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Effect of Weight Fractions in Composite of Melinjo Stem Bark Fiber (Gnetum Gnemon) - Polyester Resin on Tensile and Bending Strength

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ABSTRACT : *This research intended to determine the strength of composites made from natural fibers, melinjo stem bark fiber (Gnetum gnemon) obtained from Selayar Regency, South Sulawesi Province for use as a reinforcing material for polymer matrix composites. The research process began by soaking melinjo stem bark fibers in water and 5% NaOH for 24 hours. Each of specimens were made by weight fraction composition percentages of 95%:5%, 90%:10%, and 85%:15% using SHCP 2668 polyester matrix without heating. Tensile test specimens were made by referring to the ASTM D638 standard and tested on a Universal Testing Machine (UTM) Tensilon RTF 2425 with a capacity of 200 kN at the Laboratory of Balai Latihan Kerja (BLK) Makassar while bending test specimens referred to the ASTM D790 standard. The research results report that the highest tensile stress was obtained in the polyester-melinjo stem fiber composite with a weight fraction composition of 85% polyester resin and 15% melinjo stem fiber, with stress value of σ =24.77 MPa. and decreased as the percentage of melinjo stem fiber content decreased, it was clearly seen that the tensile strength decreased by 7.57% and 17.68% respectively for every 5% reduction in weight fraction of melinjo stem bark fiber, although the largest average strain value of ε = 4.41% was obtained with a composition of 85% polyester resin - 15% melinjo fiber. For bending test on composite where the composition ratio of 85% polyester resin and 15% fiber produced the greatest bending average strength of 73.97 MPa, also showed a tendency to decrease the bending strength of melinjo stem fiber composite between 9.94% and 11.00% respectively with a 5% reduction in melinjo stem bark fiber content.*

KEYWORDS : *melinjo stem fiber, polyester, weight fraction, tensile stress, bending strength*

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I. INTRODUCTION

Rationalizing Melinjo (Gnetum gnemon) is a plant that grows everywhere, found in many regions in Indonesia, as a multi-purpose plant almost all parts of this plant can be used. Melinjo stem bark fiber was chosen as reinforcement in composites because this fiber has a continuous fiber structure and strong natural weave, but its use is still very limited. Almost every part of the plant can be extracted to obtain fiber, plant parts such as leaves and stems have thickened lignified walls called sclerenchyma mature ones consisting of high cellulose (60-80%) and lignin called thickened dead wall cells [1] [2]. Stem bark fiber consists of an inner wood core surrounded by a collection of long hollow fibers and protected by an outer bark, usually having better mechanical properties than other groups of natural fibers. Melinjo stem bark fiber has moisture content ranging from 6.20% - 10.42%. The mechanical properties of plant fibers are closely related to the amount of cellulose, which is closely related to the crystallinity of the fiber and the angle of the micro-fibers to the main fiber axis.

The fiber's ability to be decomposed by bacteria (biodegradability) and its mechanical properties can be compared to synthetic fibers. Melinjo stem bast fiber is a natural fiber that has quite good mechanical properties compared to other natural fibers [3][15][19]. Other benefits that can be obtained from Melinjo bast fiber as a composite reinforcement [3], include:

a. The source is renewable and sustainable
b. Environmentally friendly, biodegradable
c. Can be recycled (recyclable)

d. Lightweight with weight reduction between 10% to 30%
e. Economical production costs.
f. Abundant supply and easy access

Based on these considerations, it will be very interesting to examine the tensile strength and bending strength of composites reinforced by melinjo stem bark fibers with a polyester resin matrix in various weight fraction compositions so that we can consider what composition ideally matches the expected tensile strength and bending strength according to the design for manufacturing applications. automotive interior panels, speedboats, train interior panels and the aerospace industry.

