MECHANICAL PROPERTIES OF JUTE FIBER POLYESTER HYBRID COMPOSITE FILLED WITH SUGARCANE BAGASSE

NUR SABRINA BINTI ABDUL WAHID

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Faculty of Mechanical Technology and Engineering

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A thesis submitted

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Disahkan oleh:

Nur Sabrina Binti Abdul Wahid

Alamat Tetap:
No 41, Jalan Jasmin Indah 2,
Taman Jasmin Indah,
Seremban, 70450, Negeri Sembilan

Tarikh: 11/1/2024

Cop Rasmi:
DR. NAJIYAH SAFWA BINTI KHASHI'IE
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DEDICATION

In the name of Allah, the Most Gracious, the Most Merciful, I thank you for your permission and blessing, my Creator, my Sustainer, for all I have received from the beginning of my being alive and I have completed my Bachelor Degree Project. Thank you, Universiti Teknikal Malaysia Melaka (UTeM), for providing the research platform. I'd like to express my gratitude to my supervisor, Dr. Najiyah Safwa Binti Khashi'ie, and my co-supervisor, Ts. Dr. Khairum Bin Hamzah, for all of their help and advice in preparing my PSM thesis.

ABSTRACT

In order to protect the environment by using biodegradable materials, natural fibers have become more frequently used in composites. Due to their high specific strength and modulus, fiber reinforced polymer-based composites have been employed in numerous industrial applications for a very long time. Since there are numerous natural fibers accessible, it was decided to investigate using sugarcane bagasse, a natural fiber, as reinforcement in reinforced polymers. The strength and lightness of natural fibers are matched by their affordability. Therefore, the objective of the present study was to investigate the mechanical properties of sugarcane bagasse reinforced polyester resin. This project will be carried out by the fabrication of the materials by using the hand lay-up technique. Then, the cutting of fabricated materials by using CNC router machine according to the ASTM standards. After completely done the cutting process, it will test through tensile, flexural,and impact tests to determine the mechanical properties of the samples. The collected data were analyzed using statistical analysis. Based on the tensile, flexural, impact test and water absorption of sugarcane bagasse reinforced polyester resin, the standard ASTM D3039, ASTM D790, ASTM D6110 and ASTM D570 respectively. Then, a one-way analysis of variance (ANOVA) was applied to analyze the tensile strength and elasticity, flexural load of maximum force and maximum stress, and impact strength of the jute fiber polyester hybrid composite filled with sugarcane bagasse. Five environmentally friendly ratios were used, consisting of 20% sugarcane bagasse and 80% polyester resin, 40% sugarcane bagasse and 60% polyester resin, 50% sugarcane bagasse and 50% polyester resin, 60% sugarcane bagasse and 40% polyester resin, and 80% sugarcane bagasse and 20% polyester resin.

ABSTRAK

Demi melindungi alam sekitar dengan menggunakan bahan biodegradable, serat semulajadi telah menjadi lebih kerap digunakan dalam komposit. Oleh kerana kekuatan spesifik dan modal yang tinggi, komposit berasaskan polimer yang diperkukuhkan oleh serat telah digunakan dalam pelbagai aplikasi industri dalam tempoh yang lama. Oleh kerana terdapat banyak serat semula jadi yang boleh dimanfaatkan, ia dapat membantu untuk mengkaji serat semulajadi yang digunakan seperti hampas tebu sebagai bahan penguat dalam bahan polimer. Kekuatan dan jisim serat semulajadi bergantung kepada ciri–cirinya yang tersendiri. Oleh itu,matlamat kajian ini ialah untuk mengkaji sifat mekanikal hampas tebu yang diperkuatkan oleh resin poliester. Projek ini akan dijalankan dengan melakukan fabrikasi bahan menggunakan kaedah "hand lay–up". Kemudian, pemotongan bahan-bahan yang dihasilkan dengan menggunakan mesin "CNC router" mengikut standard ASTM. Selepas proses pemotongan selesai sepenuhnya, ia akan diuji melalui ujian tegangan, lenturan dan hentaman untuk menentukan sifat mekanikal sesuatu sampel. Data yang dikumpulkan telah dianalisis menggunakan analisis statistik. Berdasarkan ujian ketegangan, kelenturan, hentaman dan proses serapan air untuk hampas tebu yang diperkuatkan oleh resin poliester melalui standard ASTM D3039, ASTM D790, ASTM-D6110 dan ASTM D570. Kemudian, analisis varians satu arah (ANOVA) digunakan untuk menganalisis kekuatan tegangan dan elastisiti, kekuatan maksimum bagi beban lenturan dan tekanan maksimum, dan juga kekuatan hentaman bagi komposit poliester hibrid yang mengandungi hampas tebu. Lima nisbah mesra alam sekitar telah digunakan untuk menjalankan projek ini yang terdiri daripada 20% hampas tebu dan 80% resin poliester, 40% hampas tebu dan 60% resin poliester, 50% hampas tebu dan 50% resin poliester, 60% hampas tebu dan 40% resin poliester, dan 80% hampas tebu dan 20% resin poliester.

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All thanks be to God for giving with His permission and blessing, my Creator, my Sustainer, for all I got since the beginning of my life and I have now completed the Bachelor Degree Project 1. Thank you, gratitude, to the Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

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LIST OF SYMBOLS AND ABBREVIATIONS

ρ	-	Density
v	-	Volume
m	-	Mass
ASTM	-	American Society for Testing and Materials
ANOVA	-	Analysis of Variance
SB	-	Sugarcane Bagasse
PR	-	Polyester Resin

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter provides a brief overview of the research background, including the problem statement, research objectives, and research scope. It also discusses the background information regarding the effect of fiber loading of jute fiber polyester hybrid composite that filled with sugarcane bagasse

1.2 Background

A material that blends jute fibers and polyester matrix with sugarcane bagasse as a filler is known as a jute fiber-polyester hybrid composite. Jute is a natural fiber made from the jute plant's stems. It's renowned for having a high tensile strength, being inexpensive, biodegradable, and renewable. Jute fibers have strong tensile characteristics, are rigid, and are resistant to impacts. A common synthetic polymer used as a matrix in composites is polyester. Natural fibers provide several technological, financial, and environmental benefits. Their high moisture absorption rate and poor dimensional stability are the main drawbacks that prevent their usage in long-term composite applications (Kumar et al., 2017).

Sugarcane bagasse is the fibrous byproduct left over after the sugarcane stalks have been squeezed for their juice. It is a cheap, plentiful, and renewable agricultural waste product. It provides a number of advantages by using sugarcane bagasse as a filler in the composite (Bartos et al., 2021). Utilizing a waste material lowers the composite's overall cost, improves its dimensional stability, and promotes its environmental sustainability.

The jute fibers, sugarcane bagasse filler, and polyester resin are normally mixed together during the production process, and the composite is then molded or compressed into the appropriate shape such as sheets or specialized pieces. Typically, fiber-reinforced composites can be used in a variety of industries, such as the automotive, building, and packaging, where it is desirable to strike a balance between mechanical properties, cost-effectiveness, and environmental sustainability (Bartos et al., 2021). The fiber-reinforced polymer composites have been used to design a wide range of building materials, from housing and interior design to fence and decking. The use of materials with higher specific strength and stiffness reduces the weight of building materials in accordance with the same principles used in automotive components (Diana et al., 2021). The amount or concentration of jute fiber packed with sugarcane bagasse in a composite, known as the "fiber loading," can have a variety of consequences on the composite's physical characteristics. The mechanical characteristics of the composite tend to get better as the fiber loading goes up. Jute fibers serve as reinforcement and improve the composite's strength, stiffness, and toughness. Increased tensile strength, flexural strength, and impact resistance of the composite are often the outcomes of higher fiber loading. Other effects are about dimensional stability. Enhancing the composite's fiber loading can result in better dimensional stability. As fillers, the sugarcane bagasse and jute fibers assist the composite have a lower coefficient of thermal expansion and shrinkage changes. As a result, temperature variations may cause less bending, distortion, and dimensional.

The density and weight also will affect to the composites when the fiber was high that typically will increase. To maintain good fiber-matrix interaction and prevent problems like voids or insufficient consolidation, high fiber loading may require additional processing stages or changes. The cost of the composite is directly impacted by the fiber loading. However, compared to other reinforcing materials, employing natural fibers as fillers, such as jute and sugarcane bagasse, is often more affordable. For example, the type and quality of jute fibers, sugarcane bagasse particles, the matrix material utilized such as polyester, and the production method can all affect the specific impacts of fiber loading (Vijayan et al., 2019.

1.3 Problem Statement

There is a plenty of research in the field of fiber-reinforced polymer composites. Natural fibers that fillers with different polymer resins have been the subject of study over the past ten years. Researchers have also experimented with hybrid composites made of synthetic fibers. To increase the mechanical and thermal qualities of polyester resin, sisal, glass, and chalk powder are added. Due to their renewable nature, natural fibers and agricultural waste are heavily employed nowadays to improve mechanical qualities. Human hairs are also discussed and determined to be acceptable for a variety of uses. The challenges of natural fiber composites can vary depending on specific application and research objectives.

Efficiency of reinforcement is the one of the common challenges to overcome, when performance of the composite can be impacted by the natural fiber's intrinsic differences in their qualities, such as fiber diameter, length, and orientation. To increase the effectiveness of the reinforcement and produce consistent mechanical characteristics, the issue is to optimize the dispersion, alignment, and interfacial adhesion between the fibers and the matrix. Other than that, natural fibers have a propensity to absorb moisture, which can result in dimensional changes, diminished mechanical qualities, and susceptibility to deterioration. To increase dimensional stability and broaden the spectrum of uses for natural fiber composites, the challenge is to create treatment techniques or change the fiber surface. Natural fibers frequently display poor compatibility with some matrix materials, particularly hydrophobic polymers. To increase the mechanical characteristics, durability, and overall performance of the composite, it is necessary to improve the adhesion and interfacial bonding between the natural fibers and the matrix. The limited supply of natural fibers and difficulty in maintaining quality control might make large-scale manufacture difficult. To assure a dependable and regular supply of natural fibers appropriate for composite manufacture, the challenge is to create sustainable farming practices, optimize processing methods, and implement quality control procedures.

The durability and aging resistance were also the common problem that always to face it when natural fibers can be susceptible to degradation over time due to factors like UV exposure, moisture, or microbial attack. The problem is to enhance the durability and aging resistance of natural fiber composites through fiber modification, surface treatment, or incorporation of protective additives, ensuring their long-term performance and suitability for outdoor or demanding applications. In comparison to synthetic fiber composites, natural fiber composites frequently struggle with cost and market competitiveness issues. The challenge is to look into low-cost processing methods, increase manufacturing effectiveness, and pinpoint specialized uses or value-added traits that might make natural fiber composites economically competitive with synthetic equivalents. Interdisciplinary research in the fields of materials science, chemistry, processing technology, and engineering is necessary to address these issue statements. Natural fiber composites can become more dependable, adaptable, and sustainable materials for a variety of applications by solving these difficulties.

Investigating the difficulties and enhancing the performance of a jute fiber-polyester hybrid composite filled with sugarcane bagasse are the goals of this study. Due to the benefits of jute fibers, polyester matrix, and sugarcane bagasse filler combined, the composite shows remarkable potential for a variety of applications. To maximize its mechanical characteristics, processability, and cost-effectiveness, a number of difficulties must be resolved. Insufficient fiber-matrix adhesion, poor filler dispersion, unfavorable mechanical qualities, and processing issues are among the major problems that this study aims to pinpoint and recommend workable solutions for. The objective is to produce a high-performance and ecologically sustainable composite material suited for a variety of industrial applications by resolving these concerns.

1.4 Objectives

I. To fabricate a jute fiber polyester hybrid composite filled with sugarcane bagasse.

II. To conduct the mechanical testing of sugarcane bagasse reinforcement on the mechanical properties of polyester resin.

III. To analyze whether the reinforced composite ratios differ significantly from one another.

1.5 Project Scope

The goal of this study is to explore the mechanical characteristics of materials made from discarded jute fiber polyester hybrid composite that filed with sugarcane bagasse. There will be four sections to this research. The hand lay-up technique is used to fabricate the materials at the initial step. While the second stage uses a CNC router machine to carve the manufactured material into the testing specimen. The specimen's mechanical characteristics are tested in the third step utilizing tensile with ASTM D3039, flexural with ASTM D790, impact tests with ASTM D6110 and water absorption with ASTM D570. Obtaining the greatest results and comparing them to earlier study is crucial. The study of the outcomes using statistical analysis (ANOVA) is the last step. Based on the mechanical characteristic's analysis results, we will determine the optimal ratio which are 20:80, 40:60, 50:50, 60:40, 80:20 for sugarcane bagasse hybrid composite.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review of mechanical properties of jute fiber polyester hybrid composite that filled with sugarcane bagasse will be covered in this chapter. This chapter was also to discuss each of the fabricated materials and equipment to performed into the specimen. Goal of this study is to identify strategies for improving the strengthens by using tensile, flexural and impact test.

2.2 Natural Fiber Composites

Natural fibers are used as the reinforcing element in composite materials to create natural fiber composites. These fibers are produced using a variety of plant materials, including jute, flax, hemp, sisal, kenaf, bamboo, and coir. Traditional composites that employ synthetic fibers like carbon fiber or glass fiber are an alternative to natural fiber composites (Vijayan et al., 2019). These composite's natural fibers have excellent mechanical qualities, such as high strength, stiffness, and toughness, which make them acceptable for reinforcing in a variety of contexts. To generate a composite material with improved characteristics, these fibers are often mixed with a matrix material, such as thermoset or thermoplastic polymers (Summerscales et al., 2018). Depending on the intended shape and use, natural fiber composites are produced by first impregnating the fibers with the matrix material and then putting them through compression molding,injection molding, or filament winding.

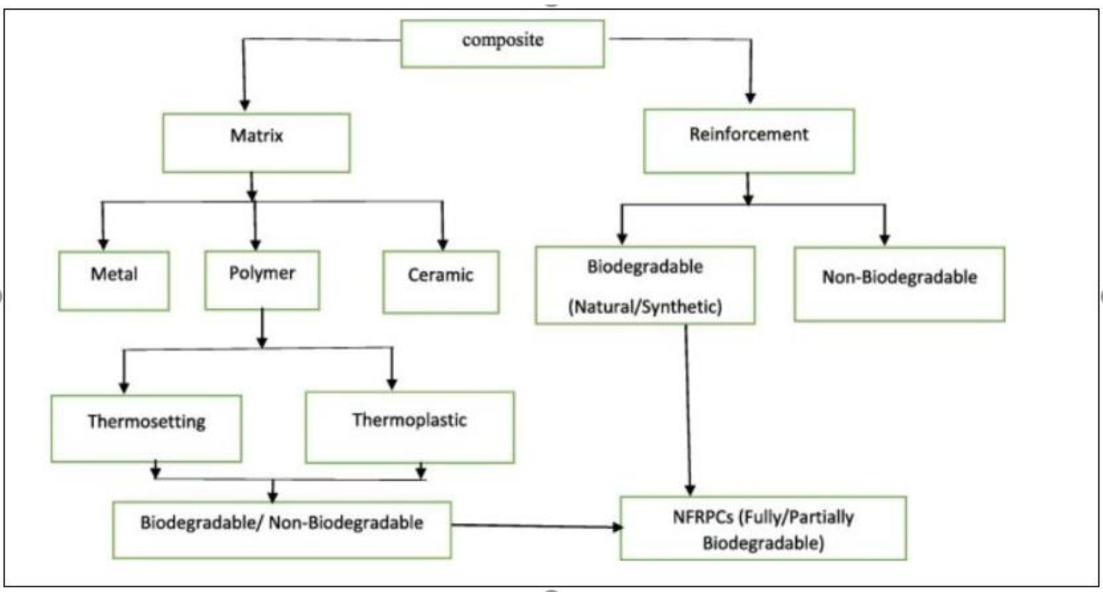


Figure 2.1: Types of natural fiber reinforced composite (Summerscales et al., 2018).

It is crucial to remember that natural fiber composites have significant drawbacks as well. They may be more prone to absorbing moisture, which might have an impact on their dimensional stability and mechanical characteristics. However, natural fibers have drawbac such as high moisture absorption, high anisotropy, limited compatibility with traditional resins, and being less homogenous than glass and carbon fibers (Guru et al., 2015). Furthermore, the variable nature of natural fibers might make it difficult to achieve consistent performance in composite materials. Despite these difficulties, the research and development of natural fiber composites has been sparked by the growing demand for environmentally friendly and sustainable materials. These efforts aim to improve the performance of natural fiber composites, broaden their scope of applications, and further investigate their potential as an alternative to synthetic fiber composites.

