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Analysis of Tensile and Bending Strength of Coconut Fiber Reinforcement Composite on Quasi-Isotropic Laminates Stacking Sequence

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Abstract
A composite is a material structure composed of two or more combinations of constituents combined macroscopically, where the two combinations do not dissolve each other. This research method is experimental in which fiber reinforced polymer composites are arranged in 3 sequences of quasi-isotropic laminates, namely [0°/0°/0°], [+45°/0°/-45°] and [+60°/ 0°/-60°]. The materials used are polyester resin and coconut fiber. For tensile test specimen testing, refer to ASTM D-3039 and bending test standards refer to ASTM D-790. The results of the blistering test obtained a maximum stress of 18.3298 N/mm^2 in the fiber layer sequence [0°/0°/0°] and a minimum stress of 10.8966 N/mm^2 in the fiber layer sequence [+60°/0°/ -60°]. Meanwhile, the bending test results showed that the maximum bending stress was 76.065 N/mm^2 in the fiber layer sequence [0°/0°/0°] and the minimum stress was 30.256 N/mm^2 in the fiber layer sequence [+45°/0°/-45 °].
Keywords: Composite, coir, tensile, and bending.

Introduction

Over the last few years, the use of natural fibers as a substitute for synthetic fibers has been widely researched. Some of the basic reasons for its use are: environmentally friendly, renewable, abundant fiber availability, mechanical properties that meet standards. Lightweight, eco-friendly, and sustainable use of natural fiber reinforced composites (NFRC) is increasingly considered by automakers and researchers (Naik et al., 2022)(Naik et al., 2022). Natural fibres are of interest for low-cost engineering applications and can compete with artificial glass fibres (E-glass fibre) when a high stiffness per unit weight is desirable (Jauhari et al., 2015). Natural fiber reinforced polymer composites are greatly influenced by fiber internalization such as: fiber type, fiber chemistry, fiber length, fiber orientation and laminate arrangement. Rigid composites have high stiffness, often these composites are made using the lamination method.

A good composite lamination method is a lamination method that takes into account the aspects of working forces and high stiffness. Laminate system composites are fiber composites where the fibers are arranged in certain directions (0^o, 30^o, 45^o, 60^o, 90^o) and arranged in layers (2 layers, 3 layers, 4 layers depending on the desired stiffness. The more distribution of force directions, the more homogeneous the strength of the

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composite and the more layers that are arranged in one composite unit, the stiffer it is. The arrangement of fiber orientation is based on the direction of the force that works, while the number of layers can be 2 or more depending on the level of stiffness of the composite material you want to achieve. The more layers, the more rigid and rigid the resulting composite. In its application, natural fiber requires a special method in its fabrication because in general natural fiber has limitations in fiber length and fiber size uniformity. The specific method for making natural fiber composites is also explained in the methods section of this research.

In this research, coconut fiber was used because it has good absorbency properties and is high in cellulose and lignin (Sasria, 2022). Coir fibers have good mechanical properties, higher fracture toughness including the best elongation among known natural fibers, as well as the ability to enhance the toughness of resin (Rachmat et al., 2023). However, coir fibers are hydrophilic, while resin is hydrophobic. The chemical composition of coconut fiber consists of water soluble 5.25%, pectin and related compounds 3.00%, hemicellulose 0.25%, lignin 45.84%, cellulose 43.44%, ash 2.22 (Pani & Mishra, 2019).

Some research on the use of natural fibers in polymer composite applications includes research on the use of natural fibers which have advantages such as: low density, high specific strength and renewable, sustainable and environmentally friendly (Kiruthika, 2017)(Saba et al., 2016). The orientation of the fiber direction greatly determines the strength of the composite relative to the existing stress distribution (Adamy et al., 2020) (Roza & Dirhamsyah, 2015), conducted research with the materials used including coconut fiber powder, sengon wood, urea formaldehyde (UF) binder, 25% emulsion (paraffin) 40% and catalyst (NH_4CL) (Roza & Dirhamsyah, 2015). Research on epoxy/carbon fiber composite laminates on unmanned aircraft wings was reported by (Siregar & Arief, 2022). The research of effect of stacking sequence on Charpy impact and flexural damage behavior of composite laminates (Caminero et al., 2016).

