

Optimization of Sulfur Soaking Water on Mechanical Properties and Physical Properties of Woven Petung Bamboo (*Dendrocalamus asper* Backer ex Heyne) Strips

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Abstract. There are about 60 species of bamboo belonging to family gramineae found in Indonesia, which is one of them is *Petung* bamboo (*Dendrocalamus asper*). Bamboo has the potential to produce environmentally friendly engineering materials. The strength and durability of the material can be increased through the immersion process using chemical or natural solutions, such as sulphur water because it is known to contain carbon elements high enough to support strength increase. The research was started by making thick bamboo slats 1 mm thick, 250 mm long, 10 mm wide, and then woven in plain shapes of 250 mm × 250 mm, then dried at 110 °C for 60 min then immersed in sulfur water. For tensile test using the ASTM D638-02 standart, ASTM D790-02 bending test, ASTM D5942-96 impact test. The test results show the tensile strength increased 89.17 %, bending strength increased 59.90 % and impact strength increased 1.59 %. The highest value of the mechanical test results occurred in sample 1 AB3, while the lowest mechanical test value occurred in 1 TP sample. The microstructure of the 1 TP sample shows a pointed and smooth fracture shape while the sample 1 AB3 has an increasingly blunt fracture shape with fine threads.

Key words: Bamboo strips, mechanical strength, microstructure, sulfur water

1 Introduction

The growth rate of bamboo plants is fast enough so that their availability can be met quickly as well and can absorb carbon dioxide quickly so that it can reduce air pollution, in addition to the large enough carbon content in the wood can increase strength. The strength

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of bamboo in the form of strips is stronger than in the form of whole bamboo. The use of bamboo which has artistic value is a product of strips that are usually made of woven for various kinds of household items, walls, and furniture. Polymer composites reinforced with woven bamboo are materials consisting of layers of woven bamboo strips that are joined together with resin, so that the use of bamboo from the strip needs to be optimized [1].

Cellulose fibers contained in bamboo provide maximum flexural tensile strength and hardness in certain directions [2]. Lignin is a component of cell walls that is difficult to break down by organisms that destroy bamboo. Bamboo is one of the abundant and interesting natural fibers to be studied. Table 1 shows the composition of bamboo compositions.

Table 1. The composition of bamboo composition

Type of Bamboo	Holocellulose (%)	Lignin (%)	Fiber Cell (μm)	Pore Cell (%)	Alcohol Solution Benzene (%)
<i>Petung</i>	73.63	27.37	0.90	12.58	4.10
<i>Sero</i>	71.96	26.18	0.80	14.96	3.43
<i>Tui</i>	72.77	26.05	0.77	13.23	3.49

The alpha cellulose content of *Tui* bamboo is relatively more than that of *Petung* bamboo and *Sero* bamboo so that it can be predicted that *Tui* bamboo will experience greater damage by termites [3]. *Petung* bamboo mechanical properties for flexural strength of 134.972 MPa, tensile strength of 228 MPa parallel fibers, compressive strength of 49.206 MPa parallel fibers, compressive strength of perpendicular fibers of 24.185 MPa, shear strength of 9.505 MPa in parallel, and flexural modulus of elasticity of 12 888.477 MPa [4].

Strength and mapping of a material can be increased through a preservation process such as immersion treatment using elements or chemical solutions but also using natural elements or solutions such as sulfur water, sea water, rice water, turmeric juice, tea leaf extract, and so on. One of the elements or solutions that are underutilized is sulfur. It is also known to be an important element in life. About 0.25 % of the total body weight of humans is sulfur. This is most concentrated in keratin, which makes hair, nails, and skin strong. This is known as the "mineral of natural beauty" because the body needs it to produce collagen, which makes the skin elastic and young-looking. So that sulfur water is used as a bath to treat skin disorders, help protect the body from environmental toxins, and people who experience arthritis can find pain relief by bathing in hot sulfur water.

