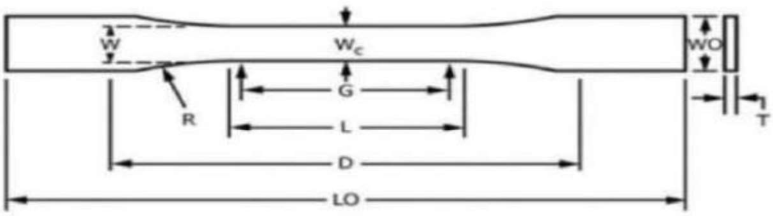


Figure 2. Tensile test specimen dimensions [20]

Table 1. Tensile test specimen dimensions [20]

Dimension	value	units
Radius of fillet (R)	76	mm
Length Overall (LO)	165	mm
Length of Narrow Section (L)	57	mm
Gage length (G)	50	mm
Width Overall (WO)	19	mm
Width of Narrow Section (W)	13	mm
Grips (D)	115	mm
Thickness (T)	5	mm
Width Center (Wc)	+0.00 – 0.10	mm

Composite tensile strength can be measured by testing samples using the ASTMD760 standard to determine the flexural strength of a material. Flexural strength, juga dikenal sebagai bending strength, is the greatest bending stress that can be experienced by external loading without experiencing significant deformation or failure. The type of material and load both affect the amount of bending strength. This is shown in Figure 3.

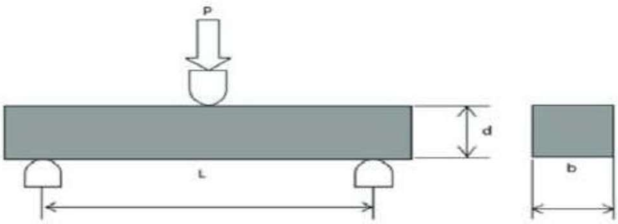


Figure 3. Bending test specimen dimensions [18]

Table 2. Bending test specimen dimensions

Dimension	value	units
Length (L)	5	mm
Width Overall (b)	25	mm
Thickness (d)	125	mm

Strength per unit area of a material that receives the force is known as tensile strength. Equation 1 can be used to determine the strength of a material to obtain this tensile force.

$$\sigma = \frac{F}{A} \tag{1}$$

The engineering stress-strain curve uses the average linear strain, which can be obtained by dividing the specimen's measuring length, ΔL, by its initial length, L0.

$$\varepsilon = \frac{\Delta L}{L_0} \tag{2}$$

$$\varepsilon = \frac{L - L_0}{L_0} \tag{3}$$

Equation 4 can be used to determine the maximum stress for testing simple homogeneous rod materials with two installation points and three bending points where the load is in the middle of the test rod.

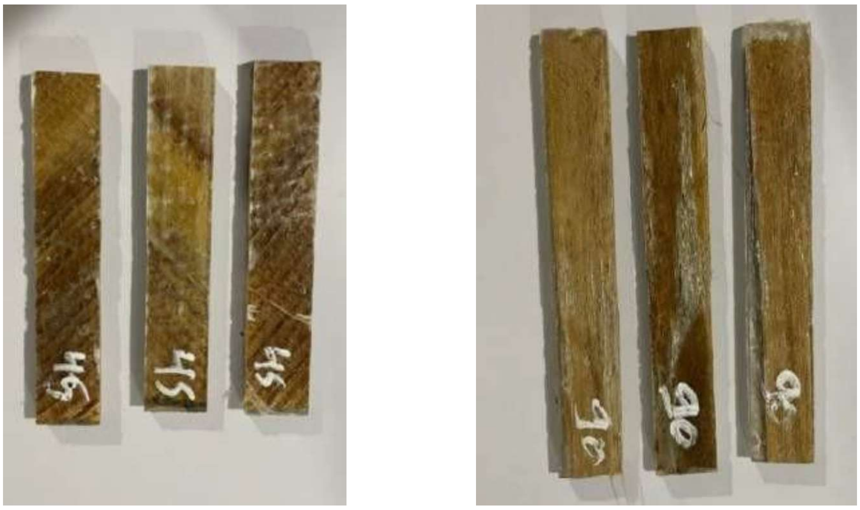
$$\varepsilon = \frac{3PL}{2bd^2} \tag{4}$$

RESULTS AND DISCUSSION

Samples are formed to conduct tensile and bending tests using ASTM D-638-03 and ASTM D-790 test standards, respectively. The shapes of the specimens are shown in Figures 4 and 5 below.

(a) (b)

Figure 4. a) 45º fiber direction tensile test specimen; b) 90º fiber direction tensile test specimen



(a) (b)

Figure 5. a) 45º fiber direction bending test specimen; b) 90º fiber direction bending test specimen

Tensile Test Result

The load, stress, and strain values in the tensile test of the specimen in the 45º fiber direction are shown in Table 3.

