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Tensile Strength Comparison of Polymer Composite Materials Reinforced by Three Types of Bamboo Fiber Treated With 5% aq. NaOH Solution

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Abstract

The specimens were prepared with polyester polymer reinforced with natural fiber from three types of bamboo, namely Gigantochloa Apus, Bambusa vulgaris, and Bambusa blumeana. Their tensile properties were compared and investigated. In this paper, the specimen utilization of hand-wet layup processes of polyester resin with natural fibers. The fibers were treated with 5% NaOH solution to remove hemicellulose and create better debonding between matrix and fiber. Bamboo-reinforced composite of 3 types of bamboo with fractions 60% volume is thorn bamboo, Bambusa vulgaris, Gigantochloa Apus, and bamboo wipe without alkali. Of the three types of bamboo, the highest tensile strength of Gigantochloa Apus was soaked using NaOH with an average value of 37.06 MPa, with a tensile strain of 4.11%. In contrast, the lowest tensile strength value is Gigantochloa Apus which was not immersed in NaOH with an average of 13.79 MPa, a tensile strain of 2.54%. This matter shows the effect of immersion on tensile strength bamboo fiber composite. The results of the tensile strength of each type of bamboo obtained in this research, among others, bamboo thorn's tensile strength of 22.81 MPa, Bambusa vulgaris tensile strength of 16.69 MPa, bamboo apus 37.06 MPa, and Gigantochloa Apus without alkali 13.79 MPa. The observations show that Gigantochloa Apuscomposites are suitable for use as alternative tensile materials.

Keywords: *Composite Material, Natural Fiber, Bamboo, Alkali.*

1. Introduction

This paper examines the tensile properties of composite materials made from natural fibers obtained from three different types of bamboo: Gigantochloa Apus, Bambusa vulgaris, and Bambusa blumeana. To prepare the specimens, a hand-layup process was used with polyester resin and natural fibers treated with a 5% NaOH solution to remove hemicellulose and enhance bonding with the matrix. The study compared the tensile properties of the three bamboo-reinforced composites with a volume fraction of 60%. The results showed that the Gigantochloa Apus composite soaked with NaOH had the highest tensile strength, making it a promising material for tensile applications. The paper also discusses the potential of natural fiber composites as an alternative to synthetic fibers and metal materials.
Indonesia has a variety of bamboo species, including Gigantochloa Apus, Bambusa vulgaris, Bambusa blumeana, and others. Natural fibers, especially bamboo fibers, have great potential to be used in composite materials that are strong, cheap, and environmentally friendly. In this study, the authors aim to investigate the effect of 5% NaOH alkaline soaking for 2 hours on natural fibers from three types of bamboo: Gigantochloa Apus, Bambusa vulgaris, and Bambusa blumeana as reinforcement for composite materials. The tensile strength results on each variation of bamboo type will be evaluated to determine the optimal percentage value of NaOH. The authors hope these natural fibers can be used as an alternative to metal materials, which have several disadvantages and are relatively expensive.

2. Literature Review

Composite materials are projected to substitute conventional structural materials such as metal and wood. For polyethylene composites with SSc reinforcement, one is expected to be used as a plastic pallet material to replace wooden pallets obtained by the layered composite method. The word composite in the sense of material means a composite consisting of two or more different materials, which are different or macroscopically mixed [1].

2.1 Material Compiler of Composite

Composites are several multi-systems combined with phase properties, namely the combination of matrix material and reinforcement reinforcements [2].

1. Epoxy resins are one type of thermoplastic resins. These resins have wide usage in chemical, electrical, mechanical, and civil industry techniques. Usually, resin-type epoxy Is used as adhesives, Coating paints, Moldings cast, and mold objects. Type resins epoxy This can be distinguished into two types that are as follows:
   a. Bisphenol A resin has Power suitable adhesive to material others, often used as paint for metal, as well as coating combined with fiberglass.
   b. Cycloaliphatic resin has a low viscosity, and equivalence epoxy is small. The material was helpful as diluent bisphenol Because of its easy handling.
2. Matrix In composite materials, the matrix in the composite structure can come from polymer, metal, or ceramic materials. The matrix is the hybrid phase with the largest (dominant) part or volume fraction. The matrix in the mixed arrangement protects and binds the fibers to work properly. The matrix also functions as a fiber coating [3]. Generally, the matrix is made of soft and clay materials. The selection of matrix and fiber materials is essential in determining the composite's mechanical properties[4].

