

# Technical analysis of biocomposite reinforced with sugar palm (*Arenga Pinnata*) fiber for jukung materials

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## Technical analysis of biocomposite reinforced with sugar palm (*Arenga Pinnata*) fiber for jukung materials

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**Abstract.** This study aimed to determine the effect of composition between sugar palm fiber (*Arenga Pinnata*) and polyester resin as composite materials. The parameters are focused on impact strength, tensile strength, and modulus of elasticity and are compared to *Badan Klasifikasi Indonesia* (BKI) standard which is Regulations for the Classification and Construction of Ship in Indonesia. The composition of fiber and resins is 30:70%, 40:60%, and 50:50% using mass fraction. The angle orientation of fiber is 0,90,0,90 and manufacturing process uses the hand lay up method. Impact testing is carried out with the ASTM D5942-96 standard and Tensile Testing is carried out with the ASTM D638-03 standard. The results showed that the composition of 50:50% is the highest test value compared to other compositions, with average impact strength of  $1.703 \times 10^{16} \text{ kg mm}^{-2}$ , tensile strength of  $27.13 \text{ N mm}^{-2}$ , and modulus of elasticity of  $790.01 \text{ N mm}^{-2}$ . Although the results of the value of the impact test, tensile test and modulus of elasticity of the composition of the mass fraction of sugar palm fiber (*Arenga Pinnata*) material are still below the BKI standard, it still has the potential to continue to be developed as an alternative raw material for making Jukung (traditional boat in Banjarmasin).

**Keywords:** fiber, mass fraction, tensile strength

### 1. Introduction

The river has become an integral part of South Kalimantan. Banjarmasin as the Main City in South Kalimantan has been pinned the "city of a thousand rivers". In earlier times, the river is the center of people's activities like transportation, trade, washing, and others. Especially in transportation, people generally use "Jukung" (Traditional Boat of South Kalimantan) for transporting people, stuff, etc. Jukung plays an important role in the lives of local people as a means of water transportation and other means of community economic activity.

Mostly, Jukung is made of woods but the use of wood potentially will increase illegal logging and deforestation. In this condition, an alternative for making Jukung as a substitute raw material for wood is required. One of the alternative materials is Natural Fibers as a composite material. Composite is a material consisting of a mixture or combination of two or more materials, both micro and macro, where the material properties differ in the original substance's shape and chemical composition [1,2]. Some study have conclude that the composite materials have great strength and stiffness like Carbon Fibers, large specific strengths, dimensional stability, lower-density fibers, and high modulus in fatigue resistance [3,4].



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In a recent study, composite is dominated by natural fibers composites. Many studies have been carried out the application of composite from natural fibers composite like automotive [5-7], marine [8] and biomedical [9]. Not only about increasing in the mechanical properties, but also there are some efforts to reduce global warming, depletion of natural resources, waste problems, and encourage renewable materials by the use of environmental materials friendly [10,11]. Moreover, studies have been conducted to see the alternative natural fiber materials for composite. Nevada *et al.* [12] conducted a study of the use of Sago (*Metroxylon sp*) as a matrix composite combined with NaOH solution and equates in alkaline process and evaluates the impact strength and good water absorption. The result shows the best impact strength is 0.0693 (J mm<sup>-2</sup>) and the water absorption rate is at 8.67% for fiber 50% in volume with the alkaline process 9%. Kusairi and Ni'mah [1] studied Palm Kernel Shells and Tapioca Adhesive as Matrix for the furniture industry. The result shows the highest compressive strength at 0.707 MPa was shown in the matrix composition of 30% matrix and 70% palm kernel shells. The water content has fulfilled the requirements of JIS A 5908-1994 for particle boards. Haliq *et al.* [13] have studied experimentally composite material for sound insulation form Galam wood (*Melaleuca Leucadendra*). The result shows that the best insulation composition is 7% sawdust filler namely 800 Hz in the frequency of sound and the highest modulus of elasticity is 18% wood chip filler.

Preliminary research regarding the use of sugar palm fiber carried out [5]. the result shows that the composite fiber from 50:50% sugar palm (*Arenga Pinnata*) and resin polyester is suitable for an alternative material for the cover automotive component. This research was conducted as an effort to increase the use of natural materials, especially the use of sugar palm fiber as a composite reinforcement. Although there have been many studies related to the use of sugar palm fibers, the research on the application of sugar palm fibers on Jukung has not been found. For Jukung's standard manufacturing, must have a tensile strength of 98 N mm<sup>-2</sup> and modulus of elasticity (MoE) of 6.86 x 10<sup>3</sup> N mm<sup>-2</sup> as set in the Rules and Regulations for the Classification and Construction of Ship of *Biro Klasifikasi Indonesia* (BKI).

