MECHANICAL PROPERTIES AND FAILURE ANALYSES OF BEMBAN FIBER REINFORCED THERMOSETS MATRIX COMPOSITES

NATRA FATHIRA BINTI NOR YATIM

BACHELOR OF MECHANICAL ENGINEERING TECHNOLOGY (BMMV) WITH HONOURS

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Faculty of Mechanical and Manufacturing Engineering Technology

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NATRA FATHIRA BINTI NOR YATIM

**A thesis submitted
in fulfilment of the requirements for the degree of
Bachelor of Mechanical Engineering Technology (BMMV) with Honours**

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2023

DECLARATION

I declare that this thesis entitled “Mechanical Properties And Failure Analyses of Bemban Fiber Reinforced Thermosets Matrix Composites” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	*natra fathira*
Name	:	NATRA FATHIRA BINTI NOR YATIM
Date	:	20 / 1 / 2023

APPROVAL

I hereby declare that I have checked this thesis, and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Mechanical Engineering Technology (BMMV) with Honours.

Signature :

Supervisor Name : TS. DR. MOHAMAD HAIDIR BIN MASLAN

Date : 20 Januari 2023

DR. MOHAMAD HAIDIR BIN MASLAN
Pensyarah Kanan
Jabatan Teknologi Kejuruteraan Mekanikal
Fakulti Teknologi Kejuruteraan Mekanikal dan Pembuatan
Universiti Teknikal Malaysia Melaka

DEDICATION

In the name of Allah S.W.T, the most gracious and merciful,

I dedicate this project to my beloved parents,

Noryatim Bin Ahmad & Fauziahanim Binti Haji Jaffar, and my siblings.

To my supervisor, Ts. Dr. Mohamad Haidir bin Maslan for guiding me through this PSM.

To my special person, Muhammad Rozhan bin Rosdin, for his encouragement who believed in me without hesitation.

ABSTRACT

The purpose of this research is to look into the mechanical properties and failure analysis of Bemban fibre and thermoset polymer turned to composite. The objective is to investigate the mechanical properties of Bemban-reinforced thermosets, to evaluate the effect of different mixture combinations on mechanical properties and the effect of water absorption, and to analyse the failure process of Bemban-reinforced thermosets. The main material used in this project is Bemban fibre and Polyester Resin for the thermoset. Bemban is processed from raw material to get the fibre by using a manual extraction method. Thermoset used is a Polyester Resin. The mixture ratio of Bemban and Polyester Resin for this study is 1:10, 1:5 and 1:1 by using the hand layup method. After the hardening process, two composite mixture samples will undergo a tensile test to get the result for mechanical properties based on ASTM test standards. One of the samples will undergo a water absorption method. The tensile properties of Bemban fibre and Polyester Resin can improve the durability of the composite mixture of natural fibre combined with the matrix.

ABSTRAK

Tujuan penyelidikan ini adalah untuk melihat sifat mekanikal dan analisis kegagalan serat Bemban dan polimer termoset bertukar kepada komposit. Objektifnya adalah untuk menyiasat sifat mekanikal termoset yang diperkuatkan dengan Bemban, untuk menilai kesan kombinasi campuran yang berbeza terhadap sifat mekanikal dan kesan penyerapan air, dan untuk menganalisis proses kegagalan termoset yang diperkuatkan dengan Bemban. Bahan utama yang digunakan dalam projek ini ialah serat Bemban dan resin poliester untuk termoset. Bemban diproses daripada bahan mentah untuk mendapatkan gentian dengan menggunakan kaedah perahan manual. Termoset yang digunakan ialah resin poliester. Nisbah campuran resin Bemban dan poliester bagi kajian ini ialah 1:10, 1:5 dan 1:1 dengan menggunakan kaedah letak tangan. Selepas proses pengerasan, dua sampel campuran komposit akan menjalani ujian tegangan untuk mendapatkan keputusan bagi sifat mekanikal berdasarkan piawaian ujian ASTM. Salah satu sampel akan menjalani kaedah penyerapan air. Sifat tegangan serat Bemban dan resin poliester boleh meningkatkan ketahanan campuran komposit gentian asli yang digabungkan dengan matriks.

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LIST OF SYMBOLS AND ABBREVIATIONS

NFPC	-	Natural Fibre Polymer Composite
ASTM	-	American Society for Testing and Materials
FRP	-	Fibre Reinforced-Polymer
CMC	-	Ceramix Matrix Composite
CFRC	-	Ceramic Fibre Reinforced Ceramic
MMC	-	Metal Matrix Composite
PMC	-	Polymer Matrix Composite
PP	-	Polypropylene
PVC	-	Polyvinyl Chloride
%	-	Percentage
E	-	Young Modulus
mm	-	millimetres
MPa	-	Mega Pascal
cm	-	centimetres

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, natural composites have several advantages, including low production costs, low energy consumption, environmental friendliness, and overall contribution to sustainable development. Many years back, natural fibres were used for strength in a more traditional than technical way. Natural fibre as reinforcement has served multiple purposes for the use of material technology in recent years. Natural fibres are in high demand among scientists and engineers in developing countries because they can be used with proper technology to produce high-quality fibre-reinforced polymer composites for housing and other applications. Natural fibres are elongated substances produced by plants and animals that can be turned into filaments, rope, woven, knitted, and shoes. Hemp, jute, kenaf, flax, sisal, banana fibre, Bemban, and other fibrous materials can be mixed with thermoset and thermoplastic which are polymeric materials. Malaysia has a plant which is hemp, jute, kenaf, flax, sisal, banana fibre, pineapple, and oil palm are just a few examples of plants with high fibrous content. Many plants, such as rattan and Bemban, have yet to be discovered but have the potential to become good natural composites.

1.2 Background Studies

Bemban leaf is a herbaceous plant, which means that its stems are soft and do not form wood. Bemban grows in the wild along rivers and lakes, forests, and plantations. In wet areas, Bemban is easy to grow. Furthermore, Bemban can be found in bamboo forests. Plants native to Southeast Asia include those found in Indonesia, Malaysia, Thailand, Cambodia, Vietnam, and the Philippines. Even Bemban can be found in the Taiwanese and Indian regions. Bemban, kenaf, flax, jute, abaca, banana leaf fibres, bamboo, wood, sisal, hemp, coconut, cotton, wheat straw, or other fibrous material can be used as the natural fibre component, and the matrix can be a polymeric material. Natural fibre reinforced polymer matrix has received considerable attention in recent years due to its superior properties and superior advantages over synthetic fibres in terms of its relatively low weight, low cost, less damage to processing equipment, good relative mechanical properties such as tensile modulus and flexural modulus, the improved surface finish of moulded parts composite, renewable resources, abundance, flexibility during processing, and biodegradability. NFPCs with high specific stiffness and strength can be made by incorporating tough and lightweight natural fibre into a polymer (thermoplastic and thermoset). Natural fibres, on the other hand, have significant flaws and properties deficiencies.

