http://jurnal.unmer.ac.id/index.php/jtmt
TRANSMISI
ISSN (print): 9-772580-228020
ISSN (online): 2580-2283

Mechanical Properties of Composites Combination of Areca Fronds with Epoxy Resin

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ARTICLE INFORMATION

Received: 16 February 2023
Revised: 21 February 2023
Accepted: 1 March 2023
Published: 15 March 2023

ABSTRACT

Technological advances in material aspects are always increasing, and one of the applications of natural fibers as a matrix in composite materials has begun to be widely used. Composite materials have mechanical properties that are sturdy, corrosion resistant, and concise, and can be used as a substitute for metal materials. Areca palm fronds are part of the areca palm tree which are widely used as storage media because they are durable and weather resistant. The aim of this study was to determine the tensile strength of areca nut composites without alkali treatment combined with epoxy. Tensile test based on ASTM D3039 test standard. The test results showed a maximum tensile strength of 4839886.67 N/m2 or 4.84 MPa, and a modulus of elasticity of 114148270.5 N/m^2 or 114.15 MPa. According to the JIS A 5905 standard, it meets the specified requirements, namely elastic strength of 32 MPa and tensile strength of 0.4 MPa.

Keywords: Composite, Areca Fronds, Tensile Stress, Strain, Modulus of Elasticity

ABSTRAK

Kemajuan teknologi di aspek material selalu meningkat, dan salah satu aplikasi serat alam sebagai matriks pada material komposit sudah mulai banyak dipakai. Material komposit memiliki sifat mekanik yang kokoh, tahan korosi, dan ringkas, serta sanggup digunakan sebagai pengganti material metal. Pelepah pinang merupakan salah satu bagian dari pohon pinang yang banyak digunakan sebagai media penyimpanan karena awet dan tahan lapuk. Tujuan dari riset ini yakni untuk mengetahui kekuatan tarik komposit pelepah pinang tanpa perlakuan alkali yang dipadukan dengan epoksi. percobaan tarik didasarkan standar pengujian ASTM D3039. Hasil pengujian memperlihatkan bahwa kekuatan tarik maksimal mencapai 4839886, 67 N/m^2 atau 4,84 MPa, dan modulus elastisitas 114148270,5 N/m^2 atau 114,15 MPa. Menurut standar JIS A 5905, memenuhi persyaratan yang ditentukan yakni kuat elastis 32 MPa dan kekuatan tarik 0,4 MPa.

DOI: 10.26905/jtmt.v19i1.9618

Kata Kunci: Komposit, Pelepah Jagung, Tegangan Tarik, Regangan, Modulus Elastisitas

1. Introduction

The areca palm is a variety of palm species from the Arecaceae or Palmae family that grows vertically with a height of between 10 and 20 meters. The stems are straight, single, and slender with a cross section of between 10 and 15 cm, and bear signs of fallen leaves. Areca nut fiber can be obtained from the fruit (areca shell), leaf stems, and tree fronds. Areca nut has potential as a natural reinforcement in polymer composites. Not only that, other types of varieties from the Arecaceae or Palmae families have also not been explored as natural fiber reinforcement in polymer composites, thus revealing other alternative natural reinforcement options that need to be studied regarding their ability to be used in fiber-based composites for the automotive, aerospace and architectural industries. 1, 2].

Areca fiber is a type of natural fiber used in the manufacture of composites. Currently, its utilization is being developed because composite materials that utilize areca fiber have not yet been found. Areca nut fiber is widely used in the furniture industry and household crafts as well as an ingredient in traditional medicine because it is easy to obtain, economical and environmentally friendly. Areca nut fronds contain 13 to 24% lignin, 35 to 64.8% hemicellulose, 4.4% ash content and the remaining 8 to 25% moisture content [3]. The development of areca fiber as a composite material is expected to overcome environmental problems and not endanger health [4]. Not only areca nut fiber, the stem can be processed into handicraft products, such as bags and dinner plates. The use of areca palm fronds among small industries is growing rapidly. Meanwhile for other products as composite materials, they have not experienced significant development. In order to advance composite board materials, it is necessary to carry out systematic engineering between material components into materials as needed. Composite boards are not only from synthetic fiber composite boards but also lead to natural (natural) fiber composite boards. This is due to the advantages of its renewable or renewable character, thereby reducing environmental disturbances. the implementation of composite board technology that utilizes natural fibers is used as an application in manufacturing as a new material. The mechanical properties of the composite board depend on the properties of the constituents. The type of fiber and matrix used will affect the character of the desired final composite board properties. In the design is very concerned about the selection of materials and durability as needed. The use of composite boards in the manufacture of various finished products requires strength [5].

