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Effect of volume fraction and alkalization treatment on mechanical properties of abaca fiber reinforced composites as a composite board substitute for wood products

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Abstract

Wood products are very popular products, especially in Indonesia. The drawback of wood products lies on their physical properties which are very susceptible to weathering in contact with water, causing wood products to be unsuitable for placing in parts of higher moisture. In addition, deforestation for processing wood products causes prolonged environmental damage. The main objective of this research is to make abaca fiber polyester composite material that can be used as a composite board for replacing wood product boards. The composite is made with varying the alkali solution treatment and fiber volume fraction by using the vacuum method (VARI). Materials used in this study are abaca banana fiber, polyester resin, hardener and wax. The primary equipment used are such as tensile testing machine, freis machine, scanning electron machine (SEM), press machine, vacuum installation and digital scales as well as other supporting tools for composite preparation and fabrication. The research design for the preparation of composite test specimens used a polyester matrix and Abaca fiber reinforcement. Variation of alkalization solution used have rate of 1%, 3%, 5%, 7%, and 9%, and the volume fraction of abaca fiber is at 15%, 20%, 25%, 30% and 35%. The composite specimens test uses a tensile test ASTMD 3039-76 standard, flexural test using the ASTM D790 standard and an impact test reaching the Charpy method. The results showed there are the highest tensile strength and modulus of elasticity were obtained from composites with specifications of 25%Vf and 5% alkali treatment of 186.89 MPa with a modulus of elasticity of 2.27 GPa. The highest bending strength value is found in the composite with a specification of 35%Vf and 5% alkali treatment with a bending strength value of 53,03 MPa. The highest impact strength value was found in the composite with a specification of 25%Vf and alkali treatment with a 5% concentration of 9,32 kJ/m^2. Based on the mechanical properties data above, the composite specifications can be recommended for the manufacture of composite boards as a substitute for wood products at 35%Vf and 5% alkali treatment

Keywords:
. Abaca, natural fiber, matrix, composite, vacuum method.

1 Introduction

Wood is a structural material that has long been known to the public. When compared to other structural materials, wood material has a very light specific gravity and the process can be carried out with the simple equipment. As a material from nature, wood can decompose completely so that there is no waste in wood construction [1].

Wood is one of Indonesia's natural resources which is a construction element that is easy to obtain and is available in relatively large quantities. The strength of wood to withstand high tensile, compressive and shear forces cause wood to be widely used in construction [2]. In the Table 1, it shows the physical and mechanical properties of several types of wood in Indonesia. From these types of wood, wood Jati seems that have superior in mechanical properties tensile stress, while other types of wood have lower quality than wood of Jati, especially wood of Meranti and Mahoni.

Table 1. properties of several woods [1][3].

Woods	Water contet (%)	Density (kg/m)	Tensile stress (Mpa)	Bending stress (Mpa)	Shear stress (Mpa)
Jati	15.47	741.33	168.57	72.70	9.79
Mahoni	14.35	576	151.17	55.85	14.46
Johar	15.20	798.33	160.75	74.41	13.27
Akasia	14.92	661.33	120.54	77.82	9.21
Meranti	16.46	648	151.90	51.40	9.18

Wood products are very popular products, especially in Indonesia, this can be seen in the large number of people who still choose wood products as a material to complement their homes including for making doors, windows and other home furnishings since it is environmentally, friendly, safe and looks luxurious [4]. However, its weakness lies in its physical properties which are so susceptible to weathering when exposed to water, causing wood products to be unsuitable for placement in parts that will be exposed to moisture, for example, on the bathroom door. Besides that, logging forests for the production of processed wood causes prolonged environmental damage.

Currently, synthetic fiber-based reinforcing materials such as glass fiber, aramid and carbon fiber are the main choice as composite materials besides metal materials. Although these composite materials show good mechanical properties, they also cause environmental pollution due to their non-degradability (recycling) [5]. Mohanty et.al [6] provided information that natural fibers began to be developed back in the 1950-s and succeeded in replacing glass fibers for applications in the structural field. This is due to several advantages of natural fibers compared to synthetic fibers, including cheaper prices, low density, biodegradable, easy to process, reduces CO2, and specific strength can meet application requirements. To address this problem, nowadays the use of natural fiber reinforcement materials has been widely used in various fields.

The research development in the field of biobased materials has accelerated after being motivated by the issue of global warming in 1997. Global warming is an international environmental problem caused by greenhouse gases. The United Nations as a world organization has responded to the issue of global warming by issuing the Kyoto Protocol, which is an amendment to the United Nations Framework Convention on climate change. The Kyoto Protocol was first submitted on December 11th, 1997 and entered into international law on February 16th, 2005. Countries that ratify this protocol are committed to reducing greenhouse gas (GHG) emissions and expenditures, namely CO_2, CH_4, N_2O, HFCS, PFCS, and SF_6. Greenhouse gas (GHG) can be generated by burning fossil fuels, from the cooking process to power generation, including the production process of synthetic fibers for composite fillers. The

European Union (EU) countries also responded to the issue of global warming by providing directives in the automotive sector, waste and product packaging. This encourages massive research in the field of green materials.