Figure 1.1: Bemban Plants

1.3 Problem Statement

Many studies have been conducted on natural fibre composites such as kenaf, jute, flax, hemp and coir according to reports. Because Bemban fibres have never been used commercially as composite materials, the goal of this study is to determine their future potential. The study focuses on the fundamental properties of this fibre composite in order to assess its potential. The main objectives of this study are to determine the mechanical properties of extracted Bemban fibres as well as Bemban fibre composites.

Bemban is a plant that has been used by the traditional community for roof construction, wardrobe and handcrafts. Bemban plant has high toughness and resistance to the tropical environment. So, it is the potential to make a good natural composite.

A tensile test will be performed on the specimen according to ASTM test standards to determine the research objectives, and the results will be used to analyse the mechanical properties of the short fibre composites of Bemban.

1.4 Objectives

The research for this project is organised and represented to achieve the following objectives, based on the project background and problem statement stated above:

1. To investigate the mechanical properties of Bemban reinforced thermoset.
2. To evaluate the effect of different mixture combinations on the mechanical properties of thermosets with Bemban and the effect of water absorption.
3. To analyse the failure process of Bemban reinforced thermoset.

1.5 Scope

The study was subjected to the following scope.

- Uses Bemban fibre as a composite reinforcement. Bemban fibre was self-processed from fresh Bemban stem.
- Thermoset (Polyester Resin) was used as a composite matrix. This is to study the effect of the different matrix-to-reinforcement ratios of 1:10, 1:5 and 1:1.
- A mechanical test was chosen which is to perform a tensile (ASTM D3039) on a mixture of Bemban fibre and thermoset polyester for effect before and after water absorption by using a Universal Testing Machine.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There are a few things to clarify before this experimental study begins. In addition, data gathered from journals, books, and websites played a significant role in the study's success. This improves the precision and effectiveness of the research equipment while also adding to its fascination.

2.2 Composite

A composite is made up of two materials with diverse physical and chemical properties that are mixed together. When these two are mixed, they form a material that is made to do a specific function, such as becoming stronger, lighter, or more resistant to electricity. They do not entirely blend or lose their own identities; they merge and contribute their most useful characteristics to improve the outcome or final product. Composites are usually created for a specific purpose, such as increased strength, efficiency, or durability.

Composites also known as Fibre-Reinforced Polymer (FRP) are made from a polymer matrix that is reinforced with a man-made, engineered or natural fibre such as glass, carbon, aramid or any other reinforcing material. The matrix shields the fibres from external and environmental degradation while also transferring the load between them. The fibres give the matrix strength and rigidity, which helps it withstand cracks and fractures. Composites have numerous advantages. The important factors among them are strength, lightweight, corrosion resistance, design flexibility and durability.

- Strength – Composites are more durable than metals such as steel. Fibres and resins, the two main components of composites, contribute to their strength. The load is carried by the fibres, and the weight is distributed as needed by the resins throughout the composite part.
- Lightweight – In comparison to most woods and metals, composites are lighter.
- Corrosion resistance – Weather and corrosive chemicals can erode away at normal materials, but composites withstand this. As a result, they are ideal for applications that are subjected to prolonged exposure to seawater, hazardous chemicals, temperature swings, and other harsh environments.
- Flexible – Composites allow for a wide range of material combinations, allowing for design flexibility. The materials can be specifically designed to fit the application's requirements. Composites can also be easily shaped into complex shapes.
- Durable – Composite structures last a long time and require little maintenance. Many composite-based products, such as boats, have been in use for over half a century.

2.2.1 Type of Reinforcement

Fibres, fabric particles, or whiskers can all be used as reinforcement. These reinforcements are fundamentally used to enhance the mechanical or physical properties of the final composite material. There are two types of reinforcement that are most used, synthetic fibre and natural fibre.

Synthetic fibres are made from synthetic materials that are usually created using chemical processes. During the process, a spinneret which is a device that takes polymers and forms fibres is typically used to extract fibres. The textile industry developed synthetic fibres as a less expensive and more easily mass-produced alternative to natural fibres. Because synthetic fabrics are made of man-made, artificial fibres, they have a number of 17 advantages for everyday use, including affordability and stain and water resistance. There are 5 examples of synthetic fibres;

1. Polyester - Polyester is coal and petroleum-based synthetic fibre. Polyester is known for its long-lasting properties. However, the material is not suitable for use in hot weather because it is not breathable and does not absorb liquids well.

2. Rayon - Rayon is a reconstituted wood pulp-based semi-synthetic fibre. Despite the fact that rayon is made from plant fibres, the chemicals used in the manufacturing process, such as sodium hydroxide and carbon disulfide, classify it as semi-synthetic. Rayon comes in the form of modal, viscose, and lyocell, and can be used to imitate silk, wool, and other fabrics.

3. Spandex – Known as Lycra or elastane, is a synthetic fibre with extreme elasticity. Spandex is a stretchy fabric that is blended with a variety of fibres and used in everything from jeans to athleisure to hosiery.

4. Acrylic fibres - Acrylic fibres are man-made fibres made from acrylonitrile or vinyl cyanide polymers. Because of its ability to retain heat, acrylic is frequently referred to as "fake wool." It's frequently used in the production of faux fur and also fleece.

5. Microfibres - Because of their ability to trap dirt, microfibers are extremely thin and short fibres with a diameter of fewer than 10 micrometres that are used in cleaning cloths. Polyester is a popular material, and it can be woven or nonwoven.

Before being used in composites, natural fibres must be separated or purified from other constituents (lignin, hemicelluloses, wax, and proteins) present in the respective sources. Natural fibres are primarily used as a reinforcement phase in composites to improve mechanical properties and produce lightweight materials. Plants, animals, and minerals are used to create natural fibres. Spun into threads and yarns from natural raw materials, which are then woven or knitted into natural fabrics. There are two types of natural fibres: animal-based and plant-based. Animal-based natural fibres include silk and wool, while plant-based natural fibres include cotton, linen, and jute. There are 5 examples of natural fibres;

1. Silk - Silk is a natural fibre that is used by insects to make nests and cocoons. The most common type of silk is produced by silkworms. Silk is a material known for its lustrous sheen and softness. It is primarily made up of a protein known as fibroin.


