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The Flexural Strength and Impact Toughness of Bamboo Reinforced Latex-Asphalt Composite

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***Abstract*— Dependence on materials for the small ship industry can cause other problems. The development of cheap, environmentally friendly, and sustainable small ship manufacturing raw materials is a challenge that must be faced, this gave rise to the idea of developing asphalt-matrixed bamboo (*Gigantochloa apus*) composite materials with added latex (*Hevea brasiliensis*) as small ship hull skin material. The asphalt-latex composite material reinforced with apus bamboo fibers was tested using a three-point bending test and a Charpy-type impact test concerning ASTM. The test results showed that the asphalt-latex composite material reinforced with bamboo fibers had an impact toughness of 57.2 kJ/m² and a flexural strength of 6.4 MPa.**

Keywords— Asphalt, Bamboo, Latex, Composite, Bending Test, Impact Test.

I. INTRODUCTION

A small ship is a ship with a length dimension of less than 20 meters [1] or a vessel that has a load water line length below 24 meters [2].Most small shipbuilding industries in Indonesia produce ships from wood raw materials or from fiber-reinforced plastic raw materials where these ships usually function as fishing boats or freighters in relatively small quantities. The use of wood materials for the shipbuilding industry seems to be irreplaceable, this cannot be separated from the role of hereditary habits and traditions or local wisdom [3] that have been carried out in the shipbuilding industry, especially in the traditional shipbuilding industry. In addition, wood has a low-density value so that it can provide great buoyancy to the ship, then wood does not produce rust like metal, and easy handling in the processing process, these things are factors why wood has not been abandoned as a shipbuilding material since thousands of years ago [4].

However, there is a phenomenon called deforestation, namely the reduction in the amount of forest area that has occurred to date, many factors have driven deforestation, one of which is the factor of meeting economic needs [5] and development that has contributed to forest destruction [6], if deforestation continues, wood material will be increasingly difficult to obtain. The scarcity of wood material sources as shipbuilding materials [7] will cause an increase in the price used for shipbuilding materials and then have implications for the selling price of the ship which also increases [8], but the problem due to the increasingly stepped wood material does not stop at skyrocketing selling prices, even shipyards can also stop producing [9].

The use of plastic materials, which was originally an alternative material to reduce the use of wood, In the shipbuilding industry, at present, the use of glass fiber reinforced plastics is dominating, but the application of synthetic products like a combination of plastic and glass fiber may create issues that have serious implications. The toxicological perspective explains that Cu (copper) and Fe (iron) found in glass fiber residues have impacts on human health, where these heavy metals are bound in the body to block the operation of enzymes and thus interrupt the metabolic processes of the body, and these heavy metals cause allergic reactions such as irritated skin, teratogenic or carcinogenic to the body.[10].

The demand for new ship construction is certainly related to needs such as fishing activities [11], but by paying attention to the increasing demand to meet the supply needs of fish catches for the community, it will certainly have a domino effect where fishing activities will also be higher so that the demand for new ship construction will also increase [12], paying close attention to the impacts that can be caused by fiber-reinforced plastic alloy materials, especially glass fiber-reinforced plastics and the continuous consumption of wood materials that will cause forests to disappear, it is deemed necessary to develop composite materials that are more environmentally friendly.

The strengths of organic fibers as reinforcement compared to manmade fibers are considerable potential, inexpensive, and easily degradable so as not to harm the environment (highly biodegradable) [13]. Generally, what is often used by people in Indonesia is tali bamboo, petung bamboo, andong bamboo, and black bamboo [14]. Therefore, in this study, Apus bamboo (*Gigantochloa apus*) or commonly called string bamboo will be used. Apus is widely distributed, particularly in Java to Bali. This variety of bamboo also has a durable resistance to attack by powder. [14].

