

Mechanical Properties of Coconut Fiber Hybrids and Non Hybrids Prepared Using Polyester Resin

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Abstract - The use and exploitation of natural fibers as reinforcement in composite materials continues to be developed with the aim of reducing the use of synthetic fibers which have an impact on the environmental problems. This research aims to experimentally study the fiber potential and coconut sticks for the manufacture of hybrid composite materials as one of the natural fiber-based composite materials that have performance for certain applications. The method used is the manufacture of hybrid composites by varying the volume of fiber and sticking with polyester resin matrices. While testing mechanical properties in succession refers to ASTM D 638, ASTM D 790, ASTM D 785 and ASTM D 256 testing standards for tensile strength testing, bending strength, hardness testing, and impact testing. The results obtained show that the most optimal mechanical properties occur in the composition of the 50% reinforcement volume fraction. Overall, the head stick as a reinforcing material on hybrid composites has not provided significant reinforcement due to the presence of a hard layer around the surface of the stick even though alkaline treatment has been carried out.

Keywords: coconut fiber, sticks, z100, alkaline, impact, bending.

I. INTRODUCTION

It is undeniable that natural fibre is a basic material as a composite for natural fibre based composites which has many advantages for various applications, especially non-structural materials in automotive, residential, railroad and aerospace industries [1,2]. Mercedes Benz, Toyota, and Daimler Chrysler have used natural fibre as part of automotive construction for users for interior / accessories. The choice of natural fibre is based on its abundant availability, fibre variation, low cost, low density, specific strength and high modulus [3]. Behind the advantages possessed by natural fibre as a composite reinforcement, but its use for structural materials is still limited. Hydrophilic properties, which are the main problem for all cellulose fibres when used as reinforcement in hydrophobic polymers. The moisture content of the fibres depends on the non-crystalline and void / vacuum contents with amounts up to 10 wt.% under standard

conditions. Hydrophilic from natural fibres will affect the overall mechanical properties and also other physical properties of the fibre [4]. This hydrophilic property which causes the compactness between the fibres and matrix is not maximal due to the ability of the binding fluid to penetrate into the fibre structure is not good or the bond between low face. Information about interfacial bonding between fibres and matrices is very important for sit material because it is very influential on its mechanical properties where a weak. Interface causes the composite to be easily damaged and its shear strength becomes low [5]. All pre-treatment of natural fibres aims to improve mechanical properties, strengthen composite properties with water absorption and increase uniformity of natural fibers [6]. Besides that, chemical treatment of fibres can also result in the cessation of the absorption process, cleaning and change the surface topography of the fiber, increase the surface hardness of the fiber so that it can increase the interfacial bonding between fibers and matrices. The rough surface fiber topography will produce better mechanical interlocking with the matrix. However, the initial treatment of fibers with immersion of chemical solutions is not totally effective, increasing the bond between fiber and matrix [7]. In addition to alkaline treatment, the mechanical properties of composites can be increased by adding other amplifiers or varying the orientation of fibers such as in hybrid composites. This type of composite is a combination of two or more types of fiber in one composition, where the fiber can be in the form of a different fiber length in one type of fiber or a combination of several types of fibers [8]. The existence of hybrid composites is to overcome the weaknesses that occur in single fiber composites such as low mechanical properties when compared to using synthetic fibers. It is natural that the use of fiber [9]. Hybrid composites have also been made using kenaf fiber, jute, and glass fiber plaited where the tensile strength reaches 124.05 MPa and there is a significant increase in absorbing impact energy [10].

In tropical countries, the availability of natural fibers is very abundant but exploration of natural fibers that can be used as composite materials has not been fully identified. However, studies conducted by researchers using natural fibers as an alternative to synthetic fiber substitutes for composite materials have been developed. Among the natural fibers that are widely studied include kenaf fiber, jute,

bamboo, flax, coir, banana, sansevieria, ramie, hemp, panacea, and sisal [11]. Coconut fiber is one of the derivative products of coconut plants that has been successfully used for automotive applications, the railroad industry, and building and residential applications [12]. Besides coconut fibre, coconut plants also produce coconut sticks but their utilization is not maximized. This research is focused on making non-hybrid and hybrid composites that utilize fibre and coconut sticks with polyester resin matrix. The investigation was carried out on tensile strength and bending strength with volume fraction variations.

