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CHARACTERIZATION OF EPOXY WITH MODIFIED WASTE BAGASSE SUGARCANE COMPOSITE

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DECLARATION

I declare that this thesis entitled “title of the thesis” is the result of my own research except as cited in the references.

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ABSTRAK

Siasatan ini dijalankan dengan untuk melihat sejauh mana prestasi epoxy dipengaruhi oleh kekuatan serat hampas tebu apabila digunakan. Hasil daripada teknik rawatan yang dilakukan ke atas serat hampas tebu, tujuan kajian adalah untuk menentukan ciri-ciri mekanikal, termal, dan fizikal yang berubah disebabkan oleh rawatan tersebut. Apabila serat hampas tebu disiasat, lapisan hemiselulosa dan lignin yang hadir dalam serat tersebut telah dikeluarkan atau dikurangkan. Penggunaan larutan natrium hidroksida (NaOH) sepanjang proses rawatan kimia adalah cara di mana objektif ini dicapai. Untuk menentukan kekuatan serat bagas tebu yang telah dirawat, sampel serat yang tidak dirawat digunakan sebagai rujukan. Ini dilakukan untuk mengukur kekuatan serat tersebut. Perbandingan melibatkan pemeriksaan morfologi permukaan bahan bio komposit, yang terdiri daripada epoksi dan serat bagas tebu. Selain itu, sifat-sifat bahan dinilai dari segi sifat mekanikal, termal, dan fizikalnya.

Kata kunci: Fiber hampas tebu, Epoxy, Natrium Hidrokisda, Lignin, Hemicellulose, mekanikal, thermal, dan fizikal.

ABSTRACT

This investigation was conducted with the intention of determining the extent to which the performance of epoxy was affected by the strength of sugarcane bagasse fiber when it was being applied. As a result of the treatment technique that was carried out on sugarcane bagasse fiber, the purpose of the study was to ascertain the mechanical, thermal, and physical characteristics that were changed because of the treatment. When the sugarcane bagasse fiber was examined, the layers of hemicellulose and lignin that were present in the fiber were either eliminated or decreased. The use of a solution of sodium hydroxide (NaOH) throughout the chemical treatment process was how this objective was brought about. To determine the strength of the sugarcane bagasse fiber that had been treated, samples of fiber that had not been treated were used as a reference. This was done to measure the strength of the fiber. The comparison consisted of examining the surface morphology of the bio composite material, which was composed of epoxy and sugarcane bagasse fiber. Additionally, the properties of the material were evaluated in terms of its mechanical, thermal, and physical properties.

Keywords: Sugarcane bagasse fiber, Epoxy, Sodium Hydroxide, Lignin, Hemicellulose, Mechanical, Thermal, Physical.

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C	Carbon	43
O	Oxygen	56

LIST OF SYMBOLS (optional)

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The background of the study for the characterization of epoxy with modified waste bagasse composite covered numerous major areas of research, including the study of materials, the study of composite materials, and the study of waste management.

Epoxy resins were used in a broad variety of industrial applications because of the superior mechanical qualities, chemical resistance, and adhesion offered by these resins. However, these materials also had a few drawbacks, including a tendency to easily break a lack of hardness. Epoxy resins could have their qualities improved in a few ways. One of these ways was by reinforcing the epoxy resin with fillers or fibres, which could increase the epoxy resin's strength, rigidity, and durability. (Hsissou et al., 2021)

The processing of sugarcane resulted in bagasse, which was often regarded as useless because of its nature as a waste product. Bagasse, on the other hand, offered a wide range of possible uses because of the high cellulose content and biodegradability of the material. The qualities of bagasse, such as its resistance to water, thermal stability, and mechanical strength, could be improved by the process of modification, which qualified it as an appropriate filler material for composites. (Hsissou et al., 2021)

It was possible to generate new composite materials with superior qualities by combining modified bagasse with epoxy resin, which was a promising technique. These new composite materials might have had higher mechanical performance, increased thermal stability, and increased resistance to water. Because bagasse was both a sustainable and renewable resource, the use of waste bagasse in the production of composite materials could also help with the mitigation of environmental pollution. Evaluating the material's physical, mechanical, and thermal characteristics was part of the process of characterizing a composite made of epoxy and modified waste bagasse. (Saroj

et al., 2022a) Testing the material's tensile strength, flexural strength, dynamic mechanical analysis, thermal analysis, and scanning electron microscopy were only some of the methods that could be used for this purpose. In general, the investigation of epoxy with modified waste bagasse as a composite material had the potential to contribute to the development of environmentally friendly and high-performance composite materials while simultaneously addressing the difficulties of waste management and environmental sustainability. (Jayamaui et al., 2020)

1.2 Problem Statement

The creation of sustainable and environmentally friendly materials for a variety of applications was becoming an increasingly significant topic in the past, which was framed as the problem statement for the characterization of epoxy with modified waste bagasse as a composite material. In that perspective, the use of waste materials as a reinforcement in composite materials, such as bagasse, which was a by-product of the processing of sugarcane, had garnered a substantial amount of interest in recent years (Atiqah et al., 2019). Because of their superior mechanical qualities and resistance to chemicals, epoxy resins found widespread use in the production of composite materials. However, the integration of waste materials into epoxy composites could dramatically change the characteristics of the composites, which was why it was vital to properly analyze and characterize these materials. As a result, the statement of the issue was to explore the mechanical, thermal, and morphological characteristics of epoxy composites reinforced with modified waste bagasse and to assess the appropriateness of these composites for a variety of applications. For example, applications in furniture. Some of the furniture made from epoxy and bagasse composite materials could be used to create lightweight and durable furniture, such as chairs, tables, and cabinets.

Besides that, even though epoxy had high performance as a material itself, there were a few reasons why epoxy needed to be composite. For example, Epoxy composites had a good strength-to-weight ratio, which meant they delivered remarkable mechanical qualities while still staying lightweight. Because of this, epoxy composites were known for their low weight. This quality was particularly useful in sectors such as aircraft, where

lowering the total weight was essential to improving fuel economy and overall performance.

The intrinsic formability of epoxy enabled the creation of elaborate and sophisticated component designs, allowing for more design flexibility. Epoxy composites were advantageous for usage in the production of streamlined and aerodynamic components because they were simple for manufacturers to mold and shape into the correct configuration. These components were used in a variety of industries.

To that characterization, a few different analytical methods, including Fourier transform infrared spectroscopy (FTIR), thermogravimetric analysis (TGA), and mechanical testing, were used. The long-term objective was to create a composite material that was both environmentally friendly and economically viable, with the intention of eventually substituting traditional materials in a variety of applications (Jayamaui et al., 2020).

1.3 Objectives

In this research, there are 2 objectives that need to be achieved. The objective is:

1. The objective is to compare the effects of 5% Sodium Hydroxide (NaOH) treatment on sugar cane bagasse fibre samples.
2. Analyse the impact of NaOH treatment on sugarcane bagasse fibre on epoxy-bagasse composite performance.

1.4 Scope of Study

In that context, the research concentrated on determining the characterization of the modification of natural fiber bagasse of epoxy and natural filler on physical and mechanical properties. The presence of cellulose fiber in bagasse sugarcane was compared, with one sample after extraction and the other with no extraction, to investigate the characterization of modification of these two different types of fibers. Meanwhile, Extrusion Compression Molding was used to conduct a series of mechanical integrity tests on both bagasse and epoxy. These tests included a bending test as well as a tensile test to evaluate the resistance of the materials to load-induced deformation.

Before beginning the procedure, Fourier transform infrared spectroscopy (FTIR), and thermogravimetric analysis (TGA) were performed on the samples to observe their characterization. To complete the procedure, the natural fiber filler and epoxy composite went through a series of steps, including washing, drying, bleaching, grinding, and combining, and then were subjected to compression. During this characterization, observations were made as planned. Additionally, the University of Malaysia Kelantan (UMK), where the testing took place, served as the location for manufacturing the sample filler and polymer composite.

1.5 Significances of Study Epoxy as Composite Material

In the past, many epoxy products used as composites often included carbon fiber as reinforcement. However, the use of carbon fiber demanded a high cost. To address this difficulty, one option explored was replacing carbon fiber with sugarcane bagasse fiber. Sugarcane bagasse was considered an ecologically friendly fiber, making it particularly suitable for the purpose of the research. It offered the advantage of low cost, ease of availability, and lack of toxicity, making it a cheap and readily available material for this application.