Table 3. Tensile test results in 45º fiber direction.

Speciment	Load (N)	Stress (MPa)	Strain (%)
1	439.909	47.55	0.116
2	502.947	54.73	0.195
3	346.602	37.47	0.238

Based on Table 3 above, a graph can be made of the relationship between stress and strain for each experiment that has been carried out. A graph of the relationship between stress and strain can be seen in Figure 6 below.

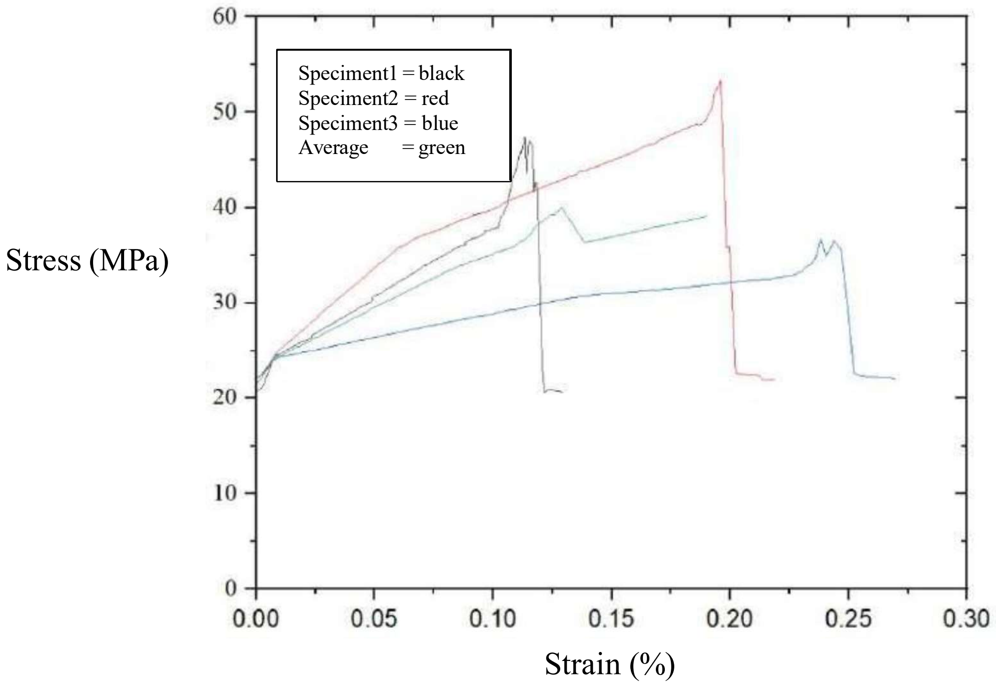


Figure 6. Graph of tensile test results in 45º fiber direction

The load, stress, and strain values in the tensile test of the specimen in the 90º fiber direction are shown in Table 4.

Table 4. Tensile test results in 90º fiber direction

Speciment	Load (N)	Stress (MPa)	Strain (%)
1	211.698	22.88	0.213
2	295.166	31.90	0.033
3	318.617	34.44	0.024

Based on Table 4 above, a graph can be made of the relationship between stress and strain for each experiment that has been carried out. A graph of the relationship between stress and strain can be seen in Figure 7 below.