II. METHODOLOGY

2.1 Material Preparation

Coir fiber and coconut sticks were obtained from coconut farmers in the Minahasa Regency of North Sulawesi province with a height above the surface of about 500 m. Furthermore, fiber and coconut sticks were soaked separately using NaOH solution with a concentration of 3% for 2 hours. Soaking results are then washed with running clean water followed by rinsing with distilled water to remove chemical effects to pH 7 levels. Drying is done in an open place for 3 days without irradiating the sun's heat. Fiber is cut to 10 mm in size and coconut stick 30 cm from the base of the stick. Non hybrid composites made are short fibers with random orientation while short fiber hybrid composites with random orientation and coconut sticks.

2.2 Manufacture of Composite Panels

In this study, composites made with fibers were randomly distributed to polyester resin with a volume fraction of 20%, 30%, 40%, 50%, and 60% and orientation of the mold in the direction of the mold. The arrangement of lemongrass and sticks in the manufacture of composites as shown in figure 1 below:



Figure 1: Cross section of fiber composition and sticks on Composite

The composite panels made by printing on steel molds that are equipped with thickness limiting according to ASTM D 638, D 790, D 765 and D 256. To make it easier for prints to be removed from the mold, the mold is first smeared using wax. Resin and catalyst are mixed using a hand mixer for + 30 seconds. Furthermore, the base of the mold with dimensions (300 x 100 x 8) mm is smeared with brush until evenly followed by the administration of fibers - sticks. Between the fibers and the sticks are resized to the top of the fiber. Emphasis was made using a hydraulic press machine and left

for 24 hours at the temperature of the housing before the composite panel was described from the mold. The non hybrid and hybrid composite composition made is shown in Table 1 below :

Table 1: Non Hibrid and Hibrid Composite Composition for Specimen Making Tensile and Bending Test

Composite Panel	Fiber length (mm)	Composite Panel Composition (vf %)		
		Fiber	Resin	Catalist
A	10	20	79	1
B	10	30	69	1
C	10	40	59	1
D	10	50	49	1
E	10	60	39	1

2.3 Tensile Testing

Tests are carried out 5 times for each type of composite panel using the Zwick Roell UTM capacity 100 kN brand at room temperature of 25° C referring to ASTM D 638 type 1 standard and specimen making using CNC milling machines. A typical graph produced from a tensile test machine on one type of fiber hybrid composite panel and coconut stick is shown in this report. Each panel type is tested 5 times and then displayed in the form of an average yield table for all types of composite panels.

2.4 Bending Testing

Bending testing uses a "three point bending" method and refers to the ASTM D 790 standard. Testing is carried out 5 times for each type of composite panel. Bending testing is done by using the Z100 type Zwick Roell machine at the room temperature of the hybrid composite, the bending test produced from the tensile testing machine is displayed to determine its bending strength. The overall results will be displayed in table form in the form of mean values of bending test characteristics.

III. RESULTS AND DISCUSSIONS

3.1 Tensile Strength

Typical tensile test results obtained from Zwick Roell 2100 UTM with the selection of ASTM test standards d 638 for each composite panel type shown in Figure 2 and figure 3. While table 2 and table 3 show the average value of tensile test results from five specimens for each type of composite panel fiber non hybrid and hybrid coconut-polyester resin sticks..

Based on the results obtained from the tensile testing machine data, tensile strength and strain increase with increasing volume of lemongrass and stick fractions up to 50%

volume fraction while in the volume fraction 60% the tensile strength and strain decreased. Increasing the tensile strength of composites is proportional to the increase in the volume fraction of reinforcing materials (fibers and coconut sticks) in a fiber hybrid composite material and coconut sticks with polyester matrix. Increased tensile strength was also experienced in random fiber composites without using coconut sticks.