Figure 2.1: Silk

2. Wool - Wool is made from the hair of sheep, goats, alpacas, llamas, and other animals. Fabrics made of cashmere, angora, mohair, and other wools are available. Wool is a durable, warm, and absorbent fibre. It is water-resistant due to the lanolin oils produced by the animals, and it is commonly used to make outerwear and cold-weather clothing such as sweaters and coats.


Figure 2.2: Wool

3. Cotton - Cotton fabric is made from the fibres of the cotton plant. Cotton is a soft, fluffy material that is primarily composed of cellulose, an insoluble organic compound that is essential to plant structure. Cotton is a soft, long-lasting fabric that is commonly used in the production of t-shirts and underwear. Different types of cotton fabric include organic cotton, denim, and canvas.

Figure 2.3: Cotton

4. Linen - Linen fabric is made from flax plants and is strong and lightweight. Linen is hypoallergenic and breathable by nature, making it an ideal fabric to wear during hot weather.

Figure 2.4: Linen

5. Jute - Jute is a coarse natural plant fibre derived from the jute plant that is used to weave burlap and other similar fabrics. Rugs and burlap sacks are commonly made of jute.

Figure 2.5: Jute

6. Bemban – Bemban grows in wetlands along streams and on hilly terrain. Bemban leaf is a herbaceous plant, which means that its stems are soft and do not form wood.

Figure 2.6: Bemban

Bemban plants will be selected for this study. Bemban or the scientific name known as Donax Canniformis Bemban grows in wetlands along streams and on hilly terrain. Water or marsh Bemban (Bemban air or Bemban paya) is more delicate and only used in mats as it grows closer to water. Stone or hill Bemban (Bemban Batu or Bemban Bukit) is a closely related plant that is tougher and can be found on higher ground, and it is used to make baskets and mats.

Figure 2.7: Bemban Basket

Figure 2.8: Bemban mats

It's also well-known for its use in complementary and alternative medicine. The roots are thought to contain a cooling substance. The roots are boiled and then drunk to help our bodies cool down. The sap from the leaves can also be used as an eye drop to help rejuvenate the eyes.

2.2.2 Type of Matrix

A composite fibre system is embedded in a matrix, which is a homogeneous, monolithic material. It goes on indefinitely. To form a solid, the matrix acts as a binding and holding medium for the reinforcements. It provides finish, texture, colour, durability, and functionality to the reinforcements while also protecting them from environmental damage. These are the three main types of composite matrix materials;

1. Ceramic matrix - Ceramic matrix composites (CMCs) are a type of composite material that comes in a variety of shapes and sizes. A ceramic fibre-reinforced ceramic (CFRC) material is made up of ceramic fibres embedded in a ceramic matrix. Any ceramic material can be used for the matrix and fibres. Traditional technical ceramics have major drawbacks such as brittleness, low fracture toughness, and thermal shock resistance. CMC materials were created to address these issues.

2. Metal matrix - MMCs (metal matrix composites) are composite materials with at least two constituent parts, one of which is a metal and the other of which is a different metal. To improve strength and wear, the other material reinforces the metal matrix. A hybrid composite is one that contains three or more constituent parts. In structural applications, the matrix is typically made of a lighter metal such as magnesium, titanium, or aluminium. High-temperature applications frequently use cobalt and cobalt-nickel alloy matrices. The manufacturing of a typical MMC can be divided into three categories: solid, liquid, and vapour. Continuous carbon, silicon carbide, and ceramic fibres are some of the materials that can be embedded in a metallic matrix material. MMCs are fire-resistant, work in a wide range of temperatures, don't absorb moisture, and have superior electrical and thermal conductivity. They've also found applications that are radiation-resistant and do not outgas. The majority of metals and alloys work well as composite matrices.

3. Polymer matrix - Thermoset, thermoplastic, and rubber are three different types of polymer matrix composites (PMCs). A polymer is a large molecule

composed of structural units linked by covalent chemical bonds. A polymer matrix and a dispersed fibrous reinforcing phase make up PMCs. Because of the simpler fabrication methods, they are less expensive. PMCs are less dense than metals or ceramics, have a higher resistance to electrical current conduction, and can withstand atmospheric and other types of corrosion.

2.3 Natural Fiber Composite

Composite materials can be natural or synthetic. Natural fibre composites combine plant-derived fibres with a polymeric matrix. The natural fibre component can be Bemban, wood, sisal, hemp, coconut, cotton, kenaf, flax, jute, abaca, banana leaf fibres, bamboo, wheat straw, or another fibrous material, and the matrix can be a polymeric material.

Natural fibre-reinforced polymer matrix has received considerable attention in recent years due to its superior properties and superior advantages over synthetic fibres in terms of its relatively low weight, low cost, less damage to processing equipment, good relative mechanical properties such as tensile modulus and flexural modulus, the improved surface finish of moulded parts composite, renewable resources, abundance, flexibility during processing, and biodegradability. NFPCs with high specific stiffness and strength can be made by incorporating tough and lightweight natural fibre into a polymer (thermoplastic and thermoset). Natural fibres, on the other hand, have significant flaws and properties deficiencies.

Natural fibres (cellulose, hemicelluloses, lignin, pectin, and waxy substances) have a structure that allows moisture to be absorbed from the environment, resulting in weak fibre-polymer bindings. Connections between natural fibre and polymer are also considered a challenge because the chemical structures of both the fibres and the matrix are different. These are the reasons for ineffective stress transfer at the interface of the composites produced. As a result, natural fibre treatments with specific treatments are unquestionably required. A common theme in these modifications is the use of reagent functional groups that can respond to fibre structures and change their composition. As a result of the fibre modifications, natural fibre moisture absorption is reduced, resulting in improved fibre-polymer matrix incompatibility.

Natural fibre polymer composites (NFPC) are composite materials made up of high-strength natural fibres embedded in a polymer matrix, such as Bemban, jute, oil palm, sisal, kenaf, and flax. Thermoplastics and thermosets are the two main types of polymers. Thermoplastic matrix materials soften at higher temperatures and then roll back their properties as they cool because their structure is made up of one or two-dimensional molecular. Thermoset polymers, on the other hand, are highly cross-linked polymers that cure with heat, heat and pressure, or light irradiation alone. This structure of thermoset polymers has good properties such as high flexibility for tailoring desired ultimate properties, great strength, and modulus.

