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The Influence of Fiberglass Fiber Arrangement Variations on the Tensile and Bending Strength of Ships

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KEYWORDS
Fiberglass Reinforced Plastic (FRP)
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ABSTRACT - The use of Fiberglass Reinforced Plastic (FRP) as a substitute for wood in the shipbuilding industry in Indonesia is increasing, particularly in small vessels under 5 GT. Challenges in obtaining high-quality wood have driven fishermen and the shipbuilding industry to shift towards composite chopped materials such as fiberglass. This research aims to evaluate the tensile and bending strengths of fiberglass composites made using the hand lay-up method with variations of random fiber layers as well as fibers oriented at 0° and 90°. The tests were conducted according to ASTM D638-14 and D790 standards, with the results showing that the chopped-woven-hybrid fiber configuration produced the highest tensile strength of 38.174 MPa, while the chopped-chopped-woven-woven configuration produced the highest bending strength of 104.44 MPa. However, all the tested fiber layer variations did not meet the standards of the Indonesian Classification Bureau (BKI), indicating the need for further optimization in layer arrangement to achieve the desired quality. Additionally, the FRP boat-building training program conducted in Gisik Cemandi Village demonstrated that traditional boat craftsmen can adapt to this new technology, which offers an effective solution to wood scarcity while enhancing the quality and safety of vessels. This research supports the development of FRP as a more reliable, efficient, and environmentally friendly material for shipbuilding, particularly in the fisheries and small shipping sectors in Indonesia. The broader adoption of FRP technology is expected to address environmental and economic challenges in the national shipbuilding industry.

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INTRODUCTION

One of Indonesia's most significant maritime legacies is the traditional wooden ship, which holds great historical and cultural value [1]. Inter-island trade among small islands in Indonesia is highly active, making water transport the dominant mode. The primary advantage of water transport is its capacity to carry large quantities of goods wood has been subject to numerous alterations and adaptations [2]. The difficulty in obtaining wood in recent years and the various advantages of FRP as a shipbuilding material have led to an increase in the use of FRP boats by fishermen in Indonesia, especially for small vessels under 5 GT [3]. Using FRP as a substitute for wood in shipbuilding is considered more practical and effective than steel, as FRP has seven times greater elasticity and requires a smaller moment of inertia for the cross-section. Study demonstrates that various FRP cross-sectional shapes, such as I-beams and T-beams, can replace Bitti wood with equivalent strength for vessels of both above and below 70 GT [4].

Fiberglass has become the primary choice, especially for fishing vessels, alongside aluminum and steel. Over time, fiber-optic-based composite material have increasingly been used as a replacement for wood. These materials offer many advantages, such as affordability, lightweight, ease of molding, high quality, environmental friendliness, and resistance to corrosion [5]. Composites are created to combine the best characteristics of each component material. Optical fibers derive strength from glass and flexibility from polymers. Polymers include well-known plastic and rubber material. These materials typically have low density and can be highly flexible [6]. A composite is a material formed from two or more different material that are combined into one and formed into a microscopic scale so that they are physically connected. The matrix (binding material) is ductile and plays a role in distributing the load through the composite reinforcement material. Polymer matrix (bending material) in the form of resin mixed with catalysts are the most commonly used material for applications in the shipbuilding industry. The most commonly used fiber as reinforcement is optical fiber [7]. The stress of optical fiber material is crucial for shipbuilding; the better the quality of a material and the higher the standards applied, the more durable the ship and the safer it is for users. This is especially true in low-quality hull laminations, where impact can reveal the importance of the strength of the ship's lamination [8]. Research previously conducted by Wenny Ririantika found that the arrangement of fiber layers significantly affects the strength of the material. Given the importance of ship strength, research on the tensile and bending tests of composites reinforced with fiberglass and woven cloth layers for shipbuilding material will be conducted. Therefore, research on the influence of variations in fiber layer arrangements is essential [9].

Fiberglass fishing boats commonly used in Indonesia often suffer from damage due to non-compliance with BKI standards, particularly in terms of design, material volume fraction, and lamination processes. Research has shown that by adjusting the fiberglass fiber volume fraction to 12.5%, a tensile strength of 79.31 MPa and a bending strength of 129.38 MPa can be achieved, which is close to meeting BKI standards. Additionally, further increasing the fiber fraction beyond 12.5% has the potential to fully comply with these standards. This suggests that optimizing the fiber volume fraction in the construction process could significantly enhance the durability and reliability of fiberglass fishing vessels, aligning them more closely with industry standards [10].

Traditional shipyards that continue to use wood as the primary material for constructing small vessels are currently facing significant challenges, particularly due to the scarcity and high cost of wood. As a result, many shipyards have been forced to halt production or even close their businesses. To address this issue, further research into alternative material such as FRP is essential, along with the development of traditional shipyards towards adopting more modern technologies. The transition to using advanced material and methods could offer a sustainable solution to the declining availability of wood, ensuring the continuity and growth of the small shipbuilding industry while maintaining economic viability [7].

The FRP (Fiberglass Reinforced Plastic) boat-building training program in Gisik Cemandi Village aims to enhance the skills of local fishing boat craftsmen, who previously focused solely on constructing uniform wooden boats. This program introduces boat design standards, FRP material, safety procedures, mold creation, and the completion process of FRP boats. The initiative serves as a solution to the challenges in sourcing wood and leverages opportunities for developing FRP boats in the region, promoting technological advancement and material efficiency in boat construction [12].