Natural fibers, such as areca nut fiber, can be useful in the composites industry because they are renewable, biodegradable and environmentally friendly. Areca nut, abundant in fiber and often wasted in large quantities by the tobacco industry [6]. The high content of cellulose fibers (57.35% by weight) provides good tensile strength (231.66 MPa) and the morphology of the porous surface (40.8%) determines good bonding with the matrix. In addition, the low fiber density (0.78g or cm3) makes it a potential alternative to hazardous synthetic fibers. The semi-crystalline nature and large crystal dimensions of the fiber also reduce water absorption. The fiber is stable up to 240℃, which is higher than the polymerization temperature, making it a potential reinforcement in bio-reinforced polymer composites for automotive and structural applications.

Natural fibers such as coconut coir, banana, pineapple, areca nut, and bamboo, have an important role in research aspects, especially in terms of price ability and strength. Natural fiber reinforced composites have properties of electrical resistance, thermal insulation and corrosion resistance, which are very important in the automotive, aerospace, maritime and structural fields. The tensile strength of natural polymer composites increases with increasing fiber volume fraction. This was also proven by the discovery of the effect of volume fraction of reinforcement on composite specimens. The longer the fiber length, the higher the strength of the composite. In a study of the tensile characteristics of areca fiber composites, it was found that chemical treatment of the fiber could change the mechanical properties, and the areca fiber treatment increased the mechanical strength when compared to non-alkali fibers. When compared with untreated fibers, fibers treated with alkali proved a significant increase in elastic strength [7].

During the processing of natural fibers to meet the needs of various industrial raw materials, alkali treatment is often used to reduce the cellulose content in the fibers, resulting in reduced fiber strength and durability. The use of alkali will certainly have an impact on the environment, causing damage and damage to the ecosystem if the concentration is high. As an alternative solution, research is needed to protect environmental contamination without reducing the quality of the fiber to be used for industrial needs. One of the traditional techniques that has long been used by rural communities is by immersing areca nut fibers in mud or running water. This treatment aims to add strength and weather resistance, so that the fiber can last for a long time.

2. Methodology of Research

In this research on the manufacture of composite materials using Crystal Clear-High Glass as the resin and areca leaf fronds for the binder, the two materials used are shown in Figure 1.

Figure 1. Epoxy resin and areca fronds

Areca leaf fronds are obtained from areca nut that has fallen from the tree around the plantation of the residents of Waena Village, located in Waena District, Jayapura City, Papua. The stems of the areca leaves are separated from the stems and soaked in the mud on the edge of Lake Sentani.

Soaking is done with the aim of flexing and freeing compounds that can damage the fronds when combined with the epoxy resin. This soaking is carried out for 25 days, after which the areca leaf fronds are dried naturally under the hot sun for 3 days. Figure 2 below shows the printed media made of plywood for media for making composite materials with dimensions of 25 mm x 150 mm x 150 m. The base of the mold is coated with lubricating oil to prevent the material from sticking to the die. The epoxy mixture consisting of 220 grams of essential liquid and 3 grams of hardener is mixed evenly, after which it is poured into a mold containing betel leaf fronds.

Figure 2. Composite material printing

After the material has hardened, it is removed from the impression medium and cut according to ASTM D-3039 standard for high strength natural fiber composite samples. The dimensions of the test specimens for composite materials are shown in Figure 3, each specimen being made of 3 (three) pieces with a uniform size. For the tensile test equipment, Universal Testing brand INSTRON 3390 series is used with a maximum load capacity of 50 kN (11,250 kgf) shown in Figure 4.