Natural fibers have various superior properties, but there are quite serious problems when we use natural fibers as engineering materials. Natural fiber materials have a very large scatter of mechanical properties, such as strength compared to metal materials. In recent years, a very important material data base has been obtained, namely the scatter properties of fiber-reinforced composites [7,8]. The mechanical properties of metallic materials have scatter within a very small probability range, the coefficient of variation (standard deviation divided by the average value) of the metal is 0.063 mm. This means that the maximum strength probability of steel is less than (1-3x0.063) xσ_{um}, meaning it has a maximum strength of 10^{-6} [7]. Therefore, more in-depth research is needed for the development of composite technology that is used in the broader structural field to replace conventional materials.

Aceh Province, Indonesia, the habitat of the abaca banana is very abundant as a germplasm and has even become a weed that grows a lot in the community environment, plantation areas and forests. After knowing the usefulness and very high economic value, many people began to cultivate these bananas. For example, the 100-hectare abaca banana plantation supported by the Ministry of state-owned enterprises is located in the mountainous area of Suak Buluh Village, East Simeulue District, which is located about 15 kilometers from Sinabang City. At Fig. 1 shows the Abaca banana cultivation garden and the fiber produced from the banana plant.

Fig. 1. Abaca plant and traditional fiber production [9].

The primary use of Abaca fiber is currently still limited to make cloth, rope, tea bag wrappers, tobacco wrappers, tissue paper, and sanitary napkins [9], while the utilization for structural materials has not been developed optimally. The results of research on abaca fiber by Satyanarayana [10] showed a relatively high tensile strength of 54-754 MPa and a density of 1350 kg/m^3. The problem of abaca fiber is its abundant availability with high tensile strength but its use is still limited to non-structural materials so that research is needed on the use of abaca fiber as composite reinforcement for structural materials.

The purpose of this research is to make composite materials reinforced with abaca fiber using the vacuum method as a composite board to replace wood products. This study has several important benefits that can contribute to solve national and international problems. The basic material for this composite reinforcement requires planting abaca bananas to produce greenery that contributes to solve the problem of climate change; Utilization of less productive land for cultivating abaca bananas. This research also can give the potential to open up employment for planting abaca bananas, and can reduce processed wood products so that it can reduce deforestation. Otherwise, this research also has the potential to open a new manufacturing system which has implications for opening factories to produce components made of these composites.

However, this research has environmental and social impact in many sectors. The positive impact on the environment is greenery which can absorb CO2 gas thereby reducing global warming and does not cause waste problems as it is biodegradable. The positive impact on social life is the opening of employment opportunities for planting abaca banana trees. The results of this study are targeted to obtain a prototype of abaca banana fiber reinforced plastic composites. This composite is expected to be widely used to replace synthetic fiber composites which are not environmentally friendly and also substitutes for wood products.

2 Method

The method used in this research is an experimental method. This method derives to find the effect of certain treatments on others under controlled conditions [11].

2.1 Tools and Materials

Some equipment used in this research show such as Vertical freis machine, Tensile testing machine type Universal Testing Machine (UTM) series AND RTF-2410, Bending testing machine type Universal Testing Machine Instron SN138, Impact testing machine type Charpy, Scanning Electron Microscope, Press machine and Balance digital Sartorius as well as other tools for the preparation and fabrication of bio composites.

In this study, the materials used to make the composite materials are: Abaca fiber, Resin BTQN 157-EX, Hardener MEXPO, NaOH and Aquades. Abaca banana fiber used as composite reinforcement comes from Alue Papeun Village, Nisam District, North Aceh Province, Aceh. Fiber is taken from banana stems that are almost fruitful which is a period of high fiber strength. The characteristic properties of Abaca banana fiber as listed in table 2.

Table 2. Properties of Abaca fiber [12].

Properties	Values	Units
Cellulose	62-64	%
Hemi cellulose	19	%
Lignin	5	%
Moisture content	10 -11,5	%
Density	1.35	g/cm^3
Flexural modulus	2-5	GPa
Tensile strength	53.7	MPa
Young's modulus	3.48	GPa

The matrix used was unsaturated polyester resin BQTN 157-EX obtained from the Justus Kimia Raya store, Medan City North Sumatra Indonesia. The properties of the resin BQTN 157-EX are listed in the table 3.

Table 3. Properties of Resin BQTN 157-EX [13].