A previous study aimed to assess the extent of classification rule implementation in the production of fiberglass fishing vessels with a 3 GT capacity. This was done by testing the tensile and flexural strength of lamination specimens sourced from two shipyards commissioned by the Ministry of Marine Affairs and Fisheries (KKP) in 2016. The evaluation focused on the conformity of lamination structures with the standards set by the Indonesian Classification (BKI). Additionally, the study provided alternative optimal lamination configurations for the construction of small fiberglass fishing vessels, with the goal of enhancing vessel quality and safety in accordance with applicable regulations. [13].

This study investigated the effect of catalyst concentration on the tensile strength of fiberglass-polyester composites. The results showed that tensile strength increased from 4.85 kgf/mm² at 0.5% catalyst to 5.49 kgf/mm² at 1.5% catalyst, but then decreased to 4.97 kgf/mm² with 2% catalyst. The highest tensile strength was achieved with a composite containing 100% resin and 1.5% catalyst. Additionally, both elongation and elastic modulus varied according to the amount of catalyst used [14]. This study focuses on the impact of the number of fiberglass-chopped and fiberglass-woven layers on the tensile and bending strength of ship composites, with the goal of determining these strengths according to BKI Standards. The research employs fiberglass composites with randomly oriented fibers as well as fibers aligned at 0° and 90°, which are subjected to tensile and bending tests. The mold used for the tests measures 19 cm x 15 cm x 0.5 cm and is made of glass. Polyester resin of the ETERNAL type, with MEPOXE catalyst, is used in the process. The study investigates the effects of using 3 to 5 layers of fiber, with orientations both random and at 0° and 90°. Each test specimen is created in triplicate and prepared following ASTM D638-14 and D790 standards. The hand lay-up method is employed for composite fabrication. The results of this study aim to provide insights into how the layer count and fiber orientation in fiberglass composites influence their tensile and bending strengths, thereby contributing to more effective and durable ship construction practices.

METHOD

This study comprised three main stages: preparation, data collection, and data processing. In the preparation stage, tasks included creating glass molds, preparing fibers, resin, and catalyst, and fabricating composite specimens. The data collection stage involved conducting tensile and flexural testing to evaluate the mechanical properties of the composite material. During this phase, various tests were performed to measure the strength, flexibility, and durability of the specimens under different conditions. Finally, the data processing stage included the creation of stress-strain graphs and involved comprehensive data analysis to interpret the test results. This analysis was crucial for understanding the performance characteristics of the composites.

The testing standard applied to material with a thickness of up to 14 mm and is specifically designed to assess the tensile properties of resin matrix composites with a modulus of less than 20 GPa. Polyester resins, which generally have a modulus ranging from 2.0 to 4.4 GPa, require adherence to specific testing parameters. Test specimens for reinforced composites must follow Type 1 dimensions as outlined in ASTM D638-14 and ASTM D790 standards. These standards ensure consistency, accuracy, and reliability in testing by defining precise size and shape requirements for specimens, facilitating meaningful comparisons across different studies and applications [15] [16]. Fabrication process of fiberglass composites using random hybrid fibers and fibers oriented at 0° and 90° (woven), woven fiber composite is composite material reinforced with woven fibers, where the fibers are interlaced into a fabric structure to enhance the strength and stiffness of the composite. Chopped fiber composite is composite material reinforced with short or randomly oriented fibers, which are dispersed within the matrix to improve its mechanical properties [17].

Table 1. Variations in research

Specimen	Variabels	Material Mix	
		Layers	Resin (ml)
A	Fiberglass *chopped-woven-chopped*	3	100 : 1,5
B	Fiberglass *chopped-chopped- woven- woven*	4	100 : 1,5
C	Fiberglass *chopped-chopped- chopped-woven -woven*	5	100 : 1,5

Involves varying thicknesses from three to five layers of fiber, with a fiber-to-resin ratio of 30% to 70%. This process is carried out using the hand lay-up method, in accordance with ASTM D638-14 and ASTM D790 standards. For each thickness variation, two test specimens are prepared, resulting in a total of 24 specimens. The production process includes preparation of material and equipment such as glass molds, fiberglass fibers, catalyst, and resin. It proceeds with mixing resin and catalyst, followed by molding and curing the composites for 24 hours. This process is repeated until the required number of specimens is achieved. The resulting composites are then cut to meet ASTM standard dimensions. Additionally, calculations of the mold volume and specimen composition are performed, with the mold having a volume of 142.51 ml consisting of 30% fiber and 70% matrix.

The Hand Lay-Up method, though simple, is highly effective for composite fabrication. In this process, composites are constructed by sequentially layering resin and reinforcing material, such as fiberglass or natural fibers, to achieve the desired thickness. Each layer is carefully positioned, and once the target thickness is reached, a roller is used to ensure a smooth and even surface. This technique guarantees uniform resin distribution and reinforcement, resulting in a composite with consistent structural properties [18].

Figure 1. Tensile and Bending test processes

After the composite is formed into test specimens according to ASTM D638-14 and D790 standards, the specimens will undergo testing using a Universal Testing Machine (UTM) for tensile and bending tests. The tensile test aims to determine the average tensile strength, strain, and bending characteristics of each fiber layer ratio variation. These tests will be conducted at the Integrated Laboratory of Institut Teknologi Kalimantan.