CHAPTER 2

LITERATURE REVIEW

2.1 Polymer

In the past, polymer development has seen consistent growth, mirroring global advancements. Polymers, compounds composed of numerous smaller units called monomers forming a repeating chain, originate from two sources: synthetic materials and natural sources. Their utilization has proliferated across various sectors, notably in medicine, automotive, and kitchen appliance manufacturing, owing to their myriad advantages. However, a significant challenge lies in the fact that the primary raw materials for polymer production are petroleum-based, thereby posing limitations due to the finite nature of petroleum resources.

Statistics indicate a continuous rise in the usage of plastics derived from petroleum products annually. This trend persists due to the numerous benefits plastics offer, including durability, lightweight properties, and cost-effectiveness. Consequently, polymer production has witnessed significant advancements over the past six decades.

Yet, amidst this rapid progress, attention to the environmental impact and safety of these polymers has been somewhat sidelined. Particularly concerning is the insufficient depth of research into their resistance to environmental factors such as oxygen, heat, and UV radiation. Consequently, most plastics either do not degrade or require an extended period, approximately 82 thousand years, to degrade, thereby exacerbating environmental concerns.

2.1.1 Thermoplastic and Thermoset in Synthetics Polymer.

The thermosets and thermoplastic categories are the two categories that may be used to classify synthetic polymers. Plastomerization is a process that thermoplastics go through at specified temperatures (Hsissou et al., 2021; Nabi & Jog, 1999). Thermoplastics originated from petroleum materials and are created from those materials. This process is reversible, which enables the material to be heated and cooled several times (Nabi & Jog, 1999). This is a key step in the process of shaping the polymer before the final product is generated. In addition, because of their platymeric qualities, thermoplastics are very simple to recycle and have minimal costs associated with the process. Certain thermoplastic polymer materials, such as polyethylene (PE) and polypropylene (PP), are examples of such materials.

On the other hand, thermosets are polymers that go through a curing process that involves the mixing of two agents: resin and hardener (Nabi & Jog, 1999). This technique causes the polymer to become permanently hard throughout the curing phase. The use of heat or ultraviolet (UV) rays, which function as catalysts, makes this curing process easier to accomplish. [Nabi & Jog, 1999] found that the cross-linking that occurs between polymer chains ultimately results in the formation of a vast network. When compared to thermoplastics, thermoset polymers often display superior levels of strength and durability, particularly with regard to their resistance to heat and their tensile strength. On the other hand, because of this, thermoset polymers cannot be recycled, which results in much higher disposal costs in comparison to thermoplastics. Bakelite and epoxy are two examples of materials that are thermosets or resinous.

2.1.2 Polymer Composite

According to Nabi and Jog (1999), polymer materials that include reinforcement are differentiated by a matrix resin that penetrates the reinforcement sets and forms bonds with them. The automobile sector makes substantial use of composite materials due to the exceptional durability and cost-effectiveness of these materials. These composites are used in a variety of automotive components, most notably in bumpers, where they function as shock-absorbing zones to minimize the impact of collisions and the likelihood of serious injuries being sustained by drivers and passengers. Examples of polymer materials that are often used in the manufacturing of vehicle components include polyester, which is a common example.

The most popular method for producing composite polymers involves mixing these polymers with fiberglass and several other materials. Since this combination not only lowers costs but also increases durability and safety, it is an excellent option to produce automotive bumpers since it boosts both qualities. For ensuring safety, composite polymers are especially well-suited for use in the car manufacturing industry since they feature a unique set of characteristics that make them appropriate for this purpose.

2.1.3 Type of Filler in Composite

Fillers were particles added to resins or binders (plastics, composites, concrete) that could improve certain properties, make the product cheaper, or be a mixture of both. The largest filler material consumption segment was elastomers and plastics. Fillers were used all over the world every year in areas of application such as paper, plastic, rubber, paint, coating, adhesive, and cover(Nabi & Jog, 1999). Therefore, fillers were produced by many industrial companies, especially in the field of construction, among the world's main raw materials, and contained in various goods for daily consumer needs.

The main fillers used were calcined calcium carbonate (GCC), precipitated calcium carbonate (PCC), kaolin, talc, and carbon black. The filler material could affect tensile strength, elasticity, heat resistance, colour, transparency, etc. A good example was the addition of talc to polypropylene. Most of the fillers used in plastics were mineral or glass-based fillers. Particulates and fibers were the main filler sub-groups. Particulates were small particles of filler mixed in a matrix where size and aspect ratio were important. Fibers were small circular strands that could be very long and have a very high aspect ratio.

2.1.4 Natural fibre

Natural fibers are a type of fine mesh material found in growing plants. Among the natural fibers that could be found in plants were bast fiber, leaf fiber, seed fiber, grass, and reed fiber. There were two ways that the fiber was obtained: one was the fiber produced by the plant itself, and the second was the fiber obtained from the product.

For the fiber produced by the plant itself, the fiber was directly taken and processed to produce the fiber. This process was cost-effective and easy because the recruitment process was very simple. Examples of fiber taken directly from these plants were kenaf and jute.

For the fiber produced as a product, it was the fiber taken after the main product was produced. The process of obtaining this fiber incurred considerable costs because after the main product was harvested, the fiber needed to be cleaned and treated to ensure quality. This process was carried out to guarantee the durability of the fiber so that the resulting product did not fail easily(Michel et al., 2013). Among the examples of fiber obtained through the product were sugarcane bagasse, where sugarcane bagasse was obtained after the glucose water of the stem had been extracted, and fiber from pineapple leaves after the pineapple fruit had been harvested(Vidyashri et al., 2019).

2.1.5 Epoxy and Bagasse

In the past, epoxy resin, a type of polymer thermoset, has been widely used in various industries due to its versatility and numerous benefits over thermoplastics. Epoxy exhibits exceptional chemical resistance, mechanical properties, and high temperature resistance, making it highly desirable for various applications. It is composed of two components, resin, and hardener, which, when mixed, create the epoxy material.

Epoxy finds extensive applications due to its excellent bonding properties, high strength, and resistance to chemicals, heat, and moisture. However, the production of epoxy plastic products has come under scrutiny as part of efforts to reduce the environmental impact of epoxy materials. With diminishing petroleum resources, there is growing pressure to reduce our reliance on this non-renewable resource, making the utilization of renewable resources more critical.(Jayamaui et al., 2020)

To address this, natural fillers have gained attention in recent years, particularly in large industries like automotive and electronics, where the development of bio-composite polymers using natural reinforcements has been advancing. By incorporating natural fillers into thermoset composites like epoxy, the overall cost of the product can be reduced without compromising performance. Researchers have also used chemical treatments and additives to further enhance the quality of thermoset products.

One such natural filler is bagasse, a fibrous material remaining after extracting juice from sugarcane. Bagasse offers several benefits over traditional fillers and reinforcing materials. It serves well as packaging material, construction panels, and insulation boards due to its thermal insulation properties, stabilizing temperature and minimizing heat transfer. Bagasse's moisture absorption capabilities make it suitable for absorbent materials like diapers and sanitary napkins, limiting leakage and enhancing comfort. Being low in density and weight, bagasse is ideal for weight-reduction applications in automotive components, leading to increased fuel efficiency and reduced carbon emissions.

Moreover, bagasse is a biodegradable and compostable material, naturally decaying without polluting landfills. Its biodegradability and adaptability make it a desirable option for industries seeking greener alternatives to synthetic fillers. Overall, the integration of natural fillers like bagasse in epoxy and other thermoset composites presents a promising avenue for sustainable material development and environmental preservation.

2.1.6 Challenging

In the previous research, there were several challenges encountered while making epoxy composites with bagasse fibers due to the manufacturing process and the required quality for a good composite material.

The first challenging aspect was fiber extraction. Bagasse fibers extracted from sugarcane typically have sizes ranging from 1-2mm. Ensuring the fibers are extracted without significant damage is difficult because the longer the fiber size, the better the quality of the composite produced. The extraction process often resulted in a higher probability of fiber damage, which could negatively impact the final product (Michel et al., 2013).

Additionally, bagasse fibers tend to have a relatively high moisture content, which can significantly affect the performance of epoxy compounds when using these fibers. Moisture can disrupt the fiber-matrix interface, leading to reduced mechanical properties and dimensional instability of the composite. Overcoming this challenge requires implementing drying and moisture management techniques during the composite preparation (Jayamaui et al., 2020).