The principal matrix must be owned by the material matrix that must forward load, so fiber must Be attached to the matrix and compatible between fiber and matrix. The generally selected matrix is the matrix that has resilience and high heat. According to [5], the matrix has functions, including:

a. Transferring voltage to fiber in a manner evenly.
b. Protect fiber from friction mechanics.
c. Protect from the detrimental environment.
d. Donate characteristic rigidity and toughness.

2.2. Types of Composite

Based on filler material, the composite material is classified into:

1. Laminated Composite
   Layered composites are a type of composite consisting of two or more layers combined into one, each with different characteristics. An example is Polywood Laminated Glass, a composite consisting of a fiber layer and a matrix layer, and this composite is often used as a building [6].

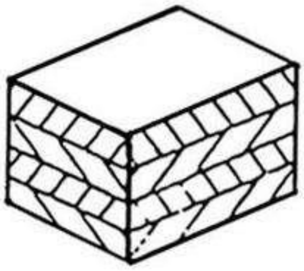


Fig 1. Laminar composites

2. Flake Composite
   A flake composite consists of flakes that bond to the surface or are embedded in a matrix. The special properties that can be obtained are its oversized shape and flat surface [7].

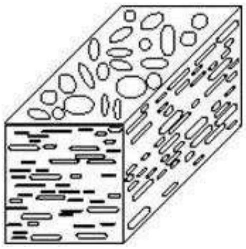


Fig 2. Flake Composite

3. Composite grains (Particulate Composite)
   Particulate composites are a type of composite where other materials in the form of powder/grain are added to the matrix. The difference between flake and fiber composites lies in the distribution and addition of materials. In particulate composites, the added material is distributed randomly or in a less controlled manner than in flake composites [8].

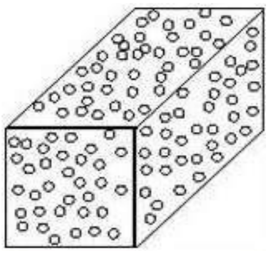
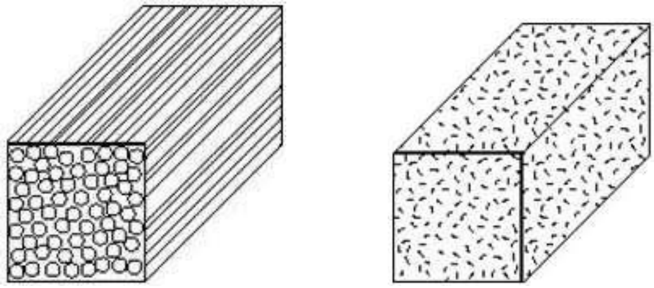


Fig 3. Particle Composite

4. Composite fiber (Fiber composite)
   Composite fiber is a type of mixed using fiber as material for the amplifier. In making composites, fibers can arrange elongated (unidirectional composites) or can cut, Then placed in a random manner (random fibers) as well as can woven (cross-ply laminate). The composite fiber is used in industrial automotive and airplanes [9].



(a)Unidirectional fiber composite (b) Random fiber composite

Fig 4. Fiber Composite

5. Filled composites
   Filled composites are composites with the addition of material into a matrix with a three-dimensional structure, and usually, a filler is also in the three-dimensional form [10].