Figure 2.2: The types of natural fibers (Kamrun et al., 2019)

A composite material that combines jute and polyester fibers as its reinforcing elements is referred to as jute fiber-polyester hybrid. It is a type of hybrid composite that makes use of both material's distinctive features to improve mechanical and structural performance. Natural fiber recognized for its high tensile strength, low density, and biodegradability is jute fiber, which is obtained from the jute plant. Due to its outstanding specific strength and stiffness, it is frequently employed as a reinforcing fiber in composites. Jute fibers are renowned for giving composite materials strong impact resistance and damping qualities. Contrarily, polyester is a synthetic polymer with superior mechanical, chemical, and dimensional stability qualities. Due to their excellent strength, hardness, and longevity, polyester fibers are frequently utilized in composite materials. They support the composite's overall strength and stiffness. A hybrid composite made of jute and polyester fibers can combine the best qualities of both fibers, producing a material with a variety of useful features.

2.3 Sugarcane Bagasse Fiber Properties

According to Mahmud et al, (2021) shows that sugarcane is widely planted in tropical areas. Around 1.84 billion tons of sugarcane were produced globally in 2017. Both sugar and alcohol mills employ it. However, it cannot be completely devoured by such mills sinceafter being used in those mills, roughly 30% of the pulpy fibrous waste is created. These were called sugarcane bagasse where the cellulose was the primary component of sugarcane bagasse. It is manufactured in huge amounts all around the world. It is a sort of waste product from the sugar industry. The paper industry is where it is most frequently utilized, however researchers have hypothesized that other mechanical and chemical processes might aid in the extraction of cellulosic fibers, pure cellulose, cellulose nanofibers, and cellulose nanocrystals. These extracted components are used in a variety of composite material and generated cellulosic fiber manufacturing processes.

The use of sugarcane bagasse in the soil to enhance the adobe’s mechanical and physical qualities has been documented in the literature. The research done by Ouedraogo et al, (2022) was shown the impact of sugarcane and synthetic termite saliva additives on the mechanical characteristics of reinforced adobes. This study examined their static bending strength and compressive strength. The results indicated that the adobe components and compressive strength interacted well, with the improvement reaching 60%. It has beenshown that the addition of sugarcane bagasse to the clayey matrix significantly enhances themechanical characteristics and decreases the thermal conductivity and water absorption kinetics of the adobes, both of which are connected to their microstructure and are mostly caused by the presence of cellulose (Aubert et al., 2020). Sugarcane bagasse's rough surface and the presence of glue of cellulose increase its observance to the clayey substrate, which slows the spread of fractures in adobes. The development of hydrogen bonds between sugarcane molecules and the clayey minerals is caused by the presence of bagasse fibers, which may account for the improvement in physic mechanical characteristics.

Figure 2.3: Sugarcane bagasse sample (Aubert et al., 2020).

It was determined that the sugarcane bagasse fiber density was 0.616 g/cm^3. In Table **2.4** shows the compares of densities of some inorganic, synthetic, and natural fibers used in buildings for sound absorption and thermal insulation with those of bagasse fiber. Bagasse has a lower density than the majority of fibers, which makes it excellent for construction applications because it is lightweight. It is also important to note that, in comparison to high-density fibers, fibers of lesser densities generate voluminous and bulky fibrous structures for a given areal density. In turn, this produces fibrous structures perfect for purposes such as thermal insulation and sound absorption (Mehrzad et al., 2022).

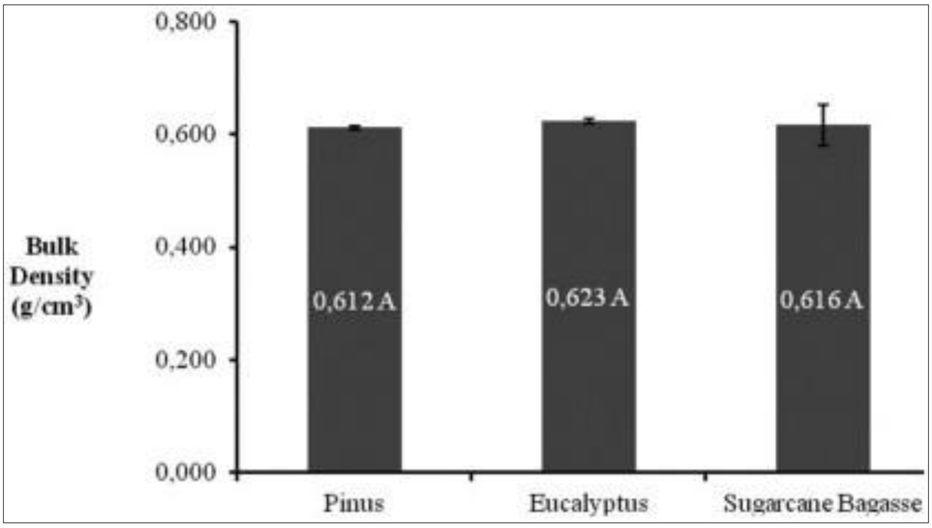


Figure 2.4: Density of different fibers (Oliviera et al., 2019)

2.4 Unsaturated Polyester Resin Hybrid Composite

Unsaturated polyester resin is a linear polymer containing an ester link and an unsaturated double bond that is created by the polycondensation of either saturated dibasic acids and unsaturated diols or unsaturated dibasic acids with unsaturated diols. Styrene unsaturated polyester and the resin molecular chain's C=C bond have the potential to crosslink copolymerize, resulting in four different structural configurations: intermolecular crosslinking with or without linking through styrene monomers intramolecular crosslinking with or without linking through styrene monomers branching on the polyester molecule by styrene and free styrene homopolymerization (Gao et al., 2019)

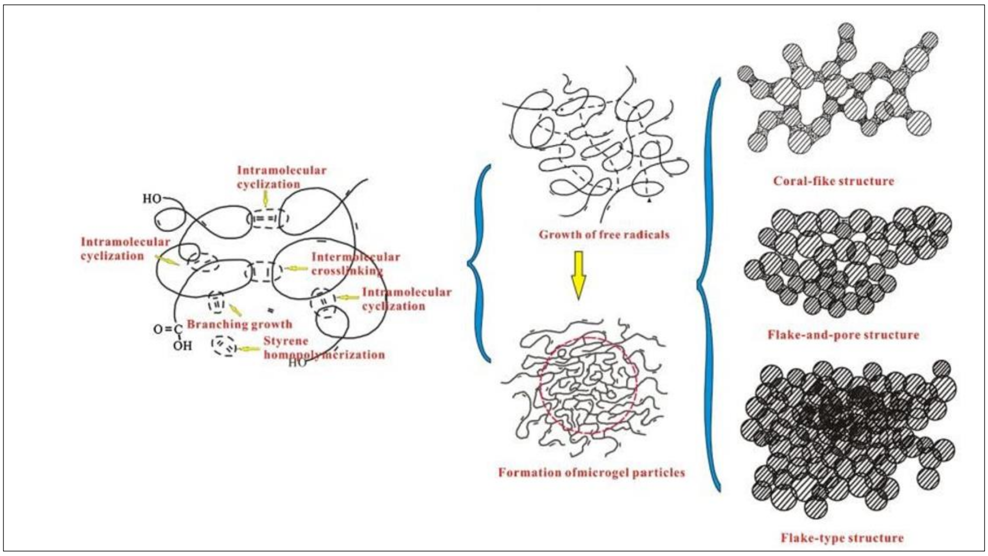


Figure 2.5: The schematic diagram of polyester resin of curing (Gao et al., 2019)

The radical curing process that involves several stages of chain initiation, chain development, chain termination, as well as chain transfer, is the method used to cure unsaturated polyester resin. Despite the fact that there are several ways to start free radicals, including heat, light, electron beams, ultrasonic waves, and others, the employment of free radical initiators is the most common. The unsaturated polyester resin initiating system can be made up of a normal temperature high-temperature initiation system, a high-temperature initiation system, a photoinitiation system, a radiation initiation system, or other initiation systems depending on the temperature of the free radical initiator and the initiation conditions.

According to Sapuan et al, (2020) said, composites that are created by combining two or more different types of fibers as reinforcement in a matrix are known as hybrid composites. Single-fiber reinforcement cannot provide certain features and qualities that hybrid composites provide. Producers can precisely alter composite qualities to meet the needs of a distinct structural consideration through hybridization. The goal of hybridization is to create new materials that retain the benefits of their components while being more affordable. Hybrid composite fiber reinforcements, however, may come in a variety of price ranges. The classification of hybrid composites as interplay and interplay hybrid composites was also stated in the same publication. While the homogeneous fibers are blended in the same layer for interplay hybrid composites, layers of two or more homogeneous fibers are stacked in layers with different stacking sequences for interplay hybrid composites. More researchers and scientists investigated the use of natural fibers including kenaf, flax, jute, and sugar palm with glass fiber in hybrid composites to protect human health and the environment (Afzaluddin et al., 2019).

Table 2.1: Density of unsaturated polyester resin (Afzaluddin et al., 2019)

Material			
Properties	Unsaturated Sugar Palm Fiber	Treated Sugar Palm Fiber	Unsaturated Polyester
Density (g/cm^3)	1.292	1.193	1.212
Tensile strength (Mpa)	156.96	332.28	44.40
Tensile modulus (GPa)	4.96	17.27	3.54
Elongation at break (%)	7.98	5.3	2.15

2.5 Tensile Strength Test

The term "tensile strength" describes the highest tensile stress that a material can sustain before it breaks or permanently deforms. First, the jute fiber is obtained from sugarcane bagasse, which is the fibrous residue left after extracting the juice from sugarcane stalks. The bagasse is collected, cleaned, and processed to extract the jute fibers. Second step, make a sample preparation by cutting the fiber into uniform lengths and any impurities or knots must be eliminated. Next, mounting the sample to the machine that equipped with clamps or grips that firmly hold the fiber ends, ensuring a solid configuration for the test. Then, the sample of jute fiber is slowly pulled by the tensile testing apparatus measures the applied force and the resulting elongation or deformation of the fiber throughout this operation. Lastly, record the data and calculate the tensile strength that expressed in units of force per unit are, such as MPa or N/mm^2.

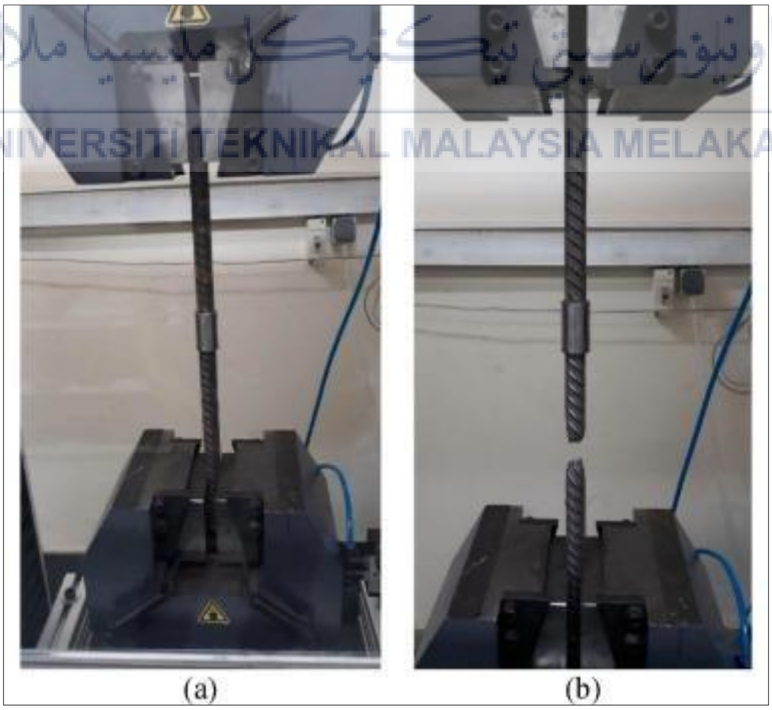


Figure 2.6: Tensile strength machine (Hamed et al., 2022)

The force necessary to stretch and lengthen the composite until it reached the break point was determined by a tensile test. The test apparatus was used to conduct the tensile test in accordance with ASTM D3039 at a specimen temperature of 23 °C and relative humidity of 50%. Each sample was 250 mm long and 25 mm wide (Aulia et al., 2019). When sugarcane bagasse fiber is utilized as a constituent in hybrid composites, a number of variables, such as the matrix material and the reinforcement combination, can affect its tensile strength qualities. In order to generate a synergistic effect and improve overall mechanical qualities, hybrid composites frequently blend several types of reinforcing components, such as fibers. In comparison to utilizing sugarcane bagasse fiber alone, combining it with additional reinforcing fibers like glass fibers or carbon fibers can increase tensile strength.

Figure 2.7: Example of tensile testing specimen (Yasir et al., 2021)

2.6 Flexural Strength Test

Flexural strength is the capacity of a material to resist bending or flexing without breaking, it calculates the maximum stress or force that a material can bear under bending conditions. The composite's capacity to withstand bending or deflection in the presence of external loads depends on its flexural strength. A composite that has a higher flexural strength may bear applied loads without experiencing considerable deformation or failure, resulting in structural stability. Flexural strength has a role in how well the composite distributes applied loads. The pressure is spread uniformly between the jute fibers and sugarcane bagasse particles thanks to a greater flexural strength, which prevents localized stress accumulation and subsequent failure. This machine is inversely proportional to the stiffness and rigidity of the composite. A material with a higher flexural strength will be stiffer and more rigid because it will be more resistant to deformation. For applications where, dimensional stability and resistance to bending are critical, this feature is significant. Jute fiber-filled composites may be designed and optimized more effectively by being aware of their flexural strength. It should have chosen the right thicknesses, forms, and dimensions to suit certain structural requirements and guarantee safety in diverse applications by understanding the material's flexural strength.

Figure 2.8: Example of flexural strength machine (Hamed et al., 2022)

The ASTM standard known as ASTM D790 (Abramovich et al., 2017) which is standard measure Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials is used to measure the flexural strength of composite materials. The standard lays forth instructions for evaluating many kinds of materials, including polymer composites. The preparation of this machine was rectangular specimens that meet certain specifications. In accordance with the thickness and predicted flexural modulus of the material, the standard offers recommendations for specimen size. The span length distance between supports is typically 48 mm for four-point bending and 64 mm for three-point bending. The specimen width is typically approximately 13 mm Chandra et al., 2019).

2.7 Impact Test

The energy that a material absorbs during fracture is calculated using an impact test. This absorbed energy serves as a tool to examine the temperature-dependent brittle-ductile transition and serves as a gauge of a material's toughness. It aims to establish the material's ductility or brittleness. It's important to keep in mind that the particular impact testing settings and methodology may change based on the testing standards or unique research needs. The assessment of impact characteristics in jute fiber products is consistent and dependable when standard techniques are followed.

Figure 2.9: Example of impact test machine (Yasir et al., 2021)

The general overview of how impact testing works in jute fiber are include specimen placement, impact force, measurement and analysis and fracture analysis. The impact test for jute fiber typically involves Preparing standardized specimens, such as jute fiber mats, woven textiles, or composite panels incorporating jute fibers. Using specialized testing apparatus like an impact pendulum or drop tower, the specimens are exposed to an impact force. By performing impact tests, engineers and researchers can evaluate and compare the impact resistance of different materials, optimize material selection for specific applications, and ensure product safety and reliability. The standard ASTM of impact test known as ASTM D6110 (Rangasamy at al., 2021). Although this standard was originally created to test plastics, composite items that contain jute fibers can also use it.

2.8 Water Absorption Test

The highest possible amount of water absorption for the produced hybrid composites was examined in accordance with ASTM D570 (Reddy., 2021). Water absorption testing is a key metric for determining jute fiber's water resistance and durability. The amount of water absorbed by jute fiber can reveal information about its moisture absorption capabilities and prospective applications in various conditions. Water absorption testing conditions include water absorption for 24 hours at 23 C, water absorption for 24 hours at 100 C, water absorption at saturation, and water absorption at equilibrium. The water absorption test determines the quantity of water absorbed by the composites. For this water absorption testing was using a standard specimen's dimensions are 60 mm x 60 mm x 10 mm. The distinct laminate test specimens will be tested in water. Before the test and weighing, the specimens are evenly dried. The specimen will be submerged in distilled water for this project to investigate the rate of water absorption and the change in thickness of the specimen. The formula may be used to compute the percentage of water absorption by mass after being immersed in water.

$$W(\%) = \frac{m2-m1}{m1} \text{ x } 100$$

Where W is the percentage weight, M2 is the mass of the specimen after immersion in water, and M1 is the mass of the specimen before immersion in water.