Another issue relates to the mechanical strength and performance of the composites. Bagasse fibers typically have lower tensile strength and stiffness compared to synthetic fibers like carbon or glass. This can limit the final mechanical properties that epoxy composites can achieve. To address this limitation, various approaches can be employed, such as subjecting bagasse fibers to chemical treatment or combining them with other types of fibers to enhance their performance.

In conclusion, while utilizing bagasse fibers in epoxy composites offers eco-friendly advantages, challenges exist in terms of fiber extraction, moisture management, and achieving optimal mechanical properties. Addressing these challenges is essential to fully realize the potential of bagasse as a reinforcement material in epoxy composites.

2.1.7 Chemical Treatment

Natural fillers such as bagasse from sugarcane can be effectively used as substitutes because they contain cellulose and lignin hydroxyl groups. These hydroxyl groups play a crucial role in hydrogen bonding, which can enhance the interaction between the natural filler and the polymer matrix in a composite material. The interface between the filler and the matrix significantly influences the physical, mechanical, and thermal properties of the composite.

By activating these hydroxyl groups, interfacial additives or chemical/physical treatments can be applied to improve the adhesion between the natural filler and the polymer matrix. This activation process creates new bonding sites for the fillers, resulting in better overall performance of the composite material. Various chemical treatments such as benzene, alcohol, NaOH extraction, and bleaching can be used to modify the natural fillers.

Chemical modifications of the natural fillers have a direct impact on their strength, compatibility with the polymer matrix, and overall adhesion. These modifications can be tailored to optimize the properties of the composite material, making it more suitable for specific applications.

In this study, the natural fillers were subjected to chemical modification, as mentioned by Saroj et al. (2022b). This approach is aimed at enhancing the performance of natural fillers when used in composite materials, providing more versatile and sustainable alternatives for various industries.

2.1.8 Characterization of polymer composite with bagasse and other natural fibre

It is possible to determine the category of a material based on some features that are shared by all materials. A property in a material is the term used to describe this phenomenon. Polymer composites, for instance, are made up of materials in which the matrix itself is made up of polymers, which are then combined with fillers made up of other materials. The use of epoxy and sugar cane fibre dregs as reinforcement in the manufacturing of polymer bio composite is one example that can be observed. Other examples include the usage of many other materials.

A few tests, including physical tests, mechanical tests, and heat resistance tests, may be carried out on this polymer bio composite. These tests are among the aspects that can be carried out on this material. To determine the actual qualities that may be seen in epoxy and sugarcane bagasse fibre that occupy the features of polymer composite, these experiments are carried out.

The characterization of this material is of utmost significance due to the fact that every material that can be discovered in this world has its own set of benefits and drawbacks when it comes to the formation of a material. For instance, polymer is a good example that may be viewed. owing to the fact that the polymer, in its natural state, is capable of flexing more than ceramics before reaching its breaking point. An illustration of the distinction between ceramics and the polymer itself has been provided by this circumstance.

2.1.9 Tensile Strength of Composite

A material undergoes a test known as tensile strength, typically conducted on materials such as metals, polymers, and composites. This test aims to determine the durability of a material by applying a load until the point of failure is reached. Such testing is crucial to ascertain the safety of a substance before it is transformed into a finished product, potentially impacting thousands of lives.

Typically, this test is conducted using established safety references, such as those provided by the American Society for Testing and Materials (ASTM). ASTM standards are commonly consulted by scientists prior to the utilization of materials by the public. The test is performed using a Universal Tensile Machine (UTM), a machine regularly employed for this purpose. The sample is subjected to increasing tension until it reaches a point of resistance to a specific weight. Subsequently, the results are analysed to improve the material's durability.

CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

The Bagasse used in this study was obtained from a flea market in Cheras Batu 9, Selangor, Malaysia. To ensure its cleanliness and remove any potentially hazardous dust, the bagasse underwent a washing process using distilled water, making it as clean as possible. This cleaning stage occurred during the washing process, resulting in the bagasse being thoroughly cleaned.

After the washing, the bagasse was subjected to a drying process in an oven at a temperature of sixty degrees Celsius for forty-eight hours. This step aimed to eliminate any remaining moisture that might have been absorbed during the cleaning process. It ensured that the bagasse was completely dry before further processing.

Subsequently, the dried bagasse was mixed until it reached a particle size of 25 microns, achieving even smaller particle size than before. This process further reduced the size of the bagasse particles to the desired level for subsequent use in the research.

3.2 Methods

To remove any lignin and hemicellulose present in the bagasse fiber, a bleaching process was conducted using a solution of NaClO2 with a concentration of thirty percent. This bleaching took place for twenty-four hours, effectively eliminating the lignin and hemicellulose from the bagasse.

After the bleaching process, the bagasse was divided into two distinct groups based on their characteristics. The first group involved treating the bagasse with NaOH, which resulted in the separation of bagasse fibers with a high concentration of cellulose. The extraction of cellulose from the bagasse could be achieved by rehydrating the bagasse in solutions containing 1% sodium hydroxide for two hours at a temperature of 25 degrees Celsius. This process rendered the extraction of cellulose unnecessary.

In the combination process, the amount of ethanol used was twenty times more than the amount of bagasse. The items that did not undergo the process of cellulose extraction were placed in a separate category designated for them (Vidyashri et al., 2019).

The epoxy resin composition and the process of making the sample for Sugarcane Bagasse Fiber Reinforced Epoxy Composites were provided in a table and figure as follows. The provided table and figure outlined the specific formulation of the epoxy resin composition and the step-by-step process involved in creating the samples for the composites using sugarcane bagasse fibers. This enabled researchers and readers to understand the experimental setup and the procedures involved in the study.

Resin	Ingredient	Ratio
BBT 7892 A	Bisphenol A	3
BBT 7892 B (Hardener)	Polyoxypropylene Diamine	1

Table 1: Epoxy Resin Composition

Sample Tag Name	Epoxy	Filler bagasse
A	97%	3%
B	94%	6%
C	91%	9%

Table 2: Sugarcane Bagasse Fibre Reinforced Epoxy Composites (Without Using Extract Cellulose Process)

Sample Tag Name	Epoxy	Filler bagasse
A`	97%	3%
B`	94%	6%
C`	91%	9%

Table 3: Sugarcane Bagasse Fibre Reinforced Epoxy Composites (Using Extract Cellulose Process)

Figure 1: Type of Epoxy and Hardener Has Been Used(Saroj et al., 2022a).

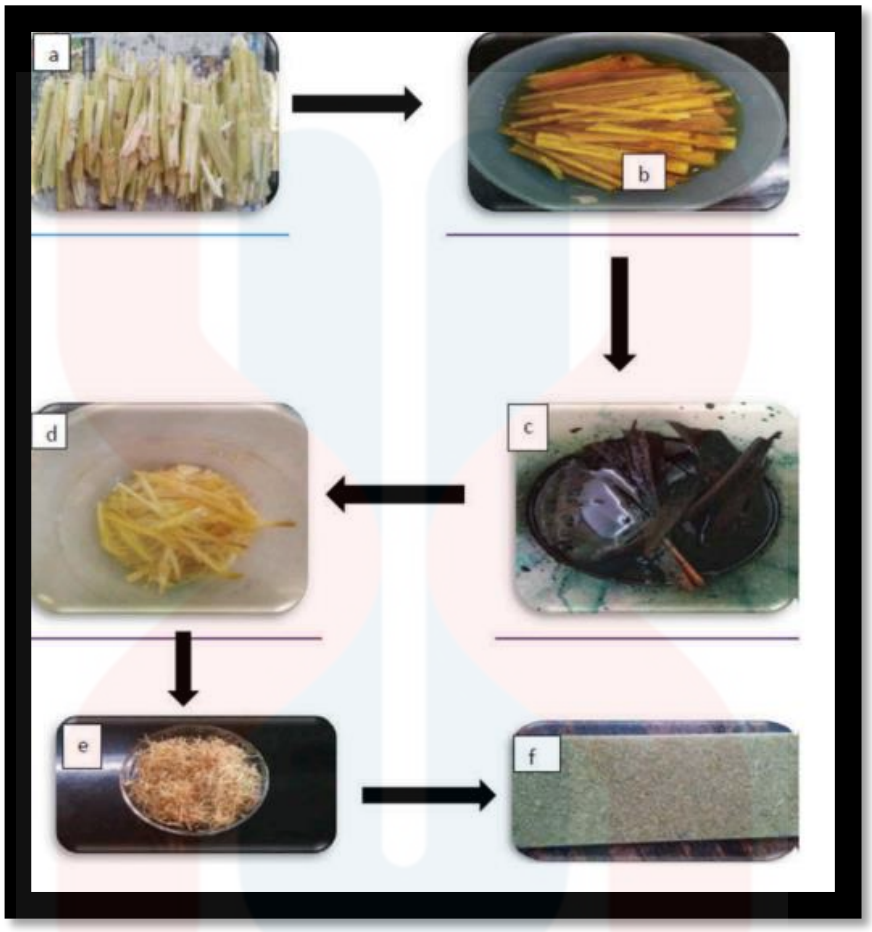

Figure 2:Process Making Bagasee(Vidyashri et al., 2019)

3.3 Characterization of Material (Physical Analysis)

3.3.1 Physical Appearance

The physical appearance of each produced sample was discerned through visual observation with the naked eye. The researcher generated a total of seven samples, classified into three distinct categories. The initial category consisted of pure epoxy, serving as the primary control. The remaining six samples were categorized based on the incorporation of three different percentages of sugarcane bagasse filler: 3%, 6%, and 9%. Notably, within these two categories, one subset underwent alkaline NaOH treatment.