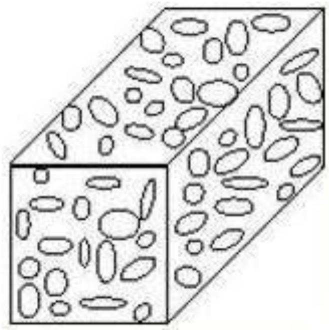


Fig 5. Filled composites

6. Fiber Composite
   Fiber composites are composites consisting of fibers and a matrix. This type of composite consists of only one layer. The fibers can be synthetic (asbestos, glass, boron) or organic fibers (cellulose, polypropylene, polyethylene). High modulus, coconut coir, palm fiber, empty palm fruit bunches, etc.). Based on the fiber size, fiber composites can be divided into long fiber composites and those with a diameter of <100mm; these short fibers can be oriented or randomly distributed. Long fiber composites are more accessible to train than short fiber composites, but short fiber composites have more design.

Based on the form of the composite matrix can be divided into 3, namely as follows. [11] The first condition that the material matrix must meet is its ability to withstand the load.

1. Polymer Matrix Composite (PMC)
   This composite type consists of the polymer as a matrix, both thermoplastic and thermosetting types. Thermoplastic is a plastic that can be softened repeatedly (recycled) using heat. Thermoplastic is a polymer that hardens when cooled. Thermoplastic will melt at a specific temperature, adhere to following temperature changes, and have reversible properties to its original properties; it hardens again when cooled. Thermoplastics that are commonly used as matrices include polyolefins (polyethylene, polypropylene), vinylic (polyvinylchloride, polystyrene, polytetrafluorethylene), nylon, polyacetal, polycarbonate, and polyphenylene.
   Thermosets cannot keep up with temperature changes (irreversible). Once hardening has occurred, the material cannot be softened again. High heating will not ease the thermoset but will form charcoal which decomposes because of its nature which is often used as a lid for kettles, such as melamine types. Today's most widely used thermosets are epoxy and unsaturated polyester [12]. Unsaturated polyester resin is the most commonly used thermosetting matrix composite manufacturer. The hand layup method uses This resin type in the manufacturing process.

2. Metal matrix composite (MMC)
   Metal matrix composites are one type of composite that has a metal matrix. These composites use a metal such as aluminum as the matrix and reinforce it with fibers such as silicon carbide. MMC materials began to be developed in 1996. MMC composites, produced in the automotive industry, manufacture automotive components such as engine cylinder blocks, pulleys, shafts, and axles.

3. Ceramic Matric Composites (CMC)
   CMC is a 2-phase material with 1 phase functioning as a reinforcement commonly used in CMC, namely oxide, carbide, and nitride. One of the manufacturing processes of CMC is the DIMOX process, which is the process of forming composites with the oxidation reaction of molten metal for the growth of the ceramic matrix around the filler area.

Based on the structure of the composite matrix can be divided into two types, namely as follows. [13]

1. A laminate structure is a composite of two or more layers combined into one, each with its characteristics.
2. A sandwich structure combines two sheets of skin arranged on two sides of a lightweight material (core) and adhesive. The skin's primary function is to withstand axial loads and bending. In contrast, the core functions distribute axial loads into shear loads over the entire area due to external force loading.

3. Methods

3.1 Test Equipment

Tools used in this research are halat test pull and bending. To carry out the test, a universal Tensile testing machine such as the Hung Ta brand will be used in Figure 6.