Figure 3. ASTM D3039 standard composite specimen dimensions

2.1. Tensile test

Tensile test experiments in a static manner by means of which the sample is pulled by loading at both ends where the tensile force exerted is P (Newtons or kgf). The goal is to determine the tensile strength properties of the composite. The increase in length (Δl) that occurs as a result of the tensile force exerted on the trial sample is called deformation. Strain illustrates the analogy between the increase in length and the initial length. Strain is a dimension for the elasticity of a material expressed in percent [8]. The stress–strain relationship in tension gives a value that varies considerably depending on the stress rate, specimen, humidity, and so on. The applied stressσ, is the applied force, F, divided by the cross-sectional area A0, namely:

$$= \frac{F}{A_o} \qquad (1)$$

Where, F is the weight given perpendicular to the cross-section of the specimen (N); A_0 is the initial cross-sectional area before loading (m^2); and σ is the tensile stress (N/m^2).

Figure 4. Universal Testing INSTRON Serial 3369

2.2. Modulus of elasticity

The modulus of elasticity is a value used to measure an object or a material's resistance to undergo elastic deformation when a force is applied to that object. The elastic modulus of a body is defined as the slope of the stress-strain curve in the elastic deformation region [9]. A stiffer material will have a greater modulus of elasticity. The elastic modulus can be determined based on equation (2).

$$E=\frac{Stress}{Strain}=\frac{\sigma}{\varepsilon} \qquad (2)$$

Where, stress is the force causing the deformation divided by the area to which the force is applied and strain is the ratio of the change in some length parameter caused by the deformation to the initial state of the length parameter.

3. Result and Discussion

3.1. Tensile test

The force per unit area (N/mm^2 or MPa) required to fracture a composite material is known as the tensile strength. This tensile test is carried out until it fails completely or breaks. The purpose of the tensile strength test was to determine the interfacial bond strength between untreated areca nut fibers and those chemically treated with a thermoplastic polypropylene matrix [10].

Based on the results of the tensile tests that have been carried out, the tensile strength data for each specimen (normal and with areca fronds) consisting of 3 (three) pieces can be seen in the appendix. Data on specimen 2 showed better values compared to specimens 1 and 3, so that the analysis was carried out referring to specimen 2 data. The resulting maximum tensile and elongation force measurement data can be seen in table 1 below.

Table 1. Comparison of maximum tensile force and elongation

Without fiber (Normal)		**With fiber**	
ΔL (mm)	F (kgf)	ΔL (mm)	F (kgf)
0,4999	10,4057	2,12	31,0818

Figure 1 shows a comparison of the tensile and elongation forces in the composite test (normal and with areca fronds). Composite without areca fronds (normal) is only able to accept a tensile force of 10.406 kgf, with the addition of areca fronds to the epoxy resin, the tensile strength of the composite increases to 31.082 kgf. The areca nut fronds used as a reinforcing matrix can increase the tensile strength of the composite.

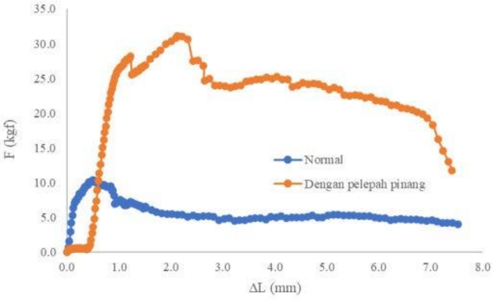

Figure 1. The relationship between tensile force and elongation

3.2. Stress and strain

Stress expresses the relationship between the tensile force exerted per unit cross-sectional area of the material. The results of the calculation of the stress and strain relationship in composites (normal and with areca fronds) are presented in table 2 below.