Table 3: The average of the hybrid composite tensile test results

panel	Tensile modulus (GPa)	Tensile strength (Mpa)	Stress at Break (Mpa)	Elongation at Tensile (%)	Elongation at Break (%)
A	1.982	25.329	22.881	1.407	1.557
B	2.437	27.516	23.671	1.485	1.758
C	2.641	29.104	25.623	1.556	1.834
D	3.243	34.053	28.575	1.696	2.013
E	2.538	30.775	26.209	1.335	1.785

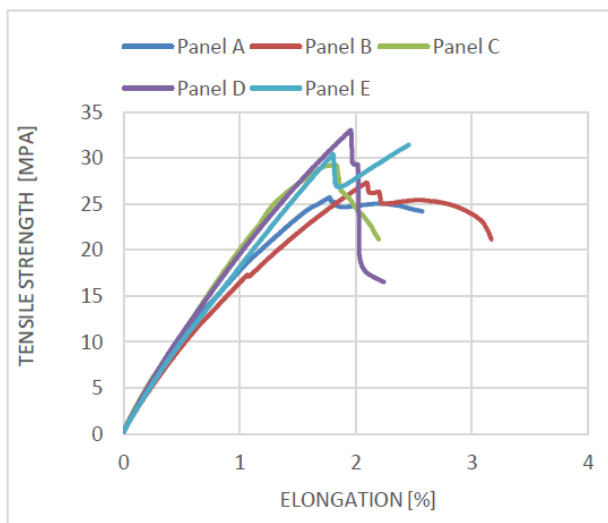


Figure 2: Typical Graph of Tensile Test Non Hybrid Composite

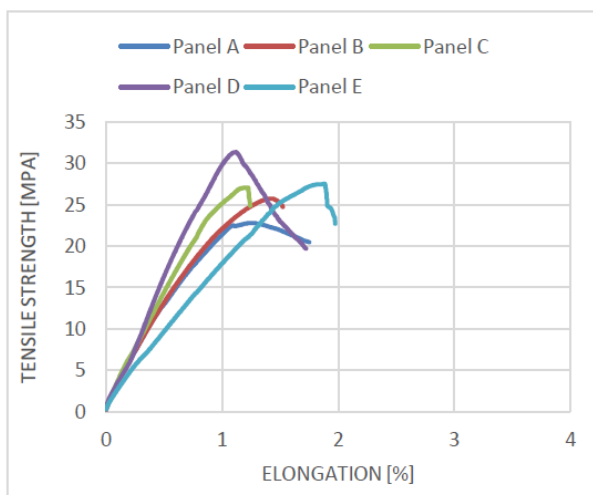


Figure 3: Typical Graph of Tensile Test Hybrid Composite

Table 2: The average of the non hybrid composite tensile test results

Panel	Tensile modulus (GPa)	Tensile strength (Mpa)	Stress at Break (Mpa)	Elongation at Tensile (%)	Elongation at Break (%)
A	1.426	22.789	16.731	1.724	2.257
B	1.271	23.326	22.248	1.905	2.458
C	2.211	27.052	23.694	1.923	2.634
D	2.193	31.316	20.320	1.326	2.214
E	2.032	27.497	22.549	1.915	2.285

In general, the increase in tensile strength in natural fiber composites is influenced by several variables including volume fraction, fiber pre-treatment, and wettability. Figure 1 and 2 shows the behavior of the tensile strength of non hybrid and hybrid composites in different volume fractions of fibers and sticks. Tensile strength and elongation has increased along with the addition of volume fractions [15]. The increase in value to this force is reached up to vf - 50%, whereas in the volume fraction 60% tends to decrease. The decrease in strength value is due to the greater number of fiber fractions and sticks in a composite will reduce the number of matrices to bind so that the bond between the amplifier and matrix is not effective. Another factor that causes an increase in the strength value is the presence of initial treatment applied to fibers and sticks. Treatment with alkaline solutions will cause the surface of the fiber to become coarser and remove some elements that inhibit the binding system such as wax and other impurities. There is soaking with alkaline solution, the fiber will be more effective to absorb the matrix because it can fill between the gaps between fibers so that the micro fibrils that make up the coco fiber become stronger [16]. The presence of coconut sticks in hybrid composites gave no significant effect on the tensile strength of the composite. This can be observed from Figures 1 and 2, where the increase in average power values is only 10.074%. Although coconut sticks get pretreatment in the form of soaking with alkaline solutions, it does not have a significant effect on the tensile strength.