Distinctions among these categories were made through visual inspection. The researcher employed a Redmi Note 12 mobile phone camera to capture images, and the lighting conditions were provided by neon lights within the University of Malaysia Kelantan (UMK) *Makmal Sains Bahan*.

3.3.2 Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM) was employed to examine the surface morphology of two distinct groups of samples: treated and untreated samples subjected to alkaline treatment for sugarcane husk fiber. Each sample was crafted with dimensions of 1 cm in width, 1 cm in length, and 0.5 cm in height. Notably, the samples were not coated with gold, and a consistent magnification rate of 1000x was applied to each sample. This SEM test was carried out at University Malaysia Kelantan (UMK), utilizing the JSM IT200 InTouchScope SEM model.

3.3.3 Fourier-Transform Infrared Spectroscopy (FTIR)

FTIR was a test that could identify the molecular bonds and functional groups of the samples used. The samples used were three types of samples. Each sample was divided into three parts: one part consisted of epoxy only, while the other two contained epoxy and sugarcane bagasse, with the sugarcane bagasse fiber comprising 3% and the rest being epoxy. The sample containing sugarcane bagasse fiber was further divided into one fiber treated with alkaline NaOH and the other untreated. The size of the sample used was 1cm wide x 1cm long x 0.5cm high. The samples were exposed

to wavelengths ranging from 400cm^{-1} to 4000cm^{-1} (Jayamaui et al., 2020). The FTIR machine used was a Nicolet iS50 model FTIR located at University Malaysia Kelantan (UMK).

3.4 Characterization of material Mechanical Analysis

3.4.1 Universal Testing Machine (UTM)

Tensile strength testing, conducted in accordance with American Society for Testing and Materials (ASTM) D3039(Saroj et al., 2022b), involved seven samples categorized into three groups. The first group comprised samples of pure epoxy, serving as a control. The second and third groups featured samples mixed with sugarcane husk fiber at 3%, 6%, and 9% fillers. Notably, within each fiber percentage category, samples were further differentiated—one subset treated with alkaline NaOH, and the other left untreated.

The testing apparatus employed for this experiment was the Universal Tensile Machine (UTM) located at University Malaysia Kelantan (UMK). Each sample was precisely cut to dimensions of 12.5 cm in length, 3 cm in width, and 0.5 cm in height. The Load Cell utilized for this test had a capacity of 50 Kilonewton (kN), and the testing speed was set at 2 mm/min.

3.4.2 Absorption Water

The samples employed for water absorption consisted of seven specimens, with each sample being classified into three groups. One sample belonged to the epoxy group exclusively, serving as the primary control for the water absorption test, devoid of any sugarcane husk fiber. Additionally, two more groups were included, where each epoxy sample was infused with sugarcane bagasse fiber. Each bagasse variant was incorporated with different fillers, specifically 3%, 6%, and 9%. Alkaline NaOH treatment was administered to each bagasse, while the remaining portion underwent no alkaline treatment, following the ASTM D570 standard.

The water absorption test involved cutting the samples to dimensions of 2 cm in length, 2 cm in width, and 0.5 cm in height. Subsequently, all samples underwent a 15-day immersion in

distilled water, with absorption percentage results recorded every three days. The formula employed for calculating the water absorption percentage is as follows:

Water absorption = $((W_3–W_4) / W4) \times 100$
W_3= weight before
W_4= weight after

3.4.3 Density

Density testing, conducted at the University Malaysia Kelantan (UMK) using the ASTM D792 standard and a machine density determination kit, encompassed seven types of samples organized into three distinct groups. The first group comprised a singular sample consisting of pure epoxy, devoid of any sugarcane bagasse fiber. In the second group, three samples were included, each containing varying fillers at 3%, 6%, and 9%, where the sugarcane bagasse filler was untreated with alkaline treatment. The final group also consisted of three samples, featuring fillers of 3%, 6%, and 9%, but in this case, the samples had undergone alkaline Sodium Hydroxide (NaOH) treatment.

The samples for density testing were cube-shaped, with dimensions of 1 cm in width, 1 cm in length, and 0.5 cm in height for each sample. The density measurements were performed in two distinct conditions: one in the air atmosphere and the other after soaking the samples in distilled water. The testing was carried out at room temperature.

The calculation formula for density is as follows:

$$D = M / V$$

D=Density

M=Mass

V= Volume

3.5 Characterization of Material (Thermal Analysis)

3.5.1 Thermogravimetry Analysis (TGA)

The thermal analysis test involved five types of samples. One sample comprised pure epoxy, while the remaining four samples contained 3% and 6% sugarcane husk fiber. Within each fiber percentage category, the samples were further distinguished—one group treated with alkaline NaOH and the other left untreated.

Each sample was utilized in solid form, with a weight ranging between 0.0025g to 0.0030g. The thermal analysis was conducted using a Thermogravimetric Analyzer (TGA) with Small Furnace (SF) Swiss Quality, located at the University of Malaysia Kelantan (UMK). The samples were subjected to temperatures ranging from 35°C to 600°C, utilizing Nitrogen gas with a flow rate of 20 ml/min.(Vidyashri et al., 2019)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

Based on the analysis obtained from the results of this analysis. The researcher has broken down several characteristics that can be seen throughout the researcher studying this experiment as follows:

4.2 Physical Analysis

4.2.1 Physical Appearance of Epoxy and Composite of (Treated and Untreated of Bagasse)

Figure 3: Epoxy sample

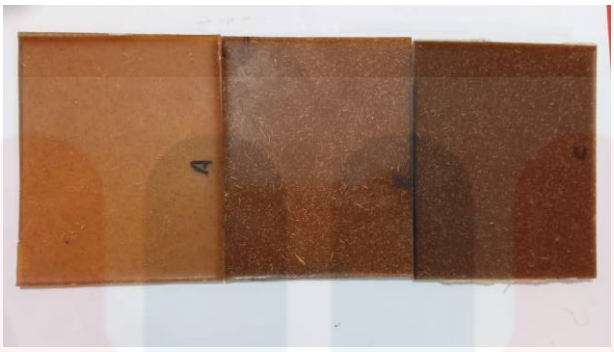

Figure 4: Untreated sample 3%, 6% and 9% filler bagasse

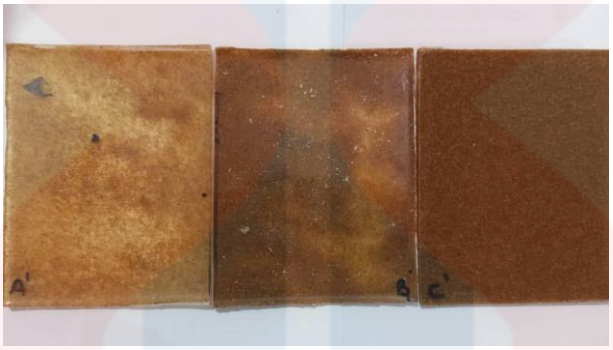

Figure 5: Treated sample 3%, 6% and 9% filler bagasse

Physical appearance can be defined as seeing the properties of a material or the characteristics of a material using the naked eye without the need for any aids (Muratore et al., 2018). According to the context in this study in figure 1,2,and 3 sample, it can be explained that the characteristics that can be seen by the researcher himself in figure 4.1, 4.2 and 4.3 that the bio-composite of epoxy and sugarcane dregs where one of the dregs has been treated with NaOH and labelled as epoxy with bagasse treated with different filler which 3%, 6%, and 9% , while one sugarcane bagasse that was not treated with NaOH with same filer are given as epoxy with bagasse fibre untreated labels shows that the sample that was not treated with NaOH, the appearance of the sample is slightly darker compared to the sample that has been treated with NaOH.