Thermoplastic bio fibres include polyethylene, polypropylene (PP), and polyvinyl chloride (PVC), while thermosetting matrices include phenolic, polyester, and epoxy resins. A number of factors can influence the characteristics and performance of NFPCs. The hydrophilic nature of natural fibres, as well as the fibre loading, have an impact on composite properties. High fibre loading is usually required to achieve good NFPC properties. The tensile properties of composites generally improve as the fibre content of the composites increases. Another important factor that affects the properties and surface characteristics of composites is the process parameters used. As a result, in order to achieve the best composite characteristics, appropriate process techniques and parameters should be carefully chosen.

2.4 Thermoset

Through a catalytic chemical reaction, raw uncured resin molecules are crossed linked in a thermoset resin. As a result of this chemical reaction, which is usually exothermic, the resin molecules form extremely strong bonds with one another, and the resin changes state from liquid to solid (J. Todd, 2021). just a sample of a very long heading level 3 which consists of two lines and several sentences.

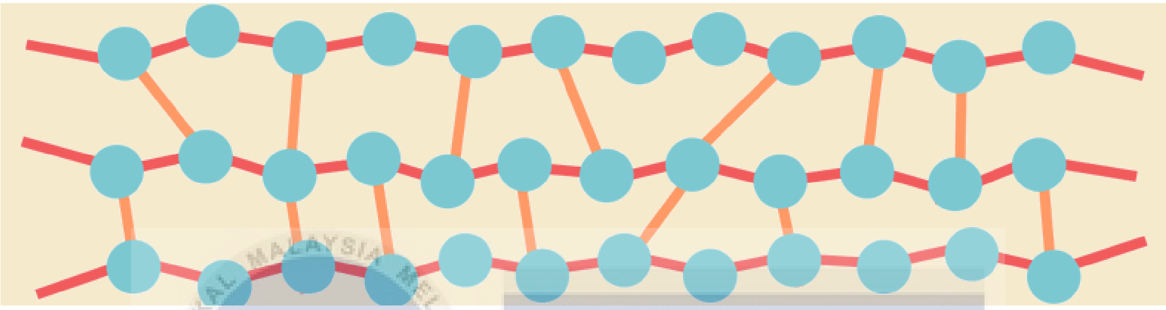

Figure 2.9: Thermosets cross-link during the curing process to form an irreversible bond

Fibre-reinforced polymer (FRP) refers to the use of reinforcing fibres that are at least 1/4 inch long. Although these components improve mechanical properties, they are not nearly as strong as continuous fibre-reinforced composites, despite the fact that they are technically fibre-reinforced composites. A thermosetting resin is used as the matrix in traditional FRP composites to keep the structural fibres in place. Thermosetting resins include the following:

Table 2.1: Thermosetting Resins

Vinyl Ester Resin	
Epoxy Resin	
Phenolic Resin	
Urethane Resin	
Polyester Resin	

Polyester Resin is the most common thermosetting resin today, followed by vinyl ester and epoxy. Thermosetting resins are popular because they are liquid when uncured and at room temperature, making it easy to impregnate reinforcing fibres like fibreglass, carbon fibre, or Kevlar.

Because of their reactive nature and ease of impregnation, the thermoset matrix dominates the composite industry. When the matrix has a low viscosity, the reaction occurs in a monomeric or oligomeric state. Glass, carbon, and aramid fibres are used in thermoset composites to improve modulus, creep resistance, impact strength, and heat resistance. Fibre addition has a number of drawbacks, including increased cost, higher viscosity, anisotropy, and abrasiveness on moulds and machinery. The orientation of the fibres is critical in determining the properties of the final composite. Polyester and epoxy resins account for more than 95% of thermoset composites; other resins used include phenolics, silicones, and polyimides. A few of the most commonly used matrices in thermoset composites are briefly discussed.

Figure 2.10: Polyester Resin

Polyester Resins stand globally as one of the most popular thermoset resins. Polyester is being used in this experimental study. Under the right circumstances, the unsaturated Polyester Resin can cure from a viscous liquid to a solid. Polyester Resins that are unsaturated are referred to as "Polyester Resin" or simply "polyester." The advantages of thermoset resins include;

- Excellent solvent and corrosive resistance,
- Heat resistance and high-temperature tolerance,
- High fatigue resistance,
- Customised elasticity,
- Outstanding adhesion,
- Excellent polishing and painting characteristics

The disadvantages are a thermosetting resin can't be reversed or reshaped once it's been catalysed, so once a thermoset composite is made, it can't be changed. Thermoset composites are extremely difficult to recycle.

2.5 Mechanical and Failure Properties of Natural Composite

Natural fibre’s abundant availability and accessibility are the primary drivers of a growing interest in sustainable technology. Natural fibres have recently piqued researchers' interest as a reinforcement material due to their advantages over other well-known materials. They're non-toxic, non-abrasive, renewable, and low-cost, as well as environmentally friendly and completely biodegradable. Some of today's most advanced engineering materials are composite materials.

When conducting composite tests, two main considerations must be made: mechanical properties and composite failure properties. These two are the most important factors to consider when conducting the test and determining the composite's strength.

2.5.1 Mechanical Properties of Natural Composite

The mechanical properties of natural composites are the reaction of a natural composite to the mechanical load such as tensile or impact test. The length and diameter of each individual fibre, as well as the experimental conditions, all influence the mechanical properties of natural fibre. The experimental conditions may differ in many cases. The factors that are affecting mechanical performance of natural fibre composite are the selection of fibre and matrix, the interface strength, fibre dispersion and orientation (T. Raja, 2017)

Young's modulus (E) measures a material's elasticity, which is defined as the relationship between a material's deformation and the force required to deform it. The equation of Young Modulus is by the ‘rules of mixtures’ which is $E_C = E_F V_F + E_M V_M$.

Tensile strength measures the maximum stress that a material can withstand. There is a limit between the plasticity and rupture zones. For Kenaf fibre-reinforced epoxy composite, it is prepared by Reza Mahjoub (2014), and investigated for tensile properties. The tensile modulus and tensile strength of unidirectional kenaf fibre-reinforced epoxy composites increased as the volume fraction of kenaf fibre increased, according to the findings.

