Mechanical Properties of Glass Fiber Polyester Hybrid Composite Filled with Sugarcane Bagasse

LOU KE XIN
B092010057

BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY (PROCESS AND TECHNOLOGY) WITH HONOURS

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Lou Ke Xin

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Disahkan oleh:

Alamat Tetap:

11, LORONG FU LIN KONG, SUNGAI PINANG BESAR, 32300 PANGKOR, PERAK.

Cop Rasmi:

TS. DR. KHAIRUM BIN HAMZAH
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Pembuatan
Fakulti Teknologi dan Kejuruteraan Industri dan Pembuatan
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Signature	:	
Supervisor Name	:	Ts Dr Khairum Bin Hamzah
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DEDICATION

I would want to dedicate this thesis to my wonderful family, who have always been by my side, providing unwavering support, strength, and motivation. Your unwavering support, unconditional love, and constant encouragement in my academic journey. Thank you for standing by me through the long hours of research, late nights, and countless sacrifices. Your belief in me has been my driving force, and I feel very grateful for the sacrifices you have made to let my dreams reality. This work is dedicated to you, as a token of my deep gratitude and appreciation for everything you have done for me.

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ABSTRACT

In recent times, the utilization of natural waste-based materials in manufacturing engineering and technology has become widespread due to their significant properties. Natural waste-based materials such as sugarcane bagasse as one of the natural fibers to prevent environmental pollution. The objectives of this research are to fabricate a glass fiber polyester hybrid composite filled with sugarcane bagasse, perform the fabricated materials into the testing specimen, and examine the mechanical characteristics and environmental aspect of the manufactured materials through assessments including tensile, flexural, impact, and water absorption tests. The hand lay-up technique was used to make the composite mixtures, yielding five ratios between natural and synthetic materials. These composites ratios are 20% of sugarcane bagasse and 80% of polyester (20SB80PR), 40% of sugarcane bagasse and 60% of polyester (40SB60PR), 50% of sugarcane bagasse and 50% of polyester (50SB50PR), 60% of sugarcane bagasse and 40% of polyester (60SB40PR), and 80% of sugarcane bagasse and 20% of polyester (80SB20PR). The fabricated material will be cut into the testing specimen using the computer numerical control (CNC) router machine and their mechanical properties and environmental aspect will be analyzed through tensile, flexural, impact, and water absorption tests. Statistical analysis will be employed to assess the collected data. Numerical computations and graphical demonstrations will be conducted to observe the mechanical performance of the sugarcane bagasse-filled glass fiber polyester composite across the five different ratios. The findings revealed that the composite with 20% sugarcane bagasse exhibited superior mechanical behavior compared to the other composites.

ABSTRAK

Dalam tempoh baru-baru ini, penggunaan bahan berasaskan sisa semulajadi dalam kejuruteraan pembuatan dan teknologi telah meluas disebabkan oleh sifat-sifat penting yang dimiliki oleh mereka. Bahan berasaskan sisa semulajadi seperti hampas tebu ialah salah satu fiber semulajadi untuk mengelakkan pencemaran alam berlaku. Objektif penyelidikan ini adalah untuk menghasilkan komposit hibrid poliester gentian kaca yang diisi dengan hampas tebu, menjadikan bahan yang dihasilkan sebagai spesimen ujian, dan mengkaji ciri-ciri mekanikal bahan dan aspek persekitaran yang dihasilkan melalui ujian seperti ujian tegangan, ujian lenturan, ujian impak, dan penyerapan air. Campuran komposit ini dihasilkan menggunakan teknik peletakan tangan, menghasilkan lima nisbah antara bahan semulajadi dan sintetik. Nisbah komposit ini adalah 20% hampas tebu dan 80% poliester (20SB80PR), 40% hampas tebu dan 60% poliester (40SB60PR), 50% hampas tebu dan 50% poliester (50SB50PR), 60% hampas tebu dan 40% poliester (60SB40PR), dan 80% hampas tebu dan 20% poliester (80SB20PR). Bahan yang dihasilkan akan dipotong menjadi spesimen ujian menggunakan mesin router kawalan berangka (CNC), dan ciri mekanikalnya dan aspek persekitaran akan dianalisis melalui ujian tegangan, ujian lenturan, ujian impak, dan penyerapan air. Analisis statistik akan digunakan untuk menilai data yang dikumpulkan. Pengiraan berangka dan persembahan grafikal akan dijalankan untuk mengkaji prestasi mekanikal komposit gentian kaca poliester yang diisi dengan hampas tebu dalam kelima-lima nisbah yang berbeza. Dapatan kajian menunjukkan bahawa komposit dengan 80% hampas tebu menunjukkan tingkah laku mekanikal yang lebih baik berbanding dengan komposit-komposit lain.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percentage
20SB80PR	-	20% of sugarcane bagasse and 80% of polyester
40SB60PR	-	40% of sugarcane bagasse and 60% of polyester
50SB50PR	-	50% of sugarcane bagasse and 50% of polyester
60SB40PR	-	60% of sugarcane bagasse and 40% of polyester
80SB20PR	-	80% of sugarcane bagasse and 20% of polyester
ANOVA	-	Analysis of Variance
ASTM	-	American Society for Testing and Materials
CNC	-	Computer Numerical Control
df	-	Degree of Freedom
E	-	Modulus
G	-	Glass Fiber
g	-	Gram
kN	-	Kilonewton
m_1	-	Weight before submerging in water (g)
m_2	-	Weight after submerging in water (g)
min	-	Minute
mm	-	Millimetre
MPa	-	MegaPascal
MS	-	Mean Square
NC	-	Numerical Control
OPEFB	-	Oil Palm Empty Fruit Bunch
rpm	-	Revolutions per minute
SBPR	-	Sugarcane Bagasse With Polyester Resin
SCB	-	Sugarcane Bagasse
SS	-	Sum of Square
UV	-	Ultraviolet
σ_{ult}	-	Tensile Strength

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CHAPTER 1

INTRODUCTION

1.1 Background

In recent times, the utilization of natural waste-based materials in manufacturing engineering and technology has become widespread due to their significant properties. To achieve cost reductions and make advancements, the utilization and application of composite materials have significantly increased in both quantity and variety. Rice husk, rice straw, wood dust, pineapple leaf, coconut leaf, sugarcane bagasse, eggshell, coconut coir, banana peel, and coconut pulp are among the waste-based material that can be used. The waste-based material used in this experimental analysis is sugarcane bagasse. Intriguing as well as crucial, research into the mechanical characteristics of the glass fibre polyester hybrid composite loaded with sugarcane bagasse.

Due to their remarkable mechanical qualities, composite materials have received a lot of attention in recent years. Due to their remarkable mechanical characteristics include an elevated strength-to-weight ratio, long-lasting durability, adaptability, resistance to corrosion, and lightweight nature, composite materials have found extensive application in diverse engineering and construction scenarios. To attain properties that surpass those of its individual components, a composite material is created by combining at least two different materials. Therefore, careful consideration is necessary when selecting the appropriate combination of fibers and resins based on the intended application (Sharma et al., 2020).

In today's modern age, natural fiber-reinforced polymer composites have become increasingly prominent as they possess several beneficial properties provided by natural fibers. These properties include being lightweight, resistant to water, having high impact strength, and being environmentally friendly (Kerni et al.,2020). Conventional techniques for producing composites rely on the utilization of materials that are not renewable, these materials are typically made by combining a reinforcing material, such as fiberglass or carbon fiber, with a matrix material, such as epoxy or polyester resin. Nevertheless, these conventional techniques for manufacturing composites incur high expenses and pose substantial adverse environmental consequences as they rely on non-renewable resources and energy-intensive procedures. Consequently, there is an increasing inclination toward the development of cost-effective and environmentally sustainable composite materials that can exhibit comparable or superior mechanical properties.

Recently, there has been an increasing focus on integrating sustainable materials into the production of composites, driven by increasing concerns regarding environmental issues and the elevated costs associated with traditional materials. Bagasse is a term used to describe the fibrous byproduct of crushing and extracting the juice from sugarcane, and it is commonly regarded as one of the most prevalent agricultural wastes in the world. Sugarcane bagasse fibers, derived from industries such as sugar, alcohol, pulp, and paper, are a valuable by-product (Hemnath et al., 2020). When employed as a filler, sugarcane bagasse has the potential to increase the mechanical properties of composite materials used in manufacturing, outperforming those of traditional composites. It is renewable, biodegradable, and has a low environmental impact compared to traditional fillers such as glass fibers.

Sugarcane bagasse is readily available in sugarcane-producing countries, such as Brazil, India, and China, and its use as a filler could provide economic benefits to these countries while also reducing waste. Numerous research studies have explored the utilization of sugarcane bagasse as a filler in diverse composite materials, such as polypropylene, polyethylene, and epoxy resins. However, there is a lack of research regarding the utilization of sugarcane bagasse as a filling material in glass fiber-polyester hybrid composites.

Hybrid composites are created through the combination of multiple fibers within a single matrix. Natural fibres, synthetic fibres, or a combination of synthetic and natural fibres can all be used to make composite materials. Hybrid composites, which incorporate a mixing of two reinforcing materials, provide unique attributes that can be customized to fulfill a wide range of design needs, encompassing factors such as cost, weight, strength, rigidity, and impact resistant. The properties of a hybrid composite can be modified through various methods, thereby affecting the constituent fibers.

This review is significant because the significant properties of natural fiber-based hybrid composites are heavily influenced by a number of variables, such as changes in the volume/weight fraction of the fibres, adjustments to the layering of the fibres, fibre treatment, and environmental conditions. Different types of hybrid composites, including combinations of synthetic-synthetic fibers, synthetic-natural fibers, and natural-natural fibers, are currently under investigation.

Glass fibers, slender strands of glass used for reinforcing composites, demonstrate a favorable strength-to-weight ratio, making them both strong and lightweight. Glass fibers possess outstanding tensile strength, stiffness, and resistance to heat and chemicals, rendering them highly suitable for a broad spectrum of applications. Glass fibres are widely available in a variety of forms, including rovings, textiles, and mats, enabling adaptability in composite manufacturing processes.

Polyester resins are synthetic polymers formed through the reaction of a dicarboxylic acid with a diol. Due to their favorable properties, they are extensively employed as matrix materials in composites. Polyester resins demonstrate favorable mechanical characteristics, such as notable tensile strength and resistance to impact. They possess outstanding durability against moisture, chemicals, and ultraviolet (UV) radiation, rendering them highly suitable for various outdoor applications. They are cost-effective compared to other resin systems, making them a popular choice for industrial applications.

Glass fiber-polyester hybrid composites are widely recognized as a popular composite material that blends the exceptional strength and rigidity of glass fibers with the versatility and resilience of polyester resin. These composites find widespread use in diverse engineering sectors like automotive, aerospace, marine, and construction industries owing to their exceptional mechanical properties, cost-effectiveness, and ease of processing. Glass fiber-polyester hybrid composites may become more sustainable and less expensive by adding sugarcane bagasse filler. However, there is still little knowledge on how the filler affects the mechanical characteristics of these composites.

Numerous studies have been done recently to examine the mechanical properties of composites that use sugarcane bagasse as a filler. These studies have demonstrated that a number of elements, such as the kind, quantity, and orientation of the fibres as well as the characteristics of the polymer matrix and filler material, can affect the mechanical properties of the composites. Additionally, several experiments have demonstrated that adding sugarcane bagasse to polyester resin might enhance the material's mechanical qualities. The use of sugarcane bagasse as a filler material in hybrid composites has, however, received relatively little attention, particularly when paired with glass fibres and a polyester matrix.

Therefore, the primary goal of this study is to ascertain how adding sugarcane bagasse filler affects the mechanical characteristics of a glass fiber-polyester hybrid composite. The study will evaluate the tensile strength, flexural strength, impact strength, and water absorption capacity of the composite material, utilizing varying ratios of sugarcane bagasse filler and polyester. The findings from this study will offer valuable insights into the prospective utilization of sugarcane bagasse as an affordable and sustainable filler material in composite manufacturing. Moreover, these findings will contribute to the advancement of novel and innovative composite materials suitable for diverse engineering and construction applications.

The study specifically seeks to answer the following questions: how does the addition of sugarcane bagasse affect the composite material from mechanical aspect, what is the optimal weightage of sugarcane bagasse filler that can be added to maximize its mechanical properties of composite material, how does the composite material with sugarcane bagasse filler compare to the composite material without the filler in terms of mechanical behaviour, and what is the best ratio of natural fiber and polyester that can be added to the composite sample. In conclusion, the experimental analysis could contribute to the development of sustainable composites, their potential use in various industries, and their environmental impact compared to conventional composites.

1.2 Problem Statement

The use of composite materials has significantly increased during the past several years in a variety of engineering and building sectors. This surge in popularity can be attributed to their noteworthy properties, including being lightweight, possessing a superior strength-to-weight ratio, offering durability, and demonstrating versatility. However, the cost and environmental impact of traditional composite manufacturing methods is a significant challenges to widespread adoption. There has been an increase in interest in the improvement of sustainable and economical fillers for composite manufacture in recent years. Sugarcane bagasse, which is a residue generated by the sugar industry, holds the potential to facilitate the creation of environmentally friendly composite materials that exhibit strength and cost-effectiveness. Sugarcane bagasse is an abundant waste material that has the potential to be used as a filler in composite manufacturing. The current research is centered on analysing experimentally a hybrid composite material made of glass fibre and polyester with the inclusion of sugarcane bagasse as a filler. The goal of this research is to look at how sugarcane bagasse affects the mechanical properties of a glass fiber-polyester hybrid composite. The research will compare the mechanical properties of the composite material filled with sugarcane bagasse with different ratios of polyester and sugarcane bagasse. The independent and dependent variables that will be analyzed include strength under tension, flexibility, and impact. The research will use a testing machine to exert force on the specimen, and the data analysis will be carried out using statistical methods. The findings of this research will contribute to the development of sustainable and cost-effective composite materials and have significant implications for the engineering and construction industries.

1.3 Research Objective

This study's primary goal is to examine the mechanical properties and environmental aspect of glass fiber polyester hybrid composite filled with sugarcane bagasse. Specifically, the objectives are as follows:

a) To fabricate a glass fiber polyester hybrid composite filled with sugarcane bagasse.
b) To perform the fabricated materials into the testing specimen.
c) To investigate the mechanical properties of the fabricated materials using tensile, flexural, and impact tests, and environmental aspect by using water absorption test.

1.4 Scope of Research

This research's goals are to investigate the mechanical properties and environmental aspect of a glass fibre polyester hybrid composite loaded with sugarcane bagasse. The research will be divided into four stages. The initial step involves fabricating the materials utilizing the hand lay-up technique. The second stage is cutting the fabricated material into the testing specimen using the CNC router machine. The third phase involves conducting tests on the specimen to assess its mechanical properties and environmental aspect, including tensile strength, flexural strength, impact resistance, and water absorption. It is a very important stage to obtain the best result and make a comparison with previous research. The final stage is the analysis of the results using statistical analysis using ANOVA. Based on the analyzed results of the mechanical properties and environmental aspects, we will figure out the ideal mixture for the glass fiber polyester hybrid composite with sugarcane bagasse.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

An extensive review will be provided in this chapter, thinking about the theoretical and foundational aspects of various concerns related to sugarcane bagasse, as well as historical and recent research in the field. Additionally, the materials and methods employed for creating a hybrid composite filled with sugarcane bagasse will be described. Examining the mechanical characteristics of a glass fiber polyester hybrid composite loaded with sugarcane bagasse is the main goal of this study. The mechanical testing will be carried out in accordance with ASTM standards.

2.2 Agriculture Waste

According to Devadiga et al. (2020) researchers have predominantly employed a range of agricultural crops including sugarcane, wheat, paddy, flax, banana, pineapple, and others to convert them into materials that possess desirable properties. There are many benefits to using agricultural crop waste for the creation of materials. These include the ability to utilise lightweight substitute materials with good acoustic properties, the development of aesthetically pleasing surroundings, the practical and safe disposal of such wastes when their useful lives are up, and the potential to increase the value of agricultural goods.