## 2. Method

Natural fibers are renewable materials because they have derived from plants. Natural fibers as a composite are widely used as raw composite materials for improving basic characteristic material. **Table 1** shows us the mechanical properties of fibers that have been widely used. As can be seen, sugar palm is one of the alternative natural fibers for composite reinforcement.

**Table 1.** Mechanical properties of fibers [8]

Fibers	Density (g/cm <sup>3</sup> )	Tensile strength (MPa)	Tensile modulus (GPa)	Tensile strain (%)
Jute	1.3–1.45	342–672	43.8	1.7–1.8
Flax	1.50	300–900	24.0	2.7–3.2
Hemp	–	142–819	4.8–34.4	1.5–4.5
Basalt	2.80	4800	90	3.1
Sisal	1.45	444–552	9.4–22.0	2.0–2.5
E-glass	2.54	3200	70	4.0
Aramid	1.44	2400–3600	60–120	2.2–4.4
Carbon	1.81	5490	294	1.9
Sugar Palm[4]	-	15.5 - 292	0.49-3.37	5.75 – 27.75

The sugar palm (*Arenga Pinnata*) tree is a plant that is used to produce sugar but all parts of the plant can be used like trunks for building, fruits, and leaves for food cover. Another product

from the sugar palm tree is fiber. Sugar palm is a common material as natural fibers and widely spread out in some parts of Indonesia. The characteristics of sugar palm fiber are high durability and their resistance to sea water [4]. These are useful as alternative materials for marine manufacturing, especially jukung manufacturing. **Table 2** shows the comparison of chemical composition from natural fibers. The cellulose, hemicelluloses, and lignin show a significant contribution to the increase in tensile strength, elongation at break, and modulus of the fibers [4]. Specifically, sugar palm contains higher cellulose compared to the other materials such as bamboo, coir, and rice husk. In this study sugar palm

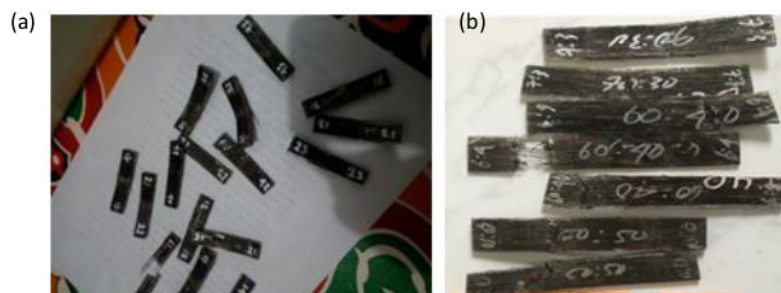
**Table 2.** The comparison of the chemical composition of natural fibers[10]

Fiber	Cellulose (%)	Hemicellulose (%)	Lignin (%)	Ash (%)
Sugar Palm Fiber Kuala Jempol	44.53	10.01	41.97	0.955
Sugar Palm Fiber Indonesia	44.47	8.93	41.425	0.91
Sugar Palm Fiber Tawau	43.75	9.94	39.54	1.34
Bamboo[14]	26-43	30	21-31	-
Coir[14]	32-43	0.15-0.25	40-45	-
Rice Husk[14]	35-45	19-25	20	-

In this study, the materials used are Sugar Palm (*Arenga Pinnata*) and Resin Polyester. Sugar Palm (*Arenga Pinnata*) as a natural fiber. Resin Polyester as the adhesive matrix, hardener, and KIT Paste Wax. The specimens were made based on a mix design to get the most excellent characterization of the composite. The proportion of natural fiber and resin polyester is 30:70%, 40:60%, and 50:50% using a mass fraction. The angle orientation is 0,90; 0,90, and the manufacturing process uses the hand lay-up method. The composite testing uses the ASTM standard. Impact testing is carried out with the ASTM D5942-96 standard, and the tensile test is carried out with the ASTM D638-03 standard [15].