Properties	Value	Units	Note
Density	1.21 ± 0.02	gr/cm^2	25^{o}C
Hardness	40	Barcol/GYZJ	934-1
Water Absorb	0.188	%	24 hours
Bending stress	9.4	kg/mm^2	
Mod of flexural	300	kg/mm^2	
Tensile stress	5.5	kg/mm^2	
Young modulus	1.18	Gpa	
Time use	>6	Month	24^{o}C

2.2 Manufacturing of Composite

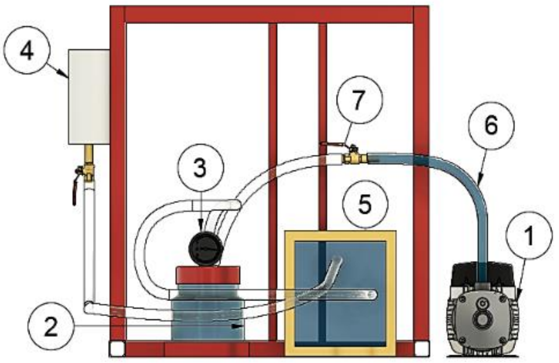
The basis for choosing Abaca fiber as a material for doing the research is that it has relatively high mechanical strength and abundant availability, also based on the research results and patents of the Daimler manufacturer who succeeded in making car interior components [14].

Abaca fiber was taken from Alue Papeun Village, Nisam Antara District, North Aceh Regency. The stem of the Abaca banana tree age after 8 to 10 months was reached from the stem bark and becomes abaca fiber. Abaca fiber was cut into 120 cm lengths and used as composite reinforcement.

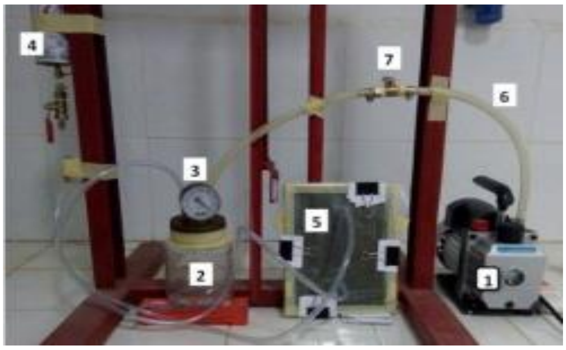
The arrangement of fibers in the manufacture of composites is arranged in the same direction with an orientation angle of zero degrees. The composite fabrication in five types of fiber volume fraction (V_f) is: 15%, 20%, 25%, 30% dan 35% [15][16]. The variation of the concentration of the alkalization solution is used: 1%, 3%, 5%, 7% and 9%.

Manufacture of composites using Vacuum Assisted Resin Infusion method (VARI) with installation is shown in fig. 2. The installation work process is after all the equipment which is arranged as shown, turn on the vacuum pump according to the instructions in the manual (1). Insert the resin mixture with hardener into the resin pot provided (4) by opening the valve on the plastic hose line then the resin will flow into the mold due to the influence of the vacuum pump (5) in a vacuum with a pressure of 10 Psi [17] If the resin has filled the mold, the resin will enter and be trapped into the resin trap (3). Then the vacuum pump is turned off and the mold is left for some time until the composite hardens. Then the composite is removed from the mold for further heating to remove trapped air bubbles (curing) for 2 hours at a constant temperature of 80ºC [13].

The dimensions of composite were made for each test that are composite for tensile test (length 240 mm, width 140 mm and thick 3,2 mm); composite for bending test (length 180 mm, width 135 mm and thick 0,5 mm); composite for impact test (length 55 mm, width 60 mm and thick 10 mm). The number of each specimen's test is five specimens.



(a)



(b)

Fig. 2. Layout of vacuum mold [15]. (a) Sketch of vacuum mold and (b) Installation of vacuum mold

Experimental variables must be formulated to produce optimal composite materials includes temperature (ºC) and molding pressure (MPa). The tensile test of composite provides technical data in the form of tensile stress (σ) and young modulus (E). In the bending test, it provides a deflection constant (δ), and the impact test provide absorption energy of a material (E_{Absorb}).

The steps in the research conducted are given. The initial stage of the research is to provide abaca fiber taken from banana tree trunks and then soaked in mud water (retting method) for one week until the fibers were formed. The fibers are washed with water until they are clean and free from lignin and other impurities. Then the fiber is dried in the sun. After drying, the alkalization process was carried out, namely soaking the fiber in NaOH solution with various concentrations: 1%, 3%, 5%, 7% and 9% for one hour. After the alkalization process is complete, the fiber is rinsed with water until clean and not slippery, then dried in the sun until the water content is below 10%.