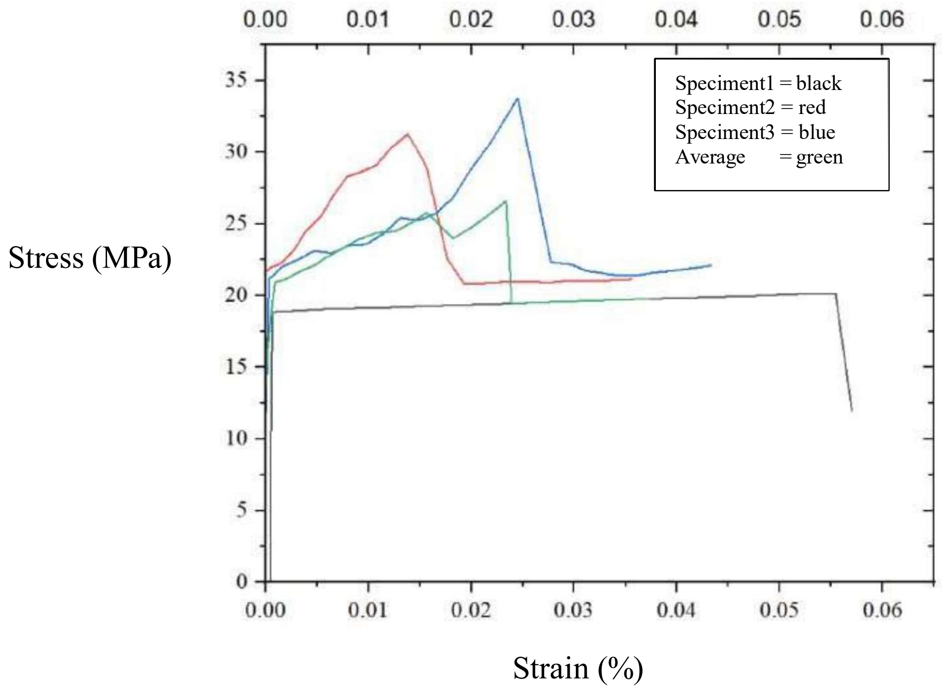


Figure 7. Graph of tensile test results in 90º fiber direction

The tensile test results in Figure 8 display the average tensile test results for fiber directions of 45º and 90º on the third specimen

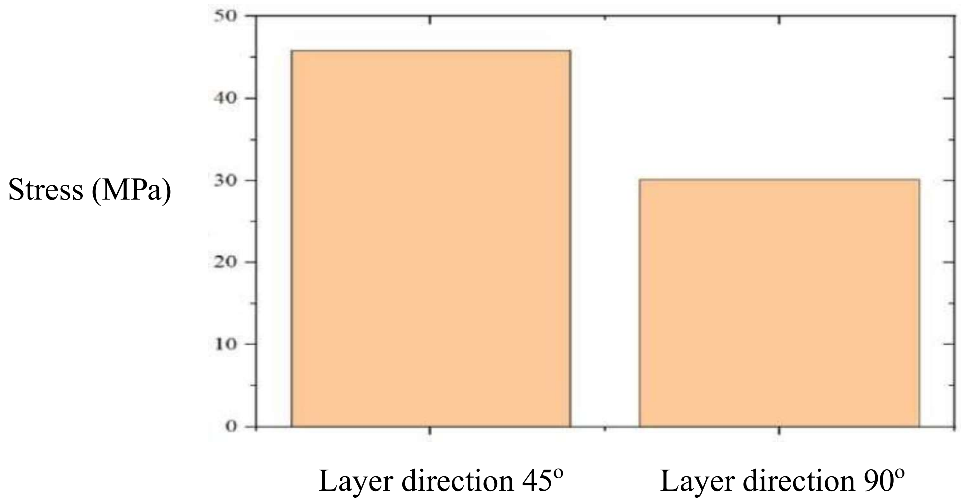


Figure 8. Comparison of tensile strength in 45º and 90º fiber directions

The average curve of the stress and strain for each fiber direction in a tensile test is shown in the image above. demonstrates that the 90º fiber direction specimen is lower than the 45º fiber direction specimen.

Bending Test Result

Table 5 displays the load and stress data obtained from the specimen's 45º fiber direction bending test.

Table 5. Fiber direction bending test results 45°.

Speciment	Load (N)	Stress (MPa)
1	58.909	22.55
2	226.977	54.55
3	126.991	32.33

A graph showing the relationship between stress and load for each experiment can be created using Table 5 above. Figure 9 below shows the stress and load relationship graph.

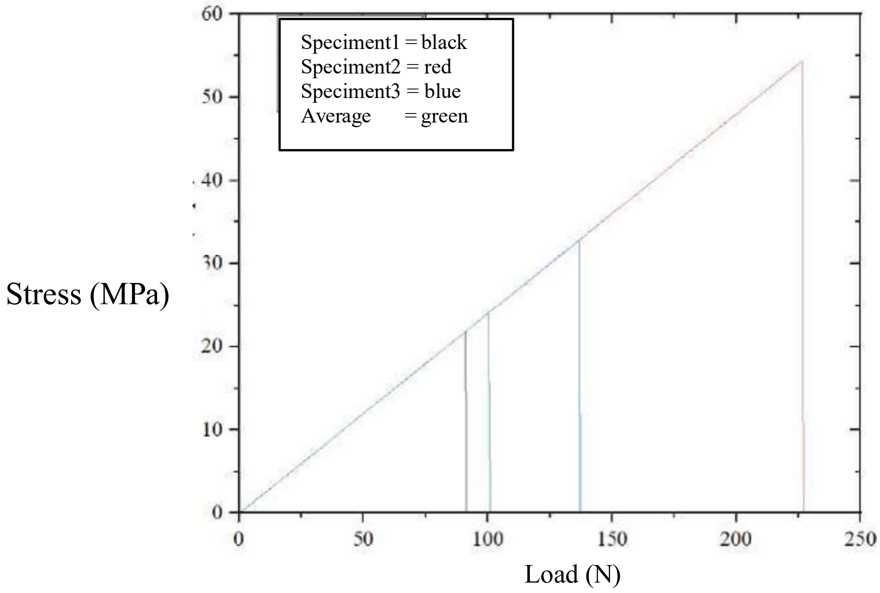


Figure 9. Graph of fiber direction bending test results 45°

The load and stress values in the 90° fiber direction bending test of the specimen are shown in Table 6.