### 3. Results and discussion

Composite specimens for impact test and tensile test, respectively, have 3 variations in the composition of the fibers and resin. They are called mass fraction compositions. The Composite variations for impact and tensile testing have codes A\_90\_50; A\_90\_40; and A\_90\_30. The code as in A\_90\_30 shows the character 90 for the angle of orientation. The character 30 is the proportion of 30% fibers and 70% resin. Each composite variation consists of 20 specimens (**Figure 1**).



**Figure 1.** Composite specimens: a) Impact test, b) Tensile test

### 3.1. Impact testing

The results of each variation can be seen graphically as shown in Figure 2. From the experiment, the A\_90\_50 variation shows the highest value of Impact energy namely  $1.703 \times 10^{-16} \text{ kg mm}^{-2}$  and it is followed by A\_90\_40 and A\_90\_30 that has value  $1.101 \times 10^{-16} \text{ kg mm}^{-2}$  and  $5.657 \times 10^{-17} \text{ kg mm}^{-2}$ , respectively. It can be inferred that the Impact value decreases with decreasing of sugar palm fiber and the fiber contents increases resulting in higher required force to break the specimen after impact testing. This result has been stated by Nevada *et al.* [12] that the higher fiber volume fraction and NaOH presentation in the alkalization process, the higher the absorption energy and value of the impact strength.

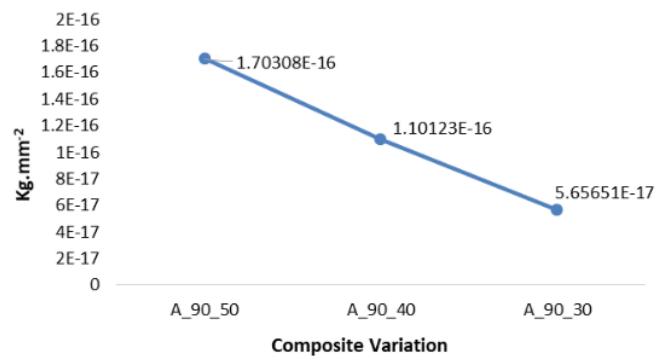


Figure 2. Impact strength results

### 3.2. Tensile testing

Data on tensile test results can be shown as graphs to show the relationship between the composition, the tensile strength, and the modulus of elasticity (MoE). Figure 3 shows the tensile strength of samples as a function of fiber content for 50%, 40%, and 30%, respectively. A\_90\_50 means that the variation contains 50% sugar Palm Fiber as the filler has the highest value of tensile strength and modulus of elasticity namely  $790 \text{ N mm}^{-2}$  and  $27.13 \text{ N mm}^{-2}$ . The tensile strength and modulus of elasticity increase about  $5 \text{ N mm}^{-2}$  and  $40\text{-}120 \text{ N mm}^{-2}$  respectively when the fiber content is increased.

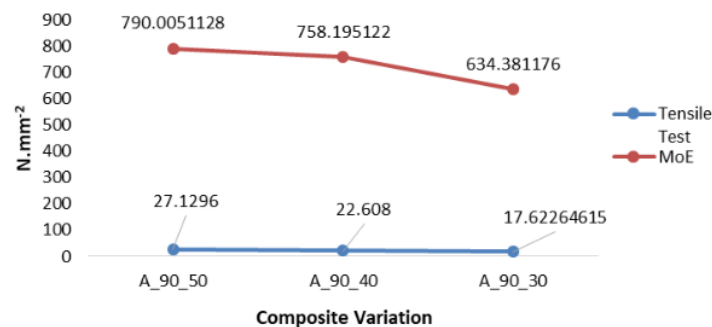


Figure 3. Tensile strength results

### 3.3. Discussion

In the composition between sugar palm fiber and resin 30:70 produces impact strength of  $5.657 \times 10^{-17} \text{ kg mm}^{-2}$ , tensile strength of  $17.62 \text{ N mm}^{-2}$  and modulus of elasticity of  $643.81 \text{ Nm m}^{-2}$  and from macro-photographic observations produce granular (crystalline) fractures. In composition 30:70%, the strength of the fiber is less than the resins that the fracture type is flat fracture shape as shown in **Figure 4**.



**Figure 4.** Macro photo of composite fracture (composite composition 30:70)

The composition of the fiber and resin 40:60% produces an impact strength of  $1.101 \times 10^{-16} \text{ kg mm}^{-2}$ , tensile strength of  $22.62 \text{ N mm}^{-2}$  and modulus of elasticity of  $758.2 \text{ N mm}^{-2}$  and from observations, Macro photos produce mixed type fractures as shown in **Figure 5**. The strength of the resin is still more dominant than the strength of the fiber, however, the fiber still contributes to withstand the load after the resin can no longer withstand the load, and this composition has ductile properties (resilient).