The second stage is the manufacture of specimens with a volume fraction of fibers that have undergone 5 (five) types of alkali treatment, namely: 1). Composite with 1% fiber alkali treatment with Vf: 15%, 20%, 25%, 30% and 35%. 2). Composite with 3% fiber alkali treatment with Vf: 15%, 20%, 25%, 30% and 35%. 3). Composite with 5% fiber alkali treatment with V_f: 15%, 20%, 25%, 30% and 35%. 4). Composite with 7% fiber alkali treatment V_f: 15%, 20%, 25%, 30% and 35%. 5) Composite with 9% fiber alkali treatment with V_f: 15%, 20%, 25%, 30% and 35%.

After that, arrange the fibers into an acrylic mold has been coated with wax until that is evenly distributed, then the mold is tightly closed with acrylic and placed in a vacuum mold until it hardens for 1 full day. After the printing process with the vacuum method is complete, the material is removed from the mold and ready to be processed for specimen preparation according to the standard sizes of ASTM D638[19] tensile test, ASTM D790[20] bending test, ASTM D6110[21] impact test and SEM.

2.3 Types of Testing

2.3.1 Tensile Test

Tensile strength is the maximum stress that a material can withstand when stretched or stretched, before breaking. Tensile strength is the opposite of compressive strength, and its values can be different. Tensile test is the application of a force or tensile stress to a material with the intention of knowing or detecting the strength of a material's young modulus, stress and strain, yield strength and ultimate tensile strength [22]. For this study, ASTM D638 standard specimens were used as shown in Fig. 3. Tensile strength can be calculated by the eq. (1), where σ is engineering stress (MPa), F is load is applied in a direction perpendicular to the specimen (N) and A is initial cross-sectional area before the specimen is loaded (mm^2).

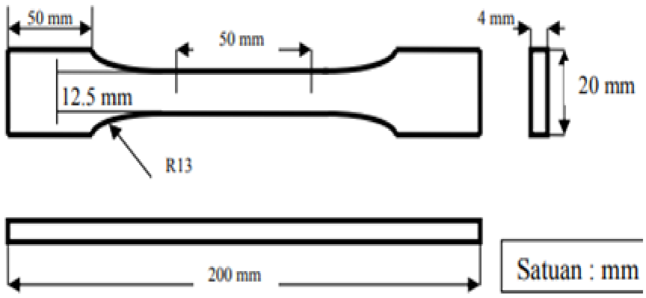


Fig. 3. Tensile test specimen.

$$\sigma = F/A \quad (1)$$

Strain of composite can be calculated by using the eq. (2), where: ε is engineering strain (%), Lo is initial length of the specimen before loading (mm) and ΔL is length increase (mm).

$$\varepsilon = \Delta L/Lo \times 100\% \quad (2)$$

Based on the test results curve, the modulus of elasticity can be calculated by using the eq. (3), where: E is Young's Modulus (GPa), σ is Engineering stress (MPa) and ε is Engineering strain (%).

$$E = \sigma\ \varepsilon \quad (3)$$

2.3.2 Bending test

Bending test is a test that aims to determine the stress on the material just before the material yields in a bending test. The transverse flexure test is most commonly used, in which a specimen having a circular or rectangular cross-section is bent until it breaks or yields using the three-point bending test technique.

In this bending test, there are using a three-point bending method. Bending testing focuses on the center point as the load point that will be given to the specimen. In this study, the standard bending test specimen used was the ASTM D790 standard as shown in Fig. 4. Bending strength can be calculated using the eq. (4), where σ is Bending strength (MPa), P is load (N), L is the length between the fulcrums (mm), b is width of specimen (mm) N and d is thickness of specimen (mm). The bending elastic modulus can be calculated by the eq. (5), where E_b is Bending elastic modulus (MPa), δ is deflection (mm).

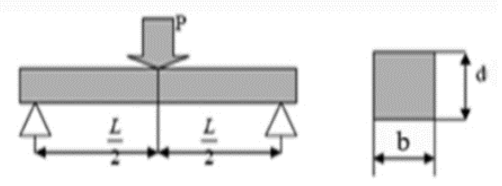


Fig 4. Bending test specimen.

$$\sigma = 3FL/2bd^2 \quad (4)$$

$$E_b = L^3P/4bd^3\,\delta \quad (5)$$

2.3.3 Impact Test

Impact testing is a test performed to measure the ability of a material to absorb energy and change shape plastically without breaking. Definition of material toughness is the amount of energy per unit volume that a material can absorb before breaking. This measure of toughness differs from that used for fracture toughness, which describes the load-bending ability of a material with defects. Impact testing consists of 2 types, namely Charpy testing and Izod testing [23]. Impact test specimens use the ASTM D6110 impact test standard, as shown in Fig. 5.