The layer around the coconut stick after alkalization



Figure 3: Cross section of coconut in matrix (micro photo enlargement 20 x objectives)

Figure 3 shows the cross section of the sticks planted in polyester resin. It can be seen that the surface of the stick has an outer layer that encloses the microstructure of the fibrils.

This layer which causes the matrix cannot bind effectively on the surface of the stick to produce a strong bond between the matrix and the coconut stick. This condition provides information that the ability of absorption or the nature of wettability is not good even though it has been done by immersing NaOH so that the type of fracture that occurs is dominated by pull out events. This can be seen from Figure 2 and 3 of the tensile test results between non hybrid composite and hybrid composite.

On the graphs of the hybrid composite composite tensile test, it can be seen that the maximum tensile strength is followed by a decrease in the stress value drastically at a fixed strain condition then an increase in tensile strength occurs. This phenomenon proves that coconut sticks are separated from the composition of fibers and matrices because there is no strong bond. Figure 3 proves that the matrix is difficult to bond with the stick because it is stuck. obstructed by the hard layer that surrounds it. Whereas in coco fiber it is clear that the matrix can penetrate between the microstructure of fiber fibrils so that strong bonding occurs

3.2 Bending Strength

Bending strength testing uses a three-point bending method for all types of composite panels. Figure 4 and 5 shows a typical graph of bending test results using Zwick Roell Z 100 UTM using ASTM D 790 standard test. From the graph the results of the bending test observed the average value of bending strength, bending modulus and maximum bending bending as shown in table 4 and 5.

Maximum bending strength, bending modulus, and maximum bending strain are obtained on D panel non hybrid composite panels of 69.886 Mpa, 59.739 Mpa and 3,509% at 50% volume fraction. For hybrid composite the bending strength 72.650 Mpa, bending modulus 61.459 Mpa, and maximum bending strain 4.709 %.

Table 4: The average of the non hybrid composite bending test

Composite panel	Flexural modulus (MPa)	Flexural strength (Mpa)	Maximum flexural strain (%)
A	54.321	56.582	3.229
B	54.873	59.411	3.304
C	56.631	62.059	3.425
D	59.739	69.886	3.509
E	57.754	62.865	3.489

Table 5: The average of the hybrid composite bending test

Composite panel	Flexural modulus (MPa)	Flexural strength (Mpa)	Maximum flexural strain (%)
A	55.236	61.435	3.829

B	56.689	65.872	3.992
C	59.783	67.971	4.225
D	61.459	72.650	4.709
E	59.321	68.433	4.421

While the minimum value is obtained on panel A non hybrid composites with bending strength, bending modulus, and maximum continuous bending bending of 56.582 Mpa, 54.321 M pa, and 3.229% in the volume fraction of 20% . For hybrid composite the bending strength 61.435 Mpa, bending modulus 55.236 Mpa, and maximum bending strain 3.829 % . Bending strength increases with the addition of volume fractions up to volume fraction 50 % and tend to decrease in strength above the volume fraction. This trend of increasing the strength value of solids on fiber hybrid composites and coconut sticks has the same phenomenon as coconut fiber and sisal fiber hybrid composites where the highest bending strength is achieved at a volume fraction of 40% while the volume fraction above the volume fraction has decreased [17].

Judging from the magnitude of the volume fraction, fiber hybrid composites and coconut sticks have better strength compared to hybrid coco fiber and sisal fiber composites. This difference shows that coconut sticks can increase bending strength up to 50% volume fraction even though the compactness between the sticks and matrices is not good due to the hard layer surrounding the coconut stick despite chemical treatment. This increase in bending strength is due to the effective bonding between fibers and matrices due to the modification of the surface of the fiber with an alkaline solution. Immersion with NaOH on the fiber causes the bonding effectiveness between the fiber and matrix to become stronger because of the matrix. This bond quality can be expressed by the ability of the matrix to absorb the matrix to form a small contact angle when viewed from the ability of the fiber wetness (wettability) [18].