Based on its composition, it can be divided into four groups, namely: composites that use elongated fiber types, composites that use woven fiber types, composites that use short fiber types and composites that use hybrid fiber types. A composite is a material structure composed of two or more combinations of constituents combined macroscopically, where the two combinations do not dissolve each other. The first phase is called reinforcement, while the second phase is called matrix (Aminur et al., 2019)(Aminur et al., 2023; Gibson, 2012).

Several terms apply to structural composites such as laminate and laminate. Lamina is defined as a plate or sheet of composite material that only has one direction of fiber orientation. Laminate is a combination of two or more laminates arranged on top of each other, each installed at varying angles(Muc, 2022). These laminae were found to have numerous uses due to their high strength to weight ratio and resistance to corrosion and surface degradation (E et al., 2020)(Ogunleye et al., 2022).

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Research on polymer composites with coir reinforcement has been widely reported by researchers as mentioned above. Most of the research on coir-reinforced polymer composites focuses on straight fiber, random fiber, hybrid, short fiber composites, but very few studies have been found that lead to research on fiber arrangement with lamination systems with fiber direction orientation. The aim of this research is to study the tensile and bending strength of composites reinforced with coconut fiber with a sequence of quasi-isotropic laminates. The fiber sequences created are [+45°/0°/-45°] and [+60°/0°/-60°]. As a comparison, the [0°/0°/0°] sequence was also created to understand the extent of the relationship between fiber arrangement and fiber orientation. Coir-reinforced quasi-isotropic composite laminates with stacking sequences were tested using tensile testing and bending testing methods. In tensile testing, tensile strength, tensile strain, elastic modulus are calculated, while in bending testing, bending strength, flexural strength and deflection modulus are calculated.

Research Methods

The fiber used in this study was coconut fiber (coir) with an average length of 160 mm and a diameter of 0.6-1.2 mm, while the matrix material used was polyester resin. To increase the adhesion of the fiber and matrix, the fiber was treated with 5% NaOH alkali for 2 hours. The composite is made by arranging coconut fiber fibers in Quasi.

Isotropic laminates, namely 3 layers with fiber direction orientations of [0°/0°/0°], [+45°/0°/-45°] and [+60°/0 °/-60°] with a thickness per layer of 1 mm. The layer thickness is the same in each composite, the only difference is in the position of fiber placement for each layer. The arrangement per layer can be seen in the following image:

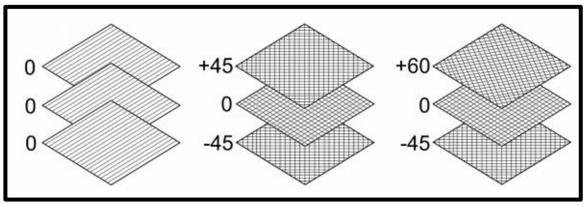

Figure 1. Scheme of fiber arrangement

The composite has been made in the form of panels with a width of 150 mm and a length of 150 mm. Composite samples are formed into tensile test specimens referring to ASTM D-3039 and bending test specimens ASTM D-7264. The test was carried out three times for each variable number of laminates, so the calculation was carried out three times. Because in this research there were three variations, nine tensile test data were produced and each was processed to calculate tensile strength, tensile strain, elastic modulus, bending stress, deflection and flexural modulus. The results of this processed data are plotted into graphs to make it easier to interpret in a discussion.

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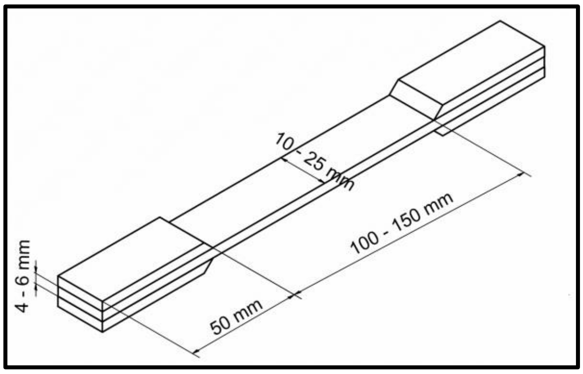