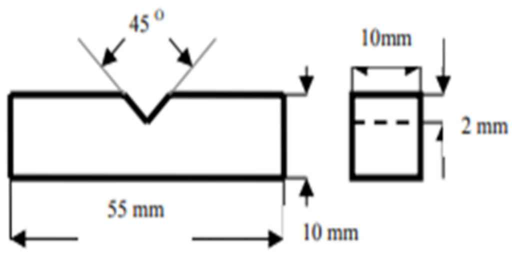


Fig. 5. Impact test specimen.

The total of potential energy absorbed by the composite specimen will show the impact strength of the test object which can be calculated by using the eq. (6), where I_s is Impact strength (J/m^2), E_s is the energy absorbed after the collision (J), E_o is Energy absorbed in not use a sample in the test equipment (J) and A is Cross section area (m^2).

$$I_s = (E_s - E_o)/A \quad (6)$$

2.3.4. SEM test

Scanning Electron Microscope (SEM) test is a test that uses a microscope tool that has a high-energy back-scattered electron beam. This light will penetrate into the composite surface to detect the condition of the deformed material structure as shown in fig. 6.

Fig. 6. Scanning Electron Microscope.

The Scanning Electron Microscope installation used in this study is shown. The result of this detection is in the form of a photographic image that displays the composition of a material. The SEM used in this study uses a Hitachi SN50 SEM machine which has magnification capabilities from 10 x to 500,000x.

3 Results and Discussion.

This study aims to determine some of the mechanical properties of the composite and binder matrix. The test carried out is a tensile test to determine the tensile strength and strain. Bending test to determine the stress on the material just before the material yields. Impact test was used to determine fracture resistance and ductility. Scanning Electron Microscope (SEM) testing is to detect deformed material structural conditions.

3.1 Tensile Tests

Tensile tests were carried out using a tensile testing machine, producing a graphical print-out of the load-length gain relationship for each test object. The tensile test process for abaca fiber reinforced composites is shown in Fig. 7.

Fig. 7. Tensile test process

The results of tensile test data for each type of composite based on volume fraction and percentage of alkali treatment are given in the table 4.

Table 4. the average tensile properties of abaca polyester composites with variations in volume fraction and percentage of alkalization solution.

Alkali Treatment (%NaOH)	Tensile stress (Mpa)				
	15%V_f	20%V_f	25%V_f	30%V_f	35%V_f
1	66.09	73.93	86.82	110.67	121.32
3	69.70	80.27	91.42	123.92	145.32
5	82.35	95.23	186.89	161.76	170.01
7	79.83	94.34	103.45	146.67	162.89
9	75.23	90.45	98.56	141.67	157.32

Based on the highest composite tensile strength value, there is a composite with specifications of 25% Vf and 5% alkali treatment, where the tensile strength value is 186.89 MPa. The magnitude of this tensile strength value exceeds the tensile strength value of several types of wood in Indonesia [1,3].

In fig. 8, it shows a graph of the relationship between the average tensile stress of the composite with the alkalization treatment of abaca fiber. The abaca-polyester composite with a volume fraction of 25% had the highest tensile strength in 5% NaOH fiber treatment for 1 hour. This shows that the 5% NaOH treatment is the most effective treatment to increase the tensile strength of the composite.

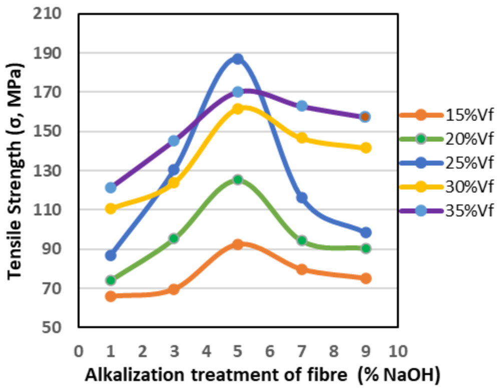


Fig. 8. Relationship between the average tensile stress vs the alkalization treatment of the composite.

In addition to the tensile strength value, the tensile test of the composite also obtained the strain value of the composite. The magnitude of the average tensile strain value is shown in table 4.

Table 5. The average tensile strain value of abaca-polyester composite with variations in volume fraction and percentage of alkalization of alkalization solution soakin.

Alkali Treatment (%NaOH)	Tensile strain (%)				
	$15\%V_f$	$20\%V_f$	$25\%V_f$	$30\%V_f$	$35\%V_f$
1	0.32	0.30	0.28	0.26	0.25
3	0.34	0.32	0.30	0.29	0.28
5	0.45	0.36	0.35	0.34	0.32
7	0.41	0.37	0.35	0.34	0.32
9	0.38	0.36	0.34	0.32	0.29

The highest tensile strain value was experienced by the composite with fiber alkali treatment of 7%. Fig. 9 shows a graph of the relationship between alkalization treatment and composite strain.