In the process of composite fabrication, fiberglass weighing 14 grams is cut to specific dimensions and weighed using a digital scale to ensure uniformity in the material. The mold is coated with wax to prevent the composite from adhering to the surface. Polyester resin is then mixed with MEPOXE catalyst in a plastic cup, with the catalyst volume precisely measured using a syringe. The resin-catalyst mixture is poured into the waxed mold, which has also been treated with a release agent, and a layer of fiberglass is subsequently added. The mold is then sealed and left to cure for 24 hours. After the curing process, the composite is carefully removed from the mold with the help of a cutter, and any excess resin is trimmed to create a smooth, even surface. This procedure is repeated with varying numbers of fiberglass layers to produce composites of different thicknesses.

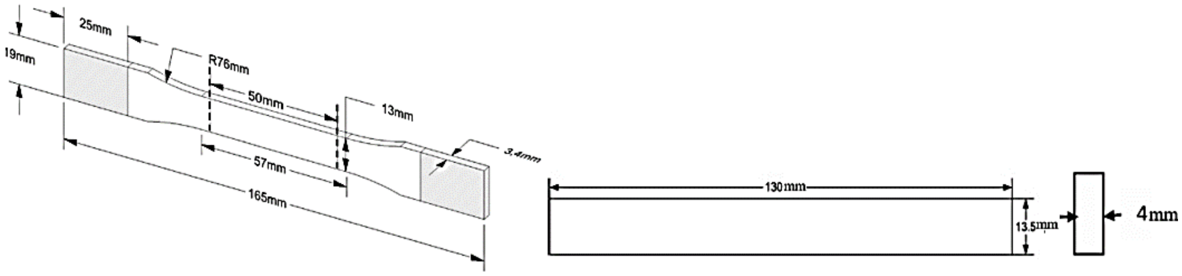

Figure 2. Dimensions of the ASTM D638-14 and ASTM D790

ASTM D638-14 is a standard used to test and determine the tensile properties of plastics and composite material. This test is crucial for evaluating the mechanical performance of material, as it measures various parameters such as tensile strength, elastic modulus, elongation, and the material's breaking point. The testing procedure is conducted using a tensile testing machine, where the specimen, typically shaped like a dogbone or a rod, is specifically designed to ensure even stress distribution during the test. The specimen is pulled until it breaks, and throughout this process, critical data on the material's tensile properties are recorded. The results from this test provide valuable insights into how a material will behave under tensile load, which is essential for the design and engineering of products that utilize plastics or composites. ASTM D790 is a testing standard used to measure the flexural properties of plastics and composite material. This flexural test aims to determine the flexural strength, flexural modulus, and toughness of a material under load. Unlike tensile testing, flexural testing involves loading a beam-shaped specimen, typically placed on two supports. The load is applied at the midpoint of the beam until the specimen undergoes deforchoppedion or breaks. This test provides insights into the material's ability to withstand bending and deforchoppedion, which is crucial for applications where the material will experience flexural or buckling loads. Both ASTM D638-14 and ASTM D790 are integral parts of the material mechanical properties evaluation process. By measuring tensile and flexural strength, along with other related parameters, engineers and material scientists can ensure that the material they use will perform as expected in real-world applications. This inforchoppedion is also valuable for improving material formulations, optimizing product design, and ensuring that the final products meet the required performance standards. Consequently, testing according to these ASTM standards plays a vital role in industries that rely on plastics and composites as primary material [14; 13].

Figure 3. Production results of the composite material into specimen shapes ASTM D638-14 dan D790.

Once the fiberglass-reinforced composite has been fabricated, the next step is to shape it into specimens for tensile testing as per ASTM D638-14 and for flexural testing as per ASTM D790-02 standards. The process begins by preparing a grinder to cut the composite into multiple pieces. The composite surface is marked with a marker to outline the standard shape and size of the specimens, and then it is cut into three sections using the grinder. These sections are subsequently shaped to the required dimensions with a bench grinder. The prepared specimens are then ready for tensile and flexural tests.

Table 2. BKI Rules for Fiberglass

A	. Tensile Strength	10	kg/mm^2
B	Modulus Of Tensile Elasticity	700	kg/mm^2
C	Bending Strength	15	kg/mm^2
D	Modulus of Bending Elasticity	700	kg/mm^2

BKI rules are shown in table 2 The regulations used for testing fiberglass vessels are outlined in the "Regulations for Fiber-Reinforced Plastic (FRP) Ships," specifically in Part 1: General Regulations, found in Part C: General Regulations for Hull Structure and Equipment, item 4 Scantling. These regulatory requirements apply to FRP constructed using fiberglass-reinforced material, unsaturated polyester resin, and epoxy resin through hand lay-up or spray-up lamination processes. For fiberglass-reinforced material filled with reinforcing fibers, the types of chopped and roving must meet specific strength standards [19].

$$\text{Tensile Strengh}$$
$$Xmin = a\left[Xref\left(\frac{\varphi}{0.4}\right)\right] - [1278\varphi^2 + 510\varphi + 123]MPa \;\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\text{Bending strengh}$$
$$Xmin = a\left[Xref\left(\frac{\varphi}{0.4}\right)\right] - [502\varphi^2 + 106.8]MPa \;\ldots\ldots\ldots\ldots\ldots \quad (2)$$

These two equations are used to calculate the minimum strength of a material, either tensile or bending strength. The minimum strength is influenced by several factors, including the intrinsic properties of the material (represented by Xref), a variable φ whose exact physical meaning is not specified, and several empirical constants. Xmin represents the minimum attainable value of a variable, often associated with the minimum strength of a material (e.g., minimum tensile strength). Xref serves as a reference or baseline value for comparison. The variable φ is a variable parameter that influences the value of Xmin, meaning that changes in φ will affect the resulting Xmin. The constants a, b, c, and d are fixed values used to fit the equation to experimental data. The constant 0.4 is used to normalize the value of φ to ensure it falls within an appropriate range. Overall, the equation involving these variables is used to model the relationship between various factors affecting material strength.