**Figure 5.** Macro photo of composite fracture (composite composition 40:60)

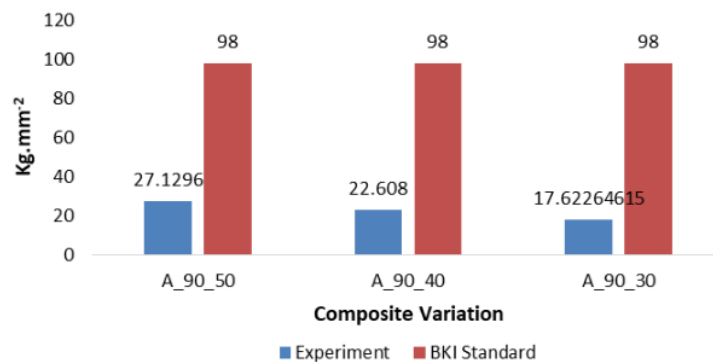
The composition 50:50% produces an impact strength of  $1.703 \times 10^{-16} \text{ kg mm}^{-2}$ , tensile strength of  $27.13 \text{ N mm}^{-2}$ , elongation of 3.43%, and Modulus of Elasticity of  $790.01 \text{ N mm}^{-2}$  from macro photographic observations produce mixed type fractures. The strength of the fiber is more dominant than the strength of the resin, the fiber contributes dominantly to hold the load after the resin can no longer withstand the load, and this composition has ductile properties (resilient).



**Figure 6.** Macro photo of composite fracture (composite composition 50:50)

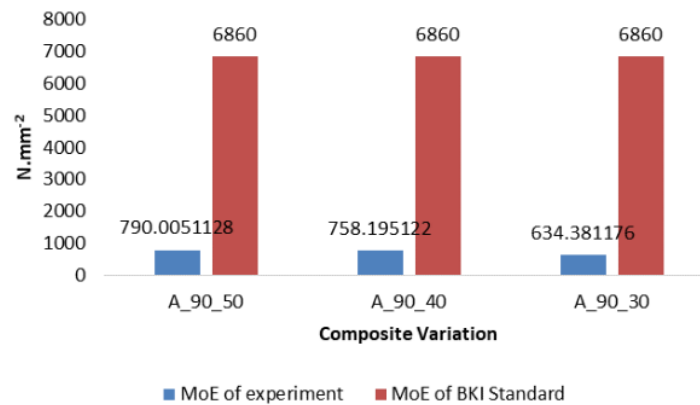
#### 3.4. Comparison of test results with KBI regulations

The comparison of the average results of the tensile strength and modulus elasticity of fiber composite fibers to BKI standards is shown in **Figure 7** and **Figure 8**. Based on BKI standards, all the compositions of the fiber-resin composite are under the BKI standard, because of the average tensile strength and modulus of elasticity (MoE) namely tensile strength of  $98 \text{ N mm}^{-2}$  and modulus of elasticity of  $6.86 \times 10^3 \text{ N mm}^{-2}$ . Some possibilities that cause the composition of the fiber under BKI standard are composite manufacturing method that uses hand lay-up the use of Polyester type resins so that fibers and resins do not blend perfectly and Mixing between resin and catalyst is less than perfect and precise.



**Figure 7.** Comparison of tensile strength with BKI Standards





**Figure 8.** Comparison of modulus of elasticity (MoE) to BKI Standards

#### 4. Conclusion

- The highest impact strength, tensile strength, and modulus of elasticity are owned by A\_90\_50 which contains 50% sugar palm fiber namely  $1.703 \times 10^{-16} \text{ kg mm}^{-2}$ ,  $27.13 \text{ N mm}^{-2}$ ,  $790.01 \text{ N mm}^{-2}$ , respectively.
- The variation A\_90\_50 results in a type of mixed fracture so that the fiber contributes dominantly to hold the load after the resin break, and this composition has ductile properties (resilient).
- Although the results of the value of the tensile test and modulus of elasticity of the compositions are still below the BKI standard for boat making, it still has the potential to be developed as an alternative raw material for making Jukung (traditional Boat in Banjarmasin).

#### 5. Acknowledgments

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