Table 2. Value of strain, stress and modulus of elasticity

Value	**Normal**	**With frond**
Strain (ε)	0,0104	0,0424
Stress, σ (MPa)	1,576	4,840
Modulus of Elasticity, E (Mpa)	114,148	151,473

The test results usually depend on the test object. Since it is highly unlikely that we will use a structure that is the same size as the test object, it is necessary to express the results of the test in a form applicable to members of any size. After carrying out tensile or compression tests and determining the stresses and strains at various load levels, the stress and strain diagrams can be plotted. The stress-strain diagram is a characteristic of the tested composite and provides important information about the mechanical magnitude and type of behavior [11]. The stress-strain diagram for normal composites subjected to tensile loading is shown in Figures 2 and 3. Where the diagram starts with a straight line from the center of the 0 axis to point A, which means that the relationship between stress and strain in this area is linear and proportional, where point A (1620321.561 N/m^2) maximum stress, where no deformation occurs when a load is applied is called the elastic limit, so the stress at A is called the proportional limit, and OA is called the elastic region.

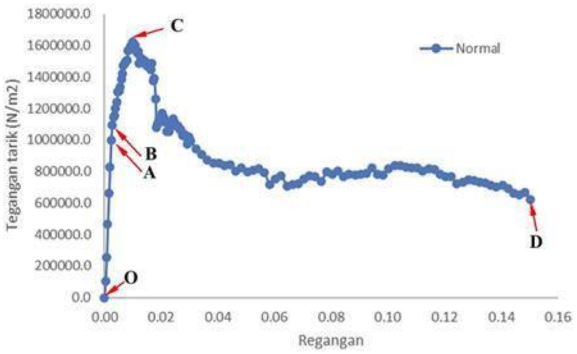

Figure 2. Diagram of normal composite tensile stress and strain

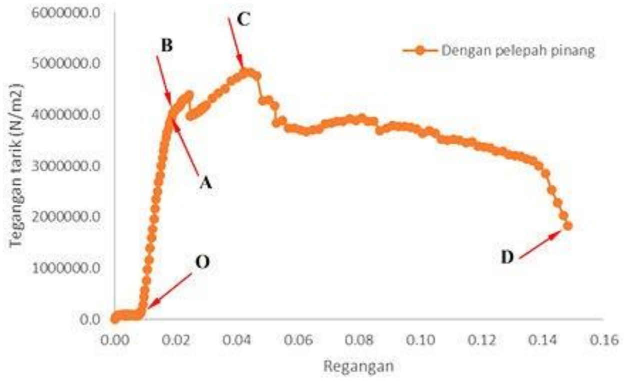

Figure 3. Diagram of tensile stress and strain of areca frond composites

As the stress increases past the proportional limit, the strain begins to increase more rapidly for each increase in stress. Thus the stress-strain curve has a slope that gradually becomes smaller until at point B (the curve becomes horizontal. Starting from point B (1092631.104 N/m^2) there is a considerable elongation of the specimen without any increase in the tensile force (from B to C), this phenomenon is called the yielding of the material, and point B is called the yield point. In the region between B and C (1620321.561 N/m^2), the material becomes perfectly plastic, which means that the material is deformed without any increase in load. After experiencing the large strain that occurs during yielding in the BC region, the elongation of the body in this region requires an increase in the tensile load, and the load eventually reaches a maximum value, and the stress at point C (1620312.561 N/m2) is called the ultimate stress. epoxy leaf composites were fractured.Maximum tensile strengths of 49.80 MPa and 135.83 MPa were found for 10 wt% and 16 wt% epoxy composites [12]. chain with reduced load and finally a break occurs at a point, namely at point D (623973.15 N/m^2).

The tensile strength of the areca nut composites increases with the alkali treatment and the separation of the fibers. Areca nut fiber has been treated with alkali using 10% NaOH. Then, a composite was made using different fiber loads, namely 0%, 5%, 10%, and 15%. After that, the composite was tested mechanically. The observed results show that the tensile strength increases gradually with increasing fiber content. It was found that the tensile strengths for 0%, 5%, 10%, and 15% fiber filling were 16 MPa, 95 MPa, 22 MPa, 58 MPa, 26 MPa, 21 MPa, and 37 MPa, respectively [13].