The utilization of natural fibers and agricultural waste is on the rise nowadays, as they possess renewable characteristics that can enhance mechanical properties (Sharma et al., 2021). Previously, reinforced composites based on synthetic fibers were used exclusively due to their affordability and desirable mechanical qualities (Jariwala et al., 2019). Elongation, ultimate tensile strength, flexural characteristics, impact resistance, acoustic absorption, processability, and crash performance are all desirable mechanical qualities of natural fibre composites. These desirable qualities contribute to their increasing demand in the manufacturing of automobile components (Ahmad et. al., 2015).

2.3 Sugarcane Bagasse

According to Abedom et al. (2021) Saccharum spp., commonly known as sugarcane, is extensively cultivated in tropical regions. Figure 2.1 illustrates the abundance of sugarcane bagasse, a fibrous residue obtained from sugarcane. It is obtained from sugarcane, and the fiber has been extracted from it. Following the treatment of bagasse with water, impurities within the bagasse were eliminated, resulting in a change of color from yellow to white (Marichelvam et. al., 2021). The natural fibers typically consist of cellulose, lignin, pectin, and hemicellulose, which determine their fiber properties. Moreover, natural fibers exhibit a hydrophilic nature.

Figure 2.1 Sugarcane Bagasse

2.4 Glass Fiber

Glass fiber is a carefully designed synthetic fiber made primarily of glass, with silica accounting for more than 50% of its composition. It also contains a blend of mineral oxides including calcium, iron, and aluminum oxides (Haris et al., 2022). According to Sharma et al. (2021) the best way to enhance thermal and mechanical properties is by including glass fibers along with silica and alumina as fillers. Glass fibers are widely used in various applications because they offer a cost-effective solution and possess relatively favorable mechanical properties compared to aramid and carbon fibers (Jariwala et al., 2019). According to Haris et al. (2022) Glass fiber is a carefully designed synthetic fiber formed primarily of glass, generally containing more than 50% silica. Various mineral oxides, including those of calcium, iron, and aluminium, are also present.

Glass fiber is a material composed of highly fine glass fibers known for their exceptional strength, durability, and lightweight nature. To produce these fibers, silica glass is extruded into thin strands that form numerous fibers with small diameters. These individual filaments are subsequently collected in large quantities and combined to create a roving. The roving is then machine-woven to create woven roving (Ram et al., 2020). When it comes to maximum tensile strength, glass fibers offer optimal performance. Conversely, composites of sisal and glass fiber demonstrate elevated flexural strength, whereas composites combining sisal, jute, and glass fiber exhibit enhanced impact properties (Messrs. Vignesh Kumar et al., 2020).

2.5 Polyester

Polyesters are durable thermoset polymeric materials that can be categorized as either synthetic or natural, and further classified as aromatic or aliphatic based on their backbone structure (Valerio et al., 2018). According to Abd El-Baky et al. (2021) unsaturated polyester, which is a commonly used thermoset material, has been utilized as the polymer matrix. It is especially suitable for hand layup applications and allows for the easy removal of air bubbles. Table 2.1 details the unsaturated polyester's mechanical characteristics. By combining the unsaturated polyester resin, catalyst, and compressed fiber, sandwich-structured hybrid composites were produced (Haris et al., 2022).

Table 2.1 Characteristics of unsaturated polyester resin provided by the supplier

Property	Polyester
Supplier	Guangdong Good Resin Co., Ltd., Guangdong, China
Apperance	Yellow translucent liquid
Proportion of hardener, methyl ethyl ketone peroxide (MEKP)	2.0–3.0% of resin volume, adjustable as per the temperature
Proportion of accelerator, cobalt naphthenate	1.0–1.5% of resin volume
Density, g/cm^3	1.09
Elongation at break, %	3.0
Young's modulus, GPa	3.1
Tensile strength, MPa	65
Flexural strength, MPa	100
Flexural elastic modulus, GPa	3.5

2.6 Hand Lay-up Method

According to Hemnath et al. (2020) the hand lay-up method is commonly regarded as the most common and economical strategy for open-molding procedures. The hand lay-up technique may cure for 24 hours at a nominal pressure of 2.5 MPa at ambient temperature. The hand layup process has been extensively employed by numerous researchers, but nowadays, additive manufacturing and vacuum techniques have emerged as prominent trends for composite production (Sharma et al., 2020).

According to Mahmoud Zaghloul et al. (2021) the hand layup method allows for the creation of composites comprising continuous fibers, resulting in a high level of uniformity even at maximum volume fractions. It ensures the absence of porosities and voids, resulting in composite parts with optimal strength and stiffness. The hand lay-up technique was employed to create the composite specimens (Karthick et al., 2018). According to Ram et al. (2020), the hand layup method is a straightforward and cost-effective approach for manufacturing composites.

2.7 Cutting Process Machine

For this project, the specimen will be cut into the desired dimensions using a CNC router machine. Specimens must be cut according to the size of ASTM standard, and cut with appropriate spindle speed.

2.7.1 CNC Router Machine

According to Bangse et al. (2020) CNC is a process that automates machine tools, utilizing computer-controlled programs to operate the machines and shape the desired product. By using computer systems, numerical control (NC), also known as CNC, automates the manipulation and control of machining instruments including drills, boring tools, and lathes (Prashil et al., 2019). According to Lin (2018) the test results indicated that the milling machine is capable of accurately working with materials such as acrylic, wood, and aluminum, achieving an accuracy of 0.02mm. A CNC mill is a piece of equipment that operates in accordance with user commands. To carry out precise machining operations, it moves the X and Y axes and manages the spindles in the Z-axis or cutter housing (Biantoro et al., 2020).

2.8 Mechanical Testing

Every design and manufacturing process must apply mechanical testing. Mechanical tests were performed on the samples to ascertain their flexibility, tensile strength, impact strength, and water absorption capability. It is crucial to obtain the best result and compare with previous study. According to Ramlee et al. (2019) the tensile, flexural, and compressive strengths of the samples were examined using the INSTRON universal testing apparatus. Following a 24-hour period, measurements of water absorption and thickness swelling are performed.

2.8.1 Tensile Testing

The ASTM D3039 standard was followed in the preparation of the specimens utilized for the tensile testing. The samples had dimensions of 250 mm in length and 25 mm in width. During testing, the composite thickness was maintained at 6.8 mm, with a slight tolerance of 0.2 mm, and the gripping length was set to 100 mm. The crosshead speed of the Shimadzu 300 kN universal testing machine was 5 mm/min. The load was steadily increased until the sample failed. This experiment's analysis was based on the average value derived from five experimental samples (Abu Shaid Sujon et al., 2020). According to Saba et al. (2018) a destructive technique called tensile testing is used to gather important information on the tensile strength, yield strength, and ductility of metallic materials. This testing procedure involves determining the amount of force necessary to break a specimen made of composite or plastic material. Additionally, it allows for the determination of the extent of elongation or stretching that the specimen undergoes before it reaches its breaking point. The ultimate tensile strength (σ_{ult}) and modulus (E) were calculated using a straightforward examination of the stress-strain data supplied from the testing equipment. (Abu El-Baky et al., 2021).

2.8.2 Flexural Testing (3-point Bending)

According to Abu Shaid Sujon et al. (2020) the flexural test, also known as the three-point bending test, was performed in accordance with the requirements of ASTM D 790. The specimens had dimensions of 250 mm in length and 25 mm in width. All samples were run at a crosshead speed of 5 mm/min with a constant span length of 100 mm between the supports. Flexural properties may be obtained by using three-point bend tests (Kerni et al., 2020). The flexural test determines the amount of force required to bend a beam under the effects of three-point stress. This kind of testing can be used on a wide range of materials, including composites made of laminated fibers, resins, and rigid and semi-rigid materials (Saba et al. 2018).

2.8.3 Impact Testing

For conducting impact testing, the guidelines set forth by ASTM D 6110 were adhered to. The specimens' length and width were 60 mm and 15 mm, respectively. The Charpy Impact test method was used to assess the targeted properties (Abu Shaid Sujon et al., 2020). The impact test's objective is to determine how a specimen made of different materials, including polymers, ceramics, and composites, responds to an abrupt application of stress. This testing procedure precisely assesses the engineering materials' toughness, brittleness, notch sensitivity, and impact strength when subjected to high-rate loading (Saba et al., 2018).

2.8.4 Water Absorption Testing

The ASTM D570 standard's recommendations were followed while calculating the hybrid composites' maximum water absorption percentage. For a period of 24 hours, the specimens were totally submerged in distilled water. Their weights were calculated after they were taken out of the water and dried with a dry cloth. At regular intervals of 24, 48, 98, 196, and up to 312 hours of exposure, this technique was repeated (Abu Shaid Sujon et al., 2020). According to Saba et al. (2018) water absorption commonly referred to as 24-hour/equilibrium water absorption. It is a crucial physical test conducted under ASTM D570 to evaluate the suitability of materials for exterior applications.

2.8.5 The Analysis of the Results Using Statistical Analysis (ANOVA)

According to Afzaluddin et al., (2020) the results of the experiment were subjected to ANOVA using the SPSS program. Turkey's test was used to compare the means, and a significance level of 0.05 ($p \leq 0.05$) was used.

2.9 Summary

Table 2.2 Summary of previous researches finding

No	Literature Title	Materials	Results	Testing	References
1	A novel palm sheath and sugarcane bagasse fiber-based hybrid composites for automotive applications: An experimental approach	Palm sheath + sugarcane bagasse fiber + resin	The findings demonstrated that the highest tensile strength of 19.80 MPa was achieved by the treated hybrid palm and bagasse fiber composite samples with a proportion of 60:40 (S6). Similarly, the combination of treated palm and bagasse fiber composite samples with a proportion of 60:40 (S6) exhibited the highest flexural strength of 28.79 MPa compared to the other composite samples. In comparison to the other composites, the 60:40 (S6) combination	-Tensile test -Flexural test -Impact test -Hardness test	Marichelvam, M. K., P. Manimaran, Akarsh Verma, M. R. Sanjay, Suchart Siengchin, K. Kandakodeeswaran, and M. Geetha. "A novel palm sheath and sugarcane bagasse fiber based hybrid composites for automotive applications: An experimental approach." *Polymer Composites* 42, no. 1 (2021): 512-521.

			of treated palm and bagasse fibre composite samples showed a higher impact strength of 2 kJ/m2. Furthermore, the treated palm and bagasse fiber composite samples with a proportion of 60:40 (S6) achieved a hardness value of 38.02 HD.		
2	Development of Natural Fiber Hybrid Composites Using Sugarcane Bagasse and Bamboo Charcoal for Automotive Thermal Insulation Material	Sugarcane bagasse + bamboo charcoal + resin	Sample C (E65-S20-J15) exhibits more powerful flexural, tensile, and impact resistance (28.142 MPa, 67.58 MPa, and 0.85 J/m2, respectively) compared to the other two samples (A and B).	-Tensile test -Flexural test -Impact test	Abedom, Fasika, S. Sakthivel, Daniel Asfaw, Bahiru Melese, Eshetu Solomon, and S. Senthil Kumar. "Development of natural fiber hybrid composites using sugarcane bagasse and bamboo charcoal for automotive thermal insulation materials." *Advances in*

					Materials Science and Engineering 2021 (2021): 1-10.
3	Development Of Sugar Palm Yarn/Glass Fibre Reinforced Unsaturated Polyester Hybrid Composites	Sugar palm yarn + glass fiber + polyester	The tensile strength, tensile modulus, flexural strength, flexural modulus, and compression strength of the hybrid composites demonstrated an increase as the glass fiber loadings increased.	-Tensile test -Flexural test -Compression test	Nurazzi, N. Mohd, A. Khalina, S. Mohd Sapuan, and M. Rahmah. "Development of sugar palm yarn/glass fibre reinforced unsaturated polyester hybrid composites." *Materials Research Express* 5, no. 4 (2018): 045308.
4	Effect of bagasse ash filled epoxy composites reinforced with hybrid plant fibres for mechanical and thermal properties	Natural fiber + epoxy + hardener	The maximum flexural strengths of the sisal/flax and banana/kenaf hybrid composites, each with a 5 wt% filler of BGA-B, were 56.78 MPa and 34.2 MPa, respectively. With a 3 wt% filler of BGA-B, sisal/kenaf and banana/flax hybrid	-Tensile test -Flexural test -Impact test	Vivek, S., and K. Kanthavel. "Effect of bagasse ash filled epoxy composites reinforced with hybrid plant fibres for mechanical and thermal properties." *Composites*

			composites both demonstrated maximum flexural strengths of 52.72 MPa and 36 MPa, respectively. The tensile behaviour followed a similar pattern, with sisal/kenaf and banana/kenaf hybrid composites, both filled with 5 wt% BGA-B, reaching maximum strengths of 30.90 MPa and 24.73 MPa, respectively. However, the sisal/flax and banana/flax hybrid composites with a 3 wt% BGA-B filler showed maximum tensile strengths of 18.73 MPa and 27.2 MPa, respectively. The sisal/kenaf and sisal/flax hybrid composites' impact resistance		*Part B: Engineering* 160 (2019): 170-176.

5	Evaluation of Mechanical Properties of Sugarcane Reinforced Hybrid Natural Fibre Composites by Conventional Fabrication and Finite Element Method	Sugarcane bagasse + glass fiber + epoxy resin	Sample 1 perform tensile test to examine tensile strength, and the value obtained is 45.98 MPa. Sample 2 carried out flexural test to determine the maximum bending load, the value obtained is 0.49kN. For sample 3, impact test is carried out to determine amount of the energy absorbed and the value obtained is 8J.	-Tensile test -Flexural test -Impact test	Kumar, PN Bharath, R. Sandeep Kumar, and B. Vijaya Ramnath. "Evaluation of mechanical properties of sugarcane reinforced hybrid natural fibre composites by conventional fabrication and finite element method." *Key Engineering Materials* 841 (2020): 327-334.
6	Mechanical characterization of glass fiber resin reinforced with sugarcane	Sugarcane + fiberglass + epoxy	Sample 4 exhibited elevated ultimate tensile stress (24.3 N/mm2), notable compressive strength (22.84 N/mm2), and absorbed a significant amount of energy, ranging from 20% to 30% of the	-Tensile test -Compressive test -Impact test	Rajesh, S., S. Madhankumar, B. Mathivanan, R. Magesh, and N. Arunkumar. "Mechanical characterization of glass fiber resin reinforced with

			weight ratio between fiberglass and sugarcane powder.		sugarcane." *Materials Today: Proceedings* 45 (2021): 6628-6632.
7	Mechanical Properties Evaluation of Sugarcane Bagasse-Glass Polyester Composites	Sugarcane bagasse (SCB) + glass fiber (G) + polyester	The composite C6 [G/SCB/G4/SCB/G] exhibits the most favorable tensile and interlaminar shear properties, whereas the composite C3 [G3/SCB2/G3] demonstrates the highest flexural strength.	-Tensile test -Flexural test -Interlaminar shear test	Abd El-Baky, Marwa A., Mona Megahed, Hend H. El-Saqqa, and Amal E. Alshorbagy. "Mechanical properties evaluation of sugarcane bagasse-glass/polyester composites." *Journal of Natural Fibers* 18, no. 8 (2021): 1163-1180.
8	Physical and mechanical properties of sugar palm/glass fiber reinforced thermoplastic	Estane® 58311 TPU + Sugar palm fiber + glass fiber	The hybrid composite's tensile strength and modulus are highest in the 30/10 SP/G ratio. The hybrid SP/G reinforced TPU with a higher sugar palm content exhibits enhanced tensile stress, strain, and higher elongation at break as	-Tensile test -Flexural test -Impact test	Afzaluddin, Atiqah, Mohammad Jawaid, Mohd Sapuan Salit, and Mohamed Ridwan Ishak. "Physical and mechanical properties of sugar palm/glass fiber reinforced thermoplastic polyurethane hybrid

	polyurethane hybrid composites		compared to TPU composites reinforced with a ratio of 0/40 SP/G. However, when considering glass fibre composites, the integration of 10% (10/30 SP/G) shows the greatest flexural strength. Additionally, the hybrid composites (0/40 SP/G) have a better impact strength than glass fiber-based composites.		composites." *Journal of Materials Research and Technology* 8, no. 1 (2019): 950-959.
9	Tensile and flexural behaviour of rice husk and sugarcane bagasse reinforced polyester composites	Sugarcane bagasse + risk husk powder + polyester	The highest tensile strength and flexural strength were obtained by Sample A, which consisted of 10% sugarcane and 0% rice husk.	-Tensile test -Flexural test	Hemnath, A., G. Anbuchezhiyan, P. NanthaKumar, and N. Senthilkumar. "Tensile and flexural behaviour of rice husk and sugarcane bagasse reinforced polyester composites." *Materials*

					Today: Proceedings 46 (2021): 3451-3454.
10	Tensile, physical and morphological properties of oil palm empty fruit bunch/sugarcane bagasse fibre reinforced phenolic hybrid composites	Oil palm empty fruit bunch (OPEFB) + sugarcane bagasse (SCB) + phenolic resin	The hybrid composites (7OPEFB: 3SCB) demonstrate superior performance compared to the other composites.	-Tensile test -Water absorption test	Ramlee, Nor Azlina, Mohammad Jawaid, Edi Syams Zainudin, and Shaikh Abdul Karim Yamani. "Tensile, physical and morphological properties of oil palm empty fruit bunch/sugarcane bagasse fibre reinforced phenolic hybrid composites." *Journal of Materials Research and Technology* 8, no. 4 (2019): 3466-3474.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter gives detailed information on the procedures used to locate, select, and assess the data pertinent to this topic. The methodology part of this chapter give opportunity to the reader to evaluate the entire procedure and reliability. This research will provide in four stages. The first stage is to fabricate the experiment material by using the hand lay-up technique into five different ratios based on volume which are 20% of sugarcane bagasse and 80% of polyester (20SB80PR), 40% of sugarcane bagasse and 60% of polyester (40SB60PR), 50% of sugarcane bagasse and 50% of polyester (50SB50PR), 60% of sugarcane bagasse and 40% of polyester (60SB40PR), and 80% of sugarcane bagasse and 20% of polyester (80SB20PR).