In addition, it can also be seen that the more sugarcane bagasse is used as filler in this bio-composite, the darker the sample is compared to the one that has been treated. In addition, the sample that has been treated has slightly harder properties and is slightly moist compared to sugarcane bagasse that has been treated with NaOH. In addition, the sample that has been treated

with NaOH has more flexible properties and is easy to mould compared to sugarcane bagasse that has not been treated with NaOH. This situation can also be seen by adding sugarcane bagasse filler that has been treated with NaOH, which is easier to form compared to sugarcane bagasse filler that has not been treated with NaOH.

4.2.2 Scanning Electron Microscopy (SEM)

S1(Untreated A)

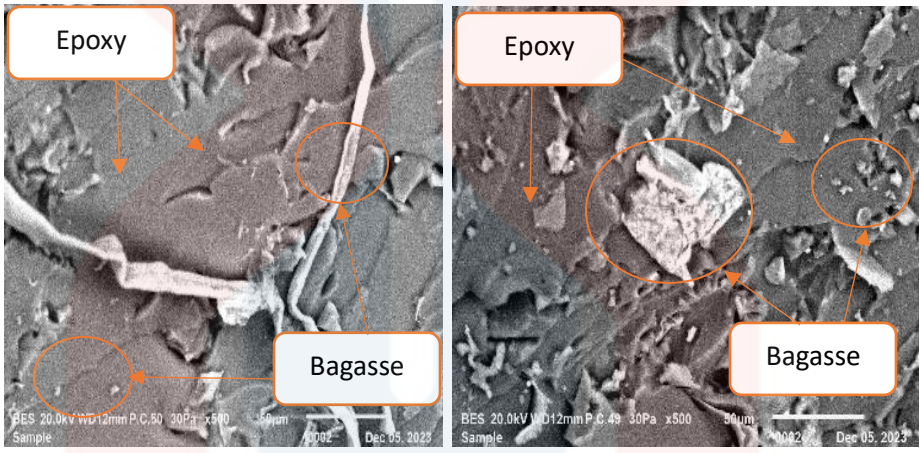

Figure 6: Cross section SEM image of the Sample A

S2(Untreated B)

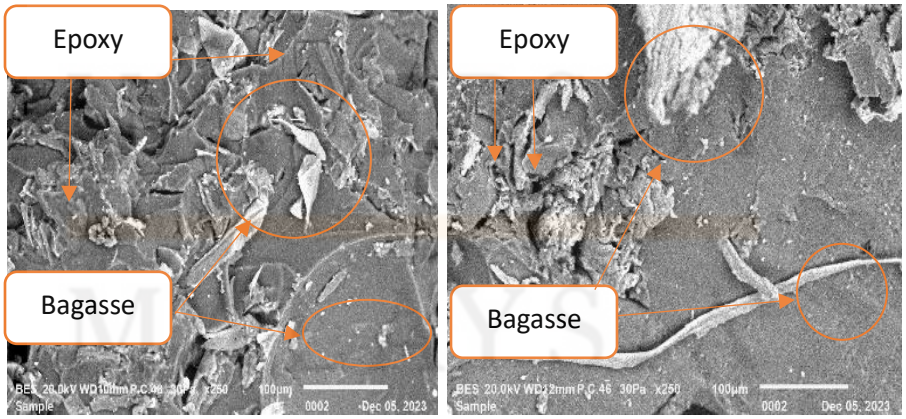

Figure 7: Cross section SEM image of the Sample B

S3(Treated A)

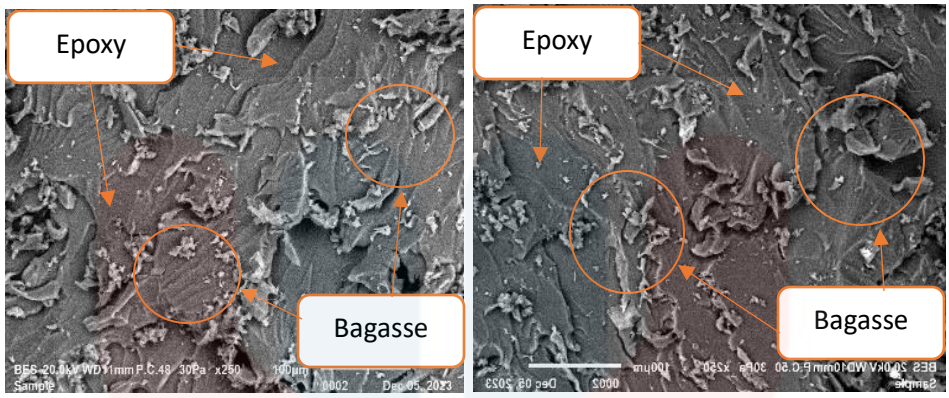

Figure 8: Cross section SEM image of the Sample A`

S4(Treated B)

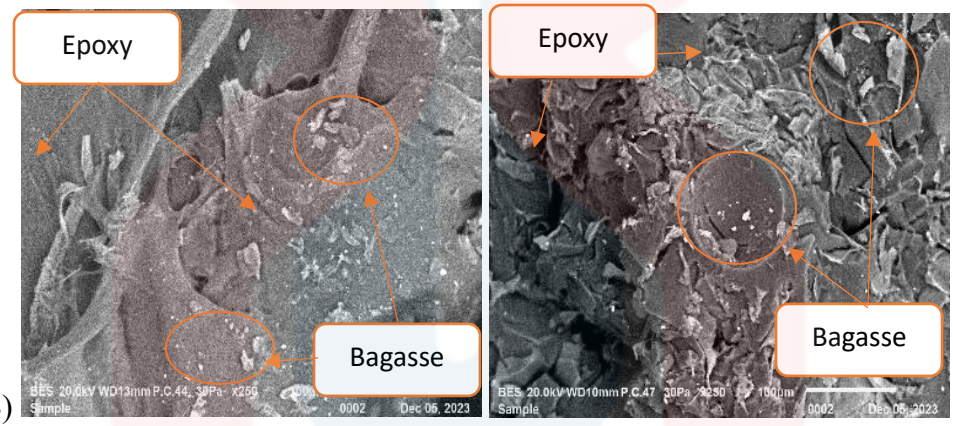

Figure 9: Cross section SEM image of the Sample B`

Morphological properties of sugarcane bagasse epoxy composites

Figures 6 and 7 as S1 and S2 show the untreated sugarcane bagasse fibre and figures 8 and 9 as S3 and S4 show the treated sugarcane bagasse fiber of morphological properties sugarcane bagasse epoxy composite. S1 shows thinner flipper and cripple structures on the fiber itself compared to S2, which is strong and thick. Besides. A significant comparison between treated and untreated fibers is the fiber size. although it has been filtered but it can be seen in this SEM that the treated samples which are S3 and S4 have almost the same fiber size but not in S1 and S2 where the untreated samples have different fiber sizes as the length of the fibers in the picture are not the same each other. The fiber Lipper and cripple structures are very weak and create improper bonding between fiber and matrix, which restrain matrix from being absorbed by the fiber. Furthermore, S2 shows the pores in the middle sample compared to S1. By comparison to the treated fibre in S3 and S4. The alkaline treatment on S3 and S4 the sugarcane fiber removed the

wax and weakened the structure of cellulose, hemicellulose, lignin, and other unknown structures on the surface, which make the size of fibre are smaller compared to untreated fibre compared to S1 and S2. Similar images for untreated and treated sugarcane bagasse can be seen in (Jayamaui et al., 2020).