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As a binder, asphalt according to ASTM is a solid or semi-solid material consisting of bitumen and is dark brown to black in color. that exists in nature or is obtained from crude oil residues. It contains 82% to 88% carbon, 8% to 11% hydrogen and 0% to 6% sulphur, and 0% to 1% nitrogen. Asphalt is the product of a refining process in which the residue is conditioned by air blast or solvents to create a finished product which meets road and highway construction specifications and other applications[15]. Asphalt's advantages include good cohesion, hydrophobicity, aggregate void fill, and lower price than epoxy. Asphalt is also insoluble in dilute acid and alkali solutions or water but is mostly soluble in ether, gasoline, and chloroform. Asphalt has properties similar to oil, namely hydrocarbons being the dominant constituent compound, hydrocarbon substances themselves are not favored by marine organisms because they can interfere with the metabolism of marine organisms [16]. So it allows asphalt to protect the hull of a small ship and prevent biofouling attacks.

This research will provide treatment by adding additives in the form of natural latex from the *Hevea brasiliensis* plant with the aim of obtaining the desired mechanics of the apus bamboo fiber-reinforced asphalt composite. Rubber plant latex (*Hevea brasiliensis*) was chosen because in Indonesia there are many rubber plantation areas that are widely spread in various provinces and are Indonesia's leading export commodity [17], thus naming Indonesia as one of the countries with the largest rubber plantation area and production in the world [18]. In fact, Indonesia is a major exporter and one of the leading products exported from the United States of Amerika [19].

Natural rubber latex composition includes rubber (30.0% to 40.0%), resin (1.0% to 2.0%), protein (2.0% to 2.5%), sugar (1.0% to 1.5%), ash (0.7% to 0.9%) and water (55.0% to 60.0%). The utilization of natural rubber latex is widely used as a raw material for the manufacture of health products, such as gloves, contraceptives, silicone mouth openers, catheters, infusion hoses, and zinc taken-Blakemore tubes. In engineering technology rubber latex has been utilized as an additive to engineer asphalt which is applied as a highway. To several studies, the content of natural rubber latex can make asphalt able to withstand high loads, more elastic [20][21], increase the softening point value of asphalt which is useful for making asphalt more resistant to pressure, thermal cracking, fatigue damage, peeling [22][23] and even better resistance to water than ordinary asphalt [24].

The advantages and advantages offered by rubber latex as an additive are considered necessary to be added to the apus bamboo fiber reinforced asphalt composite material so that it has properties that are not only elastic and strong but also tough.

Figure 1. Asphalt-latex reinforced with apus bamboo fiber composite sheet

II. Method

A. Materials and Instrumentation

This study is preceded by a literature review to obtain data on the issue to be researched. The principal materials to be used in this study will be asphalt (60/70), bamboo fiber (*Gigantochloa apus*) and Hevea brasiliensis latex. The instruments used are a marker, a pair of scissors, a balance, a ruler, an oven, a mold, a cutter, a brush, a thermometer, an impact tester, and a universal tester as a bending tester.

TABLE 1.
RESULT IN BENDING TEST VARIANT ONE

Variant	Specimen-n	Flexural Strength (MPa)*	Elastic Modulus (MPa)	Average of Flexural Strength (MPa)	Modulus Elasticity Mean (MPa)
Variant 1	Specimen-1	6.382	352.819	6.382	241.837
	Specimen-2	6.382	214.869		
	Specimen-3	6.382	215.946		
	Specimen-4	6.382	217.283		
	Specimen-5	6.382	208.267		

B. Methode and Process

1) Preparation Phase

   The preparation stage start with the preparation of the primary material, that is asphalt, which is heated up to 200°C, the temperature is lowered to 90°C when the latex is mixed evenly. Bamboo Apus woven mat will come cut in square rolls of size 60 cm²..

2) Phase of The Composite Production

   At this step, asphalt-latex binder is combined with bamboo fiber.

3) Specimen Manufacture Phase

The dimensional size of each test specimen is specified by the American Standards of Testing Materials., so the bamboo-reinforced asphalt-latex composite panel must be resized. such as ASTM D7264 and ASTM D6110, the purpose of the test is to determine flexural strengths and impact resilience of a composite material, where the composite material is representative of several samples to be used in the test.