Fig 6. Universal Tensile Testing Machine

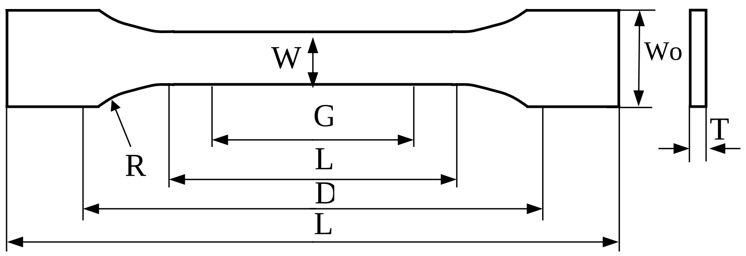
3.2. Preparation of Specimens

The manufacture of composite materials reinforced with bamboo fiber (Figure 7) first treated the bamboo fiber using a 6% NaOH solution. Combining bamboo fiber with a temporary structure with epoxy resin can be overcome by heating the epoxy resin at a temperature of 80 degrees centigrade for 15 minutes to reduce viscosity and remove trapped air. Meanwhile, the bamboo fiber is placed in the oven to ensure complete drying. Furthermore, due to the short and porous structure of the bamboo fiber, it has the potential to bring higher air into the resin during bonding. The addition of 30% more resin is the solution to remove air bubbles that are potentially trapped in the material. Finally, the resin and bamboo fiber mixture was put into the oven at 80 0 C for 2 hours. After sufficient mass was felt for fiber infiltration into the resin and all air bubbles were lifted, the catalyst mixture was added and stirred evenly for 5 minutes.

(a) (b)

Fig 7. (a) Pieces of bamboo slats for fiber, (b) Bamboo fiber

Furthermore, the mixture is poured into a mold that has been prepared to form a plate composite with a certain thickness. Moreover, the material is left for at least 24 hours to get the perfect hardening. After the composite material has obtained a stable condition, the material is shaped with a high-speed saw cut to make a test specimen following ASDM D3039 for tensile testing of fibrous polymer composite materials, as shown in Figure 8.



Notation		Size(mm)
W	Small section width	19
L	Small section length	57
Wo	total width	29
Lo	Specimen length	246
G	strain gauge length	50
D	Distance between clamps	115
Q	Specimen thickness	7 – 14
R	Radius	76

Fig 8. ASTM D638M test specimen dimensions

3.3. Testing

Mechanical testing to be carried out in this study consists of two types, namely tensile testing and bending testing. Tensile test specimens follow the ASTM D3039 standard, and bending test specimens follow the ASTM D790 standard. Both tests were carried out using a universal testing machine tensile tester brand Hung Ta with a capacity of 2000 kN. The macrostructure due to material damage due to testing will be observed using a digital microscope. Observing the fracture's structure or damage can predict the causes that occur in the composite material.

4. Results and Discussion

4.1. Tensile Testing

Tensile testing was carried out after making bamboo fiber composites with polyester resin clear to find out the magnitude of the tensile strength of the composite with the same volume of action on the bamboo fiber reinforcement composite. Tensile testing was carried out using a universal mechanical testing machine in the material testing laboratory of the Department of Mechanical Engineering, Universitas Malikussaleh.

Based on the results of the tensile test that was carried out using the ASTM D3039 standard on the reinforcing composite of three types of bamboo fiber with alkaline treatment (5% NaOH), optimization of 60% fiber volume fraction with random Orientation with tensile stress, tensile strain, and elastic modulus, the results are shown in Table 1 to table 4 to make it easier to analyze the data from the results of this test. The results are presented in the shape of the tensile properties curve composite.

Table 1. Tensile Test Result for the random arrangement of bamboo fiber with 65% fraction volume

Specimens	Area (mm2)	Max Force (Kgf)	Yield Strenght		Tensile Strength		Elongation %
			(Kgf)	(Mpa)	(Kgf)	(Mpa)	
1	125,00	265	0,49	4,80	2,12	20,78	2,65
2	125,00	312	0,55	5,39	2,50	24,51	3,24
3	125,00	295	0,17	1,66	2,36	23,14	3,27
Avarage	125,00	290,6	0,40	3,95	2,32	22,81	3,05

From the results of the tensile test carried out on three fiber test specimens bamboo thorns with vaksi volume cert 60% with Orientation random. The lowest tensile strength is found in test specimen number 3, with a value of 23.14 MPa and a yield strength of 1.66 MPa. The highest tensile strength is found in test specimen number 2, with a value of 24.51 MPa and a yield strength of 5.39 MPa. The average tensile strength is 22.81 MPa, and the average yield strength is 3.95 MPa. The following results are from the tensile test for the volumetric Bambusa vulgaris fiber specimen. 60% with Orientation random.