4.2.3 Fourier-Transform Infrared Spectroscopy (FTIR)

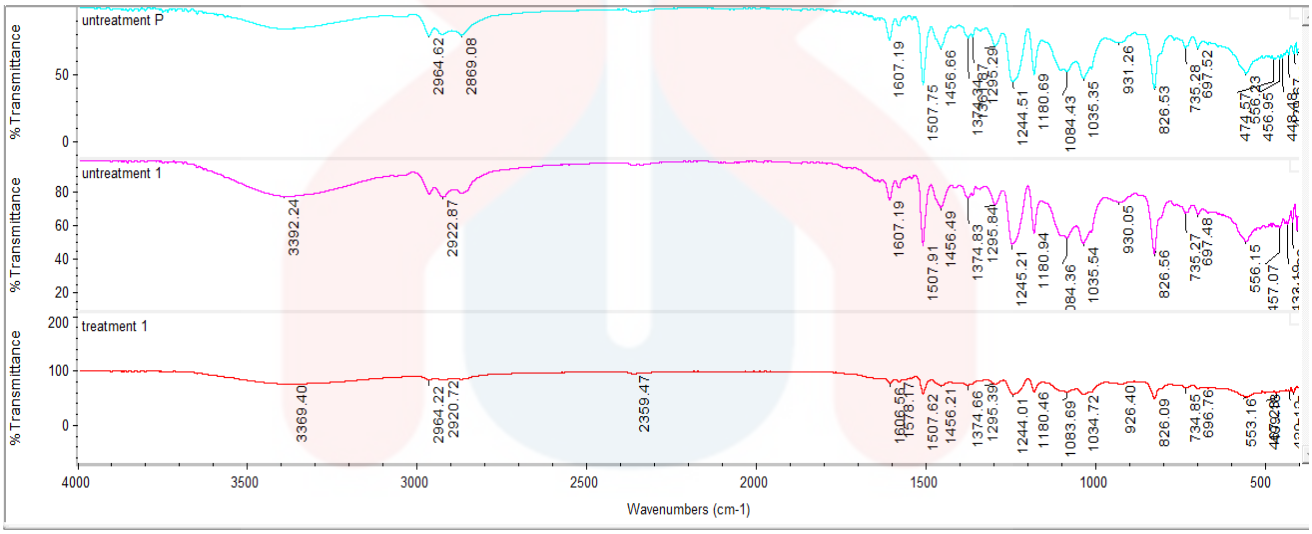

Figure 10: FTIR sample treated and untreated wavelength bagasse and epoxy.

Figure 10 shows the wavelength FTIR for 3 samples which is Pure epoxy, 6wt% fibre untreated with epoxy, and 6wt% fibre treatment alkaline NaOH with epoxy. Apart from sugarcane fibres treated with alkali and heat to remove moisture, all samples exhibit a broad O-H stretching band ranging from 3500 to 3200 cm-1 in the FTIR spectrum depicted in Figure 10. The presence of cellulose is evident in the spectrum, manifesting as C-H stretching vibrations between 2890 and 2854 cm-1. The absorption peak between 1200 and 1160 cm-1 is attributed to the O-H bending of adsorbed water (Jayamaui et al., 2020). Additionally, the C-O-C pyranose ring vibration contributes to the peak illustrated in Figure 10 at 1180 cm-1 (Jayamaui et al., 2020). Notably, a significant absorption band at approximately 826.3 cm-1 is linked to the β-glycosidic bond

between glucose. The peak at 1244.51 cm-1 is more pronounced in the O-H stretching band for untreated and pure samples, as well as treated samples, compared to other cases.

Frequency, cm^{-1}	Bond	Functional Group
826.53-697.52	C-Cl stretch	Alkyl halides
931.26	O-H bend	Carboxylic acids
1035.35-1244.51	C-N stretch	Aliphatic amines
1374.34	C-H rock	Alkanes
1456.66	C-H Bend	Alkanes
1607.14	C-C Stretch (in-ring)	Aromatics
2869.08-2964.62	C-H Stretch	Alkanes

Table 4: The frequency, bond, and functional group for epoxy

Frequency, cm^{-1}	Bond	Functional Group
697.52	-C≡C-H: C-H Bend	Alkynes
826.53	C-H	Alkyl halides
1035.54	C-N Stretch	Aliphatic amines
1245.21	C-H Wag (-CH_2X)	Alkyl halides
1507.91	N-O Asymmetric Stretch	Nitro compounds
2922.87	C-H Stretch	Alkanes
3392.24	N-H Stretch	1º, 2º amines, amide

Table 5: The frequency, bond, and functional group for epoxy and untreated fibre bagasse sugarcane.

Frequency, cm^{-1}	Bond	Functional Group
697.76	-C≡C-H: C-H Bend	Alkynes
826.09	C-H	Alkyl halides
1034.72	C-N Stretch	Aliphatic amines
1244.01	C-H Wag (-CH_2X)	Alkyl halides
1507.62	N-O Asymmetric Stretch	Nitro compounds
2920.72-2964.22	C-H Stretch	Alkanes
3369.40	N-H Stretch	1º, 2º amines, amide

Table 6: The frequency, bond, and functional group for epoxy and treated fibre bagasse sugarcane.

4.3 Mechanical Testing

4.3.1 Tensile Strength

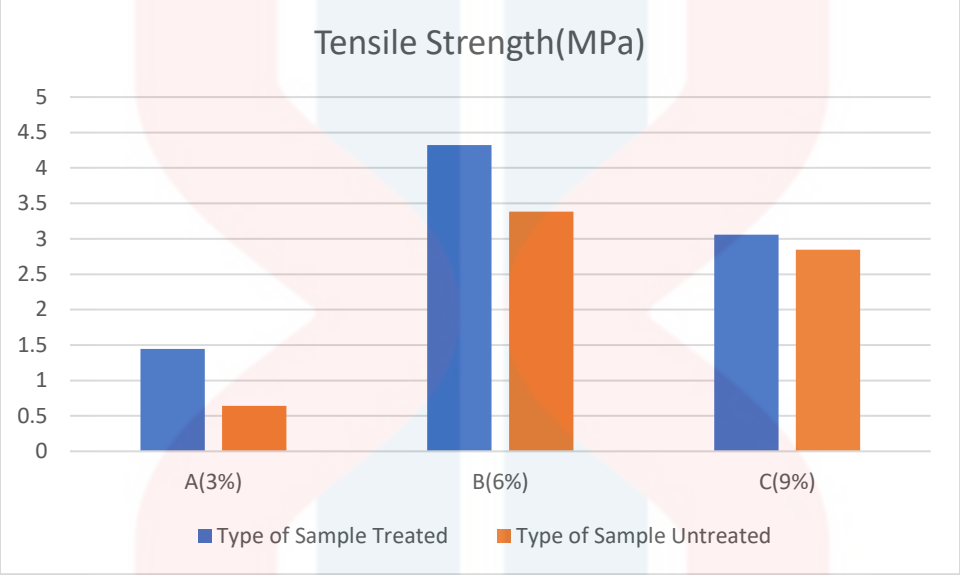

Figure 11: Tensile Strength Sample A, B, and C

The tensile strength of the Untreated and treated sample bio composite is shown in figure 11. It`s make clear that for the treated sample has higher tensile strength compared to untreated sample. The observed phenomenon is attributed to the alkaline treatment applied to the sample, which resulted in a reduction of hemicellulose and lignin content in sugarcane bagasse in figure 11. This alteration causes the cellulose fibre bonds in sugarcane to become more stable, facilitating easier bonding with epoxy. Consequently, the tensile strength of the sample increases significantly after undergoing the curing process with epoxy(Saroj et al., 2022a).

This situation underscores that alkaline treatment of fibre enhances tensile strength. However, upon examining sample C, it is evident that an increase in the amount of sugarcane bagasse filler leads to a slight decrease in tensile strength. This reduction in quality is indicative of the inverse relationship between the quantity of sugarcane bagasse filler and its tensile strength(Saroj et al., 2022a). This clear observation highlights that an excessive amount of filler in the sample can diminish the tensile strength of the material.