2 Research methods

2.1 Ingredients

The natural fiber is very widely used in the automotive and construction industries. In addition to being environmentally friendly and economically valuable, another advantage of natural fiber composites is that they are light in weight and also easily available due to their abundant availability [5]. The natural fibers used are *Petung* bamboo (*Dendrocalamus asper* Backer ex Heyne) and also sulfur water in Lembang Tokesan, Sangalla District, Tana Toraja Regency, South Sulawesi Province. *Petung* bamboo is soaked using sulfur water, which aims to increase mechanical strength. *Petung* bamboo soaked using sulfur water, which aims to increase mechanical strength. Data from laboratory analysis of sulfur water used contained carbon (C) as much as 78.0 mg L⁻¹, followed by sulfur as SO₄ as much as 39.101 mg L⁻¹, then silica as SiO₂ as much as 22.03 mg L⁻¹ and sulfur as H₂S as much as 0.009 mg L⁻¹. Bamboo species of *Petung* and also hot sulfur water used in this study were

taken at Lembang Tokesan, Sangalla 'District, Tana Toraja Regency, South Sulawesi Province.

The epoxy matrix used consisted of Epoxy resin A (Bisphenol A-epichlorohydrin) and Epoxy hardener B (Polyaminoamide) with a mixture ratio of 60 %:40 % of the total volume of composite molds which had a size of 250 mm × 250 mm × 4 mm.

2.2 Tools

The tool used as a composite print is made of steel measuring 250 mm × 250 mm and also uses supporting tools such as a 500 mL measuring cup, 3 mL syringe (for measuring catalysts), knives, spoons, scissors, brushes, space thermometers, water thermometers, calipers, sandpaper, digital scales, spoons, bamboo thinning tools and electric ovens. While the tensile test used is the Go Tech Universal Testing Machine, Model KT-7010A2, capacity 1 000 kg, the production of Kao Tieh Machinery industrial CO., LTD, in 1995. At the time of the tensile test the tensile testing machine speed is 4 mm min⁻¹.

2.3 Testing process

Availability and utilization/function of abundant natural wealth can be used as composite materials using bamboo and sulfur water. The study began with the manufacture of bamboo strips 1 mm thick, 250 mm long, 10 mm wide, and then weaved plain shapes measuring 250 mm × 250 mm. Furthermore, the woven bamboo is dried at 110 °C for 60 min then the webbing is soaked in hot sulfur water for 1 d, 2 d, and 3 d. After the bamboo webbing is soaked, the next process is composite printing and wait for 6 h to 8 h for the results to dry. Then the sample is cut to the size of the specimen for further mechanical testing. The tensile test standard used by ASTM D 638-02, bending test using ASTM D 790-02, and impact test using ASTM D 5942-96. Always weight the sample from after bamboo is woven/before it is dried after it has been dried and after composite. Figure 1 shows the specimens that have been cut according to ASTM for tensile, bending, and impact tests and are ready for mechanical testing.



Fig. 1. Tensile, bending and impact test specimens

The mechanical tests carried out in this study were tensile, bending and impact tests. Tensile strength is a test carried out to determine the ability of a material to accept loads without damage. The tensile strength of a material is determined by dividing the maximum force with the initial cross-sectional area before deforming. The tensile strength of a material can be calculated by Equation (1):

$$\sigma = \frac{F_{\max}}{A_0} \quad (1)$$

where:

σ : Tensile strength of material (kgf mm⁻²)

F_{\max} : Maximum voltage (kgf)

A_0 : Initial cross-sectional area (mm²)

Bending test is a form of testing to determine the quality of a material visually. The bending strength of a material is the strength of the material to withstand compressive loads from the outside. The value of the poisson ratio has an effect on the bending test. From the bending test a linear distribution of direct stress will be produced which varies with thickness and strain on the other surface [6]. The bending stress on the material can be calculated by the Equation (2):

$$\sigma_f = \frac{3 \times P \times L}{2 \times b \times d^2} \quad (2)$$

where:

P : load (N)

L : Support Span (mm)

b : width of the test object (mm)

d : thickness of the test object (mm)