Table 3.1 Parameter of composite ratio

Abbreviations	Sugarcane Bagasse Powder (%)	Weight (g)	Polyester Resin (%)
20SB80PR	20	24	80
40SB60PR	40	38	60
50SB50PR	50	58	50
60SB40PR	60	66	40
80SB20PR	80	89	20

The second stage is cutting the fabricated material into the desired size of testing specimen using a CNC router machine. The third stage is conducting tests on the specimen to evaluate its mechanical properties through tests such as tensile, flexural, impact, and water absorption. It is a very important stage to obtain the best result and make a comparison with previous research. As required by ASTM D 3039 for tensile testing, ASTM D 6110 for impact testing, ASTM D 790 for flexural testing, and ASTM D 570 for water absorption testing, the specimen size will be in accordance with these requirements. The final stage is the analysis of the results using statistical analysis. We will calculate the ideal ratio of the glass fibre polyester hybrid composite filled with sugarcane bagasse based on the results of the mechanical properties analysis. This chapter will give a general summary of the experiment and technique to achieve an exact outcome.

3.2 Process Flowchart

The flowchart describes a procedure in which the steps are carried out sequentially. A flow chart is a graph that shows how a workflow or process works. Flowcharts are also a visual representation of algorithms and job-related procedures. The stages are represented as various types of boxes on the flow chart, with the boxes connected to the arrows. This diagram represents a hypothetical solution to a problem. Flowcharts are used to plan and document simple system procedures. A flow chart can help you understand each step of the process and how it's done. Figure 3.1 depicts the process flow from its inception to its conclusion.

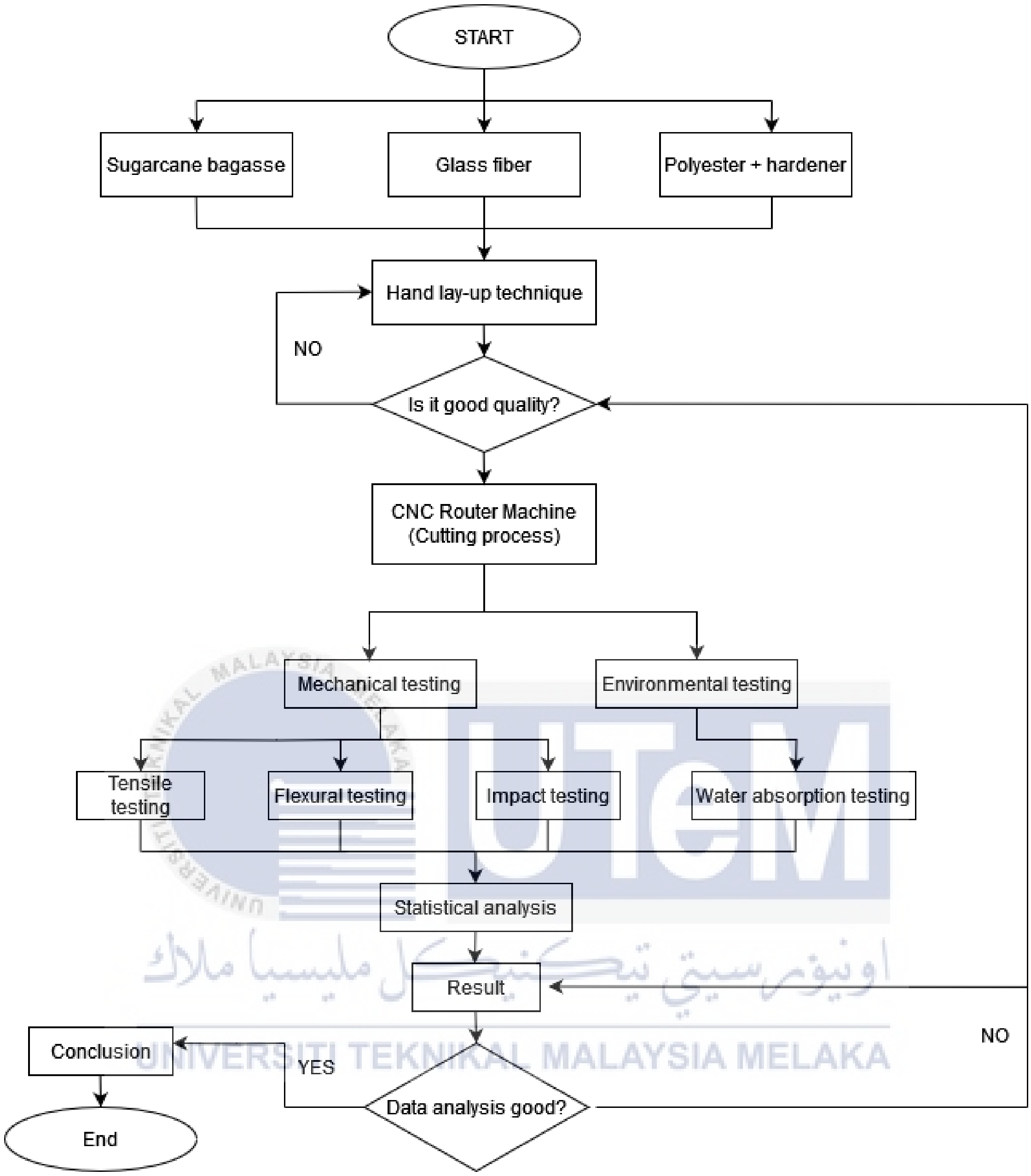

Figure 3.1 Process Flowchart

3.3 Design of Material Specimen

The specimen dimesions will be 300 mm length x 200 mm width based on Figure 3.2. For the purposes of tensile and flexural testing, the specimen will be developed and then cut into pieces of 250 mm in length and 25 mm in breadth. For the impact test, the dimension size of specimen will be 60 mm length x 15 mm width. For water absorption test, dimension size of specimen will be 12 mm in length and 20 mm in width. These specimens are fashioned to meet test standards so that material qualities can be identified after cutting. The dimensional design of the specimens for all testing, including the tensile, flexural, impact, and water absorption tests, is shown in Figures 3.2 and 3.3.

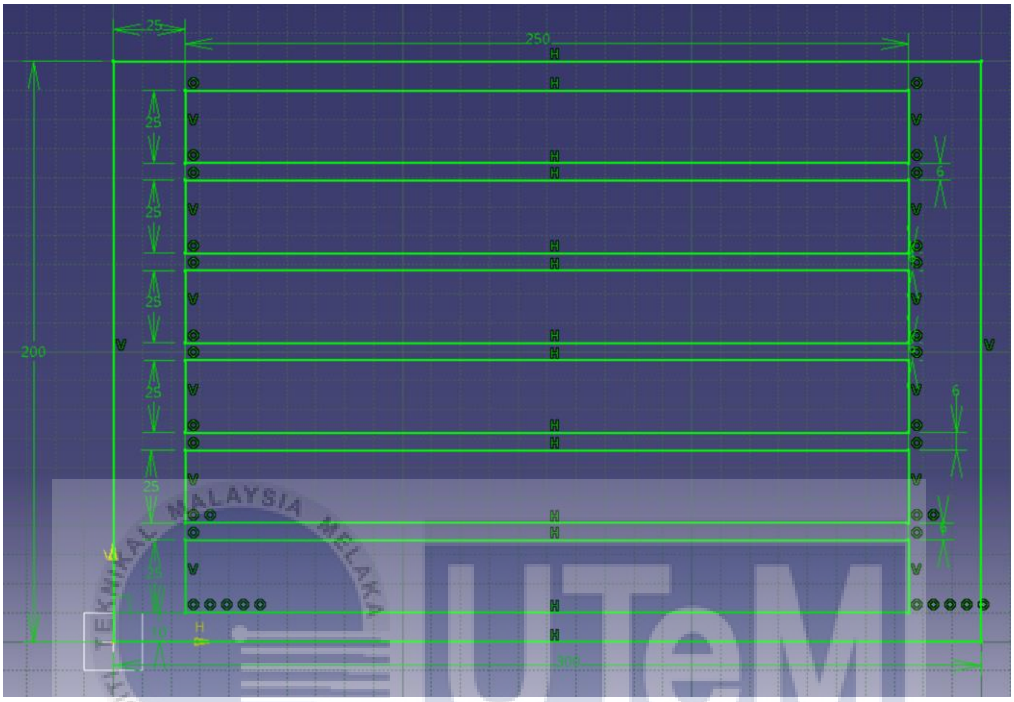

Figure 3.2 The dimensional design of specimens for tensile and flexural testing

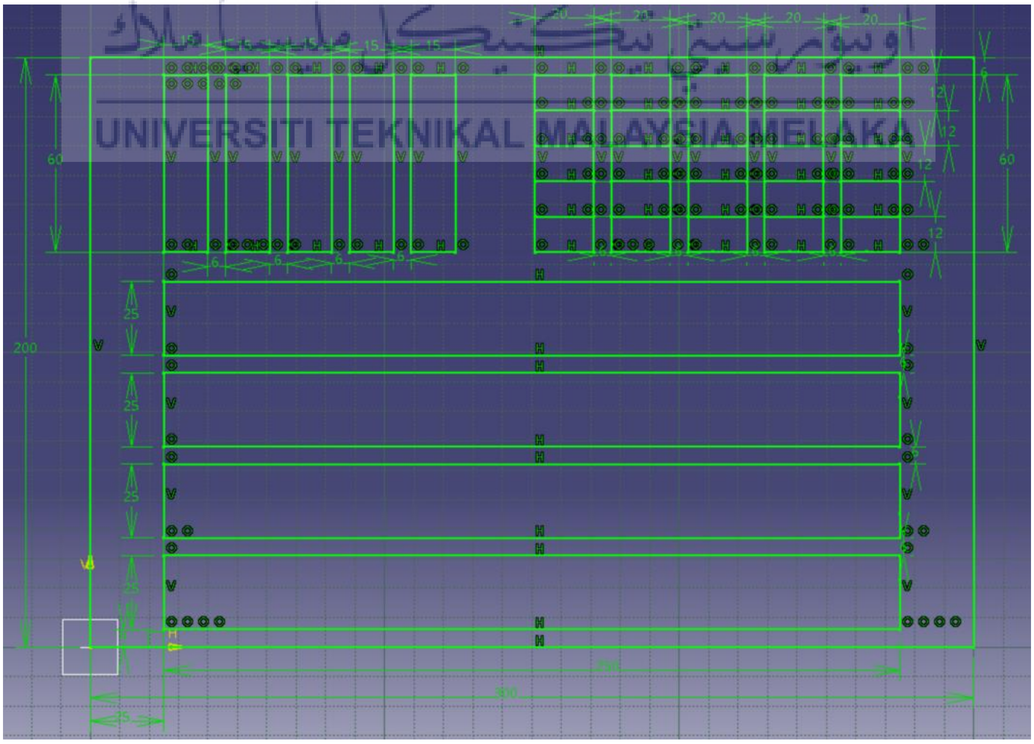

Figure 3.3 The dimensional design of specimens for flexural, impact and water absorption testing

3.4 Measurement Size of Sugarcane Bagasse

Laboratory test sieve is used to determine the size of sugarcane bagasse. Figure 3.4 shows the laboratory test sieve that we used. The process is starting by turn on the power of laboratory test sieve. Before start the process we need to pour the sugarcane bagasse at the top of the sieve and the picture is shown in Figure 3.5. From Figure 3.6 we can know that the size of sugarcane bagasse is mesh 35.

Figure 3.4 Laboratory test sieve

Figure 3.5 Sugarcane bagasse are poured on the top of sieve

Figure 3.6 Mesh size of sugarcane baggasse is 35 mesh

3.5 Experimental Procedure

The experimental method used in this study is a step-by-step strategy for each stream. These procedures are required for the processes and operations to be completed correctly. Each approach necessitates the presence of a focus point to provide accurate and precise outcomes. Following that, this part will look at numerous phases, including fabrication and CNC router cutting. Several procedures were utilized, including tensile testing, flexural testing, impact testing, and water absorption testing.

3.5.1 Fabrication Process

In the first instance, the sugarcane bagasse is a byproduct of the sugarcane industry. It is the fibrous residue that is generated during the sugar production process. The sugarcane bagasse should be soaked in water for at least 24 hours before proceeding to the next process to remove impurities. Afterwards, the sugarcane bagasse is subjected to several days of sun drying to eliminate any remaining moisture content. After the sugarcane bagasse has been fully dried, the sugarcane bagasse is then grind into small pieces using disk mill machine so that they can easy to blend into powder using a blender. After done grinding, we need to blend it so that it become more tiny size and sieve it to make sure the size of sugarcane bagasse is almost same. Once done, store the sugarcane bagasse powder that has been blended into a suitable container to avoid contact with water. After the sugarcane bagasse change into powder, mixed it along with polyester resin and hardener based on volume using manual mixing and pouring into the mould which is with glass fiber that done cut in desired size. Then, we use the hand lay-up technique to create the hybrid composite. Then left it aside at room temperature for at least 24 hours for the drying process.