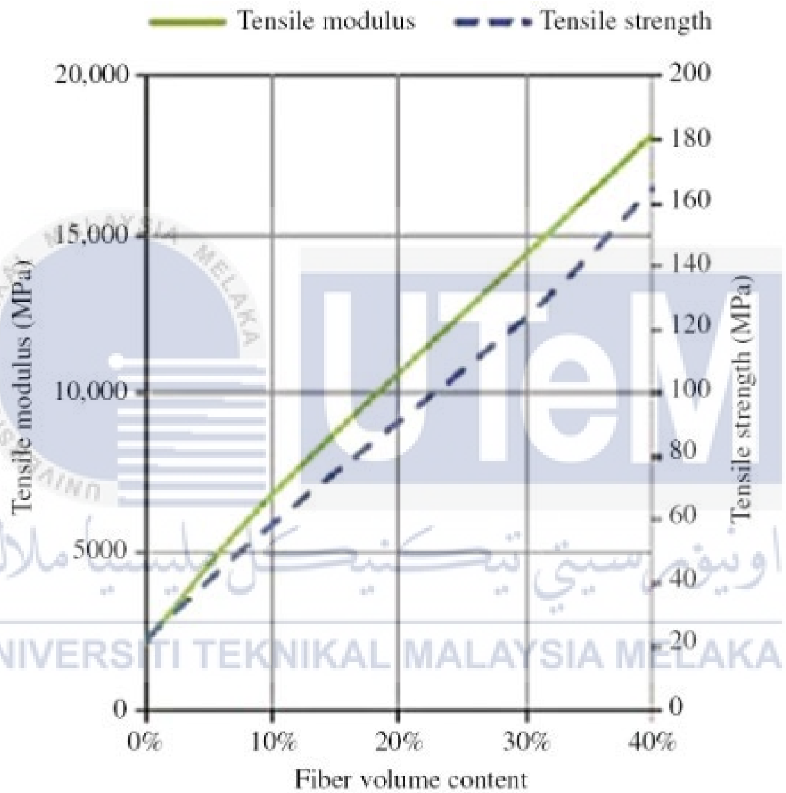

Figure 2.11: Tensile strength and tensile modulus vs Kenaf Fibre volume content in Kenaf Fiber-reinforced epoxy composites (R. Mahjoub, 2014)

While Januar Parlaungan Siregar (2014) prepared the addition of 5% volume fibre with less than 0.5 mm length of fibre in unsaturated polyester composite, the result of tensile strength and tensile modulus is in the range between 29.80 MPa and 981 MPa. The experimental result below shows that the increasing size of fibre from less than 0.5 mm to 1-2 mm increases the tensile strength of Pineapple Leaf Fibre-reinforced Unsaturated Polyester composites.

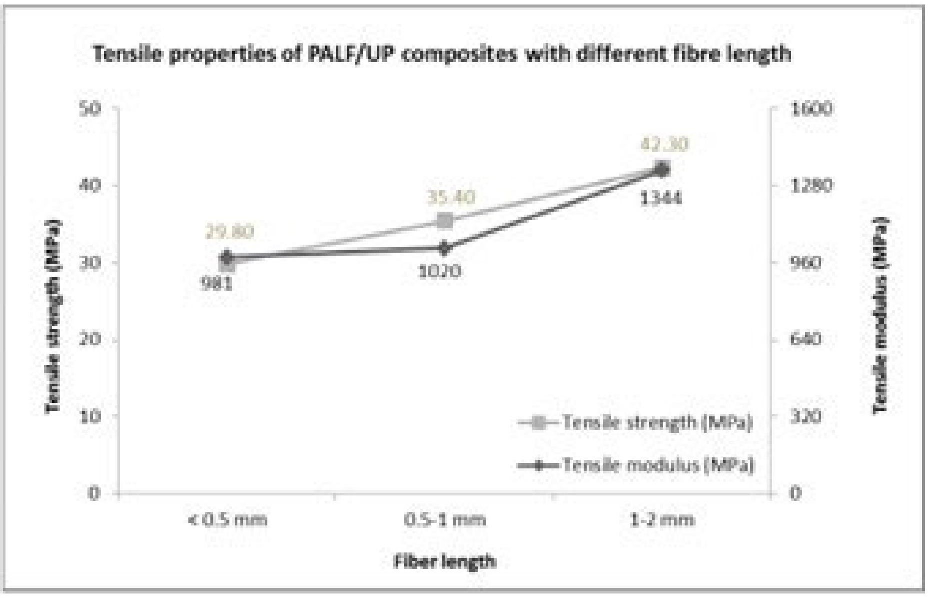

Figure 2.12: Tensile properties of PALF/UP composites with different fibre lengths (J. P. Siregar 2014)

The above study shows that fibre length has a significant impact on the properties of composites. The matrix plays an important role in transferring the applied load to the fibres in addition to holding them together. The fibre-matrix interface and the ability to transfer stress from the matrix to the fibres determine the efficiency of a fibre-reinforced composite (R. Karnani, 1997). To conclude that when the fibre size is less than 0.5 mm, the tensile strength is low because the length may not be sufficient for proper load distribution. When the proper length is not available for stress distribution, specimen failure is common. While the Pineapple Leaf Fibre-reinforced Unsaturated Polyester composites with longer fibre from 1 mm to 2 mm have the highest tensile strength and tensile modulus compared to other sizes (J. P. Siregar 2014).

2.5.2 Failure Properties of Natural Composite

In composites, the sample failure may happen in a certain condition, but its propagation and final result of failure may have happened differently. Composite failure is frequently initiated internally, and changes in composite behaviour and appearance are detected only after the failure has been observed. A composite sample's internal failure could be;

- The fractures of fibres,
- The formation of micro-cracks in a matrix,
- The debonding between fibres and matrix,
- Delamination is the process of separating the layers of a laminate.