III. RESULTS AND DISCUSSION

The results of each variation in terms of flexural strength and impact values were obtained through materials damage experiments using ASTM D7264 and ASTM D6110 standards conducted at Universitas Hang Tuah, Surabaya. In this study, the bamboo fiber-reinforced latex-asphalt composite material is grouped into 3 varieties, wich are as follows;

1) The 1st variant (V1) composite with the addition of 100% latex from the asphalt mass reinforced with three layers of woven apus bamboo fibers.
2) The variant 2 (V2) composite with the addition of 95% latex from the asphalt mass reinforced with three layers of woven apus bamboo fibers.
3) Third variant (V3) composite material with the addition of 90% latex from asphalt mass reinforced with three layers of woven apus bamboo fibers.

A. Bending Test Result

The flexural strength in variant one (V1) is 6.382 MPa with an elastic modulus of 241.837 MPa while the highest value of the five specimens is 6.382 MPa. with an elastic modulus of 352.819 MPa. The constant value of 6.382 MPa was obtained from the test results of each specimen in variant one in a row from specimen 1 to specimen 5. while the elastic modulus value (in MPa) in a row from specimen 1 to specimen 5 is 352.819; 214.869; 215.946; 217.283; 208.267.

Invariant two (V2), the test results show flexural strength of 6.382 MPa with an elastic modulus of

TABLE 2.
RESULT IN BENDING TEST VARIANT TWO

Variant	Specimen-n	Flexural Strength (MPa)*	Elastic Modulus (MPa)	Average of Flexural Strength (MPa)	Modulus Elasticity Mean (MPa)
V 2	Specimen-1	6.382	153.999	6.382	211.015
	Specimen-2	6.382	231.438		
	Specimen-3	6.382	221.326		
	Specimen-4	6.382	217.482		
	Specimen-5	6.382	219.861		

TABLE 3.
RESULT IN BENDING TEST OF THIRD VARIANT

Variant	Specimen-n	Flexural Strength (MPa)*	Elastic Modulus (MPa)	Average of Flexural Strength (MPa)	Modulus Elasticity Mean (MPa)
V 3	Specimen-1	6.382	213.897	6.382	204.220
	Specimen-2	6.382	203.108		
	Specimen-3	6.382	220.505		
	Specimen-4	6.382	195.241		
	Specimen-5	6.382	188.348		

TABLE 4.
RESULT IN IMPACT TEST VARIANT ONE

Variant	Specimen-n	Impact Toughness (kJ/m²)	Absorbed Energy (Joule)	Impact Toughness Mean (kJ/m²)	Average of Absorbed Energy (Joule)
V 1	Specimen-1	62	5	57.2	4.6
	Specimen-2	70	5.6		
	Specimen-3	37	2.9		
	Specimen-4	41	3.3		
	Specimen-5	76	6.1		

211.015 MPa, while among five specimens, the highest value is 6.382 MPa with an elastic modulus of 231.438 MPa. The value of the test results of each specimen in variant two in a row from specimen 1 to specimen 5 obtained a constant value of 6.382 MPa while the elastic modulus value (in MPa) in a row from specimen 1 to specimen 5 is 153.999; 231,438; 221.326; 217.482; 219.861.

The third variant (V3) of the test results shows the same flexural strength of 6.382 MPa with an elastic modulus of 204.220 MPa while the highest value of the five specimens is 6.382 MPa. with an elastic modulus of 220.505 MPa. The value of the test results of each specimen in variant two in a row from specimen 1 to specimen 5 obtained a fixed value of 6.382 MPa while the value of the elastic modulus (in MPa) in a row from specimen 1 to specimen 5 is 213.897; 203.108; 220.505; 195.241; 188.348.

B. *Result of Impact Test*

Impact toughness in variant one (V1) amounted to 57.2 kJ/m2 with absorbed energy of 4.6 J while of the five test specimens had the highest value of 76 kJ/m2 with absorbed energy of 6.1 J. The value of the test results of each sample in variant one in a row from sample 1 to sample 5 obtained values of 62; 70; 37; 41; 76 (in units of kJ/m2) while the value of absorbed energy in a row from specimen 1 to specimen 5 is 5.0; 5.6; 2.9; 3.3; 6.1 (J).