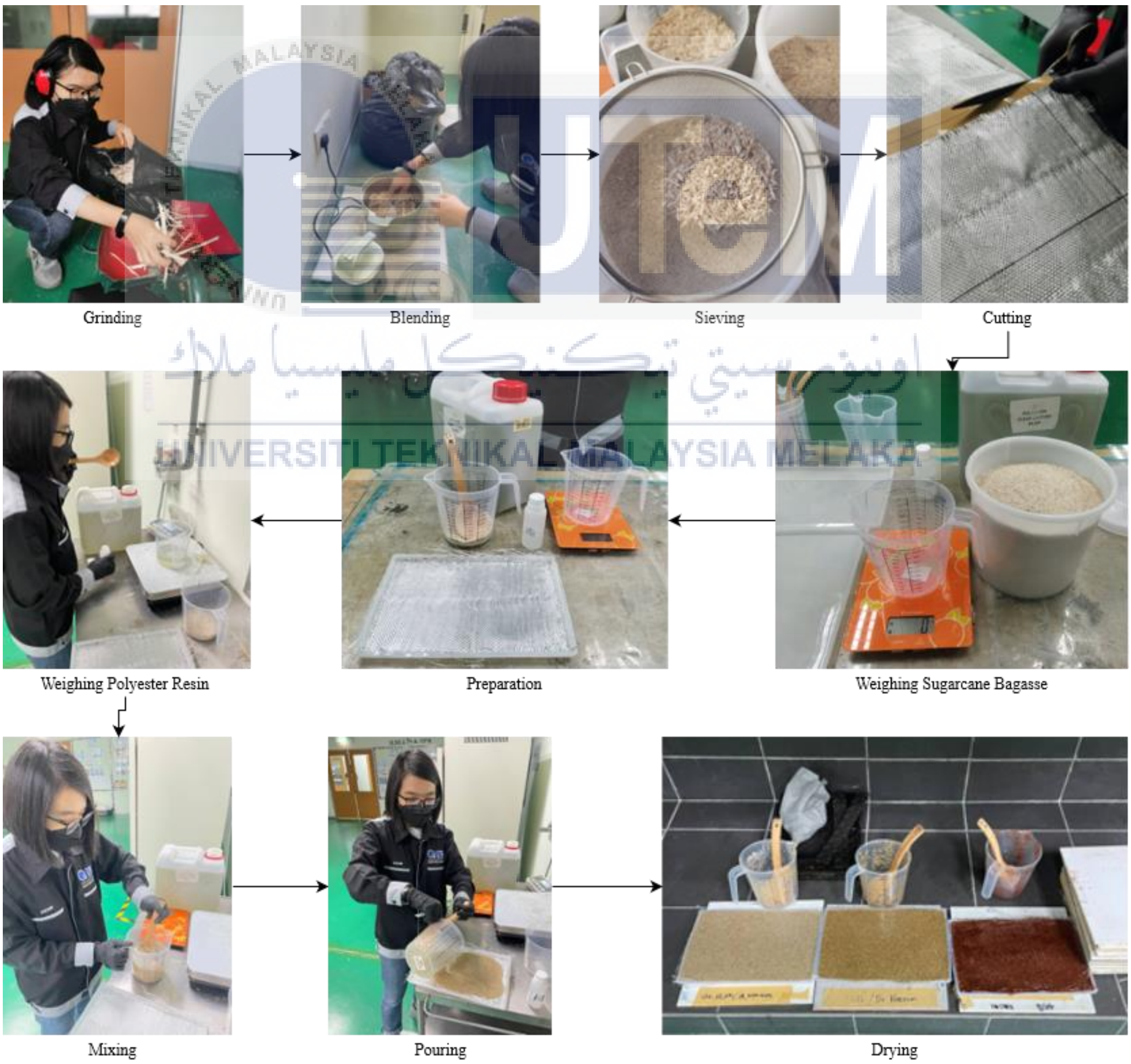

Figure 3.7 Fabrication process

A total of 40 samples per ratio will be produced from each of the two moulds that are 312 mm in length, 212 mm in width, and 12 mm in thickness.

Figure 3.8 The silicone mold of eco-friendly composites

3.5.2 CNC Router Machine Process

After the sample was dry and hardened after 24 hours, the sample was cut using a CNC router machine. The sample has to be cut according to the ASTM standards. Figure 3.9 shows the CNC router machine model MODELA PRO2 (MDX-540). The material test should then be placed on top of the vice to keep it in place. The computer control panel must be in the right position and coordinate axis is set to zero. Once the coordinates have been set in the right position, run the machine by pressing the "output" button on the control panel. Spindle speeds for the CNC router machine will be set at 100 rpm. Figure 3.10 shows the cutting process using CNC router machine while Figure 3.11 shows samples done cut by CNC router machine in same ratio.

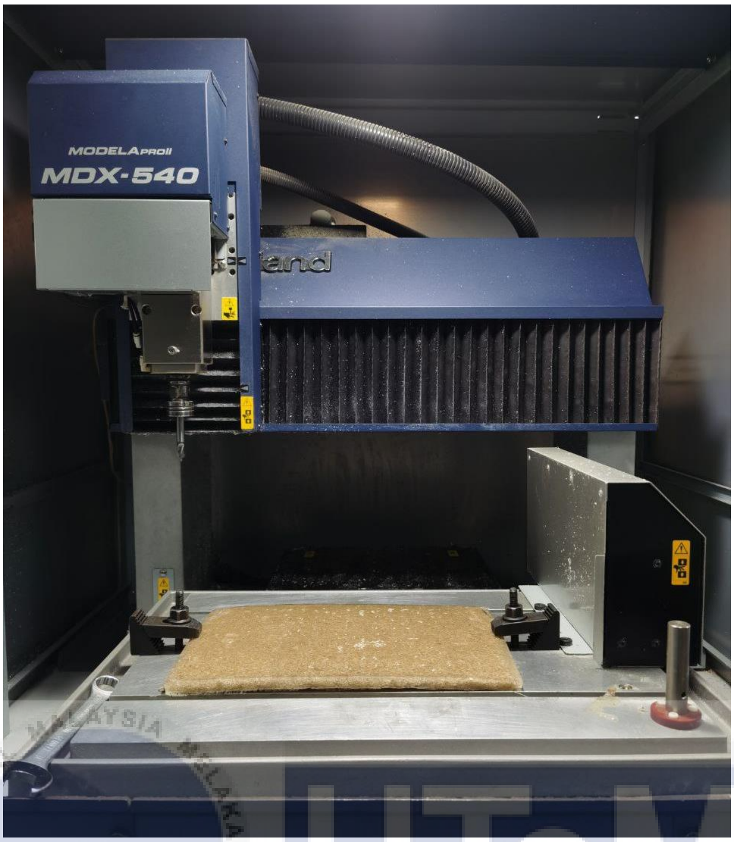

Figure 3.9   CNC router machine model MODELA PRO2 (MDX-540)

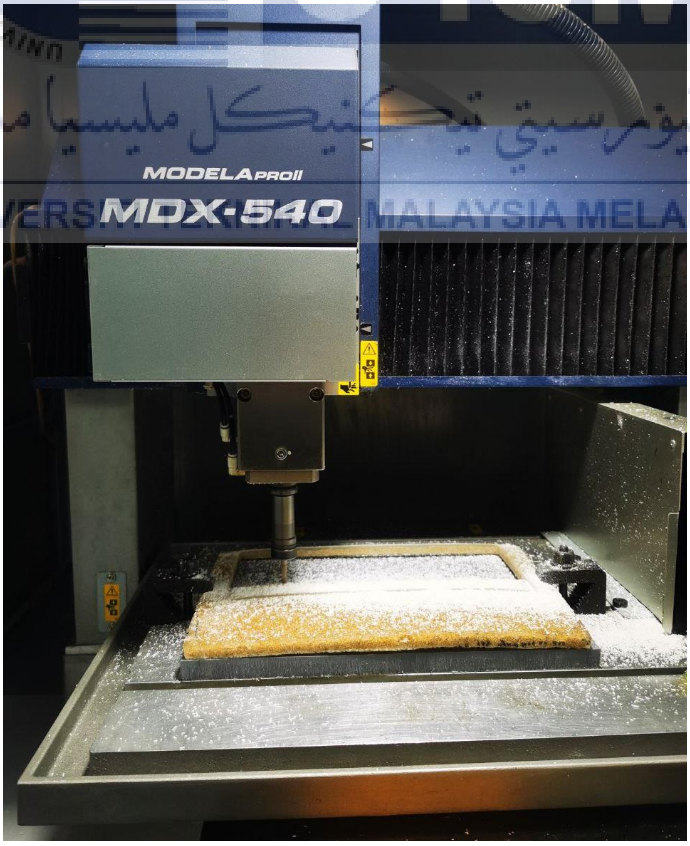

Figure 3.10   Cutting process using CNC router machine

Figure 3.11 Samples that have been done cut for all mechanical testing in one ratio

3.5.3 Tensile Testing Process

The composite samples, which have dimensions of 250 mm x 25 mm, will be tensile tested using a SHIMADZU universal testing machine in compliance with the ASTM D 3039 standard. Figure 3.12 shows the picture of SHIMADZU universal testing machine. The test will be conducted with a load cell range of 100 kN and a 5 mm/min crosshead speed. Insert all the data of samples such as material thickness, length, width, and types of material into software program under tensile test. Position the samples into lower and upper clamps in their proper position to avoid the possibility of the material fracturing in the gripped area. We have marking 30 mm grip length on the top and below of specimen. The picture of specimen been marking is shown in Figure 3.13. The programme will then be performed, and the results will be displayed in stress-strain curves. Process of tensile testing is depicted in Figure 3.14.

Figure 3.12   SHIMADZU universal testing machine (tensile test)


Figure 3.13   The specimens were marked 30 mm at gripped area


Figure 3.14   Process of Tensile Testing

3.5.4 Flexural Testing Process (3-point Bending Test)

The produced composite samples will also be subjected to a flexural test utilising a SHIMADZU universal testing machine in accordance with the ASTM D 790 standard. The machine used is the same machine which is SHIMADZU Universal Testing like tensile test but the test jig is changed for flexural test as shown in Figure 3.15. Program under flexural test (three-point bending) will be selected and insert all the required data of samples such as thickness, length, and width of sample. Before beggining the process, we have draw a centre line on the specimen’s surface as shown in Figure 3.16. The crosshead speed and the support span length was adjusted to 5 mm/min and 100 mm respectively. The flexural property of the samples was determined using an average value derived from five samples. Figure 3.17 shows the process of flexural testing.

Figure 3.15 SHIMADZU universal testing machine (flexural test)

Figure 3.16 The centre of specimens have been marked as a guide

Figure 3.17 Process of flexural testing

3.5.5 Impact Testing Porcess

The composite samples, which are fabricated and have dimensions of 60 mm x 15 mm, will also undergo impact testing. The Charpy impact testing method will be used in accordance with the ASTM D 6110 standard to evaluate the material's toughness and strength at the yield point. A V-notch should be made on the impact test specimen. To create a v-notch, we need to draw a centre line on the specimen surface and vertical line to create a notch with 2 mm depth as shown in Figure 3.18. The specimen is cut by using bendsaw machine to create the v-noch as shown in Figure 3.19. Figure 3.20 shows the result of v-notch on the specimen. V notch will be applied on the body of the samples to determine the test material's notch toughness. Then, data for all samples will be recorded to get the average values. Impact testing is carried out by using pendulum impact tester which is INSTRON CEAST 9050 machine as shown in Figure 3.21.

Figure 3.18 Specimen done marking

Figure 3.19 (a) Makita Bendsaw Machine (b) Process of cutting V-notch

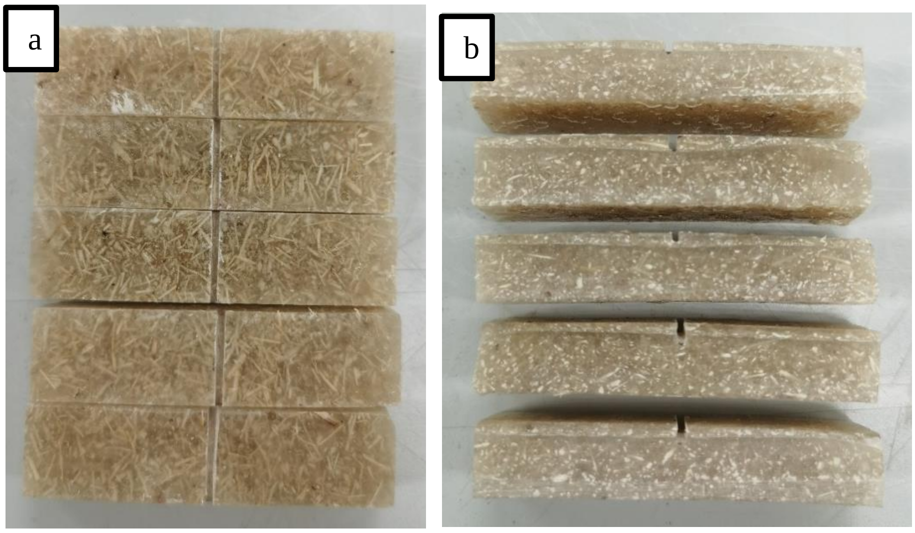

Figure 3.20 (a) Top view of v-notch (b) Side view of v-notch

Figure 3.21 INSTRON CEAST 9050 machine

3.5.6 Water Absorption Testing Process

The composite samples, fabricated with dimensions of 12 mm x 20 mm, will undergo a water absorption test. The test involves submerging the composites in distilled water for 5 days, following the ASTM D 570 standard. After removing any surface water using a clean dry cloth, the samples are weighed. This procedure is repeated at 5, 10, 15, 20, and up to 25 days of exposure. The following calculation is used to compute the water absorption content.

$$\text{Water absorption content} = m_2 - m_1$$

The weight of the samples have beeen measured and recorded before immersed in distilled water and depicted in Figure 3.22. Figure 3.23 shows the samples immersed in distilled water.

Figure 3.22   Samples before immersed in distilled water

Figure 3.23   Water absorption testing in progress

3.5.7 Statistical Analysis (ANOVA)

Microsoft Excel will be used to calculate the mean, median, or variance, and to summarise a set of results with a single value. The ANOVA approach will also be utilised to assess the strength of the specimen following the cutting process with a CNC router machine. Data for each sample was plotted using a bar chart. The ANOVA process is displayed in Table 3.2 as an example, the abbreviations SS stands for sum of squares, df stands for degree of freedom, MS stands for mean squares, F stands for test statistic, and P stands for significant value.

Table 3.2 Example of ANOVA method for tensile strength

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Ratios	479.9308	4	119.9827	460.1011	2.25E-19
Within Ratios	5.215493	20	0.260775		
Total	485.1463	24			

3.6 Summary

To accomplish all the project's objectives, it can be concluded that all these procedures and preparations must be carried out properly and in accordance with the process planning. By the end of this chapter, every planning, method, and preparation will played a major influence in reaching desired outcomes and results. Finally, all methods must be carefully and correctly followed with no errors to acquire valid results from these tests.

3.7 Gantt Chart

3.7.1 Gantt Chart PSM 1

As shown in APPENDIX A

3.7.2 Gantt Chart PSM 2

As shown in APPENDIX B

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

With the hope of attaining successful results, this chapter will provide a thorough description of the sample generation results as well as the results of each mechanical test carried out. These conclusions are based on a review of the literature undertaken at the start of the thesis. Following that, this chapter will offer some preliminary data that will allow the thesis to be completed. This study's primary focus is mechanical testing, which includes tensile, impact, flexural, and water absorption tests. These tests are used to evaluate the material's characteristics and structure.

4.2 Results and Analysis of tensile test

The tensile test is one of the mechanical tests used to determine and analyze composite material's properties such as tensile strength, yield strength, tensile modulus, elasticity, and elongation of the material. This test procedure involves determining the amount of force necessary to break a specimen. The ASTM D 3039 standard was followed in the preparation of the specimens utilized for this tensile testing. Five samples with different ratios are drawn from the specimens. The sample was cut in 250 mm in length and 25 mm in width by CNC Router machine. The samples were tested on a SHIMADZU Universal Testing Machine equipped with a 5 mm/min crosshead speed. The average values of the five samples were analyze and recorded. Figure 4.1 shown the sample attached to a tensile test machine.

Figure 4.1 Sample attached to tensile testing machine

The tensile strength of the specimen is defined as the greatest strain it can sustain, representing the maximum stress applied to the specimen by its original cross-sectional area. The modulus of elasticity characterizes a material's attributes as it experiences stress, undergoes deformation, and subsequently reverts to its initial form upon stress removal. The variation of tensile strength and elasticity of different ratio of SBPR composites is shown in Figures 4.2 and 4.3 respectively.