2.9 Statistical Analysis (ANOVA)

Analyzing the properties of jute fiber requires the use of statistical analysis, specifically Analysis of Variance (ANOVA). ANOVA permits the comparison of means across various groups or regimens, thereby facilitating the determination of whether there are significant differences between them. ANOVA permits the comparison of fiber properties, such as tensile strength, elongation, modulus, and moisture content, among various jute fiber groups or treatments. This analysis identifies any significant differences in fiber properties caused by variations in processing techniques, fiber therapies, or fiber sources. ANOVA permits the comparison of fiber properties, including tensile strength, elongation, modulus, and moisture content, among different jute fiber groups or interventions. This analysis identifies any substantial differences in fiber properties resulting from variations in processing techniques, fiber therapies, or fiber sources.

ANOVA compares the means of multiple samples to determine the effect of one or more variables on the outcome. Using the Taguchi method, Bankoti et al. (2017) optimized the tensile stress and flexural stress of an epoxy-based walnut-reinforced composite. The percent weight of filler and loading speed had a significant effect on the ANOVA for tensile stress values at a confidence level of 95%. Increasing loading speed increases tensile stress, and the optimal tensile stress value is achieved when the infill content is 10 percent and loading speed is increased. Nonetheless, in the flexural test, both the filler weight percent and the loading speed have a significant effect on the flexural stress value at the 95% confidence interval. Flexural strength reaches its maximum at 10% filler content and then begins to decline until 25% filler content. In addition, flexural strength increases as packing speed increases. Tables 2.7 and 2.8 display the ANOVA table for tensile and flexural stress values, respectively.

Table 2.2: ANOVA table for tensile stress (Bankoti *et al.*, 2017)

Source	DF	Seq (SS)	Contribution	Adj (SS)	Adj (MS)	F-Value	P-Value
A (percentage filler wt.)	5	308.5	75.90%	308.5	61.71	29.34	0
Loading Speed	2	76.91	18.92%	76.91	38.46	18.28	0
Error	10	21.03	5.17%	21.03	2.103		
Total	17	406.5	100.00%				

Table 2.3: ANOVA table for flexural stress (Bankoti *et al.*, 2017)

Source	DF	Seq (SS)	Contribution	Adj (SS)	Adj (MS)	F-Value	P-Value
A (percentage filler wt.)	5	1004	62.80%	1004	200.8	57.91	0
Loading Speed	2	560	35.04%	560	280	80.77	0
Error	10	34.67	2.17%	34.67	3.467		
Total	17	1598	100.00%				

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter gives comprehensive information on the methods or approaches used to locate and examine the data related to this topic. The methodological section of this chapter enables the reader to assess the dependability and overall procedure critically. In this study, the process flow was employed to achieve the present work aim. This process flow was used to complete the current work objective. There will be four sections to this research. The hand lay-up technique was used to fabricate the materials at the initial step. Nonetheless, the second step involves utilizing a CNC router machine to carve the manufactured material into the testing specimen. The specimen's mechanical characteristics were tested in the third step utilizing tensile, flexural, and impact tests and the balance will use to absorption test. The best outcome must be attained, and prior studies must be compared. The study of the outcomes using statistical analysis was the last step. The optimal ratio of coconut leaf reinforced by polyester resin will be produced based on the findings of the mechanical properties analysis. Finally, this chapter had defined the experimental detail.

3.2 Experimental Process

There was the process on how to run this project. The necessary material preparation must be made before moving on to the next level. Natural fiber, jute fiber, polyester resin, and mold were some of the materials that must be ready where the hand lay-up method has been used in this stage. Secondly, to cut the specimen, a CNC router machine was employed. These devices will slice the specimen once it was prepared for creation. A CNC router will beused to cut the specimen, which will then be separated into four portions for tensile testing, flexural testing, impact testing and water absorption. After the cutting process was finished, the cutting method's outcome parameters will be examined to determine the outcome. Squares measuring 250mm x 25mm x 3 mm will be cut from the cloth. Then, using testing tools, the material's tensile strength was ascertained.

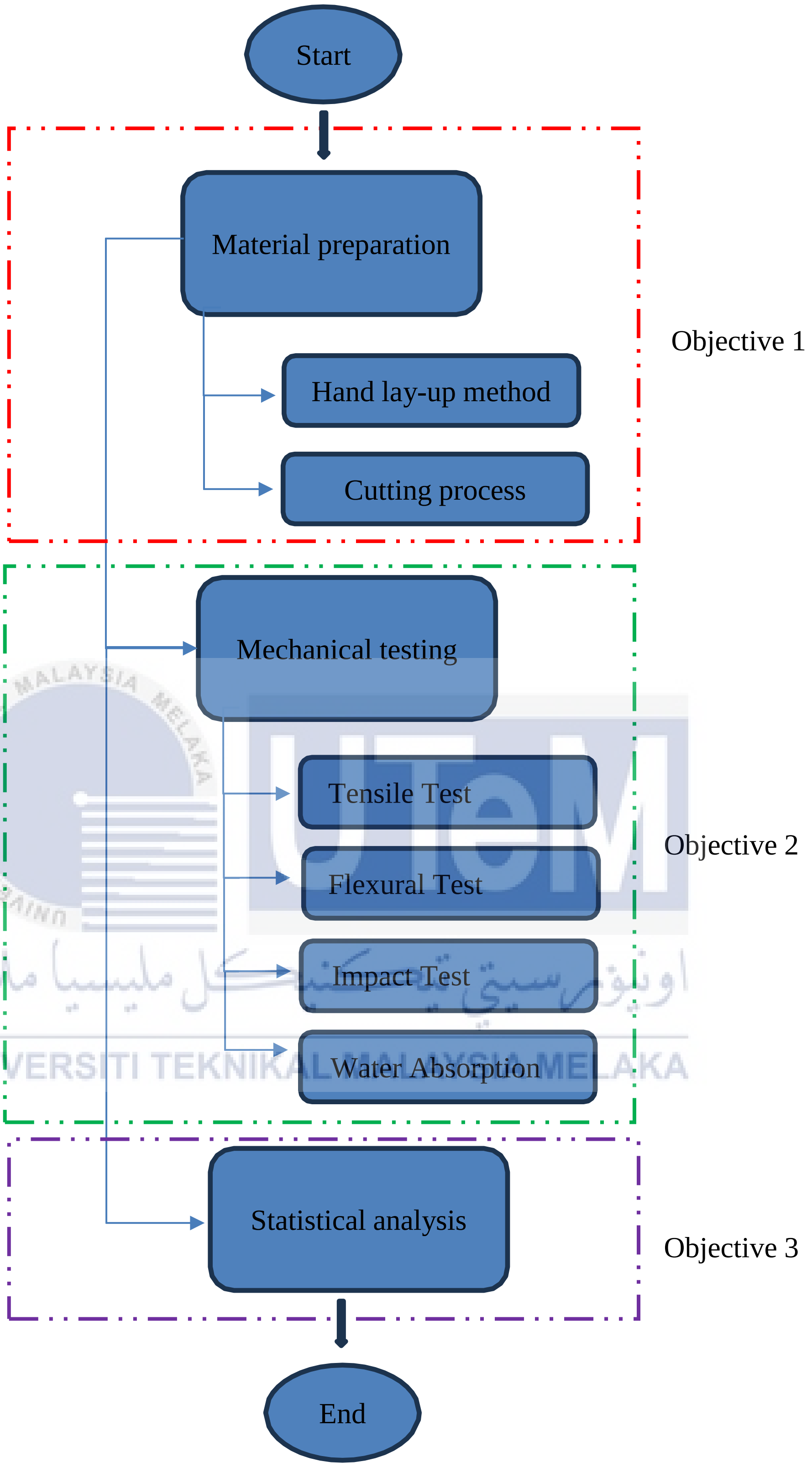


Figure 3.1: General flowchart methodology process

Several procedures were involved in assessing the mechanical characteristics of jute fiber-polyester hybrid composites packed with sugarcane bagasse. In material preparation, the jute fibers and polyester resin was the matrix material and collect the sugarcane bagasse as a filler of material. For the hand lay-up method, it was the composite fabrication where themixture of the polyester resin and fiber composite (jute fiber and sugarcane bagasse) was poured to the mold. After curing, the composite will start to cut to the desired shape and dimension by using CNC machine and will be prepared multiple samples for statistical analysis. Then, the composites will perform various mechanical test that include flexural test, tensile test, impact test and water absorption test. After passing all mechanical testing phases, the balance of the jute fibre polyester hybrid composite filled sugarcane will then be tested for water absorption.

3.3 Details flowchart process

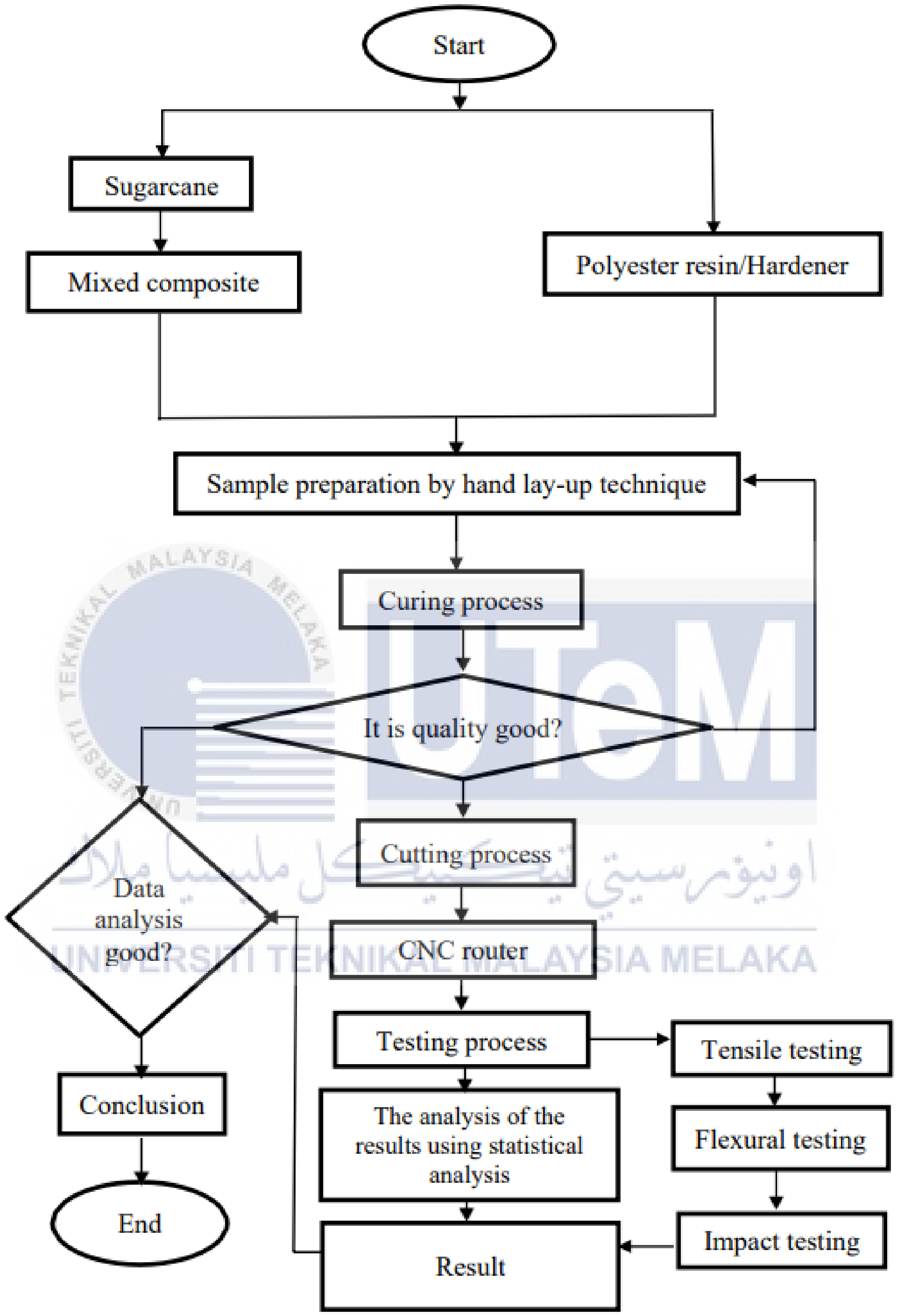


Figure 3.2: Details flowchart process

Simply understand, flowcharts were commonly used to visually illustrate project processes, workflows, and decision-making channels. It was some of the characteristics and advantages of utilizing flowcharts in project management, it gives a visual depiction ofthe project's operations, making complicated workflows and task relationships easier to grasp. Flowcharts include decision points that represent choices or conditions in the project.These decision points help project managers and team members understand the available options and make informed decisions based on predefined criteria or rules. Flowcharts were also used to illustrate algorithms and job-related operations visually. On the flow chart, the phases were represented by various sorts of boxes that were connected by arrows. This graphic depicts a possible solution to a problem. Simple system procedures were planned and documented using flowcharts. A flow chart can assist you in understanding each phase of the process and how it was carried out. Figure 3.2 displays the flow of the procedure from startto completion.

The flowchart procedures illustrate the complete or entire workflow. The research process from beginning until the end of the process were shown in Figure 3.2. For the first step, the specimen will be created where the polyester resin and hardener will be applied to the sugarcane bagasse with a technique called sandwich lamination before properly cutting it to a specific size. Second, the CNC router machine was employed in the specimen cutting method. When the specimen was finished, it will be cut by this equipment. The specimen willbe sliced with a CNC router machine and separated into three portions for tensile testing, flexural testing, and impact testing. According to ASTM D3039, the parameters for tensile testing were 250 mm length x 25 mm width x 3 mm thickness, and the measurements for flexural testing were 250 mm length x 25 mm width x 3mm thickness. According to ASTM D256, the parameters for impact testing were 55mm length x 10mm width x 10mm thickness. Following the cutting procedure on the specimen, collect and assess data. If the data collected was insufficient, the specimen will be sliced and data will be collected in order to acquire greatresults.

3.4 Material Preparation

In the initial instance, sugarcane bagasse was gathered from the "Bazaar Ramadan." The sugarcane bagasse must be peeled from the sugarcane rind in order to be collected prior to the next step, which involves cleaning the bagasse with tap water for one day. The sugarcane bagasse was then desiccated in the sun for a few days to eliminate any remaining moisture. After the sugarcane bagasse has been completely dried, it was cut into small fragments with blades or another cutting device so that it can be crushed with a crusher machine. Once finished, store the sugarcane bagasse powder near an appropriate container to prevent contact with water. Following the transformation of sugarcane bagasse into powder, collect the powder according to its density. Sugarcane bagasse powder was incorporated into certain reinforced polyester resin and hardener sandwiches. The powder then left at ambient temperature for two days. The crushed of sugarcane bagasse powder was depicted in Figure 3.3. The average dimension was used to generate composites by using microscope equipment from laboratory technology at FTKMP. To fabricate the material, hand lay-up method was used in this process. It was the open molding technique that has beenused to manufacture a variety of composite products spanning in size from small to large. This project's mold dimensions were 31.2 cm x 21.2 cm with thickness 1 cm. The measurement of the sugarcane bagasse must be measured to ensure that the majority of the bagasse has the same mass and density. Finally, the size of the material was conducted utilizing sieve analysis equipment, which assessed the sugarcane bagasse as 2 mm.

a) Cutting into small pieces b) Soak the bagasse c) Dry the bagasse

Figure 3.3: Material preparation of sugarcane bagasse

Figure 3.4: Sugarcane powder and crusher machine

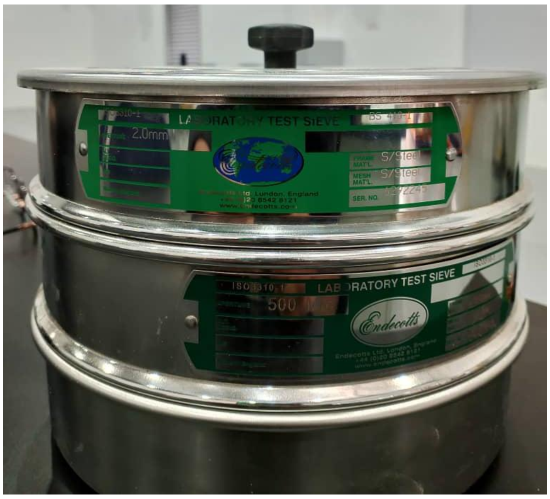


Figure 3.5: Sieve analysis equipment

3.4 Hand Lay-up Method

In order to generate a composite material, jute fibers loaded with sugarcane bagasse were manually layered in a mold before being saturated with a resin matrix. The hand lay-up method was an open molding process that has been used to create a variety of composite products in sizes ranging from small to large. To generate this process, the mold has chosen by the sizing of 31.2 cm x 21.2 cm and 1 cm of thickness. In order to pour the exact mass of mixture into the mold, it must to identify the volume of mold which was 664.44 cm^3.

Table 3.1: Procedure of Hand Lay-up Process

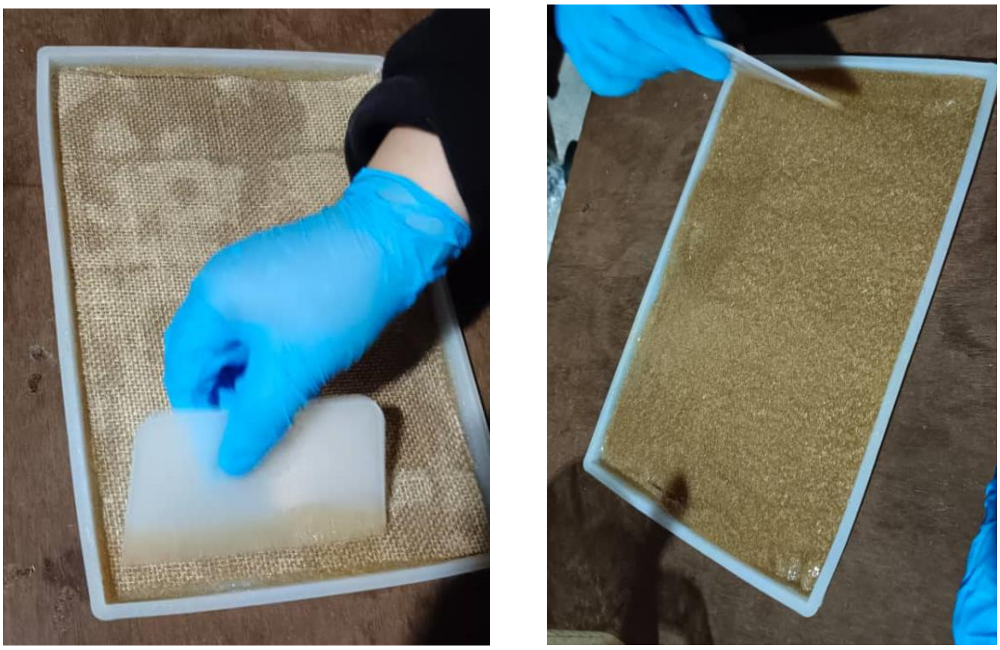
Process	Description
Material and mold preparation	Collect polyester resin, sugarcane bagasse, jute fibers, and an appropriate hardener. To get rid of any contaminants, clean and dry the jute fibers and sugarcane bagasse. Jute fibers should be cut to the desired length, which was commonly 20 to 50 mm.
Mold preparation	Choose a mold that will produce the composite in the desired form and size. To make it simple to remove the composite, apply a releaseagent to the surface of the mold. Make sure the mold was clean and contaminant-free.
Lay-up process	Blending the jute fiber with sugarcane bagasse mixture in the desired ratio where it will be 5 testing of ratio. Then, combine the polyester resin and hardener. On the mold's surface, spread a layer of the jute fiber and sugarcane bagasse mixture. Layering the fiber mixture and resin repeatedly was necessary to attain the desired composite thickness.
Curing and demolding	As instructed by the resin maker, let the composite cure. Utilize the proper curing processes. Lastly, carefully remove the composite fromthe mold after it has totally dried.

Weighing the sugarcane bagasse fiber in accordance with the intended ratios. The weighing of hardener, polyester resin, and sugarcane bagasse fiber was shown in a) of Figure 3.5. Next, utilizing a stick in the mixed container, the polyester resin and hardener were evenly combined. Pour the already-weighted sugarcane bagasse fiber into the polyester resin and hardener mixture. The polyester resin and hardener were shown in b) of Figure 3.5.

a) Natural fiber and polyester resin b) Hardener

Figure 3.6: Natural fiber and polyester resin with hardener mixtures

A specific quantity of sugarcane bagasse fiber was present in the sandwiches method that were constructed using reinforced materials composed of polyester resin and hardener. Prior to laying up the polyester resin on the mold, the mold had to be cleaned and dried using a silicone mold release.



a)Layering the jute b) layering the jute

Figure 3.7: Layering of mixtures

After carefully filling the molds with the mixture and flattening the specimen with hand lay-up procedures, the specimen was allowed to dry for 48 hours. The composites were taken out of the molds once they had completely dried.

Figure 3.8: Final sample of sugar cane bagasse

3.5 Cutting Process (CNC machine)

In cutting processes, CNC machines provide excellent precision and accuracy. This was essential when working with composite materials since accurate cutting was required to keepthe material's integrity and structural performance. For complex forms and elaborate designsin particular, CNC machines ensure consistent and reproducible cutting results. Compositesmade of jute fiber and sugarcane bagasse can be utilized to make intricate forms and parts. Complex toolpaths can be precisely followed by CNC machines, making it possible to produce elaborate designs that would be challenging or impossible to do manually. This skillenables the manufacturing of highly specialized, customized composite parts.

Next, the mixture will be taken out of the mold and cut using a CNC router into four distinct sizes to meet the requirements of each ASTM standard for specimen size. The MODELA PRO2 (MDX-540) CNC router was the one that was being used. The coordinate axiswas set to zero at the computer control while the specimen was positioned on top of the vise.By pushing the button on the control panel, the cutting operation was started with the spindlespeed set between 100 and 200 rpm. Depending on the required mechanical testing, the mold size specimen will be divided into three distinct types of ASTM standards. According to thespecifications of the ASTM D3039 and ASTM D790 model standards, the dimension utilized for tensile and flexural testing was 250 mm x 25 mm x 5 mm. According to the ASTMD6110 model standard, the dimensions for the impact testing were 60 mm x 15 mm x 5 mm. According to ASTM D570 model standard, the dimensions for the water absorption test were60 mm x 60 mm x 10 mm. Before utilizing the machine, its condition will be checked and updated, and it will be made sure the cutting tool was positioned correctly to provide a steadycutting operation.

Table 3.2: Procedure of cutting process

Process	Description
CNC programming	Create a CNC programmed containing the cutting parameters, tool selection, and toolpath instructions for a specific cutting operation. Then, generate the cutting programmed with dimension by using Computer-Aided Manufacturing Software.
Material preparation	Ensure that the jute fiber-filled sugarcane bagasse composite was securely attached to the worktable or fixture ofthe CNC machine. Align the composite material precisely with the predetermined cutting path.
Cutting parameter	Determine the cutting parameters based on the properties of the composite material, including its density, fiber orientation, and resin matrix. Adjust the spindle speed, feed rate, and depth of cut
Cutting process	Commence the programmed cutting operation on the CNC machine. Observe the cutting procedure to ensure that the machine was accurately cutting the composite material and that the material was being cut effortlessly.
Finishing	Remove the cut portions from the CNC machine when the cutting operation was complete.

Samples must be cut in accordance with the designated size. The cutting tool was positioned correctly to provide a smooth cutting process and the production of a satisfactory specimen size. The machine was prepared and will operate in good condition. The three different ASTM standards that were sliced to fit a certain size were shown in Figure 3.9 and Figure 3.10.

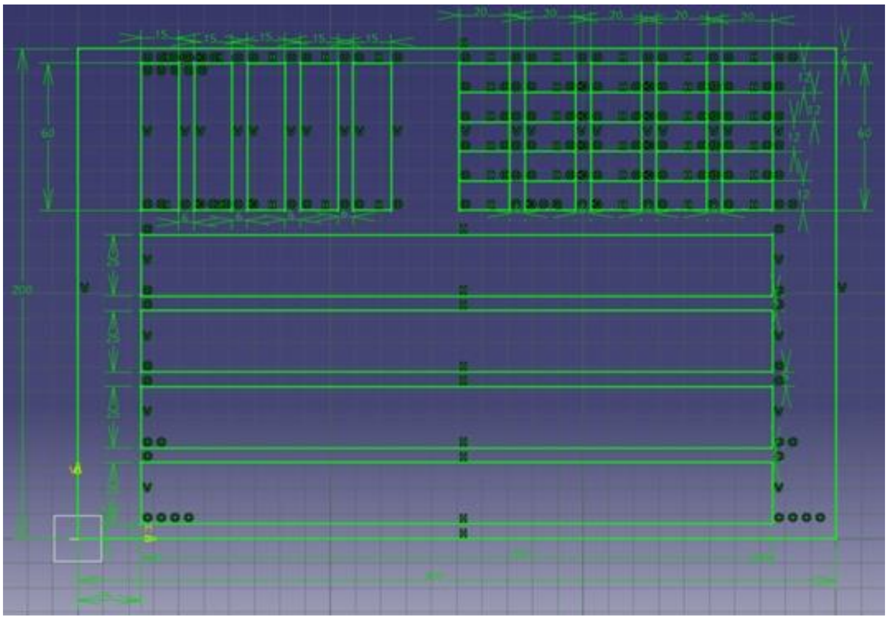


Figure 3.9: The dimensional design of specimen for tensile, impact and water absorbtion test

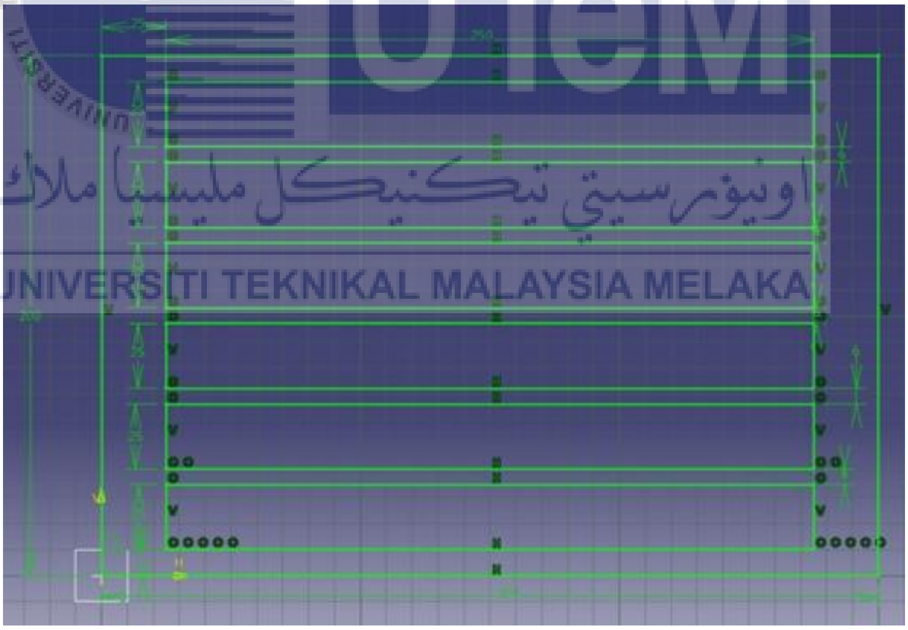


Figure 3.10: The dimensional design of flexural and tensile test

A CNC router machine was required in order to cut the composite sample. The experimental specimen's thickness and feed rate were determined by the input parameters. After the cutting process was finished, the cutting method's outcome parameters will be examined to determine the outcome.

Figure 3.11: Cutting process using CNC machine

Figure 3.12: Sample of sugarcane bagasse composite

3.6 Mechanical Testing

Evaluation of the mechanical properties and efficacy of jute fiber loaded with sugarcane bagasse composites requires mechanical testing. These tests provide quantitative data on a variety of mechanical parameters that can be used to evaluate the material's strength, rigidity, tenacity, and durability. Some typical mechanical experiments conducted on jute fiber-filled sugarcane bagasse composites were flexural testing, tensile testing and impact testing. The specimen was subjected to the tensile strength test per ASTM D3039, the flexural strength test per ASTM D790, the impact strength test per ASTM D6110, and the water absorption test per ASTM D570.

3.7.1 Flexural test

Flexural testing, also known as the three-point bending test, can be used to evaluate the flexural strength and rigidity of jute fiber loaded with sugarcane bagasse composites by using ASTM D790. Flexural testing provides valuable information regarding the bowing or flexural strength of a material. It measures the composite's flexural strength, or the utmost stress it can withstand prior to failure. This information was essential for evaluating the composite's structural integrity and load-bearing capacity in applications involving bending forces. Calculated from the linear portion of the load-deflection curve, the flexural modulus represents the resistance of the material to deformation under bending stresses. It indicates how the material will respond to applied bending forces, providing insight into its suitability for applications requiring a particular level of rigidity. The results of flexural testing can be used to predict the performance of composites containing jute fiber and sugarcane bagasse in real-world applications. Engineers can make informed judgements regarding the material's suitability, design optimization, and structural performance by correlating the flexural properties acquired from the tests with the anticipated bending loads and conditions in the intended application.

Table 3.3: Procedure of flexural test

Process	Description
Specimen preparation	According to testing standards, the typical specimen shape wasrectangular with specified length, breadth, and thickness. Verify that the margins of the specimen by using standard ASTM D790.
Test setup	Place the specimen with its longitudinal axis parallel to the supports of the flexural testing equipment.
Loading	According to the testing standards, gradually increase the load at a constant rate until the specimen fractures or reaches the specified deflection.
Data collection	During the test, load cells and displacement sensors attached to the testing equipment measure the burden and its corresponding deflection.
Flexural properties and analysis	The flexural stress and flexural strain were identified by using the formula. Lastly, the data analysis was recorded to make a graph.

Flexural testing specimens were ASTM D790 (120 mm in length, 20 mm in breadth, and 3 mm thick) and were tested at a cross-head speed of 2 mm per minute. The specimen from a flexural test on the supporting pins was displayed in Figure 3.16. The computer will provide the results of the flexural test when this procedure was complete. The following information will be required for the flexural test and flexural strain at yield.

Figure 3.13: The flexural test process

3.7.2 Tensile test

Tensile testing provides vital information regarding a material’s tensile strength and resistance to stretching or drawing forces. It determines the composite’s maximal tensile strength, or the maximum tension it can withstand before breaking. This information assists in evaluating the composite’s structural integrity and load-bearing capacity in applications involving tensile forces. It will permit analysis of the failure mode and behavior of the composite material. The failure mechanisms, such as fiber disintegration, fiber/matrix debonding, and matrix fractures, can be identified by examining the fractured specimens after testing. Understanding the failure modes improves the design, manufacturing processes, and overall performance of the composite. The test apparatus was used to conduct the tensile test in accordance with ASTM D3039 at a specimen temperature of 23 °C and relative humidity of 50%. Each sample was 250 mm long and 25 mm wide.

Table 3.4: Procedure of tensile test

Process	Description
Specimen preparation	Dog bone-shaped samples made from the jute fiber filled with sugarcane bagasse composite material can becut or fabricated. For example, ASTM D3039 specifies that specimen dimensions must be within a certain range.
Test setup	Check that the equipment has been adjusted correctly toensure precise load and displacement readings.
Tensile testing	Depending on the norms or criteria, the machine will stretch the specimen until it breaks or until a certain elongation or load was attained.

Data collection	At different times in the experiment, determine the stress (load/original cross-sectional area) and strain (displacement/original gauge length) and collect the data.
Failure analysis	Failure mode and other pertinent findings, such as fiber breaking or matrix cracking, can be determined by analyzing the broken specimen after the test was completed.
Analyzation	Use the information you gathered to calculate the material's tensile qualities, such as its strength, elasticity, yield point, and elongation at break. Visualize the material's response to tension by plotting stress-strain curves.

Figure 3.14: Universal Testing Machine model Shimadzu

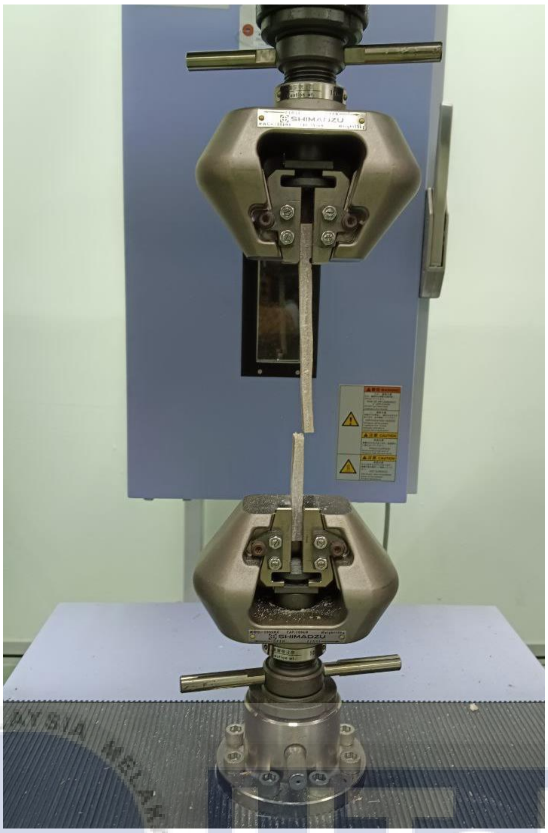


Figure 3.15: The successful fracture of tensile test

3.7.3 Impact Test

Composites made of jute fiber and sugarcane bagasse were subjected to impact testing to determine how well they can withstand shock. The toughness, energy absorption capacity, and resistance to crack propagation of a material can be learned a great deal from an impact test. There were many other kinds of impact tests, however the Izod impact test was frequently used to evaluate composites. The impact strength of a material was defined as its resistance tocracking when subjected to a sudden load or impact. It was a measure of how much impact energy a material can withstand. When the impact strength of a composite increases, it becomes more resistant to impacts and lasts longer.

A material's fracture toughness Indicates how well It can withstand Impact without cracking. It’s a measure of how well a material holds up against cracking. The composite’s ability to resist crack propagation and overall structural integrity improves with a greater fracture toughness rating. The ability of a material to absorb energy was shown through impacttesting. It determines how much force was needed to cause the composite to break or fail underimpact loading. A greater capacity to absorb and distribute impact energy was preferable sinceit suggests a lower chance of catastrophic collapse in the event of an impact.

Table 3.5: Procedure of impact test

Process	Description
Specimen preparation	Dog bone-shaped samples made from the jute fiber filled with sugarcane bagasse composite material can be cut or fabricated. For example, ASTM D6110 specifies that specimen dimensions must be within a certain range.
Test setup	Check that the equipment has been adjusted correctly to ensure precise load and displacement readings.
Test parameters	A pendulum weight, drop height, and other test parameters must be set on the impact testing equipment in accordance withthe relevant testing standards or test specifications.
Impact testing	According to the testing machine's instructions, either let the pendulum swing freely or apply the impact force. The specimen takes a hard hit when the pendulum swings and impacts the notched area.
Data collection	Using the impact testing machine's accompanying measuring scale or instrument, note the amount of energy the specimen absorbed during the impact.
Analyzation	The energy absorbed by the specimen during fracture or failure was a common representation of impact test findings, hence it was important to calculate and understand this value.

Figure 3.16: The impact testing machine INSTRON CEAST 9050

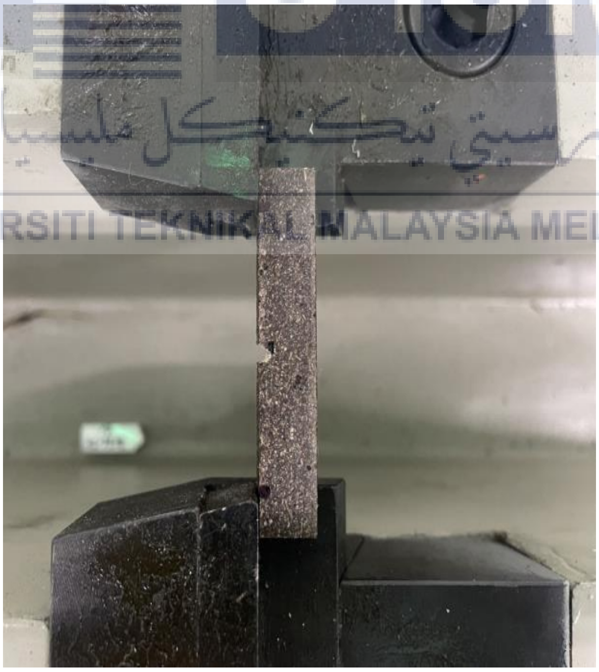


Figure 3.17: The specimen of the impact testing on an anvil and struck

3.7.4 Water Absorption

Composites made of jute fiber and sugarcane bagasse should take water absorption into account. The capacity of a substance to take in and hold water from its surrounding wet environment was known as its water absorption property. According to the ASTM D570 standard, the maximum water absorption of hybrid composites was developed. The purpose of this test was to determine the rate of water absorption by submerging the specimen for a predetermined amount of time. At 23 degrees Celsius, the specimen will be subjected to a water absorption test at 5 days, 10 days, 15 days, 20 days and 25 days.

Table 3.6: Procedure of water absorption

Process	Description
Specimen preparation	Composite jute fiber and sugarcane bagasse specimens ofthe desired size and form should be prepared and the specimens for the water absorption test was cut them as needed.
Initial Weight Measurement	Take an exact reading with a precision scale and note the starting weight of each specimen.
Water Immersed	the samples should be placed in a container or submerged entirely in water. Make sure the samples were completely submerged, not just partially, and not touching any of the container’s surfaces.
Water absorption and drying	Use a soft cloth or paper towel to carefully remove surfacewater from specimens without damaging them. Dry specimens in an oven.

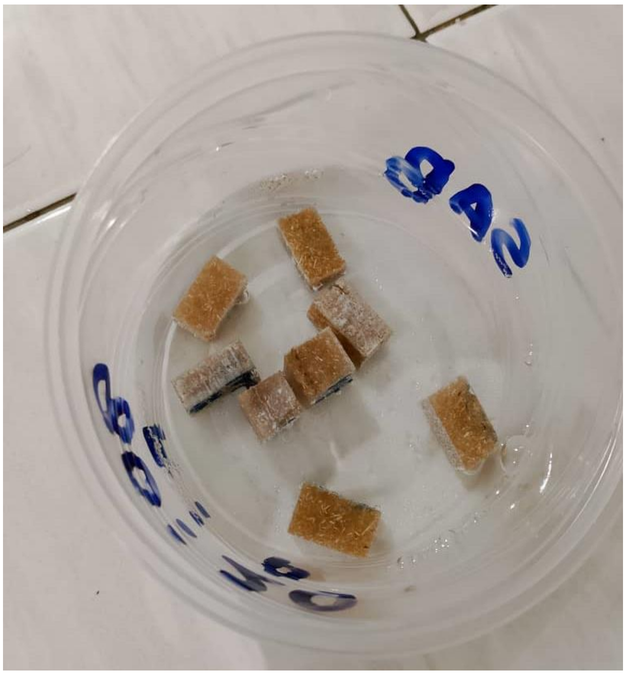


Figure 3.18: Soaking the sample

Figure 3.19: Weighing the sample

3.7.5 ANOVA Analysis

The final stage entails doing statistical analysis to examine the findings. Analyzing the mechanical property data will identify the optimal ratio for a hybrid composite of jute fiber and polyester, which was filled with sugarcane bagasse. ANOVA was a statistical technique employed to determine if the means of samples taken from a population were comparable. The energy of each composite was assessed using a one-way analysis of variance (ANOVA). This study used an Expanding ANOVA to determine the energy levels of composites corresponding to each of the five environmentally sustainable ratios. The results were deemed significant due to the P-value being below the $\alpha = 0.05$ threshold for statistical significance. Additional information should be provided to facilitate the selection of the optimal composition for the material. The ANOVA was computed using the MiniTab program.

Figure 3.19: Minitab software

CHAPTER 4

RESULT

4.1 Introduction

This section will mostly address composite’s strength. The tensile, flexural, and impact testing methods will all be used to test the sugarcane bagasse polyester resin composite. This chapter will look at and explain the results of the tests that were run, as well as the calculation that was employed.

4.2 Flexural Test

a) Before testing b) After testing

Figure 4.1: Result of flexural testing

Figure 4.1 depicts the specimen used for the flexural test, both before and after the testing process. A total of 25 samples were evaluated for each of the five ratios of eco-friendly sugarcane bagasse polyester resin composites with jute fiber, namely 20:80, 40:60, 50:50, 60:40, and 80:20, utilizing a Universal Testing Machine.

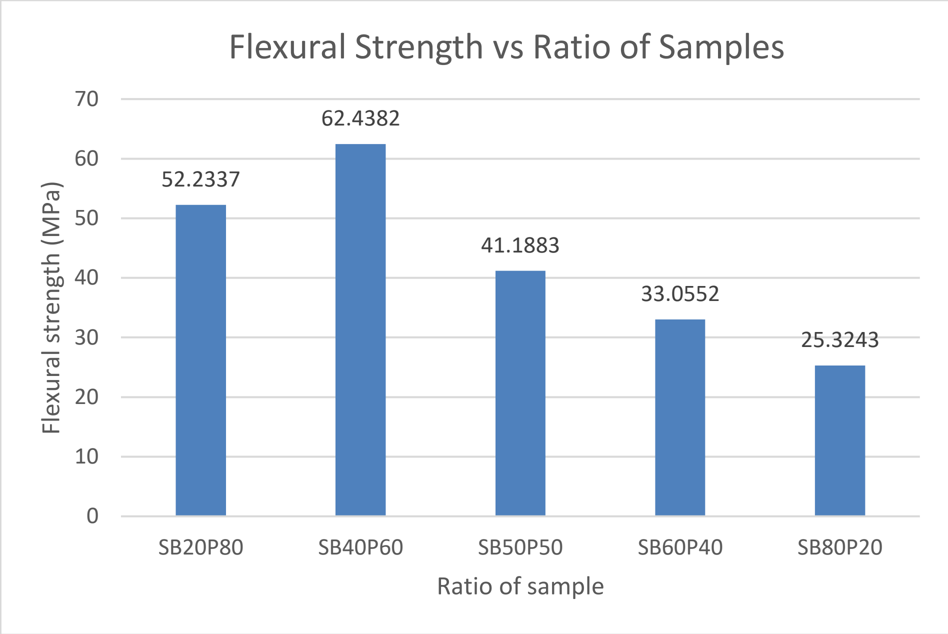


Figure 4.2: Maximum force of flexural test

Figure 4.2 displays the highest force values for each of the five ratios of eco-friendly sugarcane bagasse polyester resin composites, namely sugarcane bagasse with polyester resin, SB:PR at 20:80, 40:60, 50:50, 60:40, and 80:20. The mechanical properties of sugarcane bagasse polyester resin composite materials were assessed utilizing universal testing equipment, with a cross-head speed of 2 mm/min. The test specimens were subjected to bending tests following the ASTM D790 standard for flexural testing. From the result based on the graph, the ratio of 40:60 had the greatest of maximum force than the other ratio while the ratio of 80:20 was the lowest of maximum force. According to Mahesh S et al, (2018) said that an increase in the proportion of fiber leads to a drop in both tensile and bending strength. Experimental evidence has demonstrated that the strength of sugarcane bagasse polyester resin composites increases when the proportion of polyester resin fulfilled exceed that of natural fiber.

Table 4.1: ANOVA analysis of flexural test

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
RATIO	4	4388.00	99.75%	4388.00	1097.00	1983.25	0.000
Error	20	11.06	0.25%	11.06	0.55		
Total	24	4399.06	100.00%				

Subsequently, a one-way analysis of variance (ANOVA) was utilized to examine the maximum force of the composites made from sugarcane bagasse and polyester resin. The results for maximum force can be seen in Table 4.1. The results indicate that the maximum force of sugarcane bagasse polyester resin composites for all five eco-friendly ratios was statistically significant, as evidenced by the P-value being below the predetermined significance limit of $\alpha = 0.05$. Thus, it was evident that the average values of maximum force vary throughout the five distinct eco-friendly ratios of sugarcane bagasse polyester resin composites. Consequently, the optimal flexural characteristics were achieved by blending sugarcane bagasse with polyester resin matrix at a ratio of 40% and 60% respectively. Furthermore, the sugarcane bagasse polyester resin composite with compositions of 60% and 80% was unsuitable for use as a composite material due to its demonstrated inferior mechanical qualities. Excessive fibers can lead to the degradation of the polymer's structural integrity and a decrease in its flexural strength.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
SB40P60 - SB20P80	10.205	0.470	(8.798, 11.611)	21.69	0.000
SB50P50 - SB20P80	-11.045	0.470	(-12.452, -9.638)	-23.48	0.000
SB60P40 - SB20P80	-19.178	0.470	(-20.585, -17.772)	-40.77	0.000
SB80P20 - SB20P80	-26.909	0.470	(-28.316, -25.502)	-57.21	0.000
SB50P50 - SB40P60	-21.250	0.470	(-22.657, -19.843)	-45.18	0.000
SB60P40 - SB40P60	-29.383	0.470	(-30.790, -27.976)	-62.47	0.000
SB80P20 - SB40P60	-37.114	0.470	(-38.521, -35.707)	-78.90	0.000
SB60P40 - SB50P50	-8.133	0.470	(-9.540, -6.726)	-17.29	0.000
SB80P20 - SB50P50	-15.864	0.470	(-17.271, -14.457)	-33.73	0.000
SB80P20 - SB60P40	-7.731	0.470	(-9.138, -6.324)	-16.44	0.000

Individual confidence level = 99.28%

Figure 4.3: Tukey simultaneous of flexural test

Tukey's test as Figure 4.3 above, determines that two means were significantly different if the absolute value of their sample difference was larger. In order to demonstrate Tukey's test, we utilize the data obtained from the plasma etching experiment as presented in Table 4.1. The test was conducted with a significance level (α) of 0.05 and the degrees of freedom (f) for error were set at 20 by using Minitab software. The graph displays the disparity in averages for each pair of comparisons of means derived from distinct ratios.

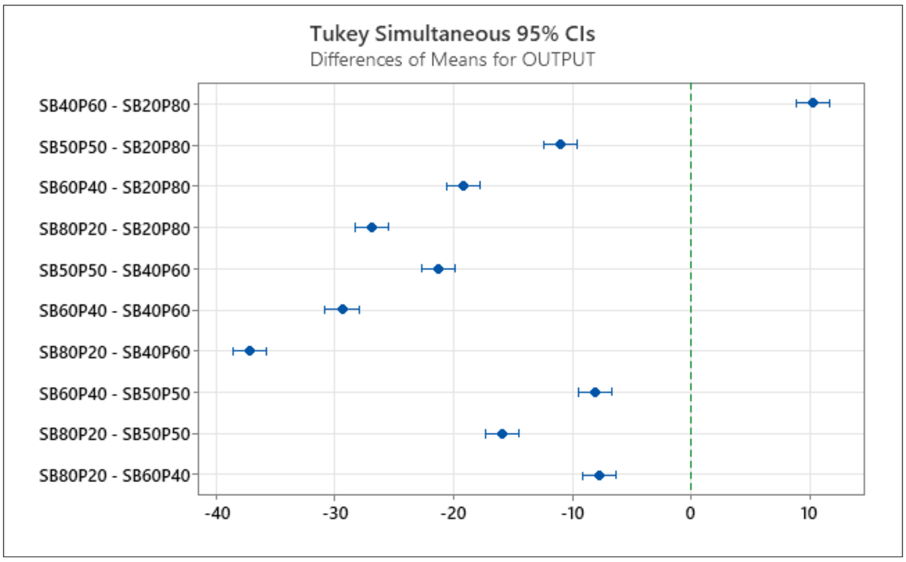
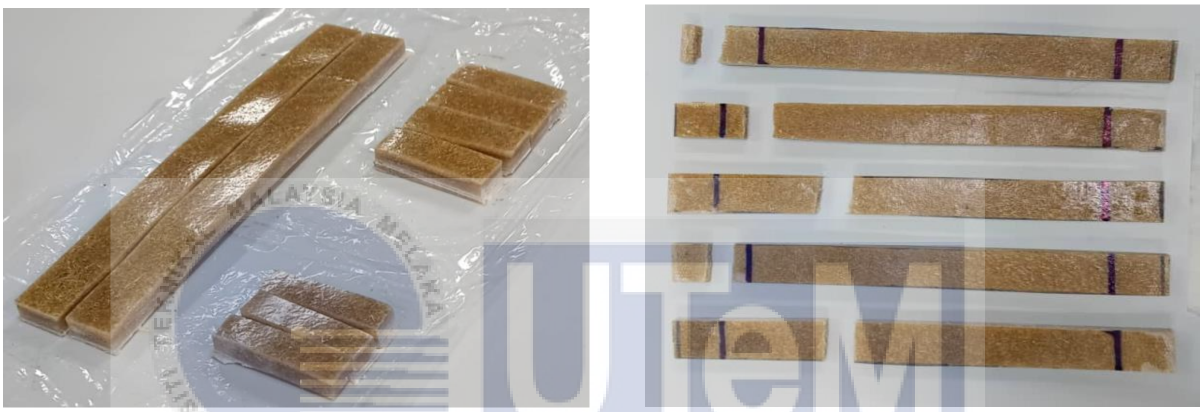


Figure 4.4: Tukey's graph of flexural test

Figure 4.4 displays the Tukey simultaneous graph, which illustrates the variations in means observed in the experiment. The Tukey approach establishes that there was a significant difference between every pair of means. Thus, it can be shown that the averages from each test results were significant since the confidence does not include the value of zero.

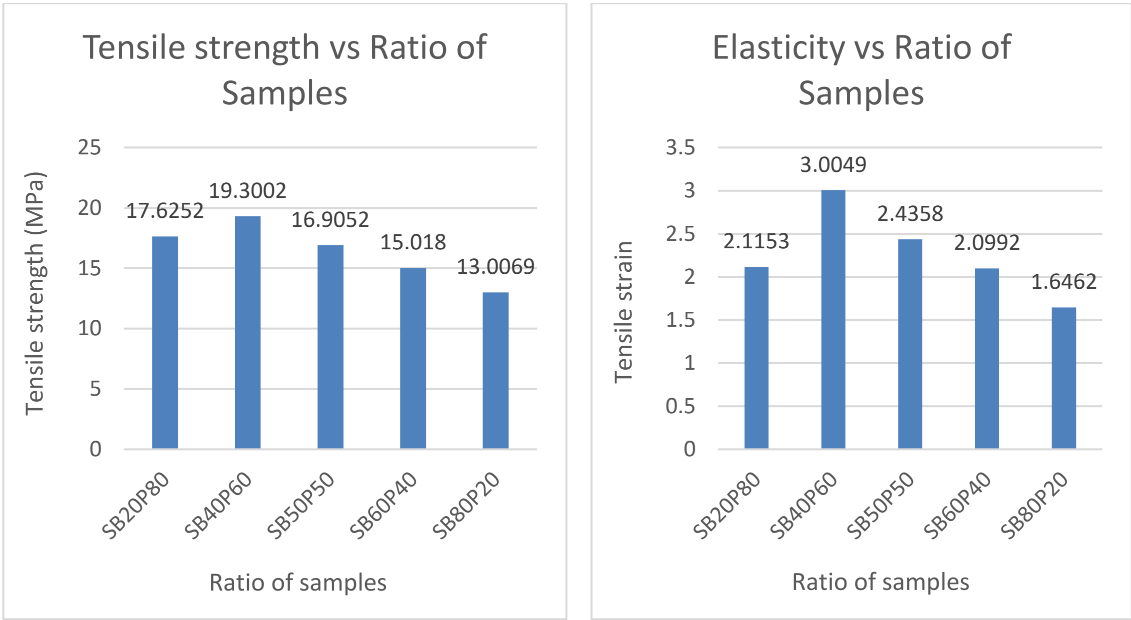
4.3 Tensile test



a) Before testing b) After testing

Figure 4.5: Result of tensile testing

Figure 4.5 depicts the specimen used for the tensile test, both before and after the testing process. A total of 25 samples were evaluated for each of the five ratios of eco-friendly sugarcane bagasse polyester resin composites with jute fiber, namely 20:80, 40:60, 50:50, 60:40, and 80:20, utilizing a Universal Testing Machine.



a) Maximum force b) Elasticity

Figure 4.6: Maximum force and elasticity of tensile test

Figure 4.6 displays the highest force and elasticity values for each of the five ratios of eco-friendly sugarcane bagasse polyester resin composites, namely sugarcane bagasse with polyester resin, SB:PR at 20:80, 40:60, 50:50, 60:40, and 80:20. The mechanical properties of sugarcane bagasse polyester resin composite materials were assessed utilizing universal testing equipment, with a cross-head speed of 2 mm/min. The test specimens were subjected to tensile and elasticity tests following the ASTM D3039 standard for tensile testing. From the result based on the graph, the ratio of 40:60 had the greatest of maximum force and elasticity than the other ratio while the ratio of 80:20 was the lowest of maximum force and elasticity. According to Mahesh S et al, (2018) said that an increase in the proportion of fiber leads to a drop in both tensile and bending strength. Experimental evidence has demonstrated that the strength of sugarcane bagasse polyester resin composites increases when the proportion of polyester resin fulfilled exceed that of natural fiber.

Table 4.2: ANOVA analysis of tensile test

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
RATIO	4	117.931	94.03%	117.931	29.4828	78.72	0.000
Error	20	7.491	5.97%	7.491	0.3745		
Total	24	125.422	100.00%				

Table 4.3: ANOVA analysis of elasticity

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
RATIO	4	5.046	53.32%	5.046	1.2616	5.71	0.003
Error	20	4.418	46.68%	4.418	0.2209		
Total	24	9.465	100.00%				

Subsequently, a one-way analysis of variance (ANOVA) was utilized to examine the maximum force and elasticity of the composites made from sugarcane bagasse and polyester resin. The results for maximum force and elasticity can be seen in Table 4.2 and Table 4.3. The results indicate that the maximum force and elasticity of sugarcane bagasse polyester resin composites for all five eco-friendly ratios was statistically significant, as evidenced by the P-value being below the predetermined significance limit of $\alpha = 0.05$. Thus, it was evident that the average values of maximum force and elasticity vary throughout the five distinct eco-friendly ratios of sugarcane bagasse polyester resin composites. Consequently, the optimal tensile and elasticity characteristics were achieved by blending sugarcane bagasse with polyester resin matrix at a ratio of 40% and 60% respectively. Furthermore, the sugarcane bagasse polyester resin composite with compositions of 60% and 80% was unsuitable for use as a composite material due to its demonstrated inferior mechanical qualities. Excessive fibers can lead to the degradation of the polymer's structural integrity and a decrease in its tensile strength and elasticity.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
SB40P60 - SB20P80	1.675	0.387	(0.517, 2.833)	4.33	0.003
SB50P50 - SB20P80	-0.720	0.387	(-1.878, 0.438)	-1.86	0.369
SB60P40 - SB20P80	-2.607	0.387	(-3.765, -1.449)	-6.74	0.000
SB80P20 - SB20P80	-4.618	0.387	(-5.776, -3.461)	-11.93	0.000
SB50P50 - SB40P60	-2.395	0.387	(-3.553, -1.237)	-6.19	0.000
SB60P40 - SB40P60	-4.282	0.387	(-5.440, -3.124)	-11.06	0.000
SB80P20 - SB40P60	-6.293	0.387	(-7.451, -5.136)	-16.26	0.000
SB60P40 - SB50P50	-1.887	0.387	(-3.045, -0.729)	-4.88	0.001
SB80P20 - SB50P50	-3.898	0.387	(-5.056, -2.741)	-10.07	0.000
SB80P20 - SB60P40	-2.011	0.387	(-3.169, -0.853)	-5.20	0.000

Individual confidence level = 99.28%

Figure 4.7: Tukey simultaneous test of tensile test

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
SB40P60 - SB20P80	0.890	0.297	(0.000, 1.779)	2.99	0.050
SB50P50 - SB20P80	0.320	0.297	(-0.569, 1.210)	1.08	0.816
SB60P40 - SB20P80	-0.016	0.297	(-0.905, 0.873)	-0.05	1.000
SB80P20 - SB20P80	-0.469	0.297	(-1.358, 0.420)	-1.58	0.527
SB50P50 - SB40P60	-0.569	0.297	(-1.458, 0.320)	-1.91	0.342
SB60P40 - SB40P60	-0.906	0.297	(-1.795, -0.017)	-3.05	0.045
SB80P20 - SB40P60	-1.359	0.297	(-2.248, -0.470)	-4.57	0.002
SB60P40 - SB50P50	-0.337	0.297	(-1.226, 0.553)	-1.13	0.788
SB80P20 - SB50P50	-0.790	0.297	(-1.679, 0.100)	-2.66	0.097
SB80P20 - SB60P40	-0.453	0.297	(-1.342, 0.436)	-1.52	0.560

Individual confidence level = 99.28%

Figure 4.8: Tukey simultaneous test of elasticity

Tukey's test as Figure 4.7 and Figure 4.8 above, determines that two means were significantly different if the absolute value of their sample difference was larger. In order to demonstrate Tukey's test, we utilize the data obtained from the plasma etching experiment as presented in Table 4.2 and Table 4.3. The test was conducted with a significance level (α) of 0.05 and the degrees of freedom (f) for error were set at 20 by using Minitab software. The graph displays the disparity in averages for each pair of comparisons of means derived from distinct ratios.

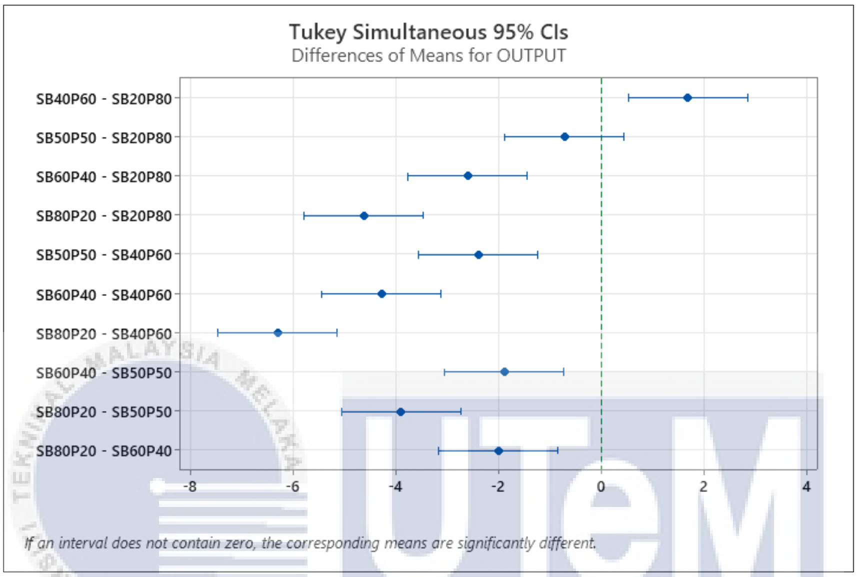


Figure 4.9: Tukey's graph of tensile test

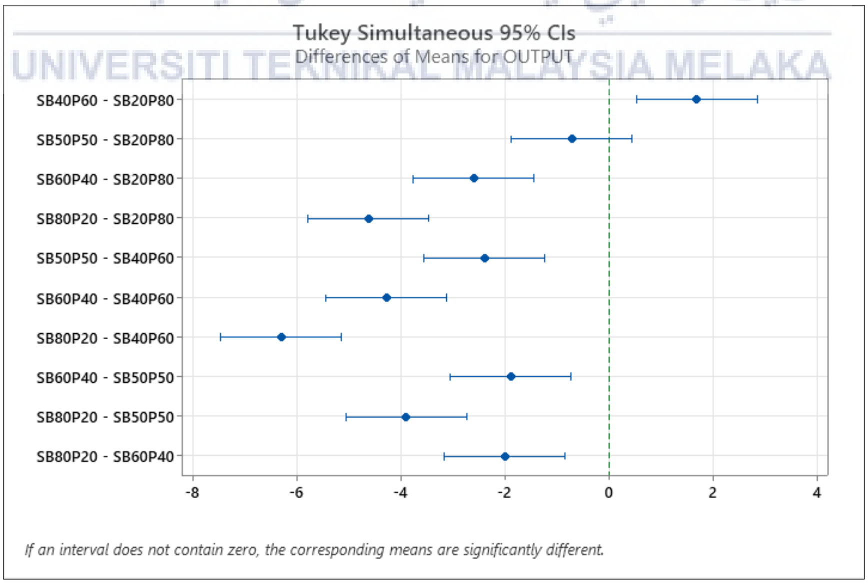


Figure 4.10: Tukey's graph of elasticity

Figure 4.9 and Figure 4.10 displays the Tukey simultaneous graph, which illustrates the variations in means observed in the experiment. The Tukey approach establishes that there was a significant difference between every pair of means. Thus, it can be shown that the averages from each test results were not significant since the confidence interval includes the value of zero.

4.4 Impact test

a) Before testing b) After testing

Figure 4.11: Result of impact testing

Figure 4.11 depicts the specimen used for the impact test, both before and after the testing process. A total of 25 samples were evaluated for each of the five ratios of eco-friendly sugarcane bagasse polyester resin composites with jute fiber, namely 20:80, 40:60, 50:50, 60:40, and 80:20, utilizing a Universal Testing Machine.

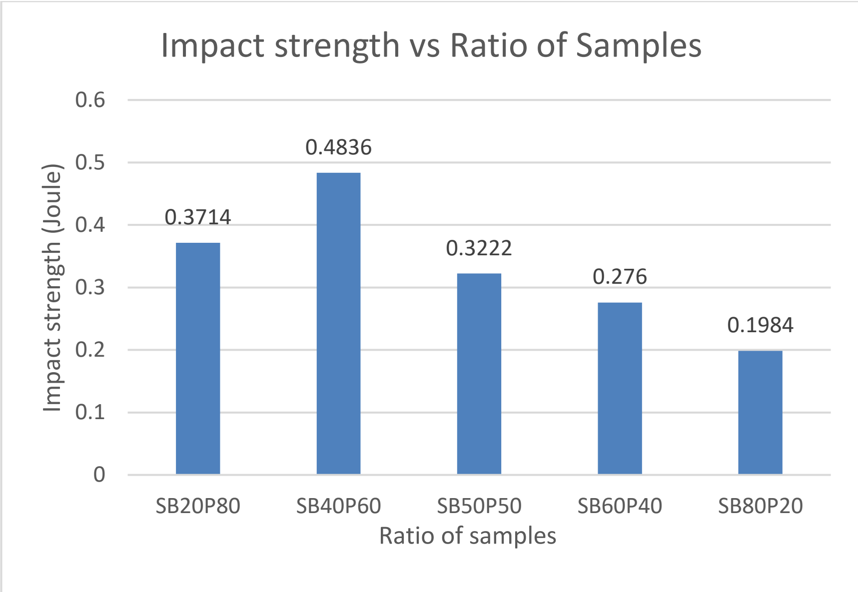


Figure 4.12: Maximum force of impact test

Figure 4.12 displays the highest force values for each of the five ratios of eco-friendly sugarcane bagasse polyester resin composites with jute fiber, namely sugarcane bagasse with polyester resin, SB:PR at 20:80, 40:60, 50:50, 60:40, and 80:20. The mechanical properties of sugarcane bagasse polyester resin composite materials were assessed utilizing universal testing equipment, with a cross-head speed of 2 mm/min. The test specimens were subjected to impact tests following the ASTM D6110 standard for impact testing. From the result based on the graph, the ratio of 40:60 had the greatest of maximum force than the other ratio while the ratio of 80:20 was the lowest of maximum force. According to Mahesh S et al, (2018) said that an increase in the proportion of fiber leads to a drop in both tensile and bending strength. Experimental evidence has demonstrated that the strength of sugarcane bagasse polyester resin composites increases when the proportion of polyester resin fulfilled exceed that of natural fiber.

Table 4.4: ANOVA analysis of impact test

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
RATIO	4	0.2280	68.39%	0.2280	0.057002	10.82	0.000
Error	20	0.1054	31.61%	0.1054	0.005268		
Total	24	0.3334	100.00%				

Subsequently, a one-way analysis of variance (ANOVA) was utilized to examine the maximum force of the composites made from sugarcane bagasse and polyester resin. The results for maximum force can be seen in Table 4.4. The results indicate that the maximum force of sugarcane bagasse polyester resin composites for all five eco-friendly ratios was statistically significant, as evidenced by the P-value being below the predetermined significance limit of $\alpha = 0.05$. Thus, it was evident that the average values of maximum force vary throughout the five distinct eco-friendly ratios of sugarcane bagasse polyester resin composites. Consequently, the optimal impact characteristics were achieved by blending sugarcane bagasse with polyester resin matrix at a ratio of 40% and 60% respectively. Furthermore, the sugarcane bagasse polyester resin composite with compositions of 60% and 80% was unsuitable for use as a composite material due to its demonstrated inferior mechanical qualities. Excessive fibers can lead to the degradation of the polymer's structural integrity and a decrease in its impact strength.

Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
SB40P60 - SB20P80	0.1122	0.0459	(-0.0251, 0.2495)	2.44	0.144
SB50P50 - SB20P80	-0.0492	0.0459	(-0.1865, 0.0881)	-1.07	0.819
SB60P40 - SB20P80	-0.0954	0.0459	(-0.2327, 0.0419)	-2.08	0.268
SB80P20 - SB20P80	-0.1730	0.0459	(-0.3103, -0.0357)	-3.77	0.009
SB50P50 - SB40P60	-0.1614	0.0459	(-0.2987, -0.0241)	-3.52	0.016
SB60P40 - SB40P60	-0.2076	0.0459	(-0.3449, -0.0703)	-4.52	0.002
SB80P20 - SB40P60	-0.2852	0.0459	(-0.4225, -0.1479)	-6.21	0.000
SB60P40 - SB50P50	-0.0462	0.0459	(-0.1835, 0.0911)	-1.01	0.849
SB80P20 - SB50P50	-0.1238	0.0459	(-0.2611, 0.0135)	-2.70	0.090
SB80P20 - SB60P40	-0.0776	0.0459	(-0.2149, 0.0597)	-1.69	0.462

Individual confidence level = 99.28%

Figure 4.13: Tukey simultaneous of impact test

Tukey's test as Figure 4.13 above, determines that two means were significantly different if the absolute value of their sample difference was larger. In order to demonstrate Tukey's test, we utilize the data obtained from the plasma etching experiment as presented in Table4.4. The test was conducted with a significance level (α) of 0.05 and the degrees of freedom (f) for error were set at 20 by using Minitab software. The graph displays the disparity in averages for each pair of comparisons of means derived from distinct ratios.

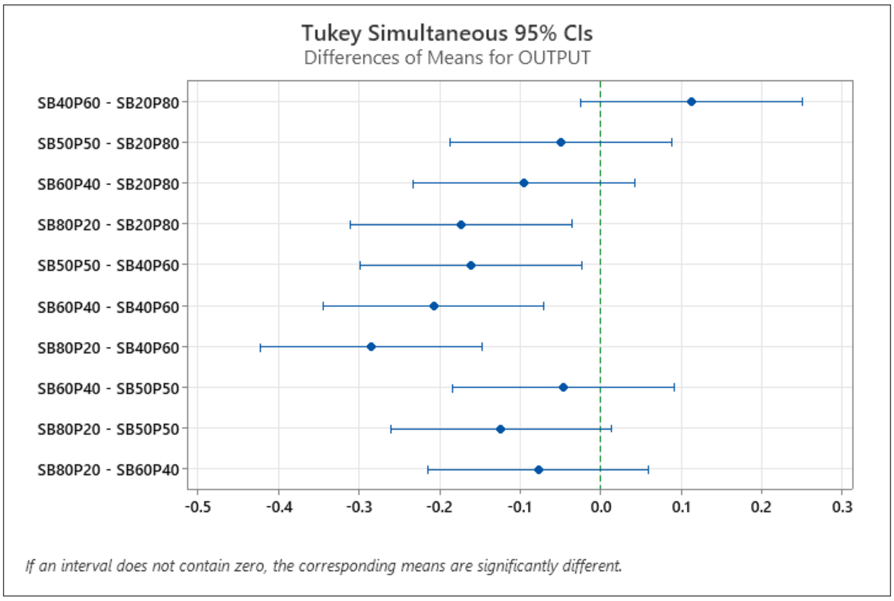
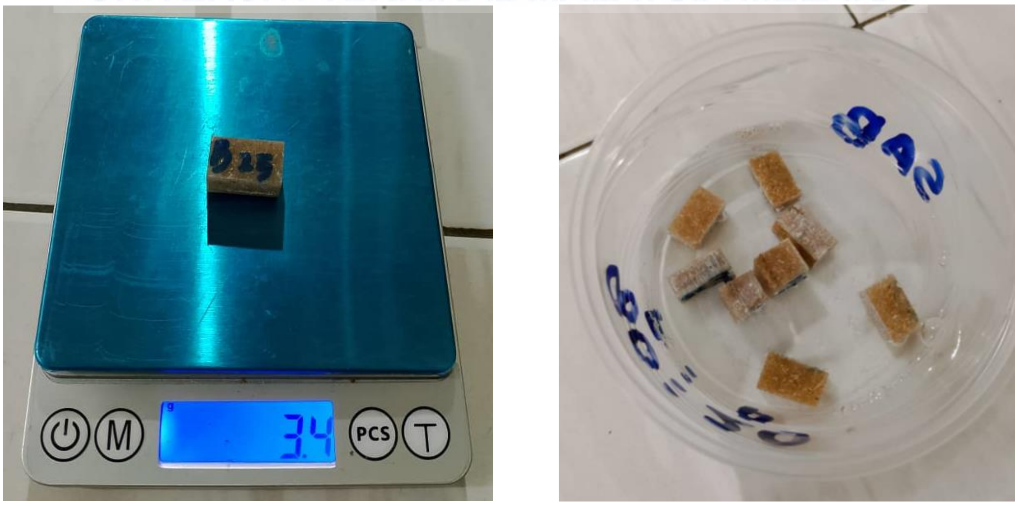


Figure 4.14: Tukey's graph of impact test

Figure 4.14 displays the Tukey simultaneous graph, which illustrates the variations in means observed in the experiment. The Tukey approach establishes that there was a significant difference between every pair of means. Thus, it can be shown that the averages from each test results were not significant since the confidence interval includes the value of zero.

4.5 Water absorption



a) Before testing b) After testing

Figure 4.15: Result of water absorption testing

Figure 4.15 depicts the specimen used for the water absorption, both before and after the testing process. A total of 25 samples were evaluated for each of the five ratios of eco-friendly sugarcane bagasse polyester resin composites with jute fiber, namely 20:80, 40:60, 50:50, 60:40, and 80:20. According to the ASTM D570 standard, the maximum water absorption of hybrid composites was developed at 23 degrees Celsius, the specimen will be subjected to a water absorption test at 5 days, 10 days, 15 days, 20 days and 25 days.

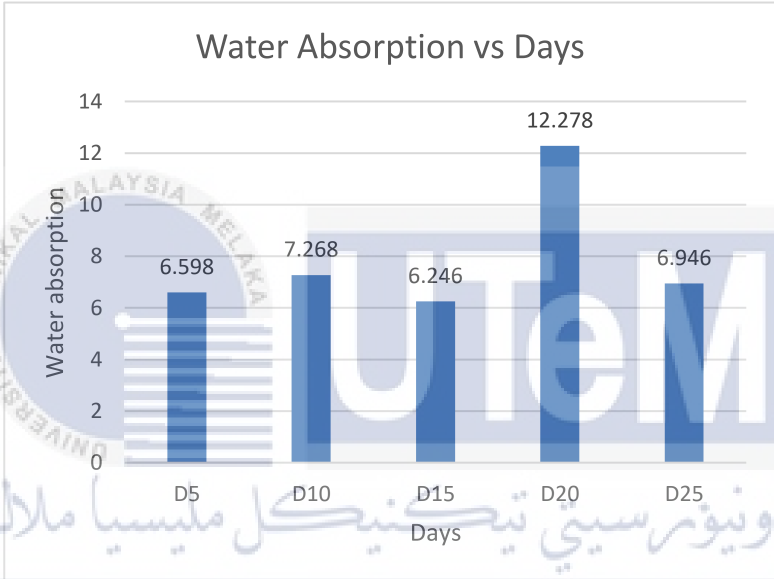


Figure 4.16: Graph of water absorption for ratio 20:80

Table 4.5: ANOVA of ratio 20:80

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	124.5098	4	31.12746	2.238987	0.101148	2.866081
Within Groups	278.0495	20	13.90247			
Total	402.5593	24				

The water absorption values for the composite ratio of sugarcane bagasse to polyester resin, known as 20:80 were illustrated in Figure 4.16. The test specimens were subjected to the ASTM D570 Water Absorption testing standard. The water absorption of the 20:80 mixture was found to gradually rise from 7.268 on day 10, reaching a high of 12.278 on day 20. However, the water absorption value decreased to its minimum level on day 15, reaching a value of 6.946. This experiment has demonstrated that when the quantity of sugarcane bagasse increases, there was a corresponding increase in the water absorption value. However, above a certain level, the water absorption value starts to decline. The water absorption test of the sugarcane bagasse polyester resin composites was then evaluated using a one-way analysis of variance (ANOVA), as presented in Table 4.17. Since the P-value above the predetermined significance level of α = 0.05, the results indicate that there was no significant in water absorption between sugarcane bagasse polyester resin composites at a ratio of 20:80. The optimal water absorption properties were achieved when a mixture of sugarcane bagasse and polyester resin matrix was used at a ratio of 20:80 after 20 days.

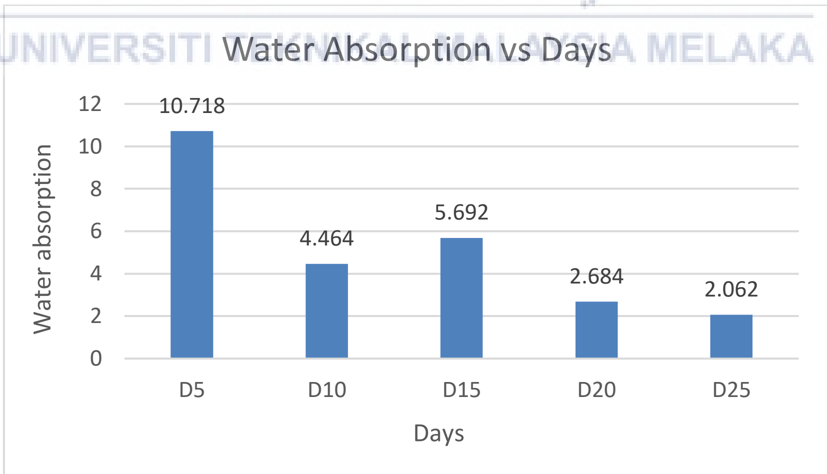


Figure 4.17: Graph of water absorption for ratio 40:60

Table 4.6: ANOVA of ratio 40:60

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
DAYS	4	236.9	48.51%	236.9	59.23	4.71	0.008
Error	20	251.5	51.49%	251.5	12.57		
Total	24	488.4	100.00%				

The water absorption values for the composite ratio of sugarcane bagasse to polyester resin, known as 40:60 were illustrated in Figure 4.17. The test specimens were subjected to the ASTM D570 Water Absorption testing standard. The water absorption of the 40:60 mixture exhibited a continuous rise, starting from 10.718 on day 5. However, the water absorption value decreased to its minimum level on day 25, reaching a value of 2.062. This experiment has demonstrated that when the quantity of sugarcane bagasse increases, there was a corresponding increase in the water absorption value. However, above a certain level, the water absorption value starts to decline. The water absorption test of the sugarcane bagasse polyester resin composites was then evaluated using a one-way analysis of variance (ANOVA), as presented in Table 4.6.

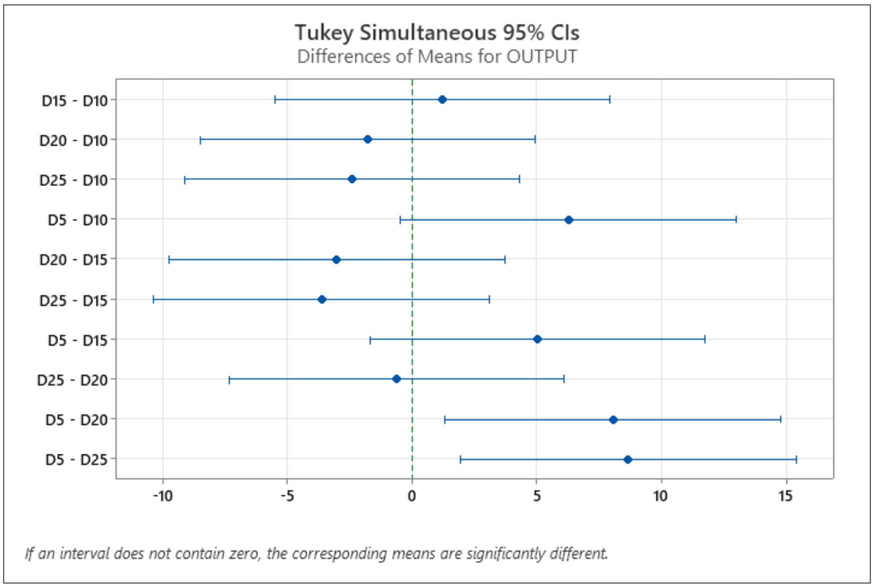


Figure 4.18: Tukey test of water absorption with ratio of 40:60

Since the P-value below the predetermined significance level of α = 0.05, the results indicate that there was a significant in water absorption between sugarcane bagasse polyester resin composites at a ratio of 40:60. The Tukey's graph, which displays the differences in experiment means was seen in Figure 4.18. It should be noted that each pair of means was distinct as shown by the tukey's approach. As a result, it may conclude that two stages of means which were D5 with D20 and D5 with D25 have been determined to be significant.

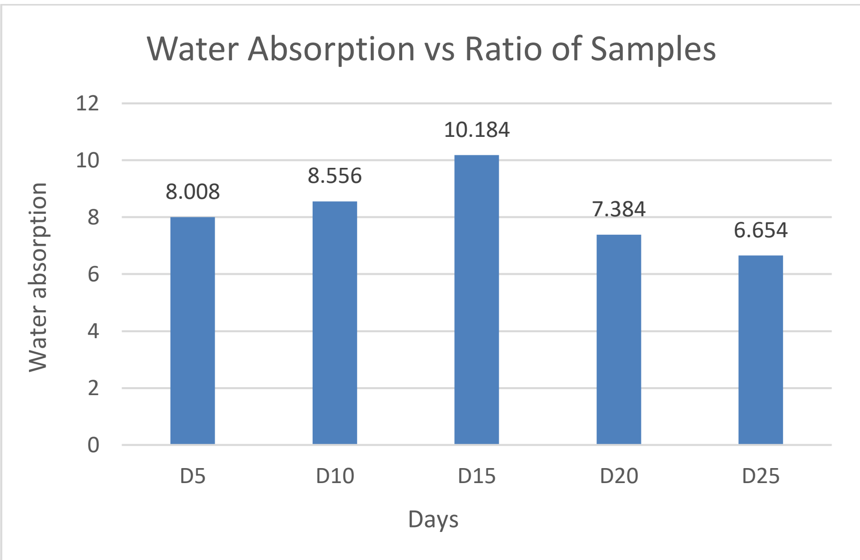


Figure 4.19: Graph of water absorption for ratio 50:50

Table 4.7: ANOVA of ratio 50:50

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	35.73334	4	8.933336	0.398329	0.807467	2.866081
Within Groups	448.5406	20	22.42703			
Total	484.2739	24				

The water absorption values for the composite ratio of sugarcane bagasse to polyester resin, known as 50:50 were illustrated in Figure 4.19. The test specimens were subjected to the ASTM D570 Water Absorption testing standard. The water absorption of the 50:50 mixture was found to gradually rise from 8.556 on day 10, reaching a high of 10.184 on day 15. However, the water absorption value decreased to its minimum level on day 25, reaching a value of 6.654. This experiment has demonstrated that when the quantity of sugarcane bagasse increases, there was a corresponding increase in the water absorption value. However, above a certain level, the water absorption value starts to decline. The water absorption test of the sugarcane bagasse polyester resin composites was then evaluated using a one-way analysis of variance (ANOVA), as presented in Table 4.7. Since the P-value above the predetermined significance level of $\alpha = 0.05$, the results indicate that there was no significant in water absorption between sugarcane bagasse polyester resin composites at a ratio of 50:50. The optimal water absorption properties were achieved when a mixture of sugarcane bagasse and polyester resin matrix was used at a ratio of 50:50 after 15 days.

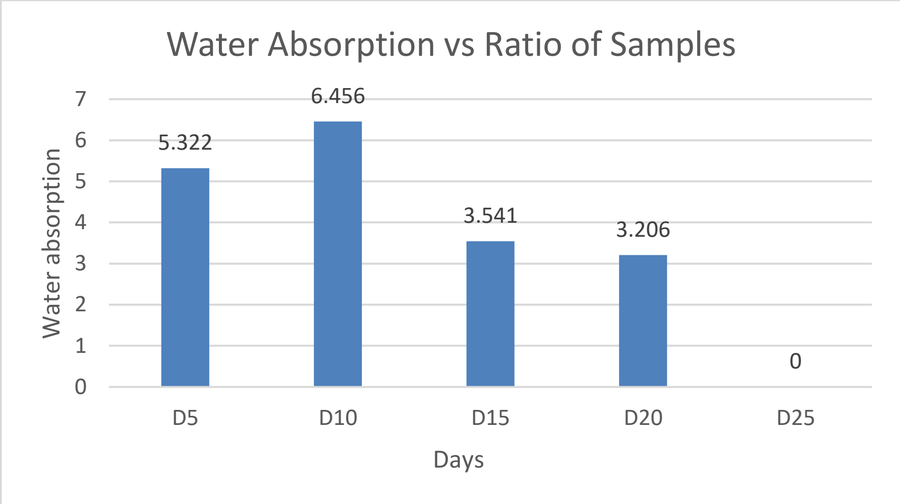


Figure 4.20: Graph of water absorption for ratio 60:40

Table 4.8: ANOVA of ratio 60:40

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	120.9281	4	30.23202	2.828794	0.052091	2.866081
Within Groups	213.7449	20	10.68725			
Total	334.673	24				

The water absorption values for the composite ratio of sugarcane bagasse to polyester resin, known as 60:40 were illustrated in Figure 4.20. The test specimens were subjected to the ASTM D570 Water Absorption testing standard. The water absorption of the 60:40 mixture was found to gradually rise from 5.322 on day 5, reaching a maximum high of 6.456 on day 10. However, the water absorption value decreased to its minimum level on day 25, which was 0. This experiment has demonstrated that when the quantity of sugarcane bagasse increases, there was a corresponding increase in the water absorption value. However, above a certain level, the water absorption value starts to decline. The water absorption test of the sugarcane bagasse polyester resin composites was then evaluated using a one-way analysis of variance (ANOVA), as presented in Table 4.8. Since the P-value above the predetermined significance level of α = 0.05, the results indicate that there was no significant in water absorption between sugarcane bagasse polyester resin composites at a ratio of 60:40. The optimal water absorption properties were achieved when a mixture of sugarcane bagasse and polyester resin matrix was used at a ratio of 60:40 after 10 days.