Figure 2. Tensile test specimen ASTM D-3039

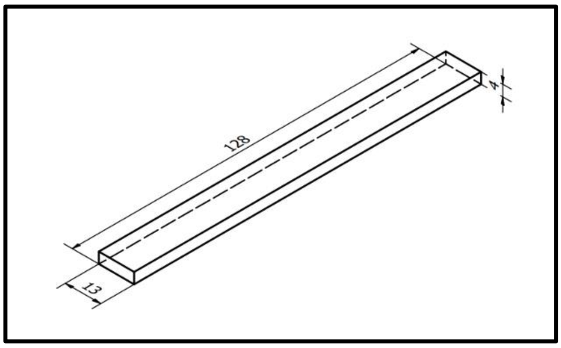

Figure 3. Tensile test specimen ASTM D-7264

Result and Discussion

Tensile Test

Table 2 shows the results of tensile tests on variations in fiber direction and fiber arrangement [0°/0°/0°], [+45°/0°/-45°] and [+60°/0°/-60°], It can be seen that the specimens with the highest mechanical properties are found in the composite specimens in the [0°/0°/0°] direction and arrangement. As for the maximum tensile strength, it reaches 18.3298 N/mm^2.

Table 1. Mechanical properties of tensile test

Fiber Sequence	**Stress (N/mm^2)**	**Strain (%)**	**Elasticity Modulus GPa**
[0°/0°/0°]	18,3298	0,7265	0,7265
[+45°/0°/-45°]	14,7958	0,6758	0,6758

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[+60°/0°/-60°]	10,8966	0,2244	0,2244

Sekuens Susunan	Tegangan (N/mm^2)	Regangan (%)	Modulus Elastisitas (GPa)
[+0°/0°/0°]	18,3298	0,7265	0,7265
[+45°/0°/-45°]	14,7958	0,6758	0,6758
[+60°/0°/-60°]	10,8966	0,2244	0,2244

Figure 3 shows the tensile test results of composites with the [0°/0°/0°] arrangement sequence having the highest tensile strength values and the [+60°/0°/-60°] arrangement sequence having the lowest tensile strength. The tensile strength of composites is influenced by the direction of the fibers, where the smaller the angle of the fiber direction to the axial force, the greater the stress value that the composite material can accept so that its strength becomes higher. On the other hand, if the greater the angle of the fiber direction to the axial force, the smaller the stress value that the composite material can accept so that its strength becomes lower.

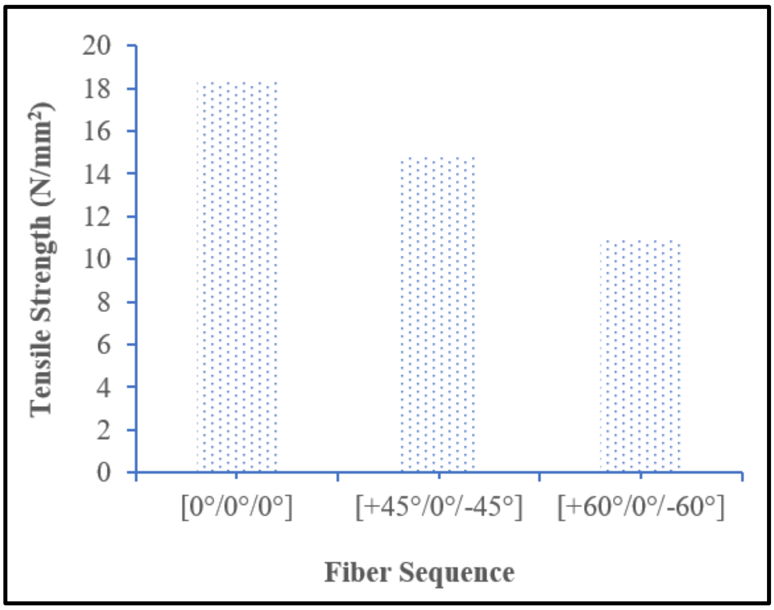

Figure 4. Tensile strength of the fiber sequence

Figure 5 shows the tensile strain of composite materials where the tensile strength is directly proportional to the tensile strain. The composite that uses the fiber direction

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[0°/0°/0°] is able to withstand a stress of 18.3298 N/mm^2 and a maximum strain of 0.7265% in (figures 4 and 5).