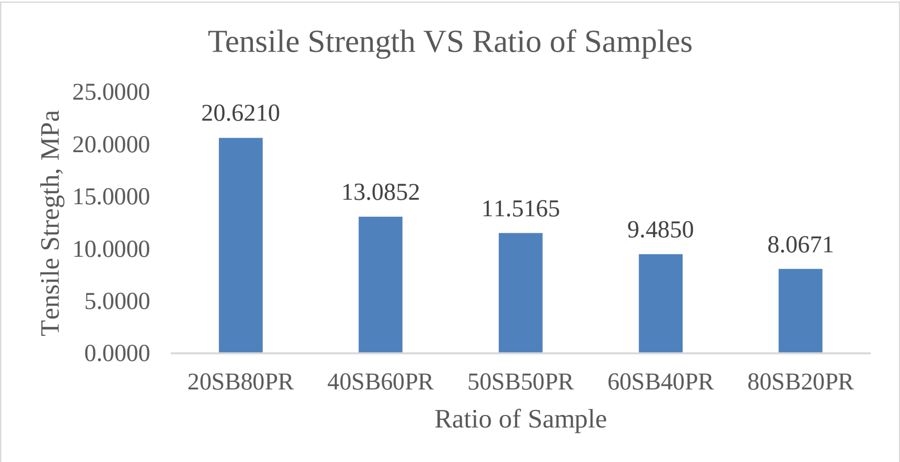

Figure 4.2 Tensile strength for five different ratios of SBPR composites

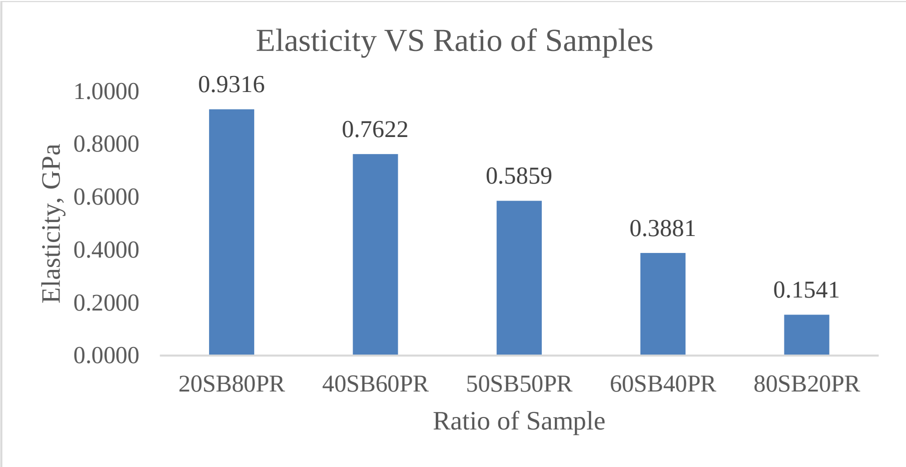

Figure 4.3 Elasticity for five different ratios of SBPR composites

Figures 4.2 and 4.3 illustrates the tensile strength and elasticity value for each of the five SBPR composite ratios which are 20SB80PR, 40SB60PR, 50SB50PR, 60SB40PR, and 80SB20PR. The tensile strength and elasticity of 20SB80PR were found to be higher than other ratios SBPR composites. The value of tensile strength is 20.6210 MPa while the value of elasticity is 0.9316 GPa. Comparatively, 80SB20PR get the lowest value of tensile strength and elasticity. According to this testing, SBPR composites with 20% or less sugarcane bagasse had better tensile strength and elasticity.

Figure 4.4 shows the tensile testing specimen that has been tested. The specimen break after the force is exerted upon on the specimen. All specimens subjected to testing performed successfully. There are 25 specimens are tested.

Figure 4.4 Results of tensile test

Table 4.1 Summary statistics result of tensile strength

SUMMARY

Ratios	Count	Sum	Average	Variance
20SB80PR	5	103.105	20.621	0.178493
40SB60PR	5	65.4262	13.08524	0.58241
50SB50PR	5	57.58267	11.51653	0.153424
60SB40PR	5	47.42512	9.485024	0.117045
80SB20PR	5	40.33537	8.067074	0.272502

Table 4.2 Summary statistics result of elasticity

SUMMARY

Ratios	Count	Sum	Average	Variance
20SB80PR	5	4.65799	0.931598	0.001243
40SB60PR	5	3.81103	0.762206	0.000189
50SB50PR	5	2.92933	0.585866	0.000217
60SB40PR	5	1.94032	0.388064	0.000609
80SB20PR	5	0.77064	0.154128	0.000527

Refer to the Tables 4.1 and 4.2, the average is the sum of all the data divided by the number of entries in the data sets. Variance is a measure of how much a set of numbers or data points deviate from their mean (average). It is a statistical measure of the spread or dispersion of a dataset. If value of variance is close to zero, this means that the result is consistent. Variance is also the power two of standard deviation. The standard deviation is always greater than or equal to 0. The value of the standard deviation can be explained as follows. If the value is 0, this means that there is no variation in the data sets and all value in the data sets are equal. Meanwhile, if the value of the standard deviation is close to 0, it means that the data are spread on a small range around the mean. Lastly, if the value of standard deviation is larger, it indicates that the value of data set gets farther from the mean or the data spread on the larger range around the mean. Since the value of variance for 60SB40PR composite is 0.117045 for Table 4.1, and the value of variance for 40SB60PR for Table 4.2 is 0.000189 so we can say that these value is consistent.

Following that, the tensile and elastic characteristics of the composite were examined using ANOVA. The result of ANOVA for five different ratios SBPR composites were attached in Tables 4.3 and 4.4 respectively. The results presented that the tensile strength and elasticity of SBPR composite for all five different ratios were significant since the P-value is lower than the significant cut-off level which is ($\alpha = 0.05$). Therefore, it demostrated that the average of the tensile strength and elasticity for the five ratios of SBPR composites are different. As a result, combining sugarcane bagasse with polyester resin in proportions of 20% and 80% respectively provides the best tensile performance.

Table 4.3 ANOVA of tensile strength for five different ratios of SBPR composites

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Ratios	479.9308	4	119.9827	460.1011	2.25E-19
Within Ratios	5.215493	20	0.260775		
Total	485.1463	24			

From the Table 4.3, since the P-value was below than the significant cut-off level which is $\alpha = 0.05$. Hence, the Turkey's test needs to be done to distinguish each means are significantly different from each other. It suppose that, by following ANOVA where needs to rejected the null hypothesis of equal ratio means. The all pairwise mean to test comparisons. The equation of Turkey's test is shown below:

$$T_\alpha = q_\alpha(k, v)\sqrt{\frac{MS_\varepsilon}{n}}$$

Refer to Appendix C, it contains value of q_α (k,v), the upper α percentage points of q, where v is the degrees of freedom associated with the MS_ε. For equal sample sizes, Turkey test declares two means significantly different of the absolute value of their sample differences exceeds.

To illustrate Turkey's test, use the data from average of the tensile strength for every ratio. With $\alpha = 0.05$ and f = 20 degrees of freedom for error, Appendix C upper percentage points of the studentized range distribution gives $q_{0.05}$ (5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5,20)\sqrt{\frac{0.260775}{5}} = 4.24\sqrt{\frac{0.260775}{5}} = 0.9683$$

Thus, any pairs of ratio averages that differ in absolute value by more than 0.9683 would imply that the corresponding pair of population means are significantly different. The five ratio averages are;

$\bar{y}_1 = 20.6210$

$\bar{y}_2 = 13.0852$

$\bar{y}_3 = 11.5165$

$\bar{y}_4 = 9.4850$

$\bar{y}_5 = 8.0671$

and the differences in averages are;

$\bar{y}_1 - \bar{y}_2 = 20.6210 – 13.0852 = 7.5358$*

$\bar{y}_1 - \bar{y}_3 = 20.6210 – 11.5165 = 9.1045$*

$\bar{y}_1 - \bar{y}_4 = 20.6210 – 9.4850 = 11.1360$*

$\bar{y}_1 - \bar{y}_5 = 20.6210 – 8.0671 = 12.5539$*

$\bar{y}_2 - \bar{y}_3 = 13.0852– 11.5165 = 1.5687$*

$\bar{y}_2 - \bar{y}_4 = 13.0852 – 9.4850 = 3.6002$*

$\bar{y}_2 - \bar{y}_5 = 13.0852 – 8.0671 = 5.018$*

$\bar{y}_3 - \bar{y}_4 = 11.5165 – 9.4850 = 2.0315$*

$\bar{y}_3 - \bar{y}_5 = 11.5165 – 8.0671 = 3.4494$*

$\bar{y}_4 - \bar{y}_5 = 9.4850 – 8.0671 = 1.4179$*

The starred values indicate the pairs of means that are significantly different. Note that the Turkey's procedure shows that there are ten different pairs of means. Therefore, $\bar{y}_1$

- $\bar{y}_2$, $\bar{y}_1$ - $\bar{y}_3$, $\bar{y}_1$ - $\bar{y}_4$, $\bar{y}_1$ - $\bar{y}_5$, $\bar{y}_2$ - $\bar{y}_3$, $\bar{y}_2$ - $\bar{y}_4$, $\bar{y}_2$ - $\bar{y}_5$, $\bar{y}_3$ - $\bar{y}_4$, $\bar{y}_3$ - $\bar{y}_5$, and $\bar{y}_4$ - $\bar{y}_5$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting.

Table 4.4 ANOVA of elasticity for five different ratios of SBPR composites

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Ratios	1.869199	4	0.4673	838.9789	5.83E-22
Within Ratios	0.01114	20	0.000557		
Total	1.880339	24			

Same as Table 4.3, since the P-value was below than the significant cut-off level which is α = 0.05. Hence, the Turkey's test needs to be done to distinguish each means are significantly different from each other. It suppose that, by following ANOVA where needs to rejected the null hypothesis of equal ratio means. The all pairwise mean to test comparisons. The equation of Turkey's test is shown below:

$$T_\alpha = q_\alpha(k, v)\sqrt{\frac{MS_\varepsilon}{n}}$$

Refer to Appendix C, it contains value of q_α (k,v), the upper α percentage points of q, where v is the degrees of freedom associated with the MS_ε. For equal sample sizes, Turkey test declares two means significantly different of the absolute value of their sample differences exceeds.

To illustrate Turkey's test, use the data from average of the elasticity for every ratio. With α = 0.05 and f = 20 degrees of freedom for error, Appendix C upper percentage points of the studentized range distribution gives $q_{0.05}$ (5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5{,}20)\sqrt{\frac{0.000557}{5}} = 4.24\sqrt{\frac{0.000557}{5}} = 0.04475$$

Thus, any pairs of ratio averages that differ in absolute value by more than 0.04475 would imply that the corresponding pair of population means are significantly different. The five ratio averages are;

$$\bar{y}_1 = 0.9316$$

$$\bar{y}_2 = 0.7622$$

$$\bar{y}_3 = 0.5859$$

$$\bar{y}_4 = 0.3881$$

$$\bar{y}_5 = 0.1541$$

and the differences in averages are;

$$\bar{y}_1 - \bar{y}_2 = 0.9316 – 0.7622 = 0.1694^*$$

$$\bar{y}_1 - \bar{y}_3 = 0.9316 – 0.5859 = 0.3457^*$$

$$\bar{y}_1 - \bar{y}_4 = 0.9316 – 0.3881 = 0.5435^*$$

$$\bar{y}_1 - \bar{y}_5 = 0.9316 – 0.1541 = 0.7775^*$$

$$\bar{y}_2 - \bar{y}_3 = 0.7622 – 0.5859 = 0.1763^*$$

$$\bar{y}_2 - \bar{y}_4 = 0.7622 – 0.3881 = 0.3741^*$$

$$\bar{y}_2 - \bar{y}_5 = 0.7622 – 0.1541 = 0.6081^*$$

$$\bar{y}_3 - \bar{y}_4 = 0.5859 – 0.3881= 0.1978^*$$

$$\bar{y}_3 - \bar{y}_5 = 0.5859 – 0.1541 = 0.4318^*$$

$$\bar{y}_4 - \bar{y}_5 = 0.3881 – 0.1541 = 0.2340^*$$

The starred values indicate the pairs of means that are significantsly different. Note that the Turkey’s procedure shows that there are ten different pairs of means. Therefore, $\bar{y}_1 - \bar{y}_2$, $\bar{y}_1 - \bar{y}_3$, $\bar{y}_1 - \bar{y}_4$, $\bar{y}_1 - \bar{y}_5$, $\bar{y}_2 - \bar{y}_3$, $\bar{y}_2 - \bar{y}_4$, $\bar{y}_2 - \bar{y}_5$, $\bar{y}_3 - \bar{y}_4$, $\bar{y}_3 - \bar{y}_5$, and $\bar{y}_4 - \bar{y}_5$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting.

4.3 Results and Analysis of flexural test

The flexural test will be performed to determine the amount of force required to bend a specimen under the effect of three-point stress. The flexural test was performed in accordance with the requirements of ASTM D 790. Five samples with different ratios are drawn from the specimens. The sample was cut in 250 mm in length and 25 mm in width by CNC Router Machine. The samples were tested on SHIMADZU Universal Testing Machine equipped with a 5 mm/min crosshead speed with a constant span length of 100 mm between the supports. The average values of the five samples were analyse and recorded. Figure 4.5 shown the sample attached to flexural testing machine.

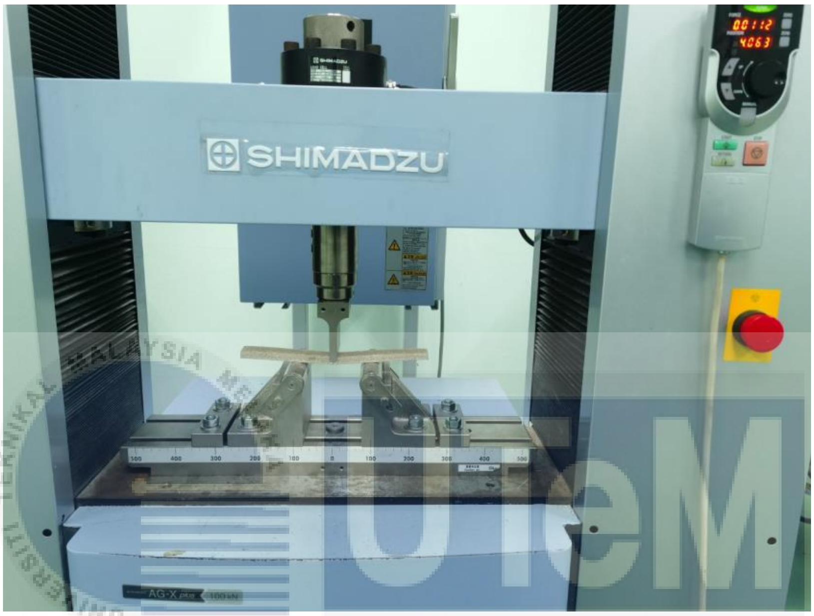

Figure 4.5 Sample attached to flexural testing machine

The maximum stress that a material can withstand before yielding under bending is referred to as its flexural strength. The most widely used method for assessing the flexural strength of a specimen is employing a transverse bending test with a three-point bending configuration. Maximum stress denotes the highest flexural stress and the lowest compressive stress, respectively. The stress range was defined by calculating the absolute difference between the maximum and minimum stress values. The variation of maximum stress for different ratio of SBPR composite is shown in Figure 4.6.