II. MATERIAL AND METHODS

Two types of basic materials used in making composite specimens were a mixture of unsaturated polyester resin SHCP 2668 with melinjo stem bark fiber used as reinforcement obtained from Melinjo plant from Selayar Regency, South Sulawesi Province. As an effort to encourage the use of natural resources which can be used as industrial composite materials to produce more environmentally friendly products. Almost every part of the plant can be extracted to obtain its fiber, melinjo stem bark fiber is very suitable for use as composite reinforcement because it has a fairly light density of $\rho = 1.2087$ g/cm^3 to 1.8069 g/cm^3 and adequate single fiber tensile strength of $\sigma = 735.4$ MPa to 1,043.04 MPa. The chemical composition of melinjo stem bark fiber is 24.02% hemicellulose, 39.3% alphacellulose, 9.82% lignin and 3.08% benzene extractive, [3][13]. The melinjo stem bark fiber (figure 1) which will be used as reinforcement is first soaked in water for 24 hours to facilitate the decomposition of the fiber which is done manually by hand, this research used a hands lay-up method, [2][14] reported that the quality and properties of fiber depend on several factors such as size, maturity (age) and the process/method used to extract the fiber, which is why stem fiber is selected from trees that are around 5 years old with the diameter ranges between 15-20 cm to maintain uniformity in the physical properties of natural fibers. The bark is peeled at a height of 1 meter from the ground surface to avoid the effects of soil environmental degradation. The quality and stability of composite materials reinforced with natural fibers depends on the development of a coherent interfacial bond between fibers and matrix.

Weaknesses that may be encountered in fiber composites reinforced with natural fibers and natural matrices include among other things the incompatibility of bonds between the hydrophobic polymer matrix and hydrophilic cellulose fibers [5][7][20]. The high absorption capacity of water and water vapor from cellulose fibers has the potential to cause swelling and plastic effects, resulting in instability in size and low mechanical properties. This causes weak interface formation, which results in low mechanical properties of the composites [6][12][15], In order to minimize the poor of interfacial bonding between the fiber and the matrix, it is soaked in an alkaline medium with a 5% NaOH solution for 24 hours to clean the fiber from lignin, wax, pectin, hemicelluloses and other impurities contained and covering the surface of the fiber walls, alkalization is one of modifications natural fibers to improve fiber-matrix compatibility, [8][9][15]. Increasing the concentration of NaOH solution can reduce the tensile strength of cellulose-based fibers. Alkaline solutions can cause the release of bonds between fibers from the fiber bundle form and changes in the fiber surface, [9][15][19]. After immersion in 5% NaOH alkaline media. Melinjo stem bark fiber is heated in an oven at 100ºC for 15 minutes including to remove the water content in the fiber. As a composite matrix in this research, SHCP 2668 polyester resin was used, considering that in general the use of polyester resin is very familiar in many fiber composites. It was recorded that in 2017 the total consumption of fiber composites was dominated by polyester at around 69%, [10][12]., where the world use of polyester resin has consistently started to grow, recorded at 7% per year since 1990 until the polyester market has also covered almost 50% of the total global fiber market, including both man-made and natural fiber applications.

Fig.1. Melinjo (Gnetum gnemon) stem bark fiber

III. MANUFACTURING AND TESTING OF COMPOSITE SPECIMENS

The composite is made through a weighing and mixing process and then molded with respective weight fractions with a composition of 95% resin and 5% melinjo fiber, 90% resin and 10% melinjo fiber and 85% resin and 15% melinjo fiber in a rectangular molding container which is able to withstand loads of up to 1 ton measuring (l x w x h) 300 x 300 x 5 mm. The fibers are arranged in such a way that they are evenly as much as possible, even in a random orientation. The curing time required for a composite with a polyester matrix and a catalyst mixture is 6 (six) hours [10][14]. Composite samples are then formed into specimens for each type of test without any treatment, where each weight fraction composition is made into 3 specimens for test replication purposes and then the results are averaged.

Composite Specimen Testing

Material engineering development, especially with the use of natural fibers of course requires technical identification including mechanical strength criteria through testing stages [17], therefore natural fiber composite products in various weight fraction compositions must go through several testing stages such as tensile strength and elongation (tensile test) as well as bending strength (bending test), These two tests were carried out using the Universal Testing Machine (UTM) Tensilon RTF 2425 test equipment at laboratory of Job Training Center (Balai Latihan Kerja) Makassar. Tensile test specimens were made referring to ASTM D638-02 standard (figure 2) and bending test specimens referred to ASTM standard D790-02.