Table 2 Tensile Test Results For Bambusa vulgaris Fiber Composites with 60% Volume Fraction

Specimens	Area (mm2)	Max Force (Kgf)	Yield Strenght		Tensile Strength		Elongation %
			(Kgf)	(Mpa)	(Kgf)	(Mpa)	
1	125,00	214	0,42	4,11	1,71	16,76	1,53
2	125,00	218	0,31	3,03	1,74	17,06	2,69
3	125,00	208	0,26	2,54	1,66	16,27	2,77
Avarage	125,00	213,3	0,33	3,22	1,70	16,69	2,33

From the results, the testing pull was done to three fiber test specimens Bambusa vulgaris with 60% cert volume fraction with Orientation random. Strength pull is the Lowest found in test specimen number 3, with a value of 16.27 MPa, with strength yielding 2.54 MPa. Force pull is the highest seen in test specimen number 2 with a value of 17.06 MPa, with strength delivering 3.03 MPa. The Power pulls average with a value of 16.69 MPa, and the value strength average yield has 3.22 MPa tensile test results For specimen fiber bamboo apus brake volume 60% with Orientation random.

Table 3. Data on Tensile Test Results for Gigantochloa ApusFiber Composites Vraksi Volume 60% With Orientation random

Specimens	Area (mm2)	Max Force (Kgf)	Yield Strenght		Tensile Strength		Elongation %
			(Kgf)	(Mpa)	(Kgf)	(Mpa)	
1	125,00	312	0,39	3,82	2,50	24,51	3,24
2	125,00	748	0,29	2,84	5,98	58,63	5,96
3	125,00	357	0,45	4,41	2,86	28,04	3,13
Avarage	125,00	472,3	0,37	3,69	3,77	37,06	4,11

From the results, the testing pull was done to three fiber test specimen bamboo wipes with vast volume cert 60% with Orientation random. The strength pull is lowest on specimen test number 1, with a mark of 24.51 MPa, with a substantial yield of 3.82 MPa. Strength pull was highest found in test specimen number 2 with a value of 58.63 MPa with a considerable gain of 2.84 MPa. The strength pulls average value is 37.06 MPa, and the value strength yield average has 3.69 MPa tensile test results For specimen fiber Gigantochloa Apus without the vast alkaline volume of 60% with Orientation random.

Table 4. Data on Tensile Test Results for Gigantochloa Apus Fiber Composites Without Alkalization Volume Fraction 60% With Orientation random

Specimens	Area (mm^2)	Max Force (Kgf)	Yield Strenght		Tensile Strength		Elongation %
			(Kgf)	(Mpa)	(Kgf)	(Mpa)	
1	125,00	210	0,21	2,05	1,68	16,47	2,76
2	125,00	159	0,31	3,03	1,27	12,45	3,16
3	125,00	159	0,41	4,02	1,27	12,45	2,22
Rata-Rata	125,00	176	0,31	3,03	1,40	13,79	2,54

From the results, testing pull that has been done to three fiber test specimen bamboo wipe without using alkali with vast volume cert 60% with Orientation random. Strength pull was the Lowest found in test specimen number 3, with a mark of 12.45 MPa, with strength melted at 4.02 MPa. The Power pulls highest there is on specimen test number 1 with the mark of 16,47 MPa with a substantial yield of 2.05 MPa. The muscle pull average mark is 13.79 MPa, And the marking strength melts average own 3.03 MPa. Following the form chart, connection strength pulls the same volume fraction of fiber bamboo spines 60% fiber Bambusa vulgaris 60% fiber Gigantochloa Apus 60% And fiber bamboo wipe without alkali 60%, like shown in Figure 9 to Figure 12.