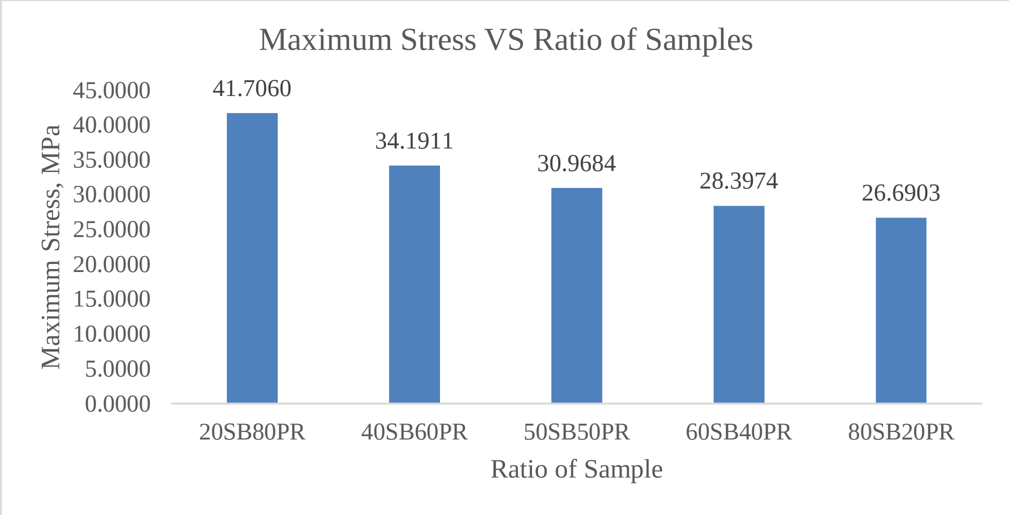

Figure 4.6 Maximum stress for five different ratios of SBPR composites

Figure 4.6 illustrates the maximum stress for five different ratio of SBPR composites respectively. The maximum stress of 20SB80PR were found to be higher which is 41.7060 MPa than other SBPR composite ratios. Comparatively, 80SB20PR had the lowest value of maximum stress. This observation showed that the flexural strength of SBPR composite become stronger as the percentage of sugarcane bagasse decrease around 20%.

Figure 4.7 shows the flexural testing specimen that has been tested. The specimen fracture after the force is exerted upon on the specimen. All specimens subjected to testing performed successfully. There are 25 specimens are tested.

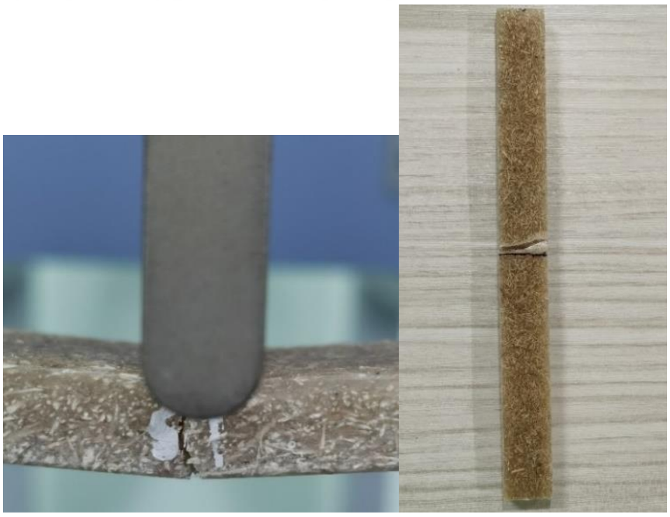

Figure 4.7 Result of flexural test

Table 4.5 Summary statistics result of maximum stress

SUMMARY

Ratios	Count	Sum	Average	Variance
20SB80PR	5	208.53	41.706	0.95606
40SB60PR	5	170.9556	34.19112	0.991491
50SB50PR	5	154.8422	30.96844	1.668835
60SB40PR	5	141.987	28.3974	0.584089
80SB20PR	5	133.4515	26.6903	0.921667

Refer to the Table 4.5, the average is the sum of all the data divided by the number of entries in the data sets. Variance is a measure of how much a set of numbers or data points deviate from their mean (average). It is a statistical measure of the spread or dispersion of a dataset. If value of variance is close to zero, this means that the result is consistent. Variance is also the power two of standard deviation. The standard deviation is always greater than or equal to 0. The value of the standard deviation can be explained as follows. If the value is 0, this means that there is no variation in the data sets and all value in the data sets are equal. Meanwhile, if the value of the standard deviation is close to 0, it means that the data are spread on a small range around the mean. Lastly, if the value of standard deviation is larger, it indicates that the value of data set gets farther from the mean or the data spread on the larger range around the mean.

Following that, the maximum stress of the SBPR composite were examined using ANOVA. The result of ANOVA for five different ratios SBPR composites were attached in Table 4.6. The results presented that the maximum stress of SBPR composite for all five different ratios were significant since the P-value is lower than the significant cut-off level which is ($\alpha = 0.05$). Therefore, it demostrated that the average of the flexural strength for the five ratios of SBPR composites are different. As a result, combining sugarcane bagasse with polyester resin in proportions of 20% and 80% respectively provides the best flexural performance.

Table 4.6 ANOVA of maximum stress for five different ratios of SBPR composites

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Ratios	702.4008	4	175.6002	171.4128	3.58E-15
Within Ratios	20.48857	20	1.024429		
Total	722.8893	24			

From the Table 4.6, since the P-value was below than the significant cut-off level which is α = 0.05. Hence, the Turkey's test needs to be done to distinguish each means are significantly different from each other. It suppose that, by following ANOVA where needs to rejected the null hypothesis of equal ratio means. The all pairwise mean to test comparisons. The equation of Turkey's test is shown below:

$$T_\alpha = q_\alpha(k, v)\sqrt{\frac{MS_\varepsilon}{n}}$$

Refer to Appendix C, it contains value of q_α (k,v), the upper α percentage points of q, where v is the degrees of freedom associated with the MS_ε. For equal sample sizes, Turkey test declares two means significantly different of the absolute value of their sample differences exceeds.

To illustrate Turkey's test, use the data from average of the energy absorb for every ratio. With α = 0.05 and f = 20 degrees of freedom for error, Appendix C upper percentage points of the studentized range distribution gives $q_{0.05}$ (5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5{,}20)\sqrt{\frac{1.024429}{5}} = 4.24\sqrt{\frac{1.024429}{5}} = 1.9192$$

Thus, any pairs of ratio averages that differ in absolute value by more than 1.9192 would imply that the corresponding pair of population means are significantly different. The five ratio averages are;

$$\bar{y}_1 = 41.7060$$

$$\bar{y}_2 = 34.1911$$

$$\bar{y}_3 = 30.9684$$

$$\bar{y}_4 = 28.3974$$

$$\bar{y}_5 = 26.0963$$

and the differences in averages are;

$$\bar{y}_1 - \bar{y}_2 = 41.7060 – 34.1911 = 7.5149^*$$

$$\bar{y}_1 - \bar{y}_3 = 41.7060 – 30.9684 = 10.7376^*$$

$$\bar{y}_1 - \bar{y}_4 = 41.7060 – 28.3974 = 13.3086^*$$

$$\bar{y}_1 - \bar{y}_5 = 41.7060 – 26.0963 = 15.6097^*$$

$$\bar{y}_2 - \bar{y}_3 = 34.1911– 30.9684 = 3.2227^*$$

$$\bar{y}_2 - \bar{y}_4 = 34.1911 – 28.3974 = 5.7937^*$$

$$\bar{y}_2 - \bar{y}_5 = 34.1911 – 26.0963 = 8.0948^*$$

$$\bar{y}_3 - \bar{y}_4 = 30.9684 – 28.3974 = 2.5710^*$$

$$\bar{y}_3 - \bar{y}_5 = 30.9684 – 26.0963 = 4.8721^*$$

$$\bar{y}_4 - \bar{y}_5 = 28.3974 – 26.0963 = 2.3011^*$$

The starred values indicate the pairs of means that are significantly different. Note that the Turkey's procedure shows that there are ten different pairs of means. Therefore, $\bar{y}_1 - \bar{y}_2$, $\bar{y}_1 - \bar{y}_3$, $\bar{y}_1 - \bar{y}_4$, $\bar{y}_1 - \bar{y}_5$, $\bar{y}_2 - \bar{y}_3$, $\bar{y}_2 - \bar{y}_4$, $\bar{y}_2 - \bar{y}_5$, $\bar{y}_3 - \bar{y}_4$, $\bar{y}_3 - \bar{y}_5$, and $\bar{y}_4 - \bar{y}_5$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting.

4.4 Results and Analysis of impact test

The mechanical properties of SBPR composite materials were determined by Charpy impact test. An impact test is performed to evaluate the impact capabilities of various specimens. The energy loss is calculating using the Charpy impact machine readout. The amount of the energy absorbed by the specimen prior to failure was measured in joules. All the specimens prepared according to the ASTM D 256 standards. The brittle properties of the composite accounts for the lower comparison values reported for impact tests in SBPR composites. The major goal of this experiment is to focus on the environment's composite nature. By exaggerating the nature of composites in material replacement, it is possible to preserve the environment and promote the usage of eco-materials. The variation of energy absorbed for various ratio of sugarcane bagasse is shown in Figure 4.8 below.

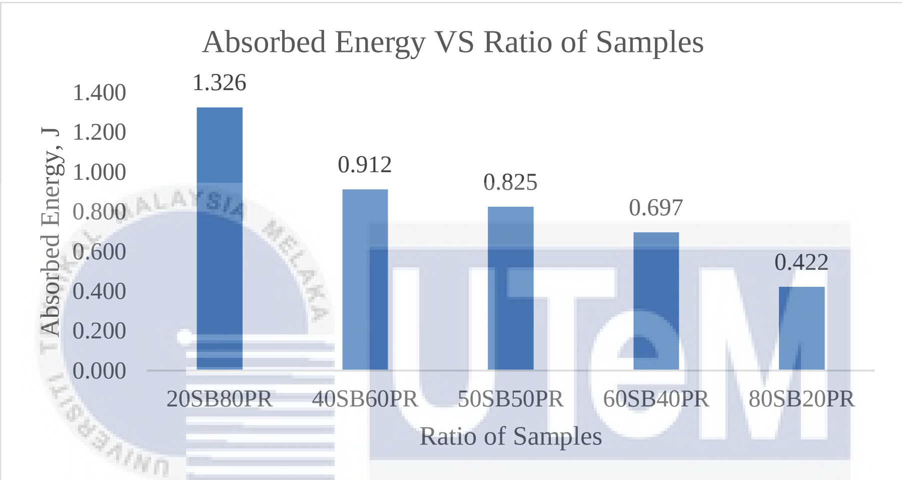

Figure 4.8 Absorbed Energy for five different ratios of composite samples

Figure 4.8 shows the energy absorb value for each of the different SBPR composite ratios which are 20SB80PR, 40SB60PR, 50SB50PR, 60SB40PR, and 80SB20PR. From the result, the energy absorb value of 20SB80PR was higher than other SBPR composite ratios. The impact strength of 20SB80PR composite is 1.326 Joule which is the highest among five different ratios of SBPR composites. The formation of cracks happens due to the absorption of energy by each specimen when exposed to a strong impact force from a pendulum. The crack is often transmitted through the SBPR composites. Significant energy absorption will occur as the fracture advances within the composite. Comparatively, 80SB20PR had the lowest value of energy absorb. This observation suggested that the energy absorb of the SBPR composite become stronger as the percentage of polyester resin is more than or equal to 80%. Figure 4.9 shows the results of impact test specimen.

Figure 4.9 Results of impact test

Table 4.7 Summary statistics result of absorbed energy

SUMMARY

Ratios	Count	Sum	Average	Variance
20SB80PR	5	6.628	1.3256	0.001519
40SB60PR	5	4.562	0.9124	0.002187
50SB50PR	5	4.127	0.8254	0.003974
60SB40PR	5	3.483	0.6966	0.008488
80SB20PR	5	2.108	0.4216	0.002222

Refer to the Table 4.7, the average is the sum of all the data divided by the number of entries in the data sets. Variance is a measure of how much a set of numbers or data points deviate from their mean (average). It is a statistical measure of the spread or dispersion of a dataset. If value of variance is close to zero, this means that the result is consistent. Variance is also the power two of standard deviation. The standard deviation is always greater than or equal to 0. The value of the standard deviation can be explained as follows. If the value is 0, this means that there is no variation in the data sets and all value in the data sets are equal. Meanwhile, if the value of the standard deviation is close to 0, it means that the data are spread on a small range around the mean. Lastly, if the value of standard deviation is larger, it indicates that the value of data set gets farther from the mean or the data spread on the larger range around the mean.

Following that, the energy absorb value of the SBPR composite were examined using ANOVA. The result of ANOVA for five different ratios SBPR composites were attached in Table 4.8. The results presented that the energy absorb value of SBPR composite for all five different ratios were significant since the P-value is lower than the significant cut-off level which is ($\alpha = 0.05$). Therefore, it demonstrated that the average of the absorbed energy for the five ratios of SBPR composites are different. As a result, combining sugarcane bagasse with polyester resin in proportions of 20% and 80% respectively provides the best impact performance.

Table 4.8 ANOVA of absorbed energy for five different ratios of SBPR composites

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Ratios	2.184083	4	0.546021	148.4478	1.44E-14
Within Ratios	0.073564	20	0.003678		
Total	2.257647	24			

From the Table 4.8, since the P-value was below than the significant cut-off level which is $\alpha = 0.05$. Hence, the Turkey's test needs to be done to distinguish each means are significantly different from each other. It suppose that, by following ANOVA where needs to rejected the null hypothesis of equal ratio means. The all pairwise mean to test comparisons. The equation of Turkey's test is shown below:

$$T_\alpha = q_\alpha(k, v)\sqrt{\frac{MS_\varepsilon}{n}}$$

Refer to Appendix C, it contains value of q_α (k,v), the upper α percentage points of q, where v is the degrees of freedom associated with the MS_ε. For equal sample sizes, Turkey test declares two means significantly different of the absolute value of their sample differences exceeds.

To illustrate Turkey's test, use the data from average of the energy absorb for every ratio. With $\alpha = 0.05$ and $f = 20$ degrees of freedom for error, Appendix C upper percentage points of the studentized range distribution gives $q_{0.05}$ (5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5,20)\sqrt{\frac{0.003678}{5}} = 4.24\sqrt{\frac{0.003678}{5}} = 0.1150$$

Thus, any pairs of ratio averages that differ in absolute value by more than 0.1150 would imply that the corresponding pair of population means are significantly different. The five ratio averages are;

$\bar{y}_1 = 1.3256$

$\bar{y}_2 = 0.9124$

$\bar{y}_3 = 0.8254$

$\bar{y}_4 = 0.6966$

$\bar{y}_5 = 0.4216$

and the differences in averages are;

$\bar{y}_1 - \bar{y}_2 = 1.3256 – 0.9124 = 0.4132$*

$\bar{y}_1 - \bar{y}_3 = 1.3256 – 0.8254 = 0.5002$*

$\bar{y}_1 - \bar{y}_4 = 1.3256 – 0.6966 = 0.6290$*

$\bar{y}_1 - \bar{y}_5 = 1.3256 – 0.4216 = 0.9040$*

$\bar{y}_2 - \bar{y}_3 = 0.9124– 0.8254 = 0.0870$

$\bar{y}_2 - \bar{y}_4 = 0.9124 – 0.6966 = 0.2158$*

$\bar{y}_2 - \bar{y}_5 = 0.9124 – 0.4216 = 0.4908$*

$\bar{y}_3 - \bar{y}_4 = 0.8254 – 0.6966 = 0.1288$*

$\bar{y}_3 - \bar{y}_5 = 0.8254 – 0.4216 = 0.4038$*

$\bar{y}_4 - \bar{y}_5 = 0.6966 – 0.4216 = 0.2750$*

The starred values indicate the pairs of means that are significantsly different. Note that the Turkey's procedure shows that there are nine different pairs of means. Therefore,

$\bar{y}_1 - \bar{y}_2$, $\bar{y}_1 - \bar{y}_3$, $\bar{y}_1 - \bar{y}_4$, $\bar{y}_1 - \bar{y}_5$, $\bar{y}_2 - \bar{y}_4$, $\bar{y}_2 - \bar{y}_5$, $\bar{y}_3 - \bar{y}_4$, $\bar{y}_3 - \bar{y}_5$, and $\bar{y}_4 - \bar{y}_5$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting.

4.5 Results and Analysis of water absorption test

The water absorption testing will be carried out to evaluate the specimen is whether resistant to water or not and also the suitability of materials for exterior applications. The ASTM D 570 standard's recommendations were followed while calculating the hybrid composites' maximum water absorption content. All the 25 samples were totally submerged in distilled water. At regular intervals of 5, 10, 15, 20, and up to 25 days of exposure. Their weights were measured after they were taken out from water and dried with a dry cloth. Figure 4.10 shown the samples of 5 different ratio were immersed in distilled water after weighing their mass.