The toughness of a material is the ability of the material to accept impact loads as measured by the amount of energy needed to break the test rod with a swing hammer. To find out the toughness value of a material an impact test must be carried out, the amount of power to break the test rod can be calculated by the Equation (3):

$$W = m \times g \times R(\cos \beta - \cos \alpha) \quad (3)$$

where:

W : Broken energy (J)

m : Weight of pendulum (kg)

g : Gravity acceleration (m s⁻²)

R : Distance of pendulum to center of rotation (mm)

β : Pendulum angle after hitting a test object (°)

α : Pendulum angle without test object (°)

As for the impact strength using the Equation (4):

$$a = \frac{W}{d \times b} \quad (4)$$

where:

a : Impact strength (J mm⁻²)

b : Specimen width (mm)

d : Thickness of specimen (mm)

W : Energy absorbed by specimens (J)

3 Results and discussion

3.1 Mechanical test results

Please composite test results of woven *Petung* bamboo treatment of soaking sulfur water 1 ply for 0 d, 1 d, 2 d and 3 d. With the sample code information as follows 1 ply without treatment (1 TP), 1 ply soaking sulfur water for 1 d (1 AB1), 1 ply soaking sulfur water for 2 d (1 AB2) and 1 ply soaking sulfur water during 3 d (1 AB3).

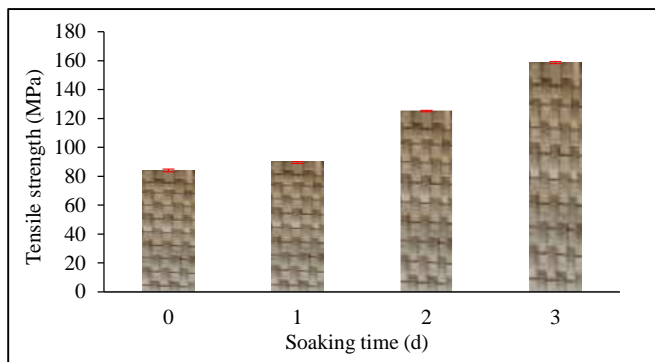


Fig. 2. Relationship between length of immersion time tensile strength 1 ply soaking sulfur water

Figure 2 shows the relationship between the time of immersion on the tensile strength of composite samples of woven *Petung* bamboo with the treatment of soaking sulfur water with 1 ply for 0 d, 1 d, 2 d and 3 d. From the results of this study, the lowest tensile strength was obtained in the sample of 0 d (1 TP), which was 84.04 MPa \pm 0.87 MPa, while the highest tensile strength occurred in samples with immersion for 3 d (1 AB3) which was 159.02 MPa \pm 0.47 MPa.

Research on the tensile strength of *Petung* bamboo is said, the tensile strength of BRP is influenced by the type of bamboo and the variety of fibers. The results of the research show that bamboo plaited woven has a tensile strength of 111.25 MPa while that which is not woven is 94.25 MPa. While research on chemicals using bamboo fiber *Petung*, borax and boric acid and distilled water as a solvent shows that preservative chemicals can increase the tensile strength of bamboo [7].

The effect of preservative chemicals on the tensile strength of *Petung* bamboo produces a non-preservative skinless *Petung* bamboo of 88.52 MPa, skinless *Petung* bamboo with borax preservative and soaked for 72 MPa of 90.62 MPa. Whereas skinless *Petung* bamboo with boric acid is 122.1 MPa and skinless *Petung* bamboo with borax 60 % boric acid is 149.37 MPa [8].

Some of the supporting studies above show that *Petung* bamboo woven later given chemical treatment can increase composite tensile strength. It also shows that the absorption of carbon elements contained in sulfur water during the immersion treatment has occurred. Because carbon is known to increase strength. The length of time the immersion treatment can also affect the composite tensile strength it is seen that the material that is still in the form of woven bamboo has not reached optimal absorption/has not reached its saturation point so that the resulting strength is still increasing.