Invariant two (V2) Impact toughness of 56 kJ/m2 with absorbed energy of 4.48 J while of the five test specimens have the highest value of 83 kJ/m2 with absorbed energy of 6.6 J. The value of the experiment outcomes of each sample in Variant 1 in a row from sample 1 to sample 5 obtained values of 47; 35; 83; 43; 72. (in units of kJ/m2) while the value of absorbed energy in a row from specimen 1 to specimen 5 is 3.8; 2.8; 6.6; 3.4; 5.8 (J).

The third (V3) Impact toughness of 43.4 kJ/m2 with absorbed energy of 3.48 J while of the five test specimens have the highest value of 68 kJ/m2 with absorbed energy of 5.4 J. The value of the test results of each sample in variant one in a row from sample 1 to sample 5 obtained values of 36; 34; 43; 68; 36 (in units of kJ/m2) while the value of absorbed energy in a row from specimen 1 to specimen 5 is 2.9; 2.7; 3.5; 5.4; 2.9 (J).

TABLE 5.
RESULT IN IMPACT TEST VARIANT TWO

Variant	Specimen-n	Impact Toughness (kJ/m²)	Absorbed Energy (Joule)	Impact Toughness Mean (kJ/m²)	Average of Absorbed Energy (Joule)
V 2	Specimen-1	47	3.8	56	4.48
	Specimen-2	35	2.8		
	Specimen-3	83	6.6		
	Specimen-4	43	3.4		
	Specimen-5	72	5.8		

TABLE 6.
RESULT IN IMPACT TEST VARIANT THREE

Variant	Specimen-n	Impact Toughness (kJ/m²)	Absorbed Energy (Joule)	Impact Toughness Mean (kJ/m²)	Average of Absorbed Energy (Joule)
V 3	Specimen-1	36	2.9	43.4	3.48
	Specimen-2	34	2.7		
	Specimen-3	43	3.5		
	Specimen-4	68	5.4		
	Specimen-5	36	2.9		

C. *Discusion*

Based on the test results data that have presented above, the addition of *Hevea brasiliensis* rubber latex to the flexural strength of asphalt composites reinforced with wormy bamboo fibers does not increase and does not decrease in flexural strength, but the addition of latex composition to wormy bamboo fiber reinforced asphalt composites has an impact on increased the value of elastic modulus as the composition of *Hevea brasiliensis* rubber latex increases. The modulus of elasticity is the quantity of force required for each unit of deformation, which affects the difficulty of a material to deform [25]. Therefore, more great value of the elastic modulus due to the addition of *Hevea brasiliensis* rubber latex dose explains that the greater the force on each unit area required to experience an increase in size. In short, it can be that the addition of rubber latex makes the ability of apus bamboo fiber-reinforced asphalt composites to accept stress without experiencing permanent changes in shape after the stress removed.

In the impact test results, the addition of latex also has an impact on impact toughness of wormy bamboo fiber reinforced asphalt composites where the impact toughness increase directly proportional to an additional dose of *Hevea brasiliensis* rubber latex. Increased impact toughness means that the increasing ability of the apus bamboo fiber reinforced asphalt composite to receive a sudden force until it is damaged. The value can also indicate how rigid the material is because the Charpy type impact test method is a simple method for measuring resistance and rigidity to impact loading from different materials or the same material but with different processing [26].

TABLE 7.
COMPARISON OF FLEXURAL STRENGTH VALUES BETWEEN LATEX ASPHALT REINFORCED WITH APUS BAMBOO, APUS BAMBOO REINFORCED ASPHALT, BAMBOO REINFORCED PLASTIC, AND LR CLASS REGULATION.