The stress-strain behaviour of unidirectional laminates is typically linear. The stress-strain response curve becomes progressively nonlinear as the externally applied load crosses a particular threshold. This threshold could be one definition of the unidirectional ply failure load. Instead, the actual load at which the composite fractures could be the failure load of a unidirectional ply (Dr. M. T. Alam, 2020)

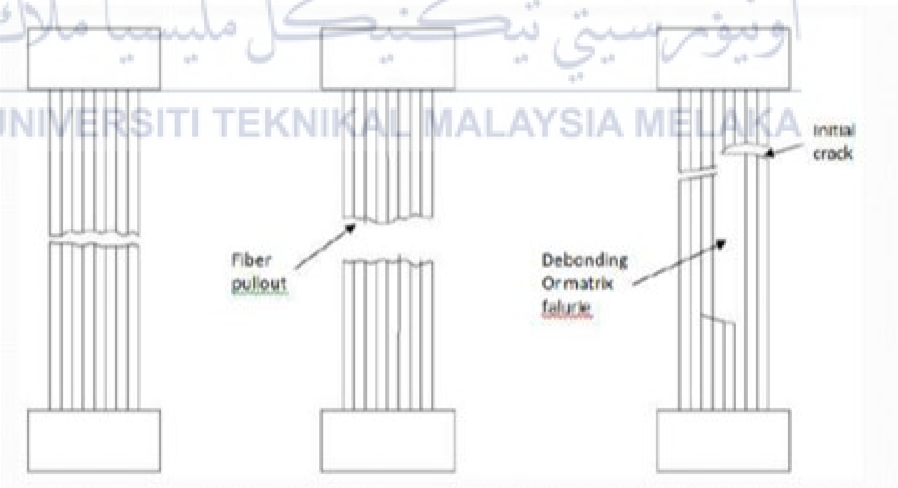

Figure 2.13: Different Tension (Left Tension Failure Modes of a Unidirectional Lamina in Longitudinal: Brittle Failure, Centre: Brittle Failure with Fibre Pull-out, right: Brittle Failure with Debonding and/or Matrix Cracking)

CHAPTER 3

METHODOLOGY

3.1 Introduction

The methodology explains how the sample is prepared and to conduct the tensile test experiment. Based on a flow chart that shows the entire procedure from beginning to end. This helps to monitor the study's progress throughout the research work. Every method or process will be thoroughly explained in each section.

3.2 Research Flowchart

The flowchart explains from the beginning of the preparation to the testing. The explanation is shown below;

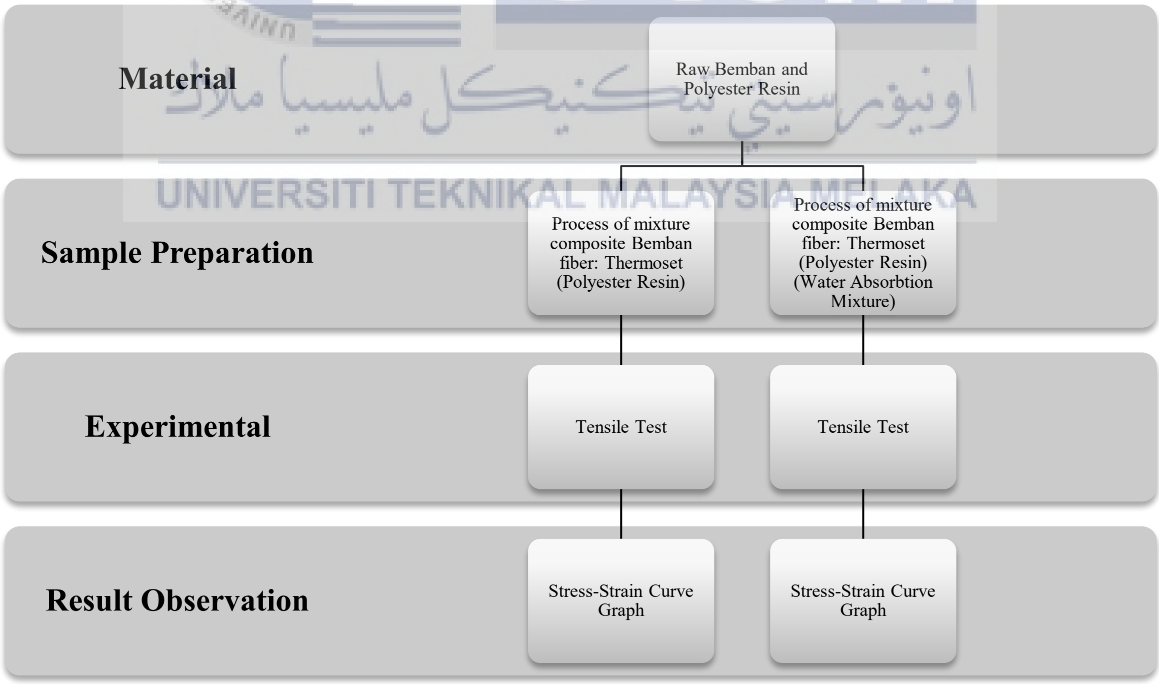

Figure 3.1: Research Flowchart

3.3 Sample Preparation

The process of Bemban and thermoset will undergo 3 different ratios of mixture with the amount of 1:1, 1:5 and 1:10 by testing the ratio with tensile test.

To prepare the specimen sample of Bemban and thermoset, the hand lay-up method is the cheapest open-moulding and the most common method because it requires the least amount of equipment.

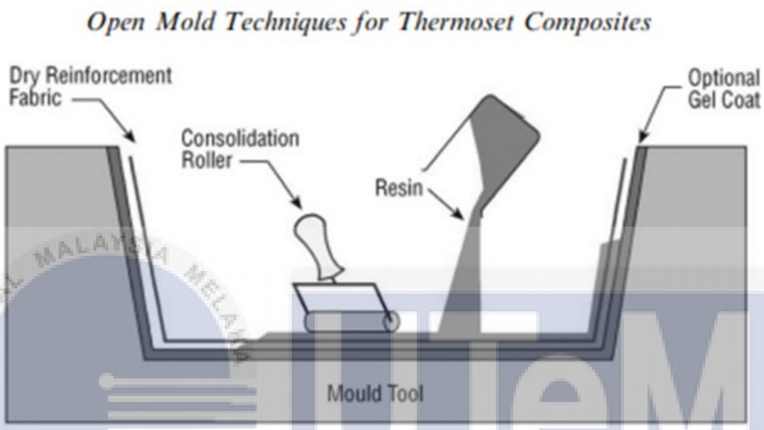

Figure 3.2: Wet lay-up or hand lay-up (Cripps, 1999)

Based on the figure above, T. J. Searle and J. Summerscales (2000) reported that liquid resin is used to moisten the fibres that are placed on or into the mould. The fibres can be woven, knitted, stitched, or bonded into strand mats, woven, knitted, stitched, or bonded fabrics. Brushes and rollers are frequently used to evenly spread the resin onto the fibres and push air bubbles out of the reinforcement and ensure complete wet out. To make it better for reinforcements, brushing is the right step. Curing (cross-linking) takes place at room temperature with no consolidation pressure applied to the mould.