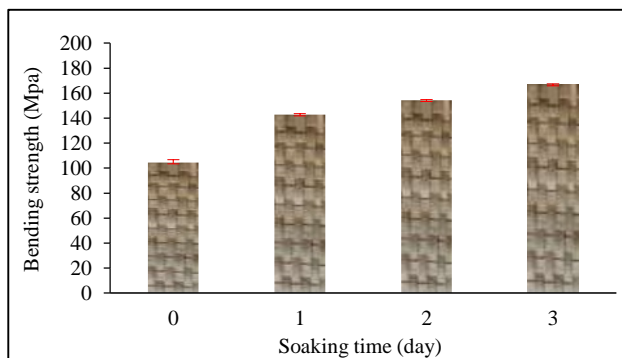


Fig. 3. Relationship between soaking time and bending strength the treatment of 1 ply sulfur water

Figure 3 shows the lowest bending strength value occurred in the sample of 0 d (1 TP) which is $104.38 \text{ MPa} \pm 1.36 \text{ MPa}$ while the highest bending strength occurs in samples with 3 d immersion (1 AB3) which is $166.90 \text{ MPa} \pm 0.50 \text{ MPa}$. The results of the above study are not much different from the influence of borax on the nature and mechanical behavior of *Petung* bamboo lamination using 5 % borax [9]. As a result of the absorption that occurs during immersion in sulfur water and also woven fibers or braids also increase the flexural strength.

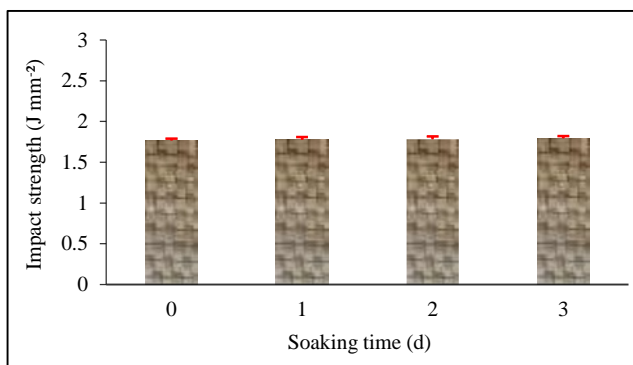


Fig. 4. Relationship between immersion time to impact strength treatment of soaking sulfur water 1 ply

Figure 4 shows the lowest impact strength value occurs in the sample of 0 day (1 TP) which is equal to $1.77 \text{ J mm}^{-2} \pm 0.03 \text{ J mm}^{-2}$ while the highest impact strength occurs in samples with 3 d immersion (1 AB3) which is equal to $1.79 \text{ J mm}^{-2} \pm 0.03 \text{ J mm}^{-2}$. The above research is in line with the manufacture of banana frond fiber composites using NaOH having the highest energy and impact prices at the 60 % fiber volume fraction and 40 % matrix having an energy of 1.799 8 L and an impact price of $0.0179 \text{ 8 J mm}^{-2}$. It can be concluded that fiber with NaOH treatment will increase its mechanical strength [10].

3.2 Measuring microscope laser test results

The results of the photo analysis of composite plaited woven bamboo samples of *Petung* were taken based on the variation of soaking time with each 1 ply good without treatment and also the soaking treatment in sulfur water. Micro photo taking is done morphologically by cutting composite test specimens measuring $0.5 \text{ cm} \times 0.5 \text{ cm}$ using a 3D Laser Measuring Microscope at 400 times magnification.

Figure 5(a) is a non-treatment 1 ply composite micro-photo showing the fracture of the material looks brittle because of the presence of a very sharp/pointed and smooth fiber fracture with neat matrix cracks and vertical crack direction towards the direction of the

fiber. Whereas Figure 5(b), Figure 5(c), and Figure 5(d) is a composite photo of 1 ply composite fault with the treatment of sulfur water for 1 d, 2 d and 3 d. Showing the fracture of the non-brittle material due to the shape of the fiber fracture that is not too sharp/blunt and looks more and more appearance/emergence of thread or fine fiber with the shape of the fracture matrix still looks neat and vertical crack direction towards the direction of the fiber.