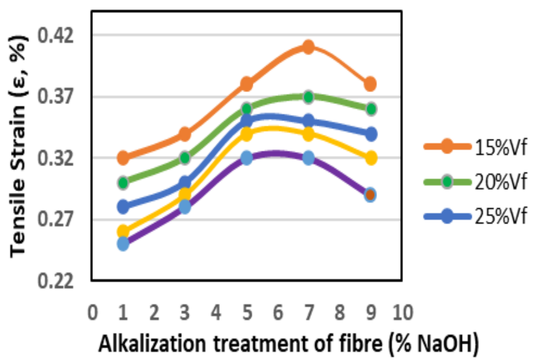


Fig. 9. The relationship between tensile strain vs alkalization treatment's fibers of composite.

The strain of abaca fiber reinforced composite materials showed the highest value in the 7% NaOH fiber treatment. This phenomenon occurs because the alkalization treatment of abaca fiber by 7% NaOH resulted in a decrease in fiber strength so that the increase in fiber length during the tensile test became greater.

In table 4 below, it can be seen that the average value of the modulus of elasticity of the composite based on the volume fraction and fiber alkalization treatment.

Table 6. The average value of the elastic modulus of abaca-polyester composite with variations in volume fraction and percentage of alkalization solution soaking

Alkali Treatment (%NaOH)	Young modulus (%)				
	$15\%V_f$	$20\%V_f$	$25\%V_f$	$30\%V_f$	$35\%V_f$
1	0.32	0.30	0.28	0.26	0.25
3	0.34	0.32	0.30	0.29	0.28
5	0.45	0.36	0.35	0.34	0.32
7	0.41	0.37	0.35	0.34	0.32
9	0.38	0.36	0.34	0.32	0.29

In fig. 10, it shows that the modulus of elasticity of the abaca polyester composite material experienced the highest increase with 5% alkalization treatment of the fiber. In the alkalization treatment above 5% there is a decrease in the elastic modulus curve, this phenomenon is dominated by the degradation effect of the mechanical properties of the fiber accompanied by the increasingly imperfect bond between the fiber and the matrix. Thus, the longer NaOH treatment of the fiber decreases the elasticity of the fiber. Even this treatment can cause the fiber to become brittle.

In untreated fiber-reinforced composites, the bond (mechanical bonding) between the fibers and the UPRs becomes imperfect because it is hindered by the presence of a wax-like coating on the surface of the fibers. The NaOH treatment aims to dissolve the wax-like coating on the fiber surface, such as lignin, hemicellulose, and other impurities.

With the loss of this wax layer, the bond between the fiber and the matrix becomes stronger, so that the tensile strength of the composite becomes higher. However, NaOH treatment with a greater percentage can cause damage to the cellulose elements. As a result, fibers subjected to prolonged alkalization treatment experience significant degradation in strength.

In untreated abaca fiber reinforced composites, failure is dominated by the loss of bonds between the fibers and the matrix caused by shear stress on.

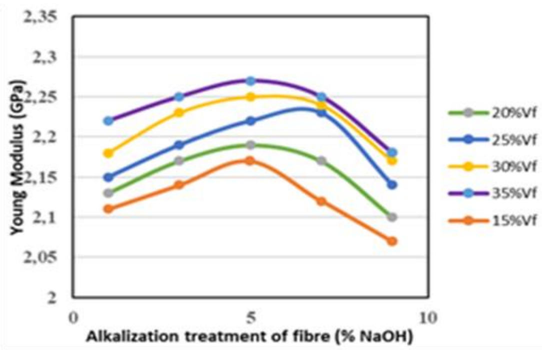


Fig. 10. Correlation curve of young modulus vs alkalization treatment's fiber of composite.

The fiber surface this type of failure is often referred to as "fiber pull out". In this failure condition, the matrix and fiber are actually still able to withstand greater loads and stretches. However, since the bond between the fiber and the matrix fails, the composite fails earlier.

3.2 Bending test result

This study uses three-point bending method to determine the magnitude of the bending moment as shown in Fig. 11. From the bending test using the Universal Testing Machine Instron SN138, the research results were obtained as shown in table 5. Bending test data in table 5 for the composite volume fraction of 15% and the percentage of alkali treatment respectively 1%, 2%, 3%, 5%, 7% and 9%.

Fig. 11. Bending test of composite.

Table 7. The average bending properties of abaca-polyester composite volume fraction (15%Vf) with alkali treatment.

Alkali Treatment (%NaOH)	Length of span (mm)	Width (mm)	Thickness (mm)	Load (N)	Bending stress (Mpa)
1	130	10	5	55.01	42.91
3	130	10	5	59.53	46.43
5	130	10	5	64.73	50.49
7	130	10	5	62.73	48.93
9	130	10	5	60.13	46.90

Based on the data in the table 5, it can be seen that the highest value of the bending test results was achieved by the abaca-polyester composite with 5% alkalization solution with a value of 50.49 MPa and the lowest in the composite with 1% alkalization treatment with a value of 42.91 MPa.