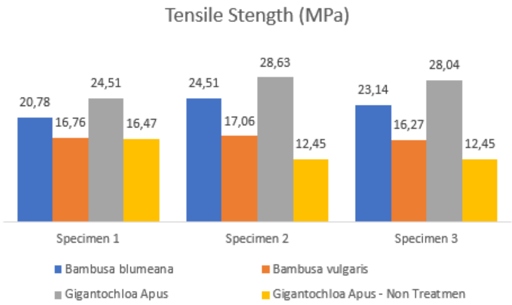


Fig 9. Graph Connection Voltage Pull Composite Fiber Bamboo 60% Bamboo Spines Yellow 60% Bamboo Apus 60% and Bamboo Apus Without Alkali 60%

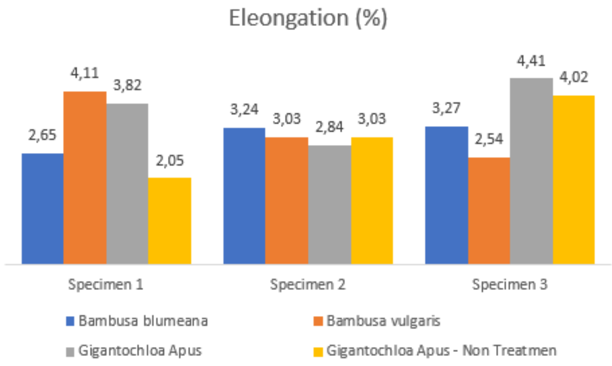


Fig 10. Graph Connection Strain Composite Fiber Bamboo 60% Bamboo Spines Yellow 60% Bamboo Apus 60% and Bamboo Apus Without Alkali 60%

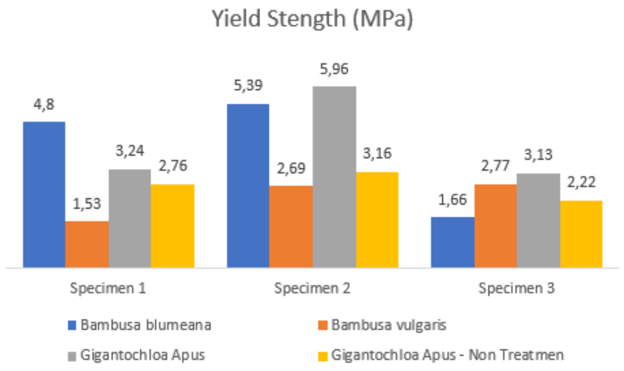


Fig 11. Yield Strength comparison

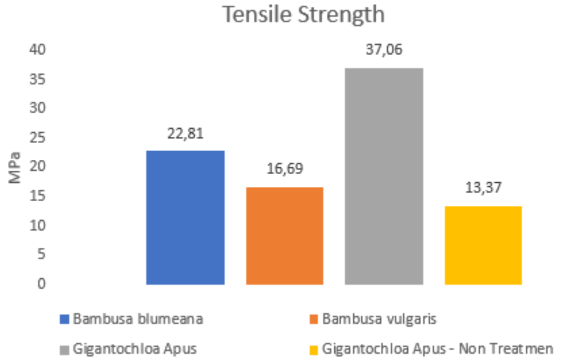


Fig 12. Comparison Histogram of Average Tensile Strength Results MPa

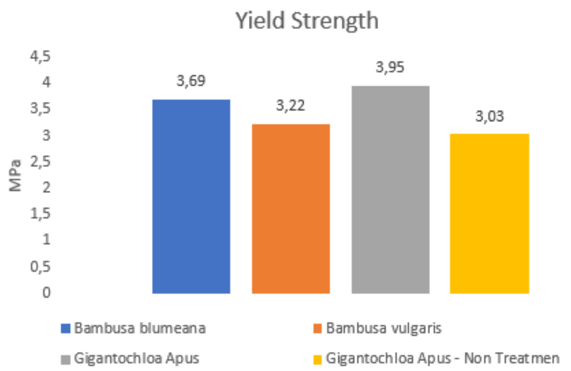


Fig 13. Histogram Comparison of Average Strength Results Melted MPa

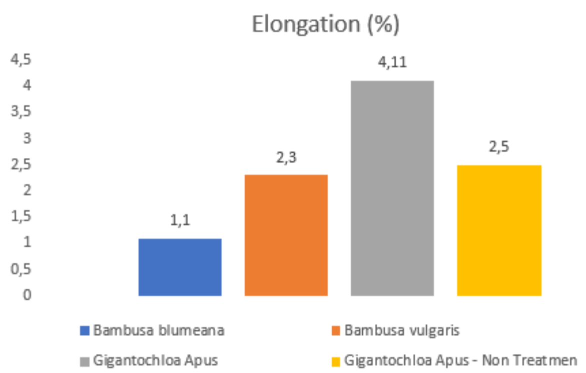


Fig 14. Histogram Comparison of Average % elongation results Analysis and Discussion