In the study of the strength of laminated composite material, fiber volume fraction (ϕ) is a crucial factor that influences the material's performance. In this example, a fiber volume fraction of 0.3 or 30% is considered, corresponding to the composition of the laminated material in the sample. The determination of material strength also refers to the minimum required strength (Xmin), expressed in MPa. For reference, the tensile strength (Xref) is set at 500 MPa, while the reference flexural strength is 650 MPa. Additionally, the factor α, which accounts for the orientation of the reinforcing fibers, is important in this analysis. For tensile and flexural strength with fibers oriented at 0°/90°, the factor α is set at 0.55, reflecting the impact of fiber orientation on the material's capacity to withstand tensile and flexural loads. The test results from the specimen include data that can be used to calculate strain, stress, elastic modulus, and maximum pressure of the specimen.

RESULTS AND DISCUSSION

Figure 4 illustrates a comparison of the average stress from tensile tests for three different types of fiber layers in composite material. The figure is presented as a bar chart, showing how the average stress varies with different numbers of fiber layers in the composite, specifically 3, 4, and 5 layers. From the results, it is observed that the composite with 3 fiber layers exhibits an average stress of 35.06 MPa, indicating that the 3-layer configuration yields the lowest stress among the three specimens tested. Subsequently, increasing the number of fiber layers to 5 results in an increase in average stress to 42.19 MPa. This demonstrates that adding more fiber layers enhances the tensile strength of the composite, although this increase does not represent the highest achievable stress. Interestingly, the highest stress is observed in the composite with a 4-layer configuration, which exhibits an average stress of 48.86 MPa. This finding suggests that the addition of fiber layers does not lead to a linear increase in strength, and that there is an optimal number of layers that provides the best performance.

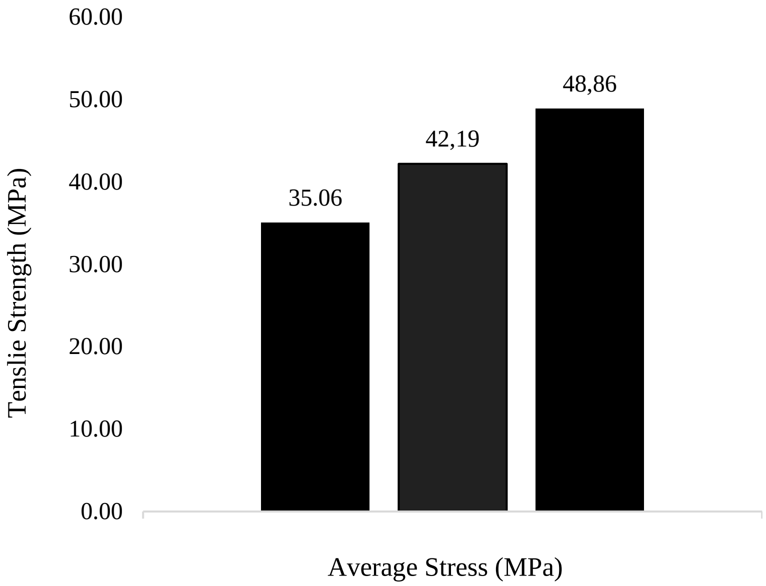

Figure 4. Comparison of the average stress from tensile testing for three types of fiber layers.

These findings emphasize that a 4-layer fiber configuration results in the highest tensile strength compared to the 3-layer and 5-layer configurations. This underscores the importance of selecting the appropriate number of layers in composite material design to achieve optimal mechanical performance. The variation in the number of fiber layers is shown to have a significant impact on the resulting stress, and therefore, the arrangement of fiber layers in composite material must be carefully considered to achieve the desired outcome. Understanding the tensile strength of a material is often a critical factor in determining the success or failure of the final product.

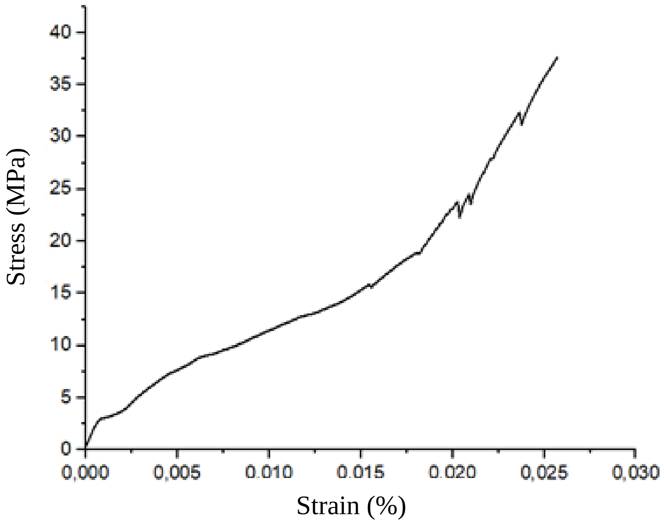

Figure 5. Stress (MPa) and Strain (%) observed in Specimen 3 with a total of 4 layers.