In order to keep the workforce comfortable, the process is usually carried out at ambient temperatures and pressures. For Polyester Resin, hand lay-up should be continuous with no more than a 24-hour break. When the break is more than 24 hours, it may be necessary to clean and/or roughen the surface.

To remove air from tricky corners for hand lamination, resin containers and laminating brushes (the process is commonly referred to as (bucket and brush)) are commonly used in combination with laminating rollers and metal/disk rollers (Noakes,1992).

Resin roller dispensers are a way to reduce styrene emissions without having to make significant changes to moulds or materials. A pump delivers resin and catalyst to a static mixer, which is then applied with a roller applicator. This method reduces vaporisation, fogging, overspray, and bounce-back losses (, T. J. Searle, 2000)

3.3.1 Process of Raw Bemban Extraction

There are a few steps to process the raw Bemban;

1. Let Bemban dry up to make it easy to extract.

Figure 3.3: Extracted Bemban

2. Extract the Bemban fibre into strands.


Figure 3.4: Bemban strand fiber

3. Blend the Bemban fibre by using Disk Mill Machine.


Figure 3.5: Disk Mill Machine

4. Collect the fibre and put it in the filter.

Figure 3.6: Filter container

5. Filter the Bemban fibre by using Laboratory Test Sieve.

Figure 3.7: Laboratory Test Sieve

6. The fibre has been filtered.

Figure 3.8: Filtered fibre

7. The fibres are collected and stored in the container.

Figure 3.9: Blended fibre in a container

3.3.2 Equipment

In this project, Bemban is the main material used and Polyester Resin is for the thermoset. A manual extraction method is used to process Bemban from raw material to form fibre and the thermoset used is a Polyester Resin. This material will undergo mixing and form a composite. The mixture ratio for this composite is 1:1, 1:5, 1:10 and a pure resin without Bemban. Each specimen will be formed into a rectangular shape with a thickness of 3 mm. The moulding method is chosen in this process to form a mixture composite into a shape that needed to undergo testing. This project study will be prepared from scratch, and there are a few pieces of equipment needed. In making the mould, there are two moulds being used along the project.

For the first mould, a piece of glass is cut into two with a measurement of 300 mm x 300 mm to act as a base and header for compression.

Figure 3.10: A piece of glass is cut

The inner frame material is Teflon being used to form a moulding texture. Teflon is a synthetic polymer that contains carbon and fluorine to form Polytetrafluoroethylene science. The characteristics of this material are very suitable for this project because it is water resistant, resistant to chemicals or solvents, has low friction which nothing will sticks with it due to the coefficient friction are lowest out of all solids, has a high melting point and it also flexible and bendable to easily takeout composite after used. Teflon is chosen due to when undergo mixing, the composite will form heating by itself due to the combination of the molecule formed. The Teflon is cut into a frame shape with an inner diameter of 250mm x 250mm.

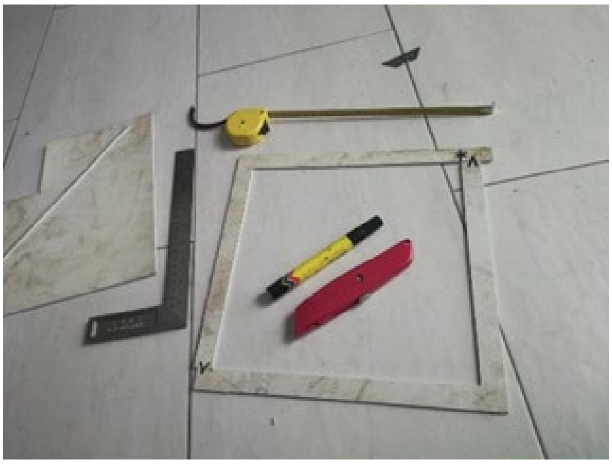

Figure 3.11: Inner frame (Teflon)

Lastly, the equipment needed in this making process is Vaseline to act as a non-stick of composite and mould, 2 pieces of the cup, a wooden stick for mixing and a weighing scale to weigh Bemban and resin.

Figure 3.12: Vaseline

Figure 3.13: A piece of cup

Figure 3.14: Weighing Scale

Figure 3.15: Wooden stick

The second mould, it is having the same concept as the first mould but different material which is a mild steel plate. The material of the mould is a mild steel plate with a thickness of 3 mm and cut using a laser cut machine in UTeM.

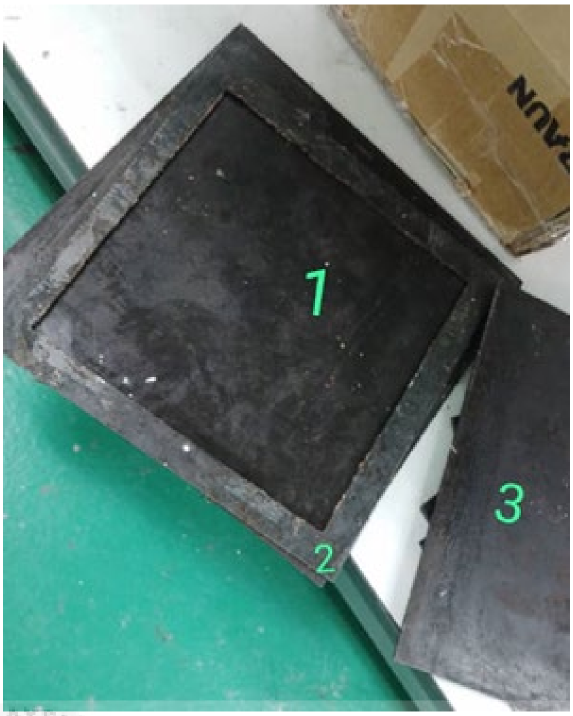

Figure 3.16: Mild Steel Plate

3.3.3 Composite Experimental Setup

The parameters used are by using weight ratios of 1:1, 1:5 and 1:10. Firstly, calculations need to be made for the preparation of composites. The volume of the mould is 25 x 25 x 0.3 (cm) = 187.5 cm. Benchmark has been made that 20 grams of Bemban fibre can fill in one mould. The density of Polyester Resin taken is 1.65 g/cm^3, an average between 1.3 – 2 (g/cm^3) (M. Jannah, 2009). So, the total mass in the mould is 309.375 grams ≈ 310 grams.