Based on testing 4 specimens of each type of bamboo for variations of differences in 3 types of bamboo fibers using alkali treatment and without alkali treatment, it is found that there are different tensile strengths according to the type of bamboo. load and tensile strength are greatly influenced by variations in 3 types of bamboo fibers using alkali and without alkali. In Table 1, Table 2, Table 3, to Table 4. In Table 1 we can see that composites with variations of bamboo fiber thorns in a shredded arrangement with a volume fraction of 60% have the highest tensile strength of 24.51 MPa in specimen 2.

In Figure 12 we can see that the average value of MPa tensile strength of these 3 types of bamboo. Thorn bamboo has an average value of tensile strength of 22.81 MPa. And bambusa vulgaris has an average value of tensile strength of 16.69 MPa. Gigantochloa Apus has an average value of tensile strength of 37.06 MPa. Gigantochloa Apus without alkali has an average tensile strength value of 13.79 MPa.In Figure 13 we can see that the average value of MPa yield strength of these 3 types of bamboo. Thorn bamboo has an average yield strength value of 3.95 MPa. And bambusa vulgaris has an average yield strength value of 3.22 MPa. Gigantochloa Apus has an average yield strength value of 3.69 MPa. Gigantochloa Apus without alkali has an average value of yield strength of 3.03 MPa.

In Figure 14 we can see that the average elongation value of these 3 types of bamboo. Thorn bamboo has an average elongation value of 3.05%. And bambusa vulgaris has an average elongation value of 2.33%. Gigantochloa Apus has an average elongation value of 4.11%. Gigantochloa Apus without alkali has an average elongation value of 2.54%. The following are the macro fracture images of the tensile testing results as shown in Figures 15, 16, 17 and 18.

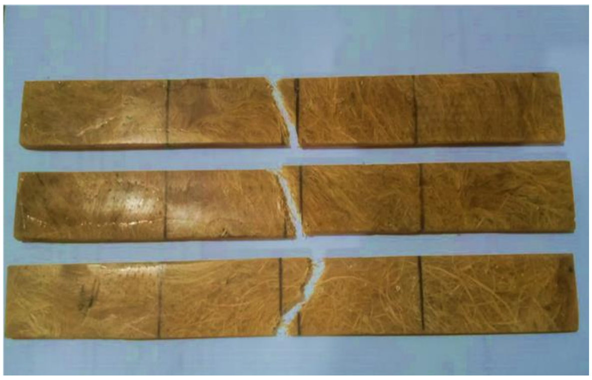


Fig 15. Tensile Test Results of Bamboosa Blumeana

Fig 16. Tensile Test Results of Bamboosa Vulgaris

Fig 17. Tensile Test Results of Gigantochloa Apus

Fig 18. Tensile Test Results of Gigantochloa Apus no-treatment

5. Conclusion

Composites reinforced with bamboo from 3 types of bamboo with a volume fraction of 60%, namely thorn bamboo, Bambusa vulgaris, and wormwood bamboo, have the highest tensile strength in wormwood bamboo with a volume fraction of 60% with an average value of 37.06 MPa, tensile strain of 4.11%, in Bambusa vulgaris fiber shows that the tensile strength of the composite has decreased with an average value of 16.69 MPa, tensile stress of 2.33%. The results obtained in this study show that the highest tensile strength value was found in the wormy bamboo fiber at 37.06 MPa with a strain of 4.11%. The results show that the wormwood bamboo composite can be an alternative tensile material.

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