In table 6, it is given that the highest average compressive strength for each composite is in the 5% alkali treatment, while the lowest average compressive strength for each composite is in the 1% alkali treatment. The maximum compressive strength value experienced by the composite with 25% Vf and 5% fiber alkali treatment is 53.03 MPa, this value is higher than the compressive strength value of Meranti wood which is only 51.40 MPa [1,3].

Table 8. The average value of bending strength of abaca-polyester composite with variations in volume fraction and percentage of alkalization treatment of fiber.

Alkali Treatment (%NaOH)	Bending stress (MPa)				
	$15\%V_f$	$20\%V_f$	$25\%V_f$	$30\%V_f$	$35\%V_f$
1	42.91	44.61	46.56	47.76	48.76
3	46.43	47.63	50.06	50.53	50.96
5	50.49	51.42	53.03	51.90	52.03
7	48.93	49.53	50.66	51.15	51.16
9	46.90	47.81	49.16	50.02	49.89

Fig. 12 shows a very significant increase in the value of bending strength due to the increasing number of fiber volume fractions compared to the matrix. From all types of composites, it can be seen that the 5% alkalization treatment has a high bending strength, this is because the 5% alkali concentration provides optimum fiber strength between its bonds (interlocking).

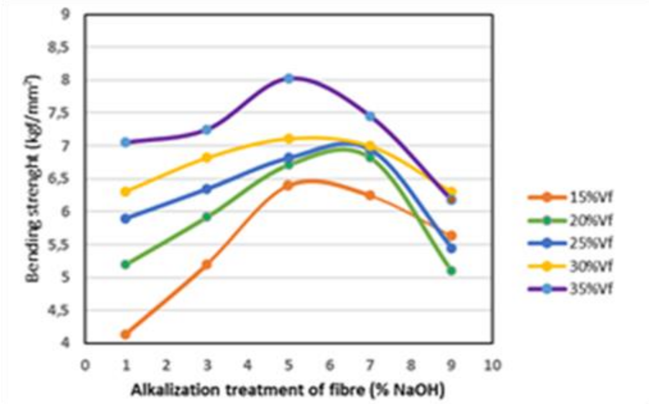


Fig. 12. Bending test graph.

3.3 Impact Test Result

The method used for this impact test is the Charpy method as shown in Fig. 13. Unlike the tensile test and bending test, there is no graphic print-out for this impact test. In this test several separate impact tests were carried out on the matrix of the binder and the resulting composite.

This is done to find out how much force is needed to break the impact test object for then the abaca polyester fiber composite is mechanically tested to determine the absorption energy and toughness to withstand shock loads. The amount of absorption energy of the abaca-polyester fiber composite from the test results is shown in table 7.

Fig. 13. Charpy test equipment for composite.

The impact toughness of the abaca polyester composite with a volume fraction of 25% with 5% alkalization treatment show in table 7. there has an optimum impact strength value of 9.32 kJ/m^2. The results show that the greater the fiber volume fraction, the impact toughness of the composite also increases.

Table 7. The average absorption energy of abaca-polyester composite volume fraction with the percentage of fiber alkali treatment.

Alkalization Treatment (%NaOH)	Average absorption energy (Kj/m^2)				
	$15\%V_f$	$20\%V_f$	$25\%V_f$	$30\%V_f$	$35\%V_f$
1	3.54	4.54	5.54	5.04	4.54
3	4.62	5.62	6.62	6.20	5.62
5	7.32	8.32	9.32	8.12	6.32
7	5.76	6.76	7.00	6.80	6.76
9	4.33	5.04	6.21	5.41	6.25

The impact toughness of abaca polyester composite with a volume fraction of 25% with 5% alkalization treatment as shown in Fig. 14 has an optimum impact strength value. This increase in absorption energy is in accordance with the ROM law, which is due to the addition of fiber [23]. However, after exceeding the optimum value tends to drop, this is because the bond between the matrix.

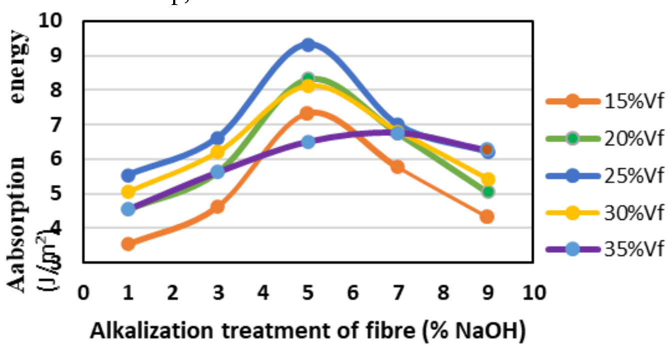


Fig. 14. Absorption energy of abaca polyester composites.

and the fiber decreases, thereby reducing the impact toughness. Impact toughness decreases in alkalization treatment above 5%. This shows that the influence of the large percentage of alkali treatment causes degradation of the fiber strength so that the absorption energy decreases.