Table 6. Fiber direction bending test results 90°.

Speciment	Load (N)	Stress (MPa)
1	75.901	17.52
2	109.879	26.29
3	176.991	45.60

A graph showing the relationship between stress and load for each experiment that has been conducted can be created using Table 6 above. Figure 10 below shows the stress and load relationship graph.

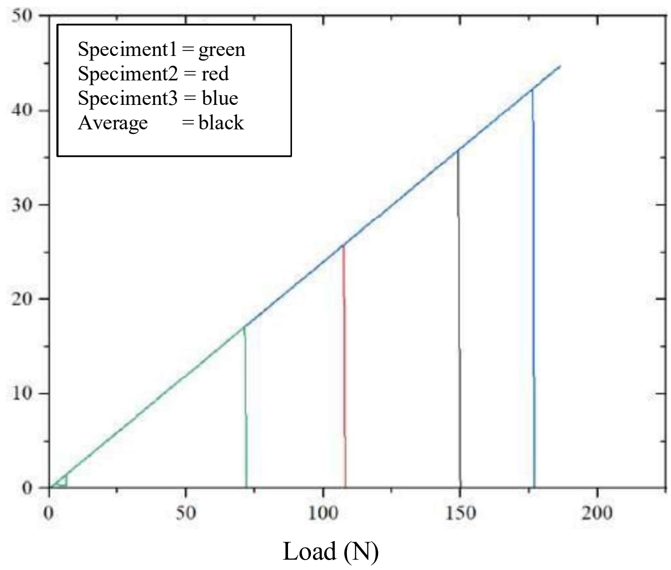


Figure 10. Graph of fiber direction bending test results 90°

The average bending test in the fiber direction of 45º and 90º on the specimen can be seen in the bending test results in Figure 11 as follows

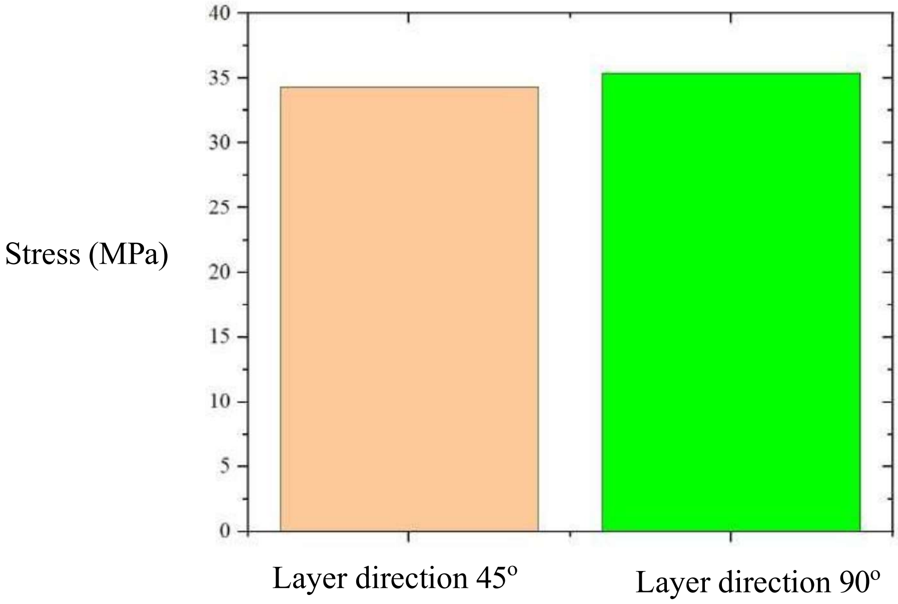


Figure 11. Comparison between layer direction 45º and 90º of bending test result average

The image above is the average curve of bending test stress and strain for each fiber direction. Shows that the specimen with a fiber direction of 90º is higher than a fiber direction of 45º.

CONCLUSION

Compared to the 90° fiber direction, the 45° fiber direction exhibits a greater value for the tensile test strength. In the meantime, the 45º fiber direction in the bending test had a lower bending strength than the 90º fiber direction. Imperfections that occurred during the test specimen's development could be the source of these results. It is known that the minimum tensile strength and bending test standards in BKI vol. 5 standards for fiberglass-reinforced plastic ships, Section 1.C.4.1.1, are still greater than the outcomes of testing natural fiber composites using banana stems. The quantity of banana frond layers used in the creation of natural fiber composites will be investigated in more research.

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