Although coconut sticks are pre-treated with alkaline immersion, the ability to transfer the load is less effective so that it gives less significant strength. Overall, the use of sticks as hybrid composite materials can provide increased tensile strength and bending. The failure that occurs in bending strength is dominated by the release of the coconut palm from the matrix shown in the bending test graph.

Figure 4 shows the strength-bending behavior of coco fiber composites without using sticks, when the bending strength reaches the maximum value no more deformation occurs.

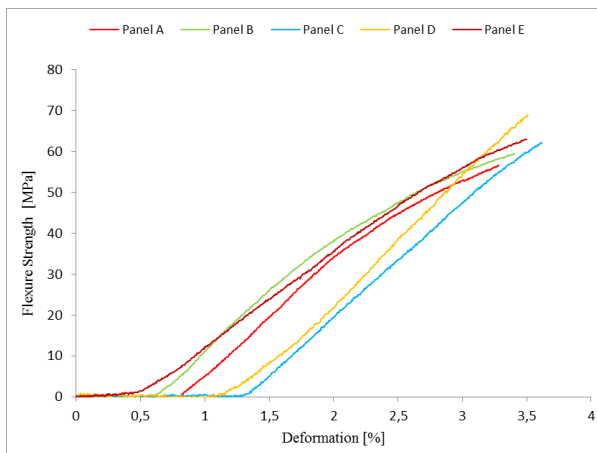


Figure 4: Typical graph of bending test non hybrid composite

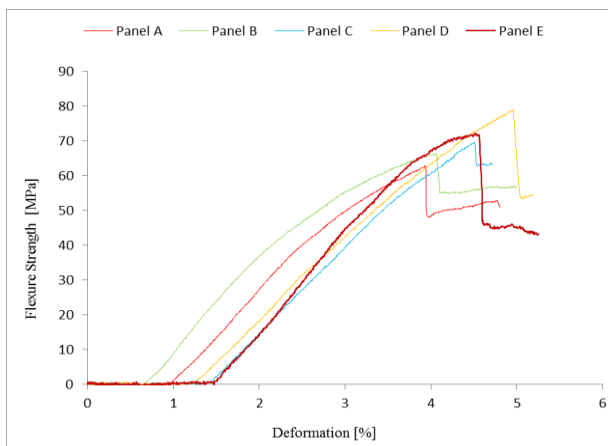


Figure 5: Typical graph of bending test hybrid composite

Whereas in Figure 5 shows the opposite condition, when the bending strength reaches the maximum value followed by a decrease in the value of its strength at fixed deformation then an increase in the value of bending strength. This information shows that coconut palm as a hybrid material has been separated from the bond with the matrix. But overall, the use of coconut sticks can increase the bending strength on average by 9.925.

IV. CONCLUSION

In this study, the main object investigated were mechanical properties such as tensile strength, bending strength, impact strength and hardness of fiber hybrid composites and coconut sticks with polyester resin. The results of the investigation obtained from these studies can be summarized as follows.

1. The optimal value of tensile strength and bending strength in fiber hybrid composites and coconut sticks is at 50% volume fraction.

2. The tensile strength and bending strength do not provide a significant increase in hybrid composite and coconut sticks.

To obtain optimal mechanical properties in the manufacture of fiber hybrid composites and coconut sticks, special treatment is needed on the sticks.