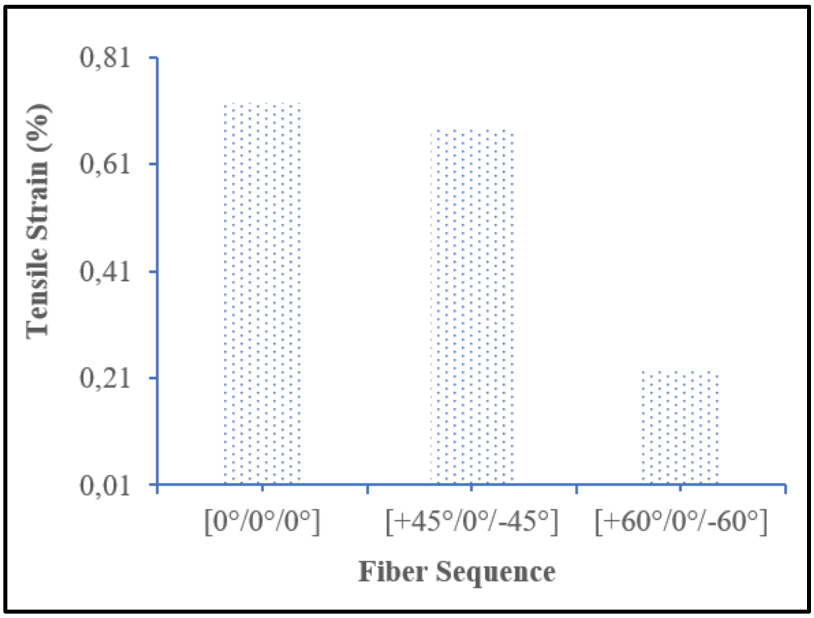

Figure 5. Tensile strain on the fiber sequence

Tensile modulus is a measure of the stiffness of an elastic material which is a characteristic of a material. The tensile elastic modulus in the fiber direction [+60°/0°/-60°] is the lowest value, namely 0.2244 GPa.

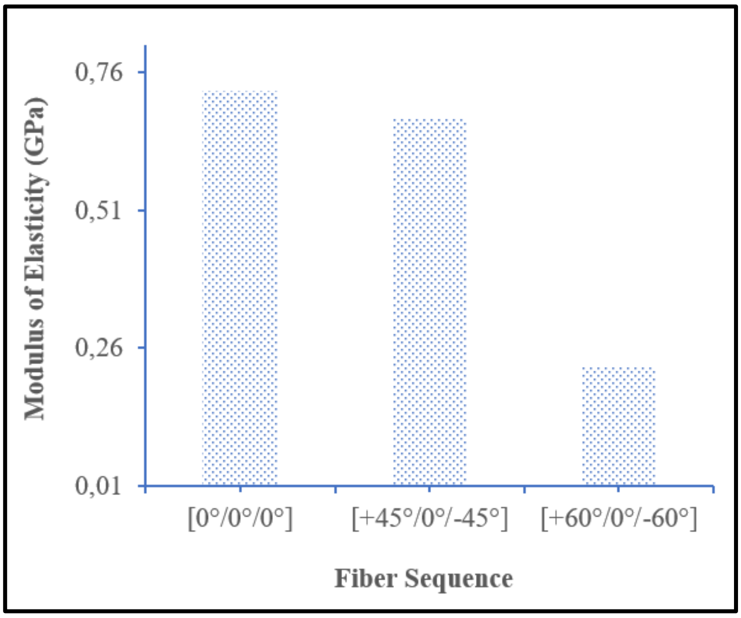

Figure 6. Modulus of Elasticity on the fiber sequence

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Bending Test

The bending test results from this research are in table 2 which shows the mechanical properties including bending stress, flexure modulus and deflection.

Table 2. Mechanical properties of bending tests

Fiber Sequence	**Stress (N/mm^2)**	**Elasticity Modulus GPa**	**Deflection**
[0°/0°/0°]	76,0659	0,15766	12,100
[+45°/0°/-45°]	30,2562	0,13247	3,300
[+60°/0°/-60°]	59,7934	0,14932	9,700