Table 3.1: Calculation of volume and total mass in the mould

The volume of mould (cm^3)	= 25 x 25 x 0.3 (cm) = 187.5 (cm^3)
Total of mass in the mould (g)	$\rho = \frac{m}{v}$ $1.65 = \frac{m}{187.5}$ m = 1.65 x 187.5 m = 309.375 grams m ≈310 grams

For a sample mixing ratio of 1:10, weigh the Bemban for 20 grams and the Polyester Resin for 290 grams according to the volume of the mould.

Table 3.2: Calculation of ratio 1:10

The ratio of 1:10	
Bemban	20 grams
Polyester Resin	**290 grams (284 grams resin + 6 grams hardener)**

For a sample mixing ratio of 1:5, weigh the Bemban for 62 grams and the Polyester Resin for 245 grams according to the volume of the mould.

Table 3.3: Calculation of ratio 1:5

Ratio of 1:5	
Bemban	62 grams
Polyester Resin	**245 grams (240 grams resin + 5 grams hardener)**

For a sample mixing ratio of 1:1, weigh the Bemban for 155 grams and the Polyester Resin for 155 grams according to the volume of the mould.

Table 3.4: Calculation of ratio 1:1

Ratio of 1:1	
Bemban	155 grams
Polyester Resin	**155 grams (152 grams resin + 3 grams hardener)**

For a sample of pure Polyester Resin, weigh the Polyester Resin for 310 grams according to the volume of the mould. Mass of Polyester Resin in the mould = **310 grams**

(**304 grams resin + 6 grams hardener**). After the calculation has been made, the preparation proceeds to make a sample composite with the data calculated.

3.3.3.1 Composite process

The process involves the application of a hand layup method in which Polyester Resins were used to evenly spread by using the steel roller to penetrate the resin is onto the fibres and push air bubbles out of the reinforcement and ensure that the composite is smooth. The curing process at room temperature was performed for 24 hours once the Polyester Resin solidified with fibres. In order to make the composite, there are a few steps that need to be taken.

For a composite of matrix only (Polyester Resin, the first step is to spread the Vaseline on both the glass surface and the Teflon frame. Nicely put a Teflon frame on top of a piece of glass. Then, pour 304 grams of resin into a cup on top of the weight machine and add 6 grams of hardening liquid and steer until the resin is completely mixed.

Figure 3.17: Vaseline is spread

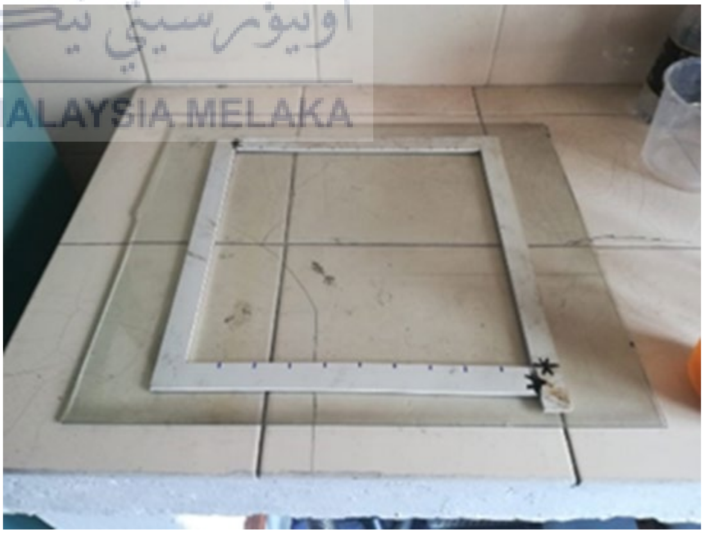

Figure 3.18: Teflon placed on top of the glass

Figure 3.19: Weigh the resin and Bemban

After that, pour the resin until filled to the frame and stack another piece of glass on top to compress the resin. After 15 minutes, the resin becomes hardened and quickly cut into pieces in a measurement of 250 mm x 250mm. A scissor can be used to cut the composite due to not being fully hardened. This cutting process needs to handle quickly. After the cutting process, keep and arrange the specimen on a flat surface and let it continue to harden for about 24 hours. The best way to keep the specimen is to sunbathe or a room temperature. Otherwise, the composite needs more time to harden in a cold atmosphere.

Figure 3.20: Pouring and Cutting Process

For the composite ratio of 1:10, the steps are just the same as all the processes. After spreading the Vaseline on top of the base glass, nicely put the Teflon frame on top of it. Pour 284 grams of resin into a cup on top of the weight machine and add 6 grams of hardening liquid and steer until the resin is completely mixed. Then, measure 20 grams of Bemban and mix it all together with the resin.

Figure 3.21: Mixed Bemban

After mixing, gently pour the mixture into the moulding frame until completely spread to the corner. The pouring process needs to handle quickly due to the composite will be hardened fast. Compressed on top of composite with a glass and put some weight on top to ensure no bubble in the composite. After 10 minutes, a scissor cannot cut through the composite then a knife is used for the cutting process. The samples were cut into dimensions of 250 mm × 25 mm x 3 mm for the tensile test.

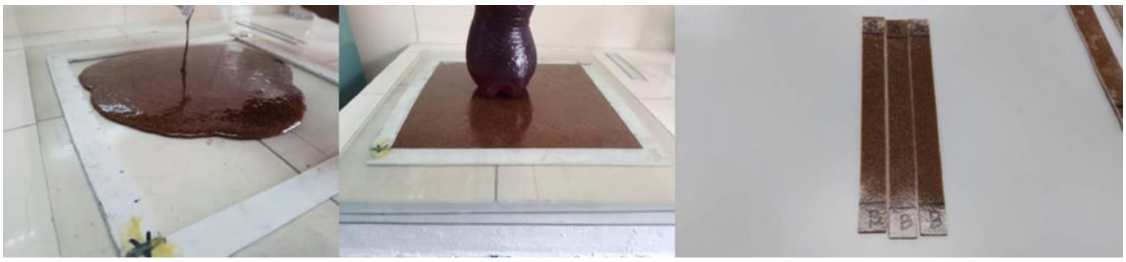

Figure 3.22: Pouring, Compressing and Cutting process

For the composite ratio of 1:5, the early steps are just the same as other ratios. After the early steps, pour 240 grams of resin into a cup on top of the weight machine and add 5 grams of hardening liquid and steer until the resin is completely mixed. Then, measure 62 grams of