3.4 SEM Test Result

SEM testing is a test that aims to observe the structure of materials that have undergone mechanical testing and is also able to detect compositional substances contained in the material 350x. In this SEM test, the specimens tested were single abaca fibers derived from alkalization solution immersion with variations of 1% (a), 3% (b), 5% (c) and 7% (d). SEM testing uses a magnification of 350x.

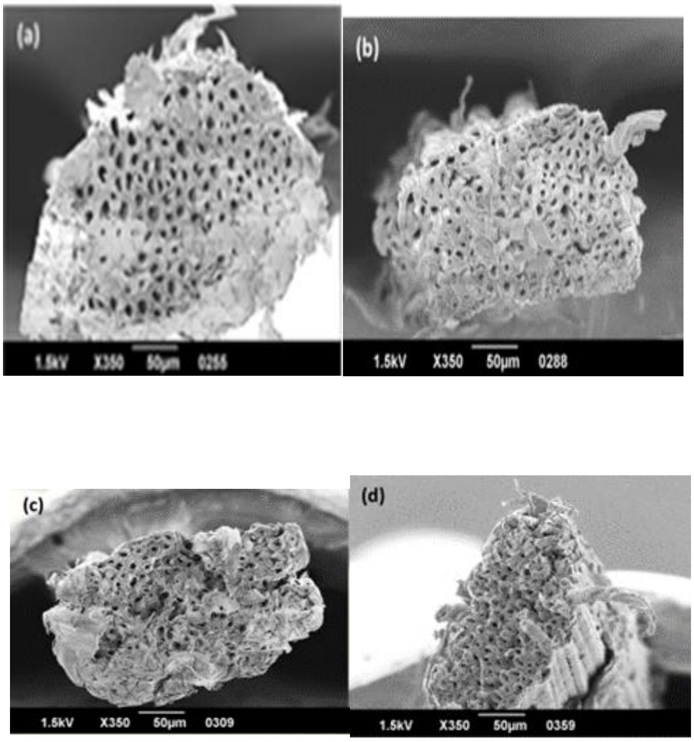


Fig. 15. Microstructure of abaca fiber percentage.in alkalization treatment. (a) 1%, (b) 3%, (c) 5% and (d) 7%.

In fig. 15.(a) It can be seen that for fiber with 1% alkalization treatment, the fiber yield still contains lignin at the bottom. In Fig. 15. (b) with 3% alkalization treatment, it can be seen that most of the lignin has been removed and the fiber is clearly visible. In fig. 15. (c) with 5% alkalization treatment it can be seen that the condition of the fiber is better than the fiber in Fig. 15. (b) Likewise in Fig. 15. (d) with 7% alkalization treatment it can be seen that most of the lignin has also been removed and the clean condition of the fibers already looks more perfect than the fibers in Fig. 15.(c)

The condition of the fiber microstructure from the SEM results illustrates that in the manufacture of composites with specifications of 15%Vf, 20%Vf, 25%Vf, 30%Vf and 35%Vf with alkali treatment respectively 1%, 3%, 5%, 7% and 9% gives significant results of tensile strength, bending strength and impact strength to the results of the mechanical strength as the volume fraction increases and the concentration of the alkalization solution increases. Fibers that undergo alkalization treatment produce better bonds (interlocking) between the fibers and the matrix. The alkalization treatment of fiber greater than 5% causes degradation of fiber strength. Within the volume fraction limit of up to 25%Vf and 5%NaOH alkalization treatment gives the optimum strength value.

4 Conclusion

From the results of the research that has been done, several conclusions can be drawn: (1). The highest composite tensile strength value is found in composites with specifications of 25%Vf and 5% alkali treatment, tensile strength value of 186.89 MPa. Higher than the tensile strength value of several woods (2). The highest bending strength value is found in the composite with a specification of 35% Vf and 5% alkali treatment with a bending strength value of 53.03 MPa higher than the flexural strength value of Meranti wood of 51.40 MPa; (3). The highest impact strength value is found in composites with specifications of 25%Vf and alkali treatment with a concentration of 5% of 9.32 kJ/m^2. (4). Based on the mechanical properties data above, the composite specifications that can be recommended for the manufacture of composite boards to replace wood products are 35% Vf and 5% alkalization treatment.

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