4.3.2 Elongation At Break (%)

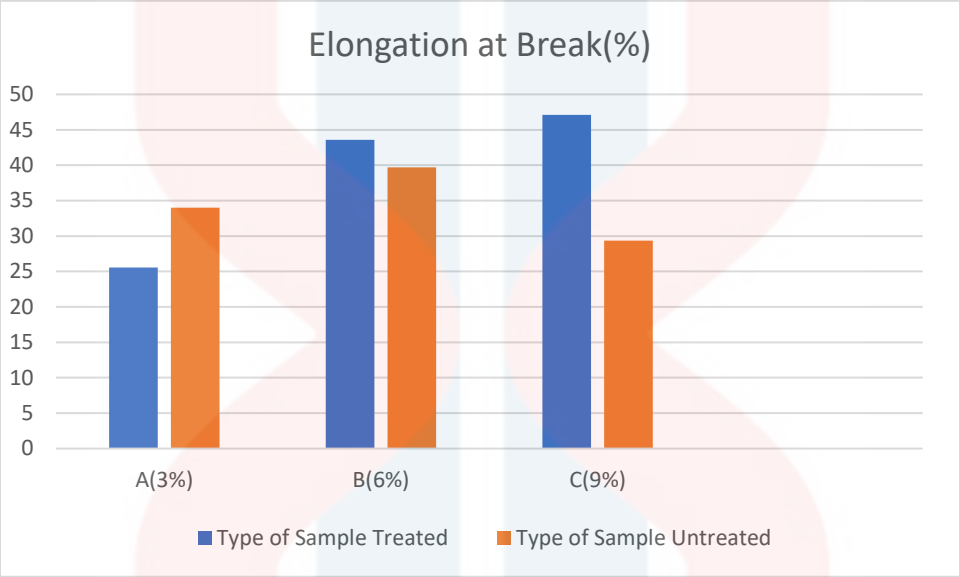

Figure 12: Elongation at Break (%) for sample A, B and C

Figure 12 depicts the elongation at break for both treated and untreated samples, revealing a positive correlation between elongation at break and filler content. Notably, the graph illustrates that alkaline NaOH-treated samples exhibit higher values compared to their untreated counterparts. This observation distinctly indicates that fibers subjected to alkaline NaOH treatment can effectively enhance the elongation at break. This assertion is supported by relevant research (Nabi & Jog, 1999) which affirms that the application of alkaline NaOH treatment can indeed augment the elongation at break. Epoxy, being inherently resistant to bending, experiences a transformative effect when combined with treated sugarcane bagasse filler. The treated filler alters the rigid nature of epoxy, making it more pliable. This outcome stands in stark contrast to the natural characteristics of epoxy.

In the result, the data from Figure 4.6.2, coupled with supporting literature, conclusively demonstrates that alkaline NaOH treatment of sugarcane bagasse filler contributes to a notable increase in the elongation at break, challenging the inherent rigidity of epoxy.

4.3.3 Young Modulus

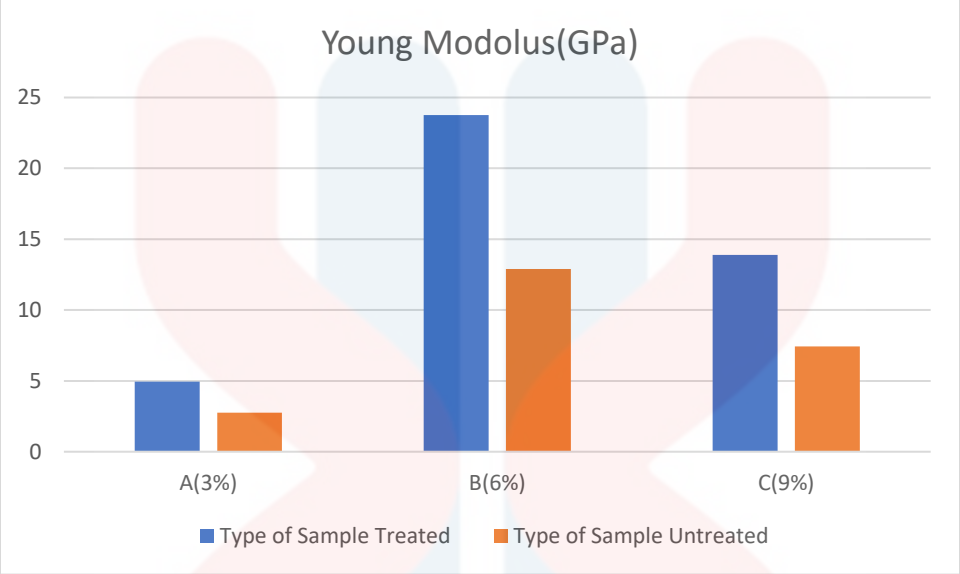

Figure 13: Young Modulus

Figure 13 depicts the young modulus for both treated and untreated bagasse sugarcane 3% wt, 6%wt and 9wt% with epoxy samples. In this figure show illustrates how the tensile modulus of this both samples. An increase in sugarcane bagasse filler in the appropriate proportion results in a stronger Young's modulus for the bio composite epoxy. This trend is evident in the figure, where the 6wt% filler in both treated and untreated Sample B outperforms the 9wt% filler in treated and untreated Sample C. Furthermore, the Young's modulus of the sample treated with alkaline NaOH is notably higher. This clearly indicates that treating sugarcane bagasse fibre with NaOH enhances Young's modulus under optimal conditions.(Mahmud & Anannya, 2021)

This enhancement is attributed to the treated sugarcane pulp, demonstrating that the fibres offer superior reinforcement when binding with matrix materials like epoxy. This situation underscores that the treatment is capable of imparting strength to the epoxy, making it more robust.

4.3.4 Absorption Water

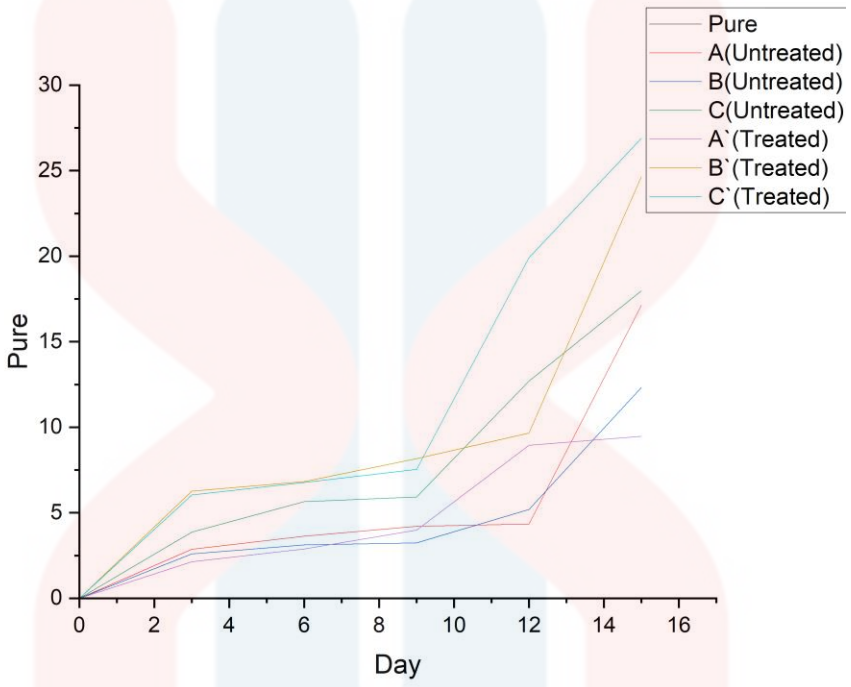

Figure 14: Untreated and Treated Epoxy with Bagasse Absorption Water Test

Based on Figure 14, the absorption water test was conducted for both types of samples: treated and untreated. For the untreated samples, there were seven categories labelled as Pure. Additionally, the untreated samples were further divided based on three filler percentages: A (3%), B (6%), and C (9%). Conversely, the treated samples were denoted as A' (3%), B' (6%), and C' (9%). The initial weights for each sample were recorded. Observations were made over a 15-day period, with data recorded every three days regarding the percentage of water absorption.

The Pure sample exhibited no weight change during the recorded 15 days. For the untreated sample with filler A, there was a weight increase on the 3rd day, amounting to a 2.59% increase. By the 6th day, the increase was 3.12%, and by the 9th, 12th, and 15th days, it escalated to 3.23%, 5.19%, and 12.33%, respectively. Besides that, for sample with filler B. There was a weight increase on the 3rd day, resulting in an increase of 2.87%. By the 6th day, this increase was 3.62%, and by the 9th, 12th, and 15th days, the percentages rose to 4.20%, 4.34%, and 17.12%, respectively. Lastly for the untreated sample with filler C, there was a weight increase on the 3rd

day, with an increase of 3.88%. By the 6th day, this rise was 5.65%. On the 9th, 12th, and 15th days, the percentages grew to 5.92%, 12.70%, and 17.98%, respectively.

The sample treated with NaOH and filled with filler A' showed an increase in weight on the 3rd day, amounting to a 2.14% gain. This increase escalated to 2.88% by the 6th day, 3.99% by the 9th day, 8.95% by the 12th day, and 9.46% by the 15th day. In contrast, for the sample containing filler B', there was a notable weight increase on the 3rd day, corresponding to a 6.26% rise. By the 6th day, this figure had risen to 6.82%. Subsequently, it increased to 8.16% on the 9th day, 19.9% by the 12th day, and 24.65% by the 15th day.