Figure 5 shows the relationship between stress (MPa) and strain (%) for a material, detailing its mechanical behavior under load. Early in the process, the material demonstrates a sharp rise in stress with minimal strain, reflecting its initial resistance to deformation. As strain approaches 0.002%, a transition occurs where the rate of stress increase diminishes, likely due to the material beginning to exhibit plastic behavior. Following this phase, stress increases almost linearly with strain, indicating the material's capacity to handle additional stress without significant damage. Ultimately, the material reaches its maximum stress at about 50 MPa with a strain of 0.012%, signifying the threshold before potential failure. The observed stress value is 53.15 MPa.

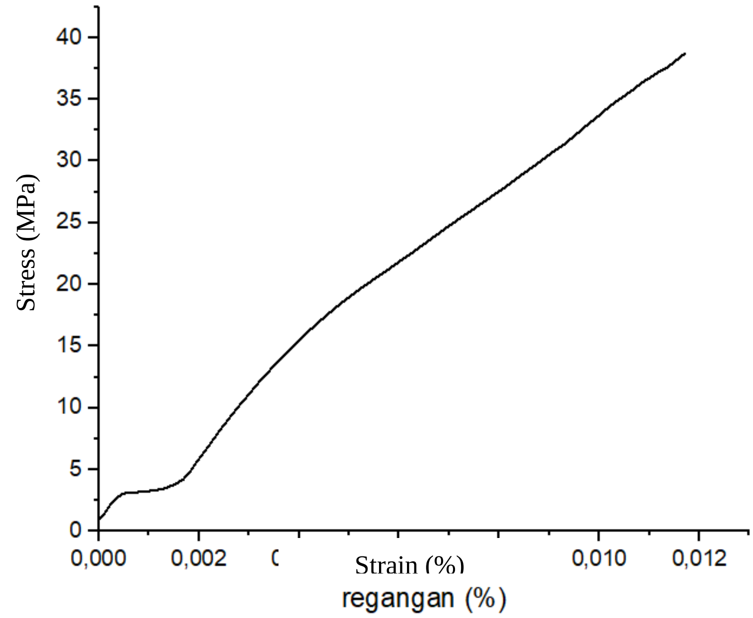

Figure 6. Stress (MPa) and Strain (%) for Specimen 3 with a total of 5 layers.

Figure 6 depicts the relationship between stress (MPa) and strain (%) for a material, illustrating its mechanical response under loading. Initially, stress increases sharply despite minimal strain, signifying the material's strong initial resistance to deformation. As the strain reaches approximately 0.004%, the rate of stress increase decelerates slightly, indicating a transition from the elastic to the plastic phase. Following this transition, stress increases more linearly, suggesting the material's continued ability to bear additional loads without substantial damage. The graph shows the material reaching a maximum stress of about 46,84 MPa at 0.012% strain, reflecting the material's strength limit before nearing failure.

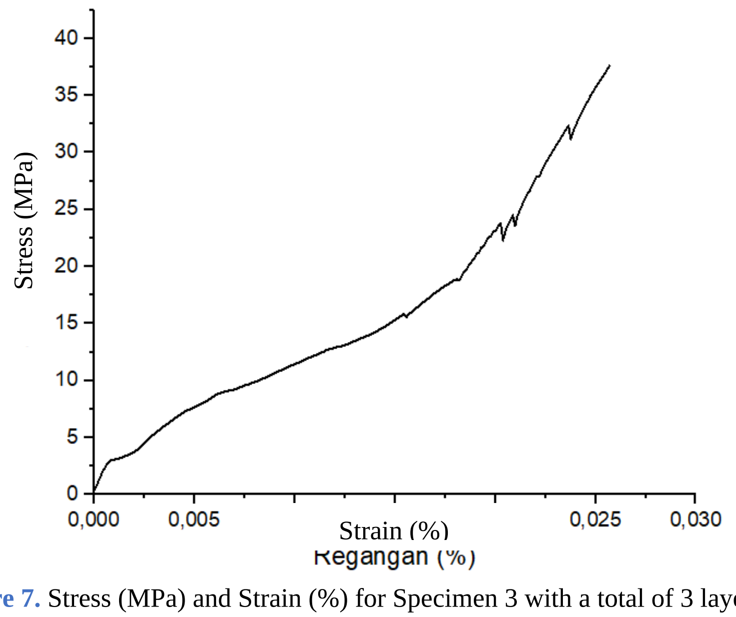

Figure 7. Stress (MPa) and Strain (%) for Specimen 3 with a total of 3 layers.

At the beginning of the graph observed in Figure 7, it is observed that when strain is still low, stress increases gradually, indicating that the material is in the elastic phase, where it can return to its original shape after the load is removed. As strain increases, stress begins to rise more rapidly, indicating the material's entry into the plastic phase, where permanent deformation starts to occur. At a certain point, the graph shows a sharp increase, suggesting that the material is approaching its strength limit. This is followed by a significant increase in stress, even as strain continues to rise, indicating that the material has undergone substantial deformation and is nearing the breaking point. Overall, the graph provides insight into the material's mechanical behavior under load, as well as its strength and resistance to deformation. The modulus of elasticity is determined to be 3119 MPa.