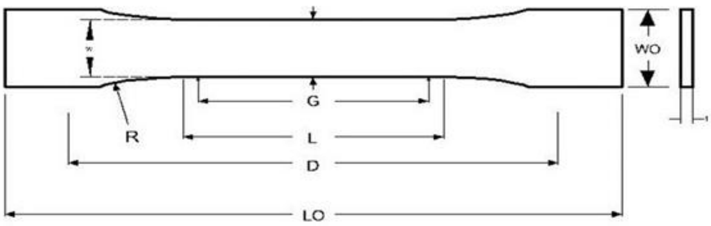

Fig. 2. Tensile Test Specimen

to determine tensile strength and elongation, refer to the tensile testing standard ASTM 638-02 with type I specimens. Tensile strength can be calculated using the equation :

$$\sigma_f = F/A \tag{1}$$

while elongation or strain can be obtained from the equation :

$$\varepsilon = \frac{\Delta l}{lo} \tag{2}$$

The elastic modulus value can be calculated using the equation :

$$E = \frac{\sigma_f}{\varepsilon} \tag{3}$$

Bending strength testing refers to the ASTM D790-02 bending testing standard. Bending strength can be calculated by carrying out bending tests which refer to the basic theory of beam bending strength, which can be calculated using the equation:

$$\sigma_f = \frac{3\,P\,L}{2w\,t^2} \tag{4}$$

IV. RESULTS AND DISCUSSION

The test results in this research can then be described and compared based on the weight fraction composition of the fiber content in the composite in each type of test.

a. Tensile Strength Test Results

Each of weight fraction was made into 3 test objects each so that test results were obtained that could represent the entire composite part formed considering that the placement of the melinjo stem bark fibers was arranged randomly while still considering the even distribution of the fibers throughout the part. composite area. The test result data was obtained as shown in tables 1, 2 and 3 below :

Table.1 weight fraction 95% Polyester – 5% Melinjo Fiber

No	A_0 (mm^2)	Fm (N)	ε max (%)	σ max (N/mm^2)	Annotation
1	100	1816,0	2,9857	19,7547	Specimen 1
2	100	1767,8	3,6590	18,6318	Specimen 2
3	100	1705,9	4,2882	18,9135	Specimen 3
Average value			3,6443	19,1000	

Table.2 weight fraction 90% Polyester – 10% Melinjo Fiber

No	A_0 (mm^2)	Fm (N)	ε max (%)	σ max (N/mm^2)	Annotation
1	100	2109,4	4,1483	24,1931	Specimen 1
2	100	1938,4	3,3759	22,8532	Specimen 2
3	100	1887,2	3,8671	22,5671	Specimen 3
Average value			3,7971	23,2044	

Table.3 weight fraction 85% Polyester – 15% Melinjo Fiber

No	A_0 (mm^2)	Fm (N)	ε max (%)	σ max (N/mm^2)	Annotation
1	100	1275,2	4,2500	25,6105	Specimen 1
2	100	1247,4	4,8675	24,7114	Specimen 2
3	100	1188,0	4,1280	24,9968	Specimen 3
Average value			4,4151	25,1062	

Table. 4 Comparison of average tensile strength test results of specimens

No.	Weight fraction	Tensile stress, σ_f (MPa)	Strain, ε (%)
1.	95% : 05%	19,1000	3,6443
2.	90% : 10%	23,2044	3,7971
3.	85% : 15%	25,1062	4,4151

In graphical form the tensile strength test results can be seen in figure 3 below :

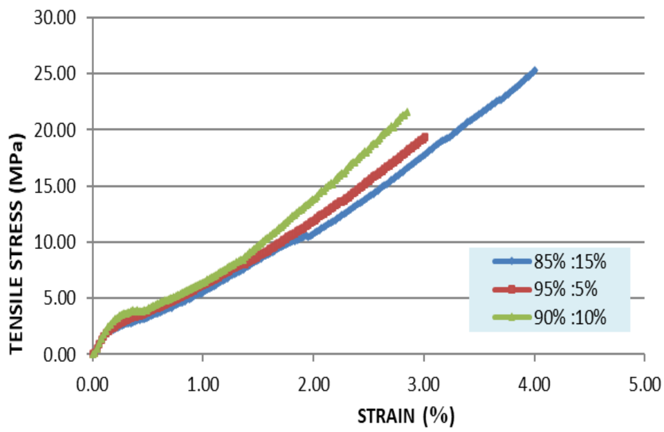

Fig. 3. Tensile Test results

Based on graph in Figure 3 above, 3 composites test objects with different weight fractions that were tested for tensile strength, it can be seen that the test object with a composition of 85% resin: 15% melinjo fiber showed the largest stress value σ_f = 25.1062 MPa with the largest strain value of ε = 4.4151%. From this test was found that the maximum stress was also the stress at which cracking of the specimen occurred, as the case with the strain that occurred where a relatively small difference in value was obtained, which shows that the role of the percentage of melinjo fiber content in composites that use polyester resin as a matrix is not very significant influential to the strain value.