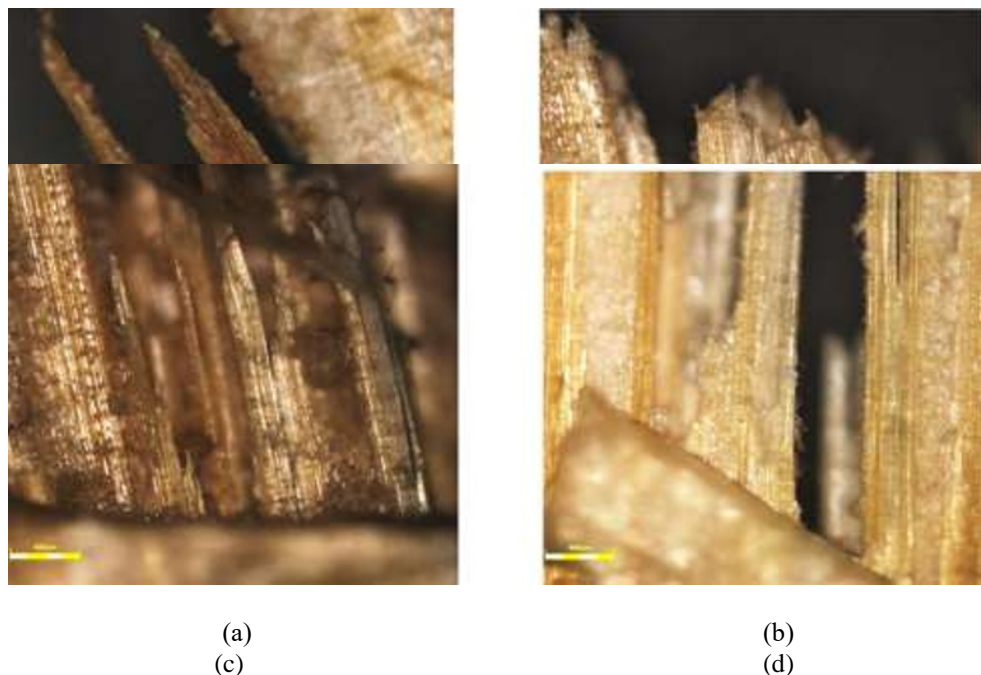


Fig. 5. Composite micro photo 1 ply woven *Petung* bamboo (a) Without treatment, (b) Soaking 1 d of sulfur water, (c) Soaking sulfur water for 2 d and (d) Soaking sulfur water for 3 d

4 Conclusion

The results of the study ‘the effect of water treatment of soaking sulfur woven *Petung* Bamboo (*Dendrocalamus asper*) on the mechanical strength of bematic composite-epoxy resin’ can be concluded that, the effect of the botanical *Petung* immersion treatment using sulfur water obtained the highest tensile strength in the 3 d sample (1 AB3) which was $159.02 \text{ MPa} \pm 0.47 \text{ MPa}$. The highest bending strength value occurred in the 3 d sample (1 AB3) which was $166.90 \text{ MPa} \pm 0.50 \text{ MPa}$. While the impact test obtained the highest strength value occurred in the sample 3 d (1 AB3) which is equal to $1.79 \text{ J mm}^{-2} \pm 0.03 \text{ J mm}^{-2}$. *Petung* bamboo which is woven or braided fiber then given chemical treatment can increase the composite mechanical strength. The length of time the immersion treatment can also affect the composite mechanical strength. Micro acyl photo shows the occurrence of fracture changes in which the sample without immersion is sharp and smooth/does not show the presence of fiber threads, while the soaking samples of woven *Petung* bamboo with hot sulfur water are slightly blunt and the threads appear on the fibers. So that there is a greater effort to maintain strength before finally breaking up.

5 Suggestion

From the results of the research obtained several things that were suggested in subsequent studies, including:

- i. In the treatment of soaking sulfur water to varying the amount of ply in the composite.
- ii. In the treatment of soaking sulfur water in order to increase the estimated immersion time which is not too much different.

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