Table 3 presents a comparison of the tensile test results of a material with the minimum standards set by the Indonesian Classification (BKI). This testing was conducted to assess whether the material meets the required strength and stiffness for specific applications. The results indicate that the tensile strength and modulus of elasticity of the tested material are significantly lower than the BKI standards, suggesting a discrepancy between the material's mechanical properties and the established requirements. Potential factors contributing to this discrepancy may include the quality of raw material, imperfections in the manufacturing process, or inadequate material structure design. This significant difference has serious implications for the material's performance in practical applications, necessitating further analysis to identify the root causes and determine the necessary corrective actions.

Table 3. Comparison of Tensile Test Results Against the Minimum Standards of BKI.

Mechanical Properties	Volume Fraction	Fiber Layer Amount	BKI Minimum Standards (MPa)	Comparison of Tensile Test Results (MPa)
Tensile Strength (MPa)	70% : 30%	3	121.23	35.06
		4	121.23	48.86
		5	121.23	42.19
Modulus of Elasticity (MPa)	70% : 30%	3	4375	2898.13
		4	4375	12050.80
		5	4375	9903.10

The bending test results for the composite, conducted on 9 specimens, involved different layer configurations: 3 layers of fiberglass chopped-woven-chopped, 4 layers of fiberglass chopped-chopped-woven-woven, and 5 layers of fiberglass chopped-chopped-chopped-woven-woven. The composite used fiberglass chopped and woven reinforcement, with a composition of 30% fiber and 70% polyester resin.

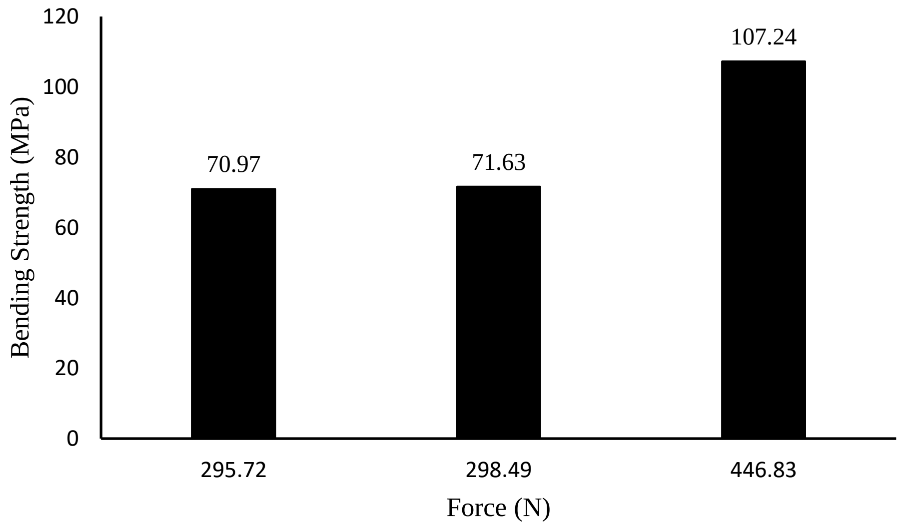

Figure 8. Force and Bending Strength (MPa) for 3 specimens with 3 layers each.

Figure 8 illustrates the relationship between force (N) and bending strength (MPa), with three data points showing variations in bending strength at different pressure levels. At a force of 295.72 N, the recorded bending strength is 70.97 MPa. As the force increases to 298.49 N, the bending strength shows a slight increase to 71.63 MPa. However, a significant increase in force to 446.83 N leads to a sharp rise in bending strength, reaching 107.24 MPa. These findings suggest that increased force can significantly enhance bending strength.

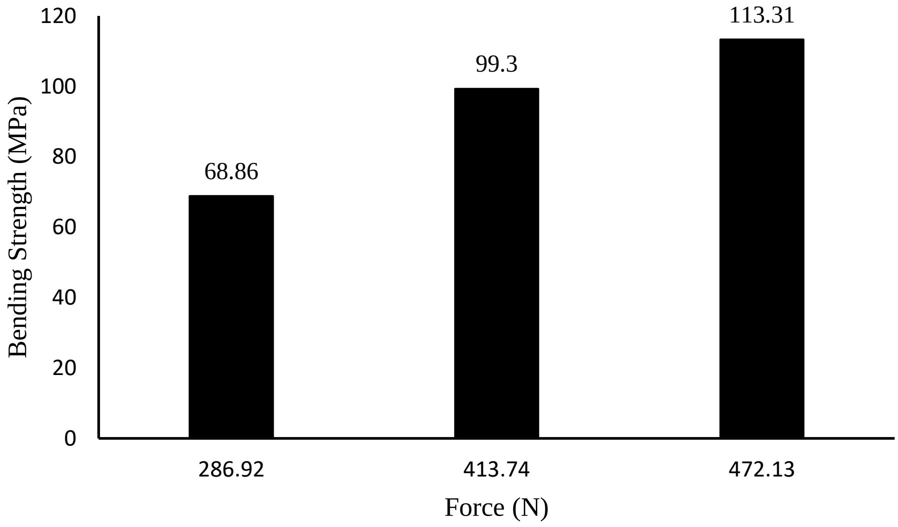

Figure 9. Force and Bending Strength (MPa) for 3 specimens with 4 layers each.