Figure 4.10 Samples immersed in distilled water

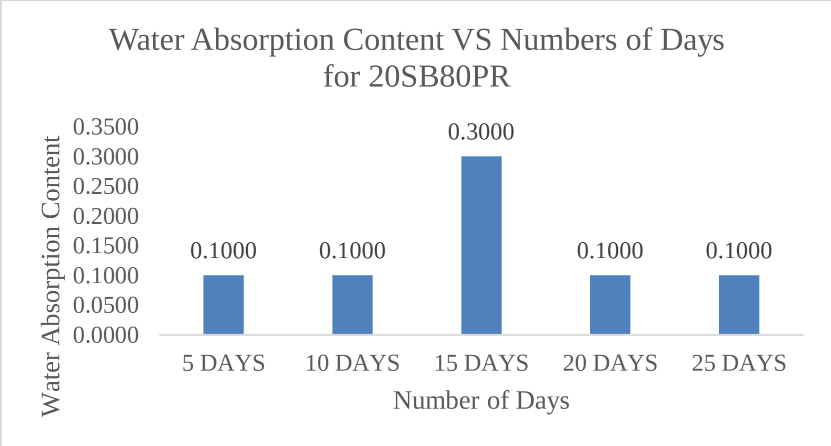

Figure 4.11 Water absorption content for 20SB80PR composites

Figure 4.11 shows the water absorption content of different duration of days for 20SB80PR composites. From the result, the water absorption content of 15 days immersed was higher than other duration of days. The water absorption content of 15 days immersed is 0.30g which is the highest among five different duration of days for 20SB80PR composites.

Table 4.9 Summary statistics result of 80SB20PR composites water absorption content

SUMMARY

Groups	Count	Sum	Average	Variance
5 DAYS	5	0.8	0.16	0.023
10 DAYS	5	0.8	0.16	0.008
15 DAYS	5	1	0.2	0.02
20 DAYS	5	0.5	0.1	0.015
25 DAYS	5	0.5	0.1	0.005

Refer to the Table 4.9, the average is the sum of all the data divided by the number of entries in the data sets. Variance is a measure of how much a set of numbers or data points deviate from their mean (average). It is a statistical measure of the spread or dispersion of a dataset. If value of variance is close to zero, this means that the result is consistent. Variance is also the power two of standard deviation. The standard deviation is always greater than or equal to 0. The value of the standard deviation can be explained as follows. If the value is 0, this means that there is no variation in the data sets and all value in the data sets are equal. Meanwhile, if the value of the standard deviation is close to 0, it means that the data are

spread on a small range around the mean. Lastly, if the value of standard deviation is larger, it indicates that the value of data set gets farther from the mean or the data spread on the larger range around the mean. Since the value of variance for 10 days is 0.008 so we can conclude that this result is consistent.

Following that, the water absorption content of the 20SB80PR composite were examined using ANOVA. The result of ANOVA for five duration of immersed days were attached in Table 4.10. The results presented that the water absorption content of 20SB80PR composite for all five different duration of days were not significant since the P-value is higher than the significant cut-off level which is ($\alpha = 0.05$). Therefore, it indicated that the resistance of water for these five different duration immersed days have equal averages that are not significantly different even though the ratio of 20SB80PR are same and this condition is applied to all different duration of days with the same ASTM standard. When different duration of days were samples immersed, it was observed that the water absorption content of 20SB80PR composite significantly different.

Table 4.10 ANOVA of water absorption content for 20SB80PR composites

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Days	0.0376	4	0.0094	0.661972	0.625624
Within Days	0.284	20	0.0142		
Total	0.3216	24			

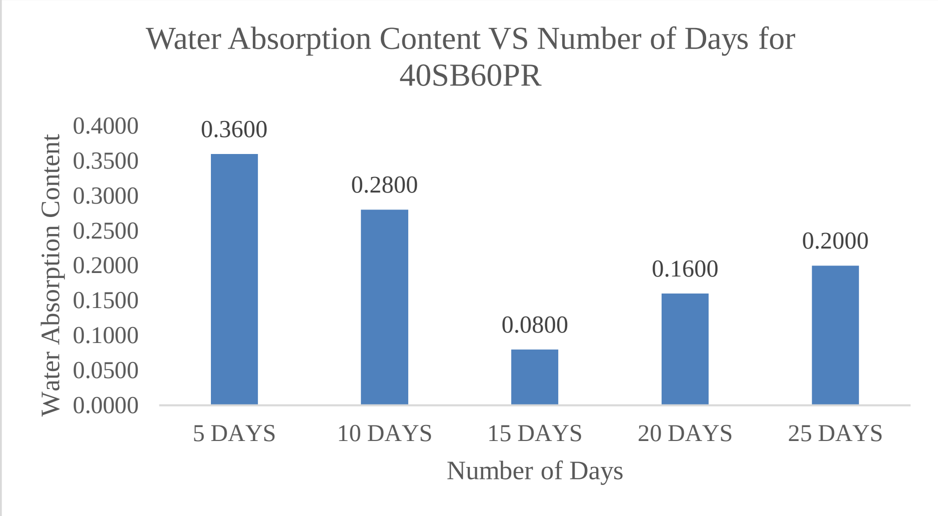

Figure 4.12 Water absorption content for 40SB60PR composites

Figure 4.12 shows the water absorption content of different duration of days for 40SB60PR composites. From the result, the water absorption content of 5 days immersed was higher than other duration of days. The water absorption content of 5 days immersed is 0.36g which is the highest among five different duration of days for 40SB60PR composites.

Table 4.11 Summary statistics result of 40SB60PR composites water absorption content

SUMMARY

Groups	Count	Sum	Average	Variance
5 DAYS	5	1.8	0.36	0.028
10 DAYS	5	1.4	0.28	0.002
15 DAYS	5	0.4	0.08	0.002
20 DAYS	5	0.8	0.16	0.018
25 DAYS	5	1	0.2	0.015

Refer to the Table 4.11, the average is the sum of all the data divided by the number of entries in the data sets. Variance is a measure of how much a set of numbers or data points deviate from their mean (average). It is a statistical measure of the spread or dispersion of a dataset. If value of variance is close to zero, this means that the result is consistent. Variance is also the power two of standard deviation. The standard deviation is always greater than or equal to 0. The value of the standard deviation can be explained as follows. If the value is 0, this means that there is no variation in the data sets and all value in the data sets are equal. Meanwhile, if the value of the standard deviation is close to 0, it means that the data are

spread on a small range around the mean. Lastly, if the value of standard deviation is larger, it indicates that the value of data set gets farther from the mean or the data spread on the larger range around the mean. Since the value of variance for 10 days and 15 days are 0.002 respectively so we can conclude that these result are consistent.

Table 4.12 ANOVA of water absorption content for 40SB60PR composites

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Days	0.2336	4	0.0584	4.492308	0.009426
Within Days	0.26	20	0.013		
Total	0.4936	24			

From the Table 4.12, since the P-value was below than the significant cut-off level which is $\alpha = 0.05$. Hence, the Turkey's test needs to be done to distinguish each means are significantly different from each other. It suppose that, by following ANOVA where needs to rejected the null hypothesis of equal ratio means. The all pairwise mean to test comparisons. The equation of Turkey's test is shown below:

$$T_{\alpha} = q_{\alpha}(k, v)\sqrt{\frac{MS_{\varepsilon}}{n}}$$

Refer to Appendix C, it contains value of q_{α} (k,v), the upper α percentage points of q, where v is the degrees of freedom associated with the MS_{ε}. For equal sample sizes, Turkey test declares two means significantly different of the absolute value of their sample differences exceeds.

To illustrate Turkey's test, use the data from average of the energy absorb for every ratio. With $\alpha = 0.05$ and f = 20 degrees of freedom for error, Appendix C upper percentage points of the studentized range distribution gives $q_{0.05}$ (5,20) = 4.24. Therefore,

$$T_{0.05} = q_{0.05}(5,20)\sqrt{\frac{0.013}{5}} = 4.24\sqrt{\frac{0.013}{5}} = 0.2162$$

Thus, any pairs of ratio averages that differ in absolute value by more than 0.2162 would imply that the corresponding pair of population means are significantly different. The five ratio averages are;

$$\bar{y}_1 = 0.36$$

$$\bar{y}_2 = 0.28$$

$$\bar{y}_3 = 0.08$$

$$\bar{y}_4 = 0.16$$

$$\bar{y}_5 = 0.20$$

and the differences in averages are;

$$\bar{y}_1 - \bar{y}_2 = 0.36 – 0.28 = 0.08$$

$$\bar{y}_1 - \bar{y}_3 = 0.36 – 0.08 = 0.28*$$

$$\bar{y}_1 - \bar{y}_4 = 0.36 – 0.16 = 0.20$$

$$\bar{y}_1 - \bar{y}_5 = 0.36 – 0.20 = 0.16$$

$$\bar{y}_2 - \bar{y}_3 = 0.28– 0.08 = 0.20$$

$$\bar{y}_2 - \bar{y}_4 = 0.28 – 0.16 = 0.12$$

$$\bar{y}_2 - \bar{y}_5 = 0.28 – 0.20 = 0.08$$

$$\bar{y}_3 - \bar{y}_4 = 0.08 – 0.16 = -0.08$$

$$\bar{y}_3 - \bar{y}_5 = 0.08 – 0.20 = -0.16$$

$$\bar{y}_4 - \bar{y}_5 = 0.16 – 0.20 = -0.04$$

The starred values indicate the pairs of means that are significantsly different. Note that the Turkey’s procedure shows that there are one different pairs of means. Therefore $\bar{y}_1 - \bar{y}_3$ power setting results in a mean etch rate that differs from the mean etch rate at any other power setting.

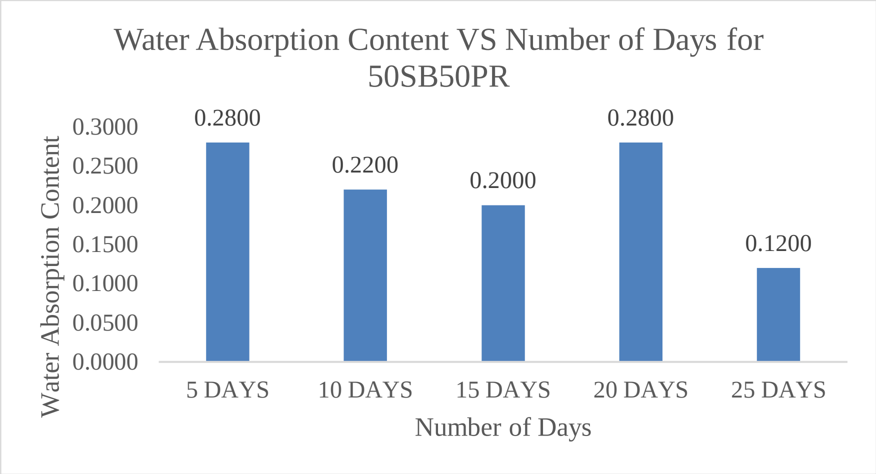

Figure 4.13 Water absorption content for 50SB50PR composites

Figure 4.13 shows the water absorption content of different duration of days for 50SB50PR composites. From the result, the water absorption content of 5 and 20 days immersed both were achieve the highest value compared to other duration of days. The water absorption content of 5 and 20 days immersed are 0.28g which are the highest among five different duration of days for 50SB50PR composites.

Table 4.13 Summary statistics result of 50SB50PR composites water absorption content

SUMMARY

Groups	Count	Sum	Average	Variance
5 DAYS	5	1.4	0.28	0.052
10 DAYS	5	1.1	0.22	0.037
15 DAYS	5	1	0.2	0.01
20 DAYS	5	1.4	0.28	0.022
25 DAYS	5	0.6	0.12	0.012

Refer to the Table 4.13, the average is the sum of all the data divided by the number of entries in the data sets. Variance is a measure of how much a set of numbers or data points deviate from their mean (average). It is a statistical measure of the spread or dispersion of a dataset. If value of variance is close to zero, this means that the result is consistent. Variance is also the power two of standard deviation. The standard deviation is always greater than or equal to 0. The value of the standard deviation can be explained as follows. If the value is 0, this means that there is no variation in the data sets and all value in the data sets are equal. Meanwhile, if the value of the standard deviation is close to 0, it means that the data are

spread on a small range around the mean. Lastly, if the value of standard deviation is larger, it indicates that the value of data set gets farther from the mean or the data spread on the larger range around the mean. Since the value of variance for 15 days is 0.01 so we can conclude that this result is consistent.

Following that, the water absorption content of the 50SB50PR composite were examined using ANOVA. The result of ANOVA for five duration of immersion days were attached in Table 4.14. The results presented that the water absorption content of 50SB50PR composite for all five different duration of days were not significant since the P-value is higher than the significant cut-off level which is ($\alpha = 0.05$). Therefore, it indicated that the resistance of water for these five different duration immersed days have equal averages that are not significantly different even though the ratio of 50SB50PR are same and this condition is applied to all different duration of days with the same ASTM standard. When different duration of days were samples immersed, it was observed that the water absorption content of 50SB50PR composite significantly different.

Table 4.14 ANOVA of water absorption content for 50SB50PR composites

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Days	0.088	4	0.022	0.827068	0.523479
Within Days	0.532	20	0.0266		
Total	0.62	24			

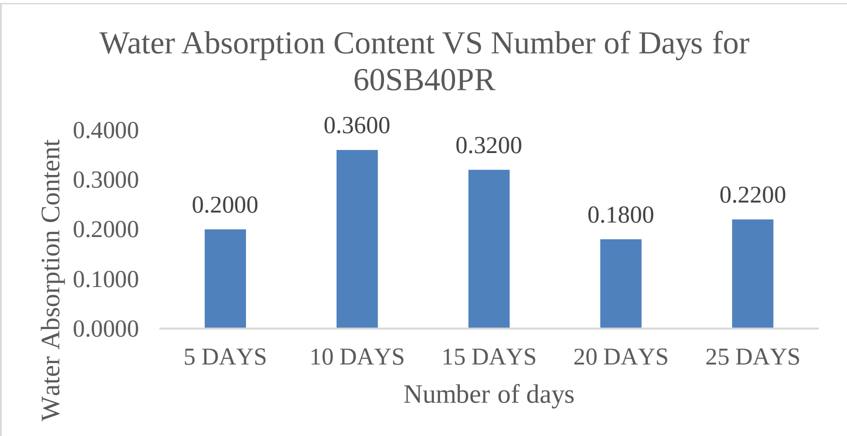

Figure 4.14 Water absorption content for 60SB40PR composites

Figure 4.14 shows the water absorption content of different duration of days for 60SB40PR composites. From the result, the water absorption content of 10 days immersed was higher than other duration of days. The water absorption content of 10 days immersed is 0.36g which is the highest among five different duration of days for 60SB40PR composites.

Table 4.15 Summary statistics result of 60SB40PR composites water absorption content

SUMMARY

Groups	Count	Sum	Average	Variance
5 DAYS	5	1	0.2	0.005
10 DAYS	5	1.8	0.36	0.008
15 DAYS	5	1.6	0.32	0.037
20 DAYS	5	0.9	0.18	0.007
25 DAYS	5	1.1	0.22	0.017

Refer to the Table 4.15, the average is the sum of all the data divided by the number of entries in the data sets. Variance is a measure of how much a set of numbers or data points deviate from their mean (average). It is a statistical measure of the spread or dispersion of a dataset. If value of variance is close to zero, this means that the result is consistent. Variance is also the power two of standard deviation. The standard deviation is always greater than or equal to 0. The value of the standard deviation can be explained as follows. If the value is 0, this means that there is no variation in the data sets and all value in the data sets are equal. Meanwhile, if the value of the standard deviation is close to 0, it means that the data are spread on a small range around the mean. Lastly, if the value of standard deviation is larger, it indicates that the value of data set gets farther from the mean or the data spread on the larger range around the mean. Since the value of variance for 5 days is 0.005 so we can conclude that this result is consistent.