Figure 4 shows a comparison of the two types of composites, where the composite with the addition of areca nut reinforcement can increase the tensile strength. The tensile force is distributed to the areca nut fronds, so that in order to break the material, a greater force is required than normal.

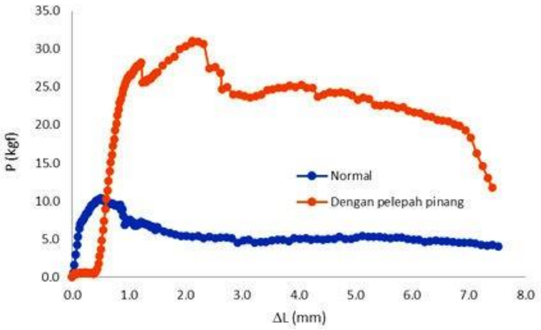

Figure 4. Comparison of tensile stress and strain

3.3. Modulus of elasticity

The elastic modulus or Young's modulus is a measure of a material's stiffness which provides information on how much stress is required to stretch a material until it reaches twice its initial length. Figure 5 shows a comparison of the modulus of elasticity of the normal composite (without areca fronds) and with the use of areca fronds.

According to table 2, the maximum composite modulus of elasticity for normal conditions is 151473498.3 N/m^2 or 151.473 MPa, and by using areca frond reinforcement the value decreases by 30% or 114148270.5 N/m^2 (114.148 MPa). This shows that the addition of areca leaf fronds will cause an increase in the stiffness of the composite material, so that the elastic ability decreases if the load is continuously applied. The modulus of elasticity in this test is better than that of the same study, namely 90.285MPa [3].

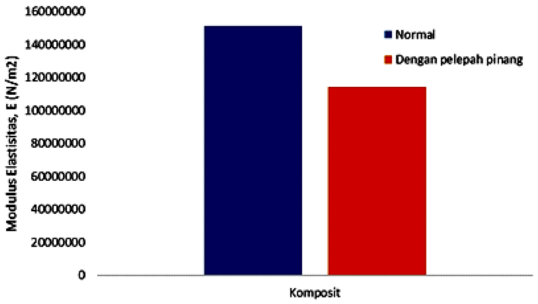

Figure 5. Comparison of elastic modulus

Based on the research that has been done and the data that has been obtained the advantages of the research that has been done. Where the mechanical properties test was based on the quality standard JIS A5905: 2003, where the tested fiberboard only obtained a tensile strength greater than 0.4 MPa, while in the same test a tensile strength of 1.62 MPa was obtained.

The tensile behavior of 5%, 10%, and 15% of the areca frond composites treated with NaOH has been tested. During mechanical testing, the double-layered areca frond composites showed higher tensile strength of 20.51 MPa for 10% NaOH with alkali treatment, the areca frond composites were 5 layers, and the age was 6 years. Mechanical properties such as tensile strength and flexural strength were found to increase with an increase in the number of layers and the concentration of NaOH treatment up to 10% [14].

The composite containing areca fiber of 50% by weight showed the highest tensile strength of 42 MPa. When the fiber weight fraction decreases, the bond between the fiber and the composite matrix becomes weak. Fiber content less than 30% by weight results in uneven fiber orientation, which reduces the tensile strength of the composite specimen. The tensile strength of the composite is affected by the weight fraction of the fiber, as shown in the graph. When the fiber weight fraction reaches the required percentage, the mechanical strength of the composite specimen increases again. Therefore, it can be estimated that a fiber weight percentage of 50% is an important ingredient for the composite [15].

4. Conclusion

Areca frond bark can be used as a natural fiber-based material combined with epoxy resin based on experimental results and data analysis, as follows the maximum tensile strength reaches 4839886.67 N/m^2 or 4.84 MPa, and the modulus of elasticity is 114148270.5 N/m^2 or 114.15 MPa. Based on the JIS A 5905 standard, this material meets the specified requirements, namely flexural strength of 32 MPa, density of 0.3–1.3 gr/cm^3, tensile strength of 0.4 MPa. Areca leaf stalks can be used as fillers in the manufacture of composites to increase tensile strength and compressive strength.

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