Figure 9 illustrates the relationship between force (N) and bending strength (MPa) under three different conditions. At a force of 413.73 N, the recorded bending strength is 99.29 MPa, indicating a relatively high value. However, when the force decreases to 286.92 N, the bending strength drops significantly to 68.861 MPa, the lowest among the three conditions. Conversely, increasing the force to 472.13 N results in a sharp rise in bending strength to 113.31 MPa, the highest value recorded in this diagram. This data suggests a direct correlation between increased force and enhanced bending strength, while a reduction in force can lead to a significant decrease in bending strength. Additionally, the results indicate that bending strength tends to increase more sharply at higher force levels. This analysis highlights the importance of considering force variations to optimize the bending strength of a material.

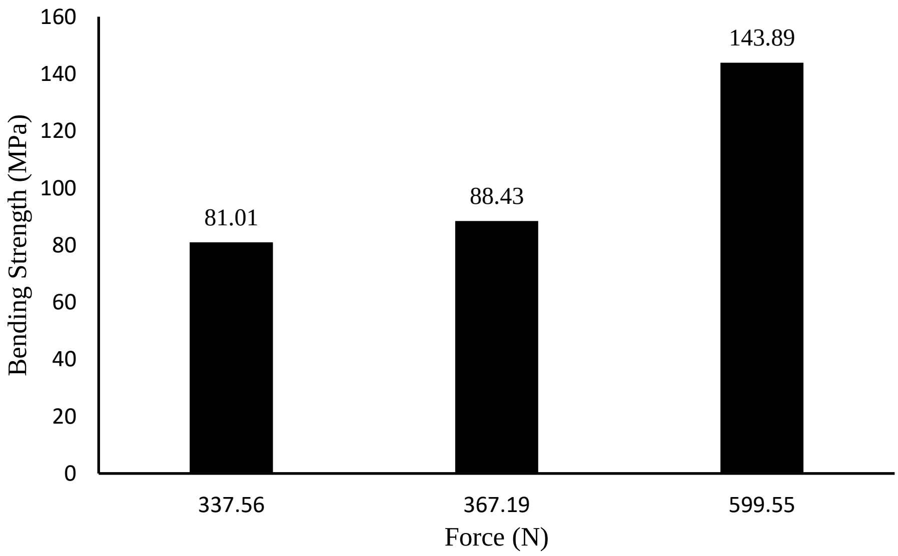

Figure 10. Force and Bending Strength (MPa) for 3 specimens with 4 layers each.

The diagram illustrates the relationship between force (N) and bending strength (MPa) across three different conditions. At the highest force of 599.55 N, the bending strength reaches 143.89 MPa, the maximum value in this dataset. When the force is reduced to 367.18 N, the bending strength significantly decreases to 88.44 MPa. Further reduction in force to 337.55 N results in an additional decrease in bending strength to 81.01 MPa, the lowest recorded value. This data shows a positive correlation between increased force and enhanced bending strength, particularly at higher force levels. Conversely, reduced force is associated with a notable decrease in bending strength. These findings emphasize the importance of maintaining optimal force to maximize material bending strength. Additionally, the drastic reduction in bending strength with decreasing force indicates the material's sensitivity to pressure changes, underscoring the need for careful force management to ensure material integrity in applications requiring high bending strength.

Table 4 presents the bending strength (MPa) results for a composite material with a volume fraction of 70% fiber and 30% matrix. The tests were conducted with varying amounts of fiber: 3, 4, and 5 layers. The Indonesian Classification minimum standard for bending strength is 116.14 MPa. The results indicate that the average bending strength increases with the number of fiber layers, showing values of 83.28 MPa, 93.82 MPa, and 104.44 MPa, respectively. Although the results do not yet meet the minimum standard, there is a significant increase in strength with the addition of more fiber layers.

Table 4. Comparison of Bending Test Results Against the Minimum Standards Indonesia Klasifikasi.

Mechanical Properties	Volume Fraction	Fiber Layer Amount	BKI Minimum Standards (MPa)	Comparison of Bending Test Results (MPa)
Bending strength (MPa)	70% : 30%	3	116.145	83.28
		4	116.145	93.82
		5	116.145	104.44

CONCLUSION

The tensile test results for the composite with fiberglass reinforcement exhibit significant variation depending on the type and arrangement of fibers used. In the initial test, the composite with the fiberglass chopped-woven-hybrid configuration achieved the highest tensile strength value of 38.17 MPa, with an average stress of 35.06 MPa across three specimens. Meanwhile, the composite with the fiberglass chopped-chopped-woven-woven configuration showed improved strength, with a maximum strength of 53.16 MPa and an average stress of 48.87 MPa across four specimens. The final configuration, using fiberglass chopped-chopped-chopped-woven-woven, resulted in a maximum tensile strength of 46.84 MPa, with an average stress of 42.19 MPa from five specimens. In addition to tensile testing, bending tests were conducted to assess the composite's strength. The average bending strength for the fiberglass composite with the chopped-woven-chopped configuration was 83.28 MPa. The fiberglass chopped-chopped-woven-woven configuration showed higher bending strength at 93.82 MPa. The final configuration, fiberglass chopped-chopped-chopped-woven-woven, demonstrated the highest bending strength with a value of 104.44 MPa.