Lastly, the sample untreated with filler C' exhibited a weight gain of 6.04% on the 3rd day. This figure increased to 6.77% by the 6th day, 7.54% by the 9th day, 9.66% by the 12th day, and notably, 26.88% by the 15th day. Across all samples, it's evident that the rate of water absorption increased with the addition of more filler.

4.3.5 Density

Density

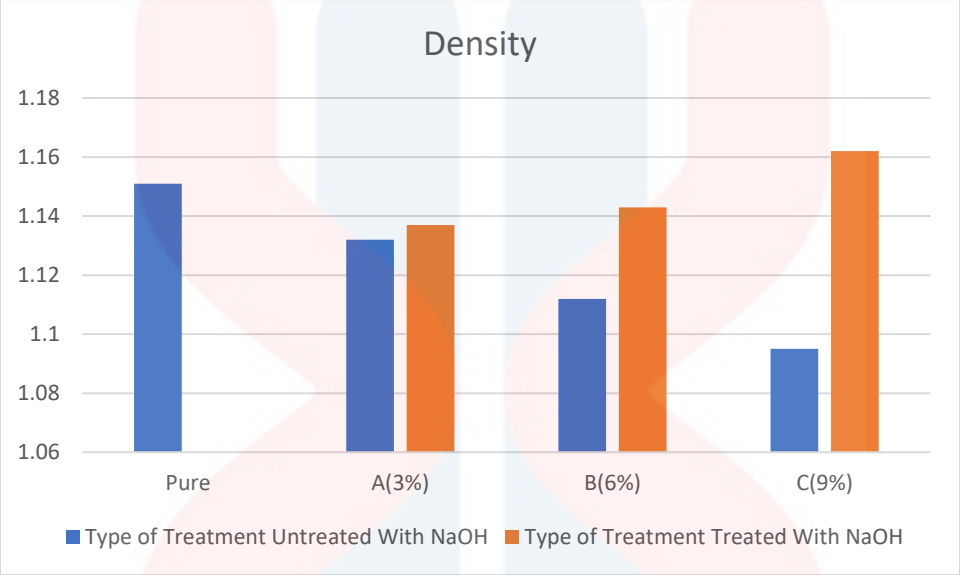

Figure 15: Density graph

Based on figure 15, which illustrates the results obtained from various epoxy samples with distinct sugarcane bagasse fillers at concentrations of 3%, 6%, and 9%, a notable disparity in the increase in density between treated and untreated specimens is evident. Figure 11 vividly demonstrates a significant elevation in the bar graph, with the treated sample registering a greater height compared to the untreated fibre. This observation highlights a direct correlation between the addition of fillers and the augmented density of the samples.

This phenomenon can be attributed to the alkaline NaOH treatment applied to the filler, which results in the modification of hemicellulose and lignin. Consequently, the weight of the fibre is reduced, leading to its contraction and, subsequently, an increased density in the treated sample compared to its untreated counterpart. Despite the treated fibre being slightly heavier than the untreated one, it maintains a lower density than the pure sample devoid of any fibre. This compelling evidence underscores the ability of fibre in a sample to diminish the material density in a bio composite, as clearly elucidated in the referenced article (Nabi & Jog, 1999).

4.4 Thermal Analysis

4.4.1 Thermogravimetry Analysis (TGA)

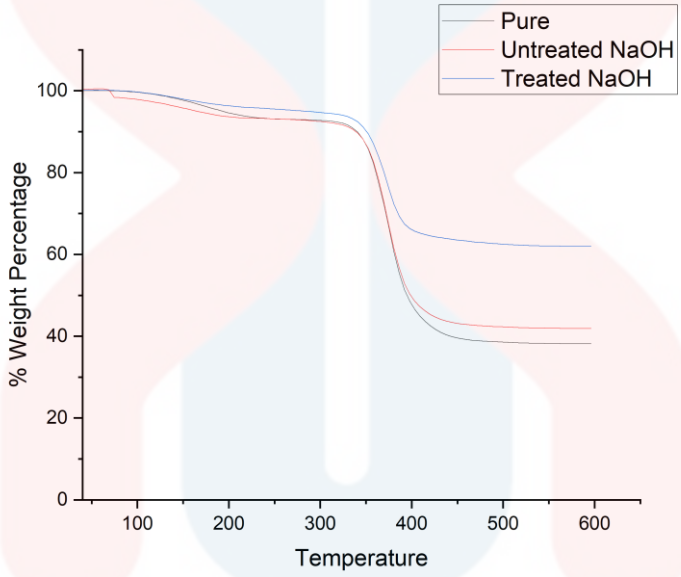

Figure 16: TGA graph Analysis

The thermal characteristics of epoxy composites reinforced with sugarcane fibres were studied using a thermogravimetric analysis (TGA). Three different kinds of samples are shown in Figure 12: one with 6 wt% treated fibre bagasse and epoxy composites (6%TF + 94% E), one with 6 wt% untreated fibre NaOH bagasse and epoxy composites (6% + 94% E), and one with 100% epoxy and no bagasse filler at all. The graph shows that at 75 °C, the examined samples started to lose weight. Afterwards, the presence of moisture in the filler fibres was indicated by the second phase of weight loss occurring at 98°C for both the untreated and treated fibres. Significant weight loss occurred during the third phase, which occurred at 324.8 °C and was caused by a breakdown reaction that followed the dissolution of the hardener (Vidyashri et al., 2019). At 409.0 °C, pure

epoxy, treated fibre, and untreated fibre all reached their final weight loss degrees, whereas treated fibre reached 397.2 °C and untreated fibre 426 °C.

The graph behaved similarly to a plain epoxy sample, according to previous research, even though the treated fibre had a fibre concentration of 6 wt% (Vidyashri et al., 2019). The sample's weight loss rate is also lower for 100wt% epoxy. The absence of fibre in the sample makes it resistant to temperatures that would otherwise destroy sugarcane dregs; consequently, it loses less weight than samples that include sugarcane bagasse fibre.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In conclusion, it turned out that the incorporation of sugarcane bagasse fibres that had been exposed to chemical treatment led to an improvement in the mechanical, thermal, and physical properties of epoxy composites. This was the conclusion reached by the researchers. The use of a sodium hydroxide (NaOH) treatment at a concentration of 5% resulted in improvements in the performance of composites made from sugarcane bagasse fibres. alterations in the composition of the fibres, which in turn led to enhanced interfacial interactions between the fibres and the epoxy matrix, were the cause of these improvements. These improvements followed the compositional alterations. The results of this research demonstrated the relevance of optimizing the extraction process and controlling the amount of moisture present in order to ensure that the composite features are consistent and reliable. It seemed, based on the data, that sugarcane bagasse fibres offered a sustainable alternative to conventional reinforcements, which contributed to the efforts that were made to conserve the environment.

5.2 Recommendations

A valuable addition that the researcher could express is the hope for the expanded utilization of fiber from sugarcane bagasse. This hope stems from several factors. Firstly, sugarcane bagasse fiber is cost-effective, making it an economically viable option. Additionally, it is abundantly available, which is attributed to Malaysia being one of the world's leading producers of sugarcane and having a robust market, particularly during the month of Ramadan. Therefore, leveraging the abundant and accessible resource of sugarcane bagasse fiber could lead to widespread benefits across various industries.

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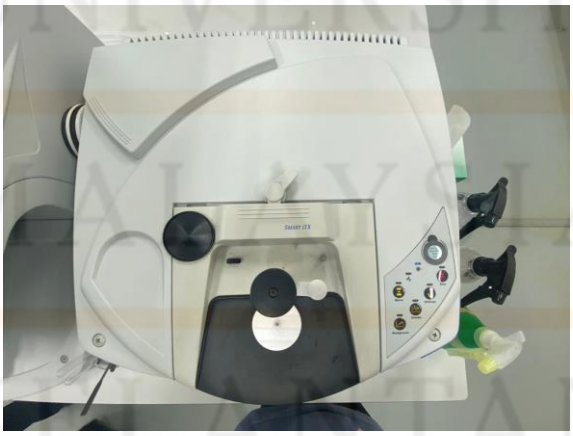
APPENDIX A



APPENDIX B

APPENDIX C

APPENDIX D