Variant	Flexural Strength (MPa)	Modulus of Elasticity (Mpa)
Latex asphalt reinforced with apus bamboo	6.382	241.837
Apus bamboo reinforced asphalt	27.018	9953.28
Bamboo reinforced plastic,	160.80	23171.66
Lloyd's Register regulation	80	As measured

Changes in the properties of the material due to the presence of rubber content in pen60/70 asphalt where during the process of mixing asphalt with rubber, the distance between asphalt particles will be stretched due to high temperatures so that the rubber particles will fill the space between asphalt particles and then absorb the oil contained in the asphalt and cause the rubber particles to expand if the more levels of rubber particles added, the more rubber particles will fill the space between asphalt particles this causes the asphalt to become denser and harder [22].

TABLE 8.
COMPARISON OF IMPACT TOUGHNESS VALUES BETWEEN LATEX ASPHALT REINFORCED WITH APUS BAMBOO, APUS BAMBOO REINFORCED ASPHALT, AND LR CLASS REGULATION.

Variant	Impact Toughness (kJ/m²)	Absorbed Energy (J)
Latex asphalt reinforced with apus bamboo	57.2	4.6
Apus bamboo reinforced asphalt	40	3.18
Bamboo reinforced plastic	186.22	-
LR class regulation	-	-

The value of mechanical properties obtained in this study is then compared with the value of mechanical properties that existed previously through previous studies related to bamboo (apus) fiber reinforced asphalt composite materials, bamboo (apus) fiber reinforced plastic composite and compare with the flexural strength and impact toughness values required by class regulations.

Based on the data presented in Table 7, the flexural strength value of apus bamboo-reinforced latex-asphalt is 6.382 MPa, the flexural strength value of apus bamboo-reinforced asphalt is 27.018 MPa [27], the bamboo reinforced plastic variant has a flexural strength value of 160.80 MPa [13], and Lloyd's Register sets a minimum flexural strength value of 80 MPa [28]. Latex-asphalt reinforced with apus bamboo is far below the flexural strength value of apus bamboo-reinforced asphalt (which is a variant of 3 layers of apus bamboo fiber reinforcement without latex addition) with a difference of 20.636 MPa. When compared to bamboo-reinforced plastic, latex asphalt reinforced with apus bamboo is also still adrift with a difference in flexural strength value of 154.418 MPa. With a flexural strength value of latex asphalt reinforced with apus bamboo of 6,382 MPa, it cannot meet the minimum flexural strength value set by Lloyd's Register.

Furthermore, through the data presented in Table 8, the toughness of impact value of apus bamboo reinforced latex-asphalt is 57.2 kJ/m², the toughness value of apus bamboo-reinforced asphalt is 40 kJ/m² [29], and the bamboo reinforced plastic variant has an toughness of impact value of 186.22 kJ/m² [13]. Latex-asphalt reinforced with bamboo (apus) is above the impact toughness value of apus bamboo reinforced asphalt (which is a variant of 3 layers of apus bamboo fiber reinforcement without latex addition) with a difference of 17.2 kJ/m². When compared to bamboo-reinforced plastic, latex asphalt reinforced with apus bamboo is still adrift with a difference in toughness of impact value of 129.02 kJ/m². Provides the durability of bamboo reinforced latex-asphalt, it still cannot exceed the toughness of bamboo-reinforced plastic material

IV. CONCLUSION

Thus in this study, the above description can be concluded that:

1. The addition of *Hevea brasiliensis* latex to apus bamboo fiber-reinforced asphalt composites provides positive changes to elasticity and ductility of the material thereby improving the mechanical characteristics of the material, as indicated by changes in the impact toughness value. and flexural modulus of bamboo (apus) fiber reinforced asphalt composite materials.
2. Flexural strength of asphalt-latex composite reinforced with apus bamboo fiber does not meet Lloyd's Register regulations;
3. So that the mechanical strength of the material can be used in small ship parts that require low flexibility.
4. The impact experiments outcomes of asphalt-latex reinforced by bamboo (apus) fibers composite changes better than the impact experiments outcomes of asphalt composite reinforced with apus bamboo fibers without addition of latex.

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