Despite the observed increase in strength with the addition of more fiber layers in both tensile and bending tests, these values still fall short of the minimum standards set by the Indonesian Classification (BKI). With fiber layers numbering 3, 4, and 5, the results do not meet the required minimum standards. This indicates that while there is a trend of increased strength with additional fiber layers, the improvement is insufficient to meet the required standards for specific applications. Further evaluation and potential adjustments in the composite's composition or manufacturing process are necessary to achieve compliance with BKI standards. The tensile test results for the composite with fiberglass reinforcement exhibit significant variation depending on the type and arrangement of fibers used. In the initial test, the composite with the fiberglass chopped-woven-chopped configuration achieved the highest tensile strength value of 38.17 MPa, with an average stress of 35.06 MPa across three specimens. Meanwhile, the composite with the fiberglass chopped-chopped-woven-woven configuration showed improved strength, with a maximum strength of 53.16 MPa and an average stress of 48.87 MPa across four specimens. The final configuration, using fiberglass chopped-chopped-chopped-woven-woven, resulted in a maximum tensile strength of 46.84 MPa, with an average stress of 42.19 MPa from five specimens.

In addition to tensile testing, bending tests were conducted to assess the composite's strength. The average bending strength for the fiberglass composite with the chopped-woven-chopped configuration was 83.28 MPa. The fiberglass chopped-chopped-woven-woven configuration showed higher bending strength at 93.82 MPa. The final configuration, fiberglass chopped-chopped-chopped-woven-woven, demonstrated the highest bending strength with a value of 104.44 MPa. Despite the observed increase in strength with the addition of more fiber layers in both tensile and bending tests, these values still fall short of the minimum standards set by the Indonesian Classification (BKI). With fiber layers numbering 3, 4, and 5, the results do not meet the required minimum standards. This indicates that while there is a trend of increased strength with additional fiber layers, the improvement is insufficient to meet the required standards for specific applications. Further evaluation and potential adjustments in the composite's composition or manufacturing process are necessary to achieve compliance with BKI standards.

REFERENCES

[1]. P. A. Wibawa, "Sustainable Fishing Vessel Development by Prioritising Stakeholders Engagement in Indonesian Small-Scale Fisheries," 2016.

[2]. S. M. Sapuan, *Composite Material*, 2017.

[3]. H. Syahab et al., "Structural design evaluation for Underwater Remotely Operated Vehicle (ROV), case study: Madura Straits," *IOP Conf. Ser.: Earth Environ. Sci.* **1198** 012007, 2023. 10.1088/1755-1315/1198/1/012007

[4]. R. F. Gibson, *Principles of Composite Material Mechanics*. New York: McGraw-Hill, 1994.

[5]. B. Ma'ruf, "Studi Standardisasi Konstruksi Laminasi Lambung Kapal," *Jurnal Standarisasi*, 2011.
[6]. W. Ririantika, Syaifuddin, and R. M. Hutahuruk, "Pengaruh Variasi Susunan Serat terhadap Kekuatan *Material* Fiberglass pada Kapal Perikanan Produksi Galangan Kapal Karya Sakti Bengkalis," 2013.
[7]. S. A. Rahmawaty, A. W. Y. Putra Parmita, and A. D. Laksono, "Analisa Kekuatan Tarik dan Tekuk pada Komposit Fiberglas-Polyester Berpenguat Serat Gelas dengan Variasi Fraksi Volume Serat," *Jurnal Teknik Mesin – ITI*, 2021.
[8]. Nofrizal, M. Ahmad, and Syaifuddin, "Industri Galangan Kapal Tradisional di Bagansiapiapi," *Jurnal Perikanan dan Kelautan*, 2014.
[9]. P. A. Wibawa, A. Wahidin, Fathulloh, P. S. Asmara, Budianto, and Sumardiyono, "Pelatihan Pembuatan Perahu Berbahan FRP (Fiberglass Reinforced Plastic) untuk Pengrajin Perahu Nelayan di Desa Gisik Cemandi, Sidoarjo, Jawa Timur," *Jurnal Cakrawala Maritim*, 2018.
[10]. Marzuki, A. Zubaydi, and B. Ma'ruf, "Kajian Penerapan Aturan Klasifikasi pada Laminasi Struktur Konstruksi Lambung Kapal Ikan Fiberglass 3 GT," 2017.
[11]. Alamsyah, R. J. Ikhwani, T. Hidayat, and Suardi, "Kekuatan Fiberglass Reinforced Plastic (FRP) sebagai Bahan Gading Kapal Kayu," *Wave: Jurnal Ilmiah Teknologi Maritim*, 2021.
[12]. T. Alamsyah, T. Hidayat, and A. N. Iskandar, "Pengaruh Perbandingan Resin dan Katalis terhadap Kekuatan Tarik Komposit Fiberglass-Polyester untuk Bahan Pembuatan Kapal," *Zona Laut: Journal of Ocean Science and Technology Innovation*, 2021.
[13]. ASTM, "Standard Test Method for Tensile Properties of Plastics D638-14," 2014.
[14]. ASTM, "Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating *Material*," ASTM International, U.S. Department of Defense, West Conshohocken, 2015.
[15]. M. Akay, An Introduction to Polymer-Matrix Composites. London: Bookboon, 2015.
[16]. Biro Klasifikasi Indonesia, *Part 1 Seagoing Ships*. Jakarta: Biro Klasifikasi Indonesia, 2018.