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REFERENCES

- [1] Giuseppe C, Alberta L, Giuseppe R, Gianluca C. Composites based on natural fibre fabrics. Croatia: Polona Dobnik Dubrovski; 2010.
- [2] Sukhdeep S, Dharmpal D, Lakshya A, Gupta VK. Tensile and flexural behaviour of hemp fiber reinforced virgin-recycled HDPE matrix composites, *Procedia Materials Science* ; (6): 1696-1702, 2014.
- [3] Joseph K, Filbo RDT, Thomas S, de Carvalho L. H. A review on sisal fiber reinforced polymer composites. *Revista Brasileira de Engenharia e Ambiental*; 3(3): pp.367-379, 1999.
- [4] Bledzki AK, Gassan J. Composites reinforced with cellulose based fibres. *Progress and Polymers Science*; 24(2): pp. 221–274., 1999.
- [5] Brígida AIS, Calado VMA, Gonçalves LRB, Coelho MAZ, Effect of chemical treatments on properties of green coconut fiber, *Carbohydrate Polymers* : pp. 832–838., 2009.
- [6] Carvalho CCK, Daniella R, Mulinari, Herman, Voorwald JC, Cioffi OHM, Chemical modification effect on the mechanical properties of hips/cCoconut fiber composite. *Bio Resources* ; 5(2) : pp. 1143–1155., 2010.
- [7] Thangavel T, Anand K, Chandru S, Krishnan GC, Boopathi P. Flexural and impact behaviour of kevlar/e-glass reinforced epoxy matrix composites. *International Journal for Research in Applied Science & Engineering Technology* ; 6(7):pp. 916-920., 2018.
- [8] Nor AFM, Sultan MTH, Hamdan A, Azmi AMR, Jayakrish K, Hybrid composites based on kenaf, jute, fiberglass woven fabrics: tensile and impact properties. In: *International Conference on Materials Manufacturing and Modelling*, Vellore, India, pp. 11198–11207; 2018.
- [9] Mwaikambo LY, Ansell MP. The effect of chemical treatment on the properties of hemp, sisal, jute and

- kapok fibres for composite reinforcement. In: 2nd International Wood and Natural Fibre Composites Symposium, Kassel, Germany, pp.12.1 -12.16; 1999.
- [10] Nunna S, Chandra PR, Shrivastava S, Jalan A. A review on mechanical behavior of natural fiber based hybrid composites. *Journal of Reinforced Plastic Composite* ; 31(11): pp. 759–769, 2012.
- [11] Mukhopadhyay S, Figueiro R. Physical modification of natural fibers and thermoplastic films for composites - a review. *Journal of Thermoplastic Composite Materials* ; 22(2): pp. 135–162., 2009.
- [12] Munawar SS, Umemura K, Kawai S, Characterized the morphological, physical, and mechanical properties of the Non-wood plant fibre bundles. *The Japan Wood Research Society* ; 53: pp. 108 113, 2007.
- [13] Verma D, Gope PC, Shandilya A, Gupta A, Maheshwari MK, Coir fibre reinforcement and application in polymer composites. *Journal of Materials and Environmental Science*; 4(2): pp. 263-276., 2013.
- [14] Nadir A, Songklod J, Vallayuth F, Piyawade B, Robert HW. Coir fiber Reinforced polypropylene composite panel for automotive interior applications. *Fibers and Polymers*; 12(7): pp. 919-926., 2011.
- [15] Santafé Júnior HPG, Lopes FPD, Costa LL, Monteiro SN. Tensile behaviour of lignocellulosic reinforced polyester composites. *Matéria (Rio Journal)* ; 15(2): pp. 202-207., 2010.
- [16] Akash KV, Sreenivasa R, Venkatesha NS, Gupta, Kumar DSA. Mechanical properties of sisal/coir fiber reinforced hybrid composites fabricated by cold pressing method. In: *International Conference on Advances in Materials and Manufacturing Applications*, Bangalore, India; 14-16 July, 2016.
- [17] Musanif I, Thomas A. Effect of Alkali Treatments of physical and mechanical. properties of coir fiber. *Chemical and Materials Engineering* ; 3(2): pp. 23-28., 2015.
- [18] Musanif I, Sirun A, Boedi SD. Wettability properties of coconut fiber on resin. *International Journal of Science and Research* ; 7(9): pp. 1432 – 1434., 2018.
- [19] Kumar MA, Reddy GR, Bharathi YS, Naidu V. Frictional coefficient, hardness, impact strength, and chemical resistance of reinforced sisal-glass fiber epoxy hybrid composites. *Journal of Composite Materials*; 44(26): pp. 3195-3202, 2010.

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