b. Bending Strength Test Results

Likewise, with the specimens prepared for bending testing, 3 specimens each were made for each weight fraction and then analysis of the bending test results was obtained in the following table 5, 6 and table 7, the specimens were made in plate form with the following dimensions:

Table 5. Weight fraction 95% Resin – 5% Melinjo fiber

No	P maks (N)	Bending Strength (N/mm^2)	Annotation
1	270,12	57,88	damaged
2	259,97	53,56	damaged
3	301,59	63,91	damaged
Average value	277,23	58,45	

Table 6. Weight fraction 90% Resin – 10% Melinjo fiber

No	P maks (N)	Bending Strength (N/mm^2)	Annotation
1	305,49	65,46	damaged
2	330,19	72,18	damaged
3	283,68	62,22	damaged
Average value	306,45	66,62	

Table 7. Weight fraction 85% Resin – 15% Melinjo fiber

No	P maks (N)	Bending Strength (N/mm^2)	Annotation
1	295,25	69,84	damaged
2	386,71	78,86	damaged
3	341,70	73,22	damaged
Average value	341,22	73,97	

The average bending strength of composite specimens in various weight fractions that have been tested can be seen on diagram Figure 4 below:

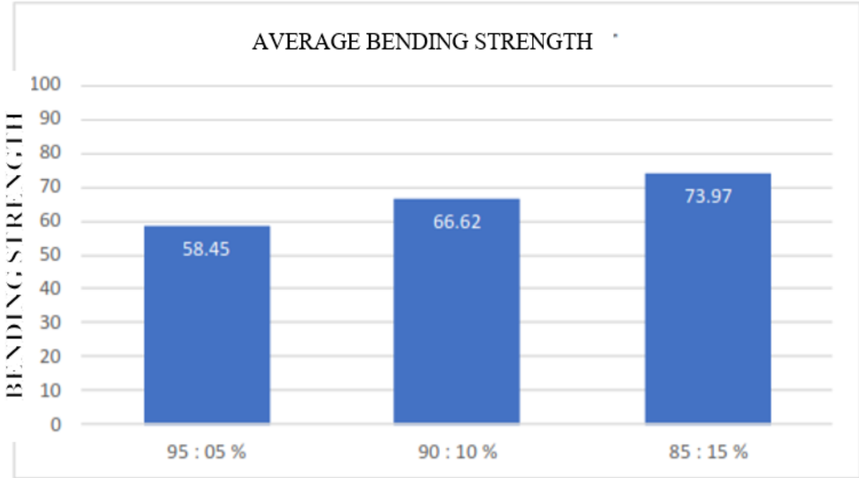

Figure 4. Average Bending strength for each weight fraction

Based on the diagram in Figure 4, showing different bending strength for different weight fractions, It is clear that the greater the weight fraction of melinjo fiber, the bending strength of the composite will increase, it can be seen that the bending strength of the weight fraction of 85% polyester resin and 15% melinjo fiber was obtained at σf = 73.97 MPa with an average load of P = 341.22 N, other results can be seen in tables 5 and 6 above. Thus, it can be stated that more melinjo bark fiber mixture is given to the composite, the bending strength value will increase.

V. CONCLUTION

As a conclusion of the test results on the three weight fractions of composite specimens of 95%-05%, 90%-10%, and 85%-15%, it can be stated that the highest tensile strength was obtained in the melinjo stem fiber composite with a weight fraction composition of 85%: 15% with the largest average stress value σf = 25.1062 MPa, tensile strength decreased by 7.57% and 17.68% respectively for every 5% reduction in the weight fraction of melinjo stem fiber, while in the same fraction (85%:15%) the largest strain value was also obtained at ε = 4.4151%. However, it appears that there is a relatively small difference in values, which shows that the role of the percentage of melinjo fiber content in composites that use polyester resin as a matrix does not have a significant effect on the strain value. The same thing also happened in bending test on composite specimens which produced the largest bending strength on average of 73.97 MPa from a weight fraction composition of 85% polyester resin and 15% melinjo fiber, showed a tendency to decrease the bending strength of the melinjo stem fiber composite between 9.94% and 11.00% respectively with a decrease every 5% of the Melinjo stem fiber content in the composite. From this test, it was found that the maximum stress that occurred was also the stress at which the specimen damaged (failure).

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