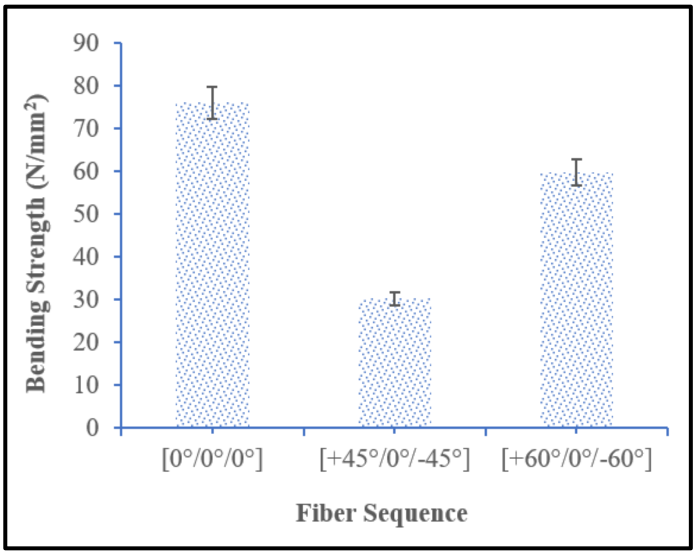

Figure 7. Bending strength on the fiber sequence

Figure 7 shows the largest bending stress, namely 76.065 N/mm^2 in the [0°/0°/0°] arrangement sequence and the smallest bending stress, namely 30.256 N/mm^2 in the [+45°/0°/-45°] arrangement sequence. Bending tests are used to measure material strength due to loading and elasticity of the specimen.

Figure 8 shows the effect of bending elastic modulus on fiber arrangement sequences [0°/0°/0°], [+45°/0°/-45°] and [+60°/0°/-60°]. The highest average bending elastic modulus value is shown by the [0°/0°/0°] sequence of 0.157 GPa and the lowest average bending elastic modulus value is 0.132 GPa in the [+45°/0°/-45°] sequence.

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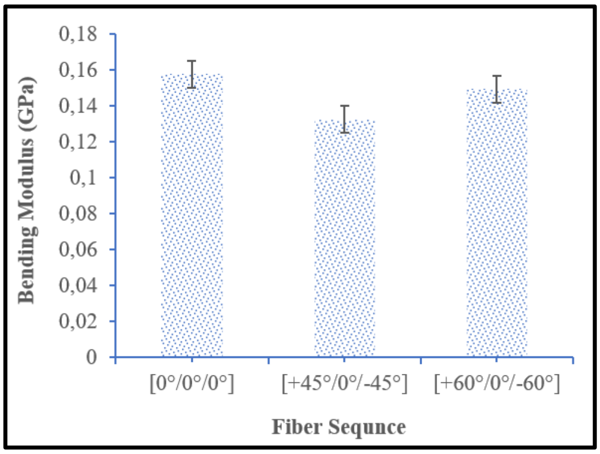

Figure 8. Bending modulus on the fiber sequence

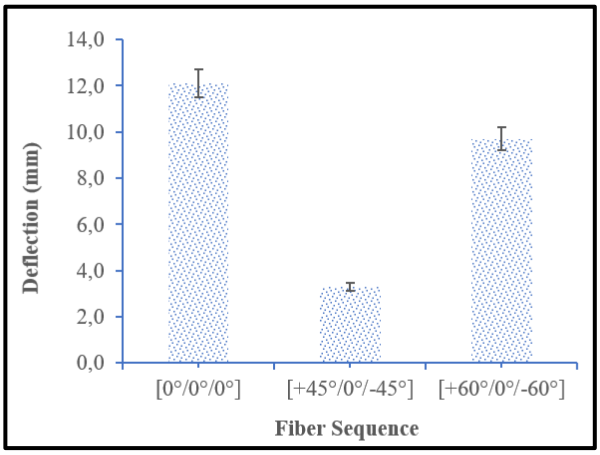

Figure 9. Deflection of the fiber sequence

Deflection is a change in shape of a beam in the y direction due to the vertical load applied to the beam or rod. Figure 8 shows the deflection that occurs in each fiber arrangement sequence. The largest deflection is shown in the fiber arrangement sequence [0°/0°/0°], namely 12.10 mm and the smallest deflection of 3.3 mm is shown in the fiber arrangement sequence [+45°/0°/-45°].

Conclusions

The results of data analysis obtained from tensile and bending tests show that specimens with the arrangement sequence [0°/0°/0°] are the variations that have the best mechanical properties. Where the average maximum tensile strength reaches 18.3292 N/mm^2 and bending stress is 76.065 N/mm^2.

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