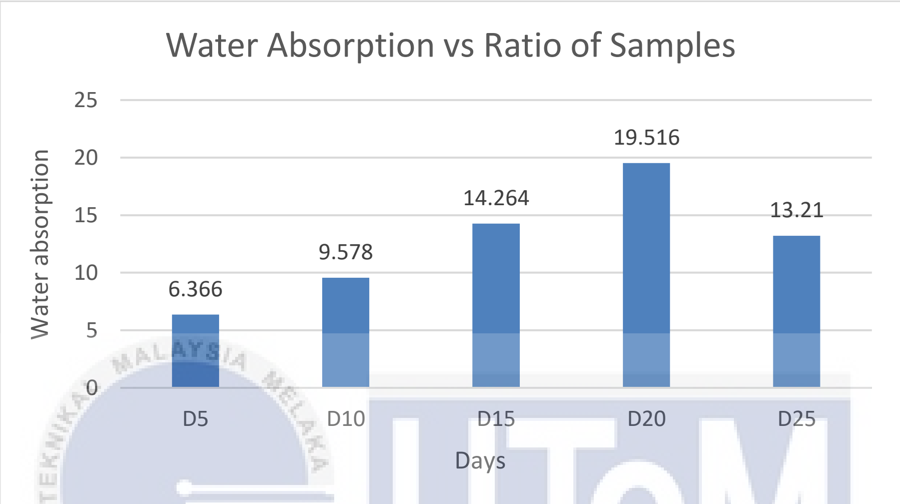


Figure 4.21: Graph of water absorption for ratio 80:20

Table 4.9: ANOVA of ratio 80:20

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	494.8321	4	123.708	4.348745	0.010823	2.866081
Within Groups	568.9366	20	28.44683			
Total	1063.769	24				

The water absorption values for the composite ratio of sugarcane bagasse to polyester resin, known as 80:20 were illustrated in Figure 4.21. The test specimens were subjected to the ASTM D570 Water Absorption testing standard. The water absorption of the 80:20 mixture was found to gradually rise from 9.578 on day 10, reaching a high of 19.516 on day 20. However, the water absorption value decreased to its minimum level on day 5, reaching a value of 6.366. This experiment has demonstrated that when the quantity of sugarcane bagasse increases, there was a corresponding increase in the water absorption value. However, above a certain level, the water absorption value starts to decline. The water absorption test of the sugarcane bagasse polyester resin composites was then evaluated using a one-way analysis of variance (ANOVA), as presented in Table 4.9.

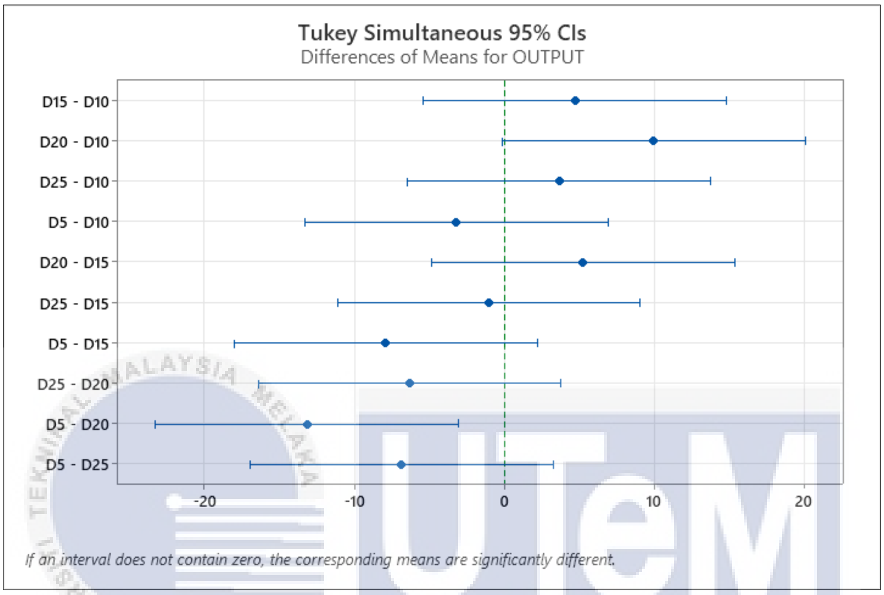


Figure 4.22: Tukey test of water absorption with ratio of 80:20

Since the P-value below the predetermined significance level of α = 0.05, the results indicate that there was a significant in water absorption between sugarcane bagasse polyester resin composites at a ratio of 80:20. The Tukey's graph, which displays the differences in experiment means was seen in Figure 4.22. It should be noted that each pair of means was distinct as shown by the tukey’s approach. As a result, it may conclude that one stages of means which were D5 with D20 have been determined to be significant.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter provides a concise overview of the discoveries and suggestions for future investigation derived from this experiment. The objective of this study was to employ three distinct testing methodologies, including tensile testing, flexural testing, and impact testing, to enhance the data pertaining to achieving optimal strength characteristics in coconut leaf composite materials.

5.2 Conclusion

In order to properly accomplish this research, it was necessary to satisfy three specific objectives. The mechanical properties of a composite material produced by using discarded sugarcane bagasse as a reinforcing component in a polyester resin matrix. The specimen was created by combining several proportions of SB (Sugarcane Bagasse) and polyester resin. These proportions include 20% SB and 80% polyester resin, 40% SB and 60% polyester resin, 50% SB and 50% polyester resin, 60% SB and 40% polyester resin and lastly 80% SB and 20% polyester resin in terms of volume in the Sugarcane Bagasse Polyester Resin composite. Following the successful examination on the mechanical properties of the Sugarcane Bagasse Polyester Resin composite using the tensile test, flexural test, impact test and water absorption all the data and findings from this experiment have been documented and stored. The mechanical characteristics of sugarcane bagasse reinforced by polyester resin have been thoroughly examined by using all these testing. All specimens undergo tensile testing, flexural testing, impact testing and water absorption in line with the ASTM standard. Furthermore, the hand lay-up technique was employed to manufacture the specimen. It was necessary to verify that the specimen was generated using high-quality materials.

According to the previous findings, the flexural test of a composite material consisting of 40% sugarcane and 60% polyester resin exhibited better flexural strength compared to other composite ratios. Specifically, the flexural strength was measured to be 62.4382 MPa. The combination of 80% sugarcane bagasse and 20% polyester resin had the lowest flexural strength value, measuring 25.3243 MPa. This finding indicates that the flexural strength of the eco-friendly ratios of composites made from Sugarcane Bagasse Polyester Resin increases when the proportion sugarcane bagasse reaches 40% with 60% of polyester resin. Subsequently, a unidirectional analysis of variance (ANOVA) was employed to examine the flexural strength of the composites made from Sugarcane Bagasse Polyester Resin.

During the Tensile testing, it was observed that the composite consisting of 40% sugarcane bagasse and 60% polyester resin exhibited greater maximum force and elasticity compared to other composite ratios. The highest force recorded for this composite was 19.3002 MPa, while the elasticity was measured at 3.0049. The combination of 80% sugarcane bagasse and 20% polyester resin resulted in the lowest maximum force value of 13.0069 MPa and an elasticity measurement of 1.6462. The results indicate that the maximum force and elasticity of composites made from Sugarcane Bagasse Polyester Resin at all five eco-friendly ratios were statistically significant, as evidenced by the P-value being lower than the predetermined significance level of $\alpha = 0.05$. Thus, it was evident that the average values of maximum force and elasticity vary throughout the five eco-friendly ratios of Sugarcane Bagasse Polyester Resin composites. In addition, this implies that the composite material consisting of 40 percent sugarcane bagasse and 60 percent polyester resin has greater strength compared to other ratios of sugarcane bagasse composites.

After conducting impact test, it was found that the sugarcane bagasse polyester resin composite with a 40% sugarcane bagasse and 60% polyester resin mixture exhibited a higher energy value of 0.4836 Joule compared to other environmentally friendly ratios of sugarcane bagasse polyester resin composites with jute fiber. The ANOVA findings indicate that the impact strength of composites made from Sugarcane Bagasse Polyester Resin with different eco-friendly ratios of jute fiber had a significant effect. This conclusion was based on the P-value was lower than the predetermined significance level of $\alpha = 0.05$. Optimal impact qualities were achieved by blending sugarcane bagasse and polyester resin composites with jute fiber at a ratio of 40% and 60% corresponding.

The sugarcane bagasse polyester resin composite, which contains 80% sugarcane bagasse and 20% polyester, has the greatest moisture point (19.516) when compared to other moisture ratios, according to the results of a water absorption test. This experiment has shown that the water absorption value rises in proportion to the amount of sugarcane bagasse present. The water absorption value however does begin to decrease at a certain point. The results of the ANOVA indicate that there was not a significant difference in the water absorption of composites manufactured from Sugarcane Bagasse Polyester Resin and eco-friendly ratios of jute fiber. however just two ratios 40:60 and 80:20 had a significant impact. Two phases of means, D5 with D20 and D5 with D25, were shown to be a significant in the 40:60 ratio. In the meanwhile, a single stage of the means for the 80:20 ratio was D5, and D20 was shown to be significant. This occurred as a result of the P-value of the phases of means being below than the $\alpha = 0.05$ predefined significance level.

5.3 Recommendation

It was advisable to include further mechanical testing on composites made of Sugarcane Bagasse Polyester Resin with jute fiber for future study. The compression testing of sugarcane bagasse-polyester resin composites with jute fiber entails applying compressive pressures to the material to assess its response to pressure. This evaluation also examines how the material reacts to the applied compressive load, including deformation, strain, and failure modes. Compression testing allows for the evaluation of the performance and appropriateness of sugarcane bagasse-polyester resin composites with jute fiber for certain applications that need resistance to compressive pressures.

Additionally, it was advised to do microstructural study of composites made from sugarcane bagasse-polyester resin and jute fiber, which entails evaluating the internal structure of the composite at a microscopic scale. This research offers valuable information on the dispersion, alignment, attachment, and interactions at the interface between the components. Researchers can enhance their comprehension of the internal structure of sugarcane bagasse-polyester resin composites with jute fiber by utilizing microstructural characterization techniques such as SEM and optical microscopy. This understanding was crucial for enhancing the characteristics and performance of these materials in many applications. Furthermore, it proposed improving the water absorption test by replacing regular water with salt water, since this would demonstrate the water resistance of the sugarcane bagasse in the bio-composites. It is recommended to reduce the immersion period of the sample, which would decrease the duration from 5 days to either 1 day or a few hours.

5.4 Project Potential

The utilization of jute fiber hybrid sugarcane bagasse reinforced polyester resin composites has the potential to be environmentally friendly. This was due to the use of natural and renewable resources such as jute and sugarcane bagasse, which reduces the reliance on non-renewable materials. Additionally, these composites have the ability to biodegrade, making them suitable for applications that require eco-friendly disposability and can help reduce environmental impact. Composite materials were currently employed in the automotive industry as components, specifically for interior parts, panels, and non-structural elements. This was due to their advantageous lightweight nature and satisfactory mechanical properties. In the field of construction, composite materials were suitable for non-load-bearing structures, interior designs, and as sustainable building materials.

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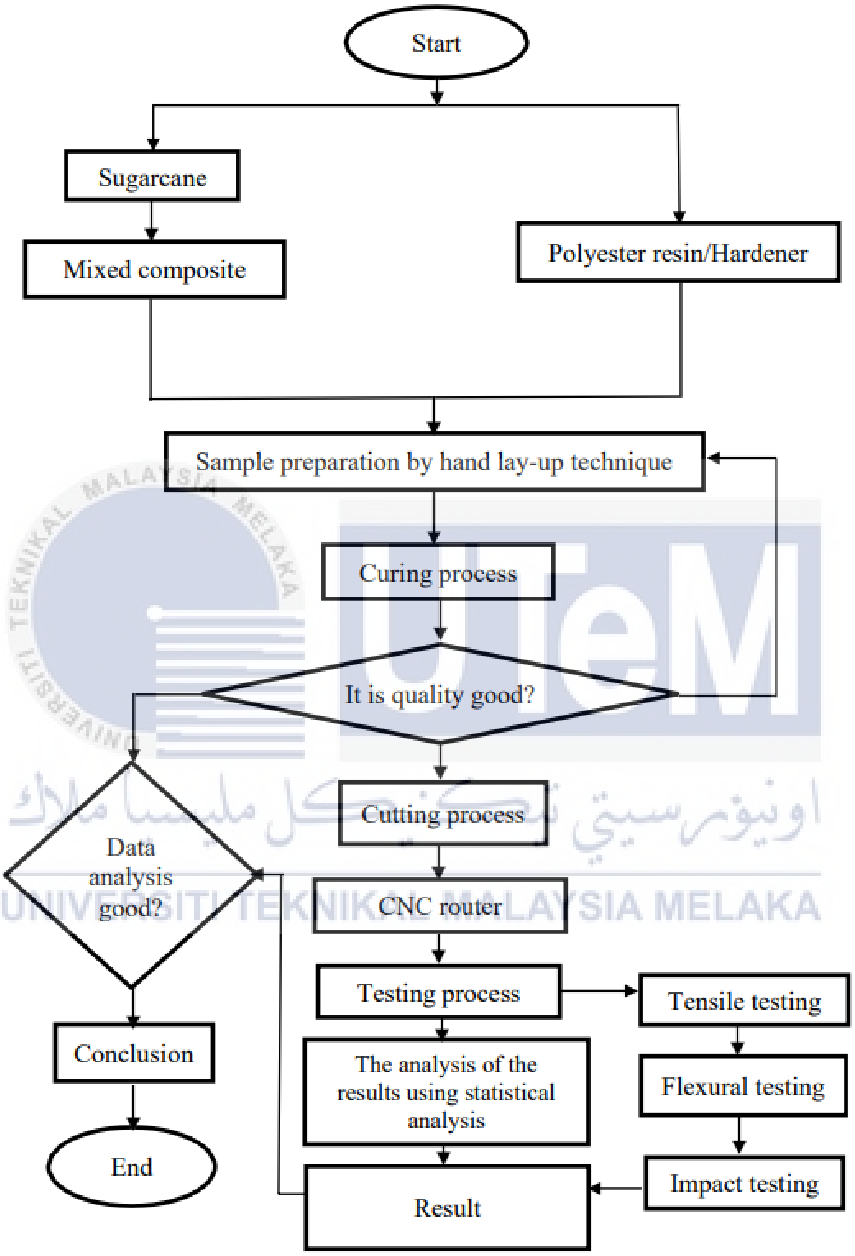
APPENDICES

APPENDIX A Flow Chart of Project



APPENDIX B Gantt Chart of the PSM 1

Activities	Status	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Supervisor and Title Registration	Plan														
	Actual														
Project Explanation and Briefing by Supervisor	Plan														
	Actual														
Defining Problem Statement, Objective and Project Scope	Plan														
	Actual														
Drafting and Writing Chapter 1	Plan														
	Actual														
Material Preparation	Plan														
	Actual														
Defining and Finding Source for Literature Review	Plan														
	Actual														
Drafting and Writing Chapter 2	Plan														
	Actual														
Defining Methodology on How to Conduct the Project	Plan														
	Actual														
Drafting and Writing Chapter 3	Plan														
	Actual														
Revising Report Chapter 1,2 and 3 before Submission	Plan														
	Actual														

APPENDIX C Gantt Chart of the PSM 2

Activities	Status	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Material Grinding Process	Plan														
	Actual														
Hand Lay-up Fabrication	Plan														
	Actual														
Laboratory Booking	Plan														
	Actual														
Cutting Process using CNC Machine	Plan														
	Actual														
Water Absorption	Plan														
	Actual														
Tensile Testing	Plan														
	Actual														
Flexural Testing	Plan														
	Actual														
Impact Testing	Plan														
	Actual														
Meeting with Supervisor for Improvement	Plan														
	Actual														
Full Report Correction	Plan														
	Actual														
Oral Presentation	Plan														
	Actual														