Following that, the water absorption content of the 60SB40PR composite were examined using ANOVA. The result of ANOVA for five duration of immersion days were attached in Table 4.16. The results presented that the water absorption content of 60SB40PR composite for all five different duration of days were not significant since the P-value is higher than the significant cut-off level which is (α = 0.05). Therefore, it indicated that the resistance of water for these five different duration immersed days have equal averages that are not significantly different even though the ratio of 60SB40PR are same and this condition is applied to all different duration of days with the same ASTM standard. When different duration of days were samples immersed, it was observed that the water absorption content of 60SB40PR composite significantly different.

Table 4.16 ANOVA of water absorption content for 60SB40PR composites

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Days	0.1256	4	0.0314	2.121622	0.115797
Within Days	0.296	20	0.0148		
Total	0.4216	24			

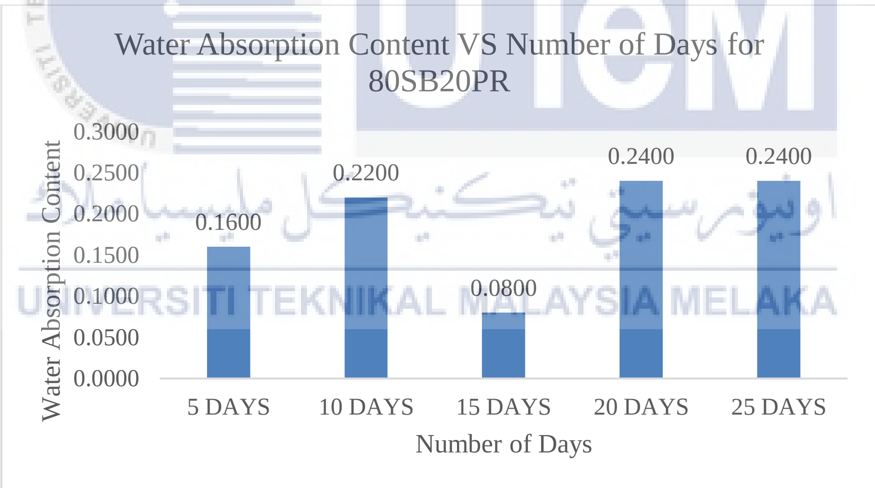

Figure 4.15 Water absorption content for 80SB20PR composites

Figure 4.15 shows the water absorption content different duration of days for 80SB20PR composites. From the result, the water absorption content of 20 and 25 days immersed both were achieve the most higher than other duration of days. The water absorption content of 20 and 25 days immersed are 0.24g which are the highest among five different duration of days for 80SB20PR composites.

Table 4.17 Summary statistics result of 80SB20PR composites water absorption content

SUMMARY

Groups	Count	Sum	Average	Variance
5 DAYS	5	0.8	0.16	0.023
10 DAYS	5	1.1	0.22	0.017
15 DAYS	5	0.4	0.08	0.007
20 DAYS	5	1.2	0.24	0.023
25 DAYS	5	1.2	0.24	0.023

Refer to the Table 4.17, the average is the sum of all the data divided by the number of entries in the data sets. Variance is a measure of how much a set of numbers or data points deviate from their mean (average). It is a statistical measure of the spread or dispersion of a dataset. If value of variance is close to zero, this means that the result is consistent. Variance is also the power two of standard deviation. The standard deviation is always greater than or equal to 0. The value of the standard deviation can be explained as follows. If the value is 0, this means that there is no variation in the data sets and all value in the data sets are equal. Meanwhile, if the value of the standard deviation is close to 0, it means that the data are spread on a small range around the mean. Lastly, if the value of standard deviation is larger, it indicates that the value of data set gets farther from the mean or the data spread on the larger range around the mean. Since the value of variance for 15 days is 0.007 so we can conclude that this result is consistent.

Following that, the water absorption content of the 80SB20PR composite were examined using ANOVA. The result of ANOVA for five duration of immersion days were attached in Table 4.18. The results presented that the water absorption content of 80SB20PR composite for all five different duration of days were not significant since the P-value is higher than the significant cut-off level which is ($\alpha = 0.05$). Therefore, it indicated that the resistance of water for these five different duration immersed days have equal averages that are not significantly different even though the ratio of 80SB20PR are same and this condition is applied to all different duration of days with the same ASTM standard. When different duration of days were samples immersed, it was observed that the water absorption content of 80SB20PR composite significantly different.

Table 4.18 ANOVA of water absorption content for 80SB20PR composites

ANOVA

Source of Variation	SS	df	MS	F	P-value
Between Groups	0.0944	4	0.0236	1.268817	0.315085
Within Groups	0.372	20	0.0186		
Total	0.4664	24			

4.6 Summary

In the summary, tensile tests revealed that the 20SB80PR composite ratio outperformed the other sugarcane bagasse with polyester resin (SBPR) ratios evaluated. The elasticity and tensile strength of 80SB20PR were the lowest of the five SBPR composites tested. According to this report, SBPR composites with 80% or more polyester resin had better tensile strength. To produce the best tensile properties, sugarcane bagasse and polyester resin should be blended at a ratio of 20% to 80% or more than 80% polyester resin.

Furthermore, the bending properties of the composites were studied using a three-point bending test, which is a flexural test. The flexural characteristics of 20SB80PR were found to be greater than those of other SBPR ratios. Despite this, the flexural property of this composite is greater than that of the other samples tested. This observation demonstrated that as the percentage of polyester resin in SBPR composites reaches 80% and above.

Additionally, as a result of this, when conducting impact testing, the viability of composite materials for such applications should be confirmed not only by conventional design criteria but also by impact properties. Compared to other SBPR composite ratios, 20SB80PR absorbs more energy. This result suggests that the sugarcane bagasse with the lowest percentage will absorb more energy during the impact test. As the percentage of sugarcane bagasse was decrease, the impact strength of SBPR composites also increase. This result showed that the average power impact of the total energy absorbed during the impact test for five SBPR composite ratios varied.

Utilising water absorption testing, the capacity of composites to absorb water was examined. Based on the testing, we can see that the 20SB80PR composite absorbed more at a at 15 days of immersed, 40SB60PR composite absorbed more at 5 days of immersed, 50SB50PR composite absorbed more at 5 and 20 days of immersed, 60SB40PR composite absorbed more at 10 days of immersed,and 80SB20PR composite absorbed more at 20 and 25 days of immersed. The capacity to absorb water was varied when the duration of days immersed and percentage of sugarcane bagasse is changed.

Finally, the results demonstrate that environmentally acceptable SBPR composite ratios function mechanically better when around 20% sugarcane bagasse and 80% polyester resin are present in the total composition of the composites. This application is a great choice since it combines lightweight and medium-duty fiber-reinforced composites.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

As stated in the previous chapter, this research must achieve three objectives in order to be successful. In this study, the mechanical properties and environmental aspect of the SBPR with five different ratios which are 20% sugarcane bagasse with 80% polyester resin (20SB80PR), 40% sugarcane bagasse with 60% polyester resin (40SB60PR), 50% sugarcane bagasse with 50% polyester resin (50SB50PR), 60% sugarcane bagasse with 40% polyester resin (60SB40PR), and 80% sugarcane bagasse with 20% polyester resin (80SB80PR) were studied. The analysis of the experiment material using statistical analysis also have been investigated using ANOVA. Based on the results obtained from the analysis and experimental data, the following conclusions can be drawn:

i. According to the tensile experiment data, the SBPR composite of 20SB80PR resulted highest value tensile strength and elasticity compared to the other ratio of SBPR composites. When the ratio of sugarcane bagasse decreased, the value of tensile strength and elasticity increased significantly.

ii. The SBPR composite of 20SB80PR had highest flexural strength compared to other ratio of SBPR composites. It was determined that the maximum flexural strength values in SBPR composites increase when sugarcane bagasse content is 20% or lower than that.

iii. The impact strength of 20SB80PR composite resulted highest value among five different ratios of SBPR composites. This observation suggested that the energy absorb of the SBPR composite become stronger as the percentage of sugarcane bagasse is less than or equal to 20%.

iv. The water absorption content of 15 days immersed resulted the highest value among five different duration of days for 20SB80PR composites.

v. The water absorption content of 5 days immersed resulted the highest value among five different duration of days for 40SB60PR composites.

vi. The water absorption content of 5 and 20 days immersed resulted the highest values among five different duration of days for 50SB50PR composites.

vii. The water absorption content of 10 days immersed resulted the highest value among five different duration of days for 60SB40PR composites.

viii. The water absorption content of 20 and 25 days immersed resulted the highest values among five different duration of days for 80SB20PR composites.

ix. Based on ANOVA results, if the P-value was below than the significant cut-off level which is $\alpha = 0.05$, Turkey's test needs to be done to distinguish each means are significantly different from each other. While if the P-value is higher than the significant cut-off level which is ($\alpha = 0.05$) , the results presented that each others were not significant.

x. Finally, when the percentage of sugarcane bagasse in the total percentage of is around 20%, the results showed that all SBPR composite ratios demonstrated enhanced performance.

To address the initial problem statement raised at the start of the experiment, the utilization of sugarcane bagasse waste in the creation of valuable composites holds potential benefits. Moreover, this approach offers a means to mitigate and manage air pollution resulting from the burning and disposal of plantation waste. By repurposing sugarcane bagasse waste, the need for its open burning as a disposal method is eliminated, contributing simultaneously to improved air quality and a reduction in environmental impact.

5.2 Recommendations

In this study, 20SB80PR composite results in greater tensile, flexural and impact strength. Based on the experiment results, the mechanical properties of 20SB80PR has been the strongest composites reinforced polyester resin. For upcoming research for this project will lead to gain peak value of mechanical properties for tensile, flexural and impact testing and also water absorption testing for environmental aspect. To determine which ratios are suitable to get optimum resuls, it will suggest a various ratio, such as 20SB80PR, which is lower than 20% of usgarcane bagasse. To analyze more mechanical properties of SBPR composite, can apply compression testing, hardness testing and others. Besides that, we also can enhanced our mixing method instead using hand mixing. Since it will affect the results of testing.

5.3 Project Potential

Hybrid composites, combining glass fibers and sugarcane bagasse, have the potential to offer a balance between lightweight properties and high strength. This makes them suitable for applications where weight reduction is critical without compromising structural integrity. Sugarcane bagasse is a byproduct of the sugar industry and is often considered a low-cost or even waste material. Investigating its use in composites can lead to cost-effective materials, especially when compared to traditional fillers. The lightweight and potentially high-strength characteristics of these composites could make them suitable for applications in the automotive and aerospace industries. The project has the potential to demonstrate improved mechanical properties of the hybrid composite compared to conventional materials. This could include enhanced tensile strength, impact resistance, and other mechanical attributes.

These composites can be defined as multipurpose material to be used in different sector. For examples, composite materials are now used as components for buildings, and structures, such as swimming pool panels, storage tanks, interior components, and other parts. Moreover, the use of composites in automotive industry have also lead to the substituition of numerous traditional materials in the manufacture of dashboard, door panel, and engine compartment. Composite materials, when directly compared to steel, may satisfy the material requirements for the automobile sector, including corrosion resistance in damp conditions and high-impact strength to sustain repeated usage. It may be concluded that the obtained results of SBPR composites are not negotiable and may be of potential value since it encourages higher utilisation of already-existing natural fibres and its composites will be beneficial to the economy of the country.

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APPENDICES

APPENDIX A GANTT CHART PSM 1

No	Task	Status	Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Supervisor Selection and Registered PSM Title**	Plan														
		Actual														
2	**Briefing of PSM title**	Plan														
		Actual														
3	**Module 1: Research Design And Planning**	Plan														
		Actual														
4	**Discuss Problem Statement And Objective For Chapter 1**	Plan														
		Actual														
5	**Drafting And Writing Chapter 1**	Plan														
		Actual														
6	**Module 2: Final Year Project Literature Review**	Plan														
		Actual														
7	**Drafting And Writing Chapter 2**	Plan														
		Actual														
8	**Module 3: Research Methodology**	Plan														
		Actual														
9	**Drafting And Writing Chapter 3**	Plan														
		Actual														
10	**Drafting And Writing Chapter 4 (Expected Results)**	Plan														
		Actual														
11	**Recheck And Submit Chapter 1,2, 3, And 4**	Plan														
		Actual														
12	**Preparation And Presentation of PSM 1**	Plan														
		Actual														

APPENDIX B GANTT CHART PSM 2

No	Task	Status	Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Meeting And Discussion**	Plan														
		Actual														
2	**Conducting Experiment**	Plan														
		Actual														
3	**Collecting Data And Analysis On Sample**	Plan														
		Actual														
4	**Make Discussion On Result**	Plan														
		Actual														
5	**Drafting and Writing Chapter 4**	Plan														
		Actual														
6	**Drafting And Writing Chapter 5**	Plan														
		Actual														
7	**First's Submission Draft PSM 2**	Plan														
		Actual														
8	**Second's Submission Draft PSM 2**	Plan														
		Actual														
9	**Submission Full Report PSM 2**	Plan														
		Actual														
10	**Make a Correction Of Full Report**	Plan														
		Actual														
11	**Oral Presentation PSM 2**	Plan														
		Actual														

APPENDIX C Upper Percentage Points Of The Studentized Range Distribution

Table A.12 Upper Percentage Points of the Studentized Range Distribution: Values of $q(0.05; k, v)$

Degrees of Freedom, v	Number of Treatments k: 2	3	4	5	6	7	8	9	10
1	18.0	27.0	32.8	37.2	40.5	43.1	15.1	47.1	49.1
2	6.09	5.33	9.80	10.89	11.73	12.43	13.03	13.54	13.99
3	4.50	5.91	6.83	7.51	8.04	8.47	8.85	9.18	9.46
4	3.93	5.04	5.76	6.29	6.71	7.06	7.35	7.60	7.83
5	3.64	4.60	5.22	5.67	6.03	6.33	6.58	6.80	6.99
6	3.46	4.34	4.90	5.31	5.63	5.89	6.12	6.32	6.49
7	3.34	4.16	4.68	5.06	5.35	5.59	5.80	5.99	6.15
8	3.26	4.04	4.53	4.89	5.17	5.40	5.60	5.77	5.92
9	3.20	3.95	4.42	4.76	5.02	5.24	5.43	5.60	5.74
10	3.15	3.88	4.33	4.66	4.91	5.12	5.30	5.46	5.60
11	3.11	3.82	4.26	4.58	4.82	5.03	5.20	5.35	5.49
12	3.08	3.77	4.20	4.51	4.75	4.95	5.12	5.27	5.40
13	3.06	3.73	4.15	4.46	4.69	4.88	5.05	5.19	5.32
14	3.03	3.70	4.11	4.41	4.65	4.83	4.99	5.13	5.25
15	3.01	3.67	4.08	4.37	4.59	4.78	4.94	5.08	5.20
16	3.00	3.65	4.05	4.34	4.56	4.74	4.90	5.03	5.05
17	2.98	3.62	4.02	4.31	4.52	4.70	4.86	4.99	5.11
18	2.97	3.61	4.00	4.28	4.49	4.67	4.83	4.96	5.07
19	2.96	3.59	3.98	4.26	4.47	4.64	4.79	4.92	5.04
20	2.95	3.58	3.96	4.24	4.45	4.62	4.77	4.90	5.01
24	2.92	3.53	3.90	4.17	4.37	4.54	4.68	4.81	4.92
30	2.89	3.48	3.84	4.11	4.30	4.46	4.60	4.72	4.83
40	2.86	3.44	3.79	4.04	4.23	4.39	4.52	4.63	4.74
60	2.83	3.40	3.74	3.98	4.16	4.31	4.44	4.55	4.65
120	2.80	3.36	3.69	3.92	4.10	4.24	4.36	4.47	4.56
∞	2.77	3.32	3.63	3.86	4.03	4.17	4.29	4.39	4.47

PSM 2

ORIGINALITY REPORT

28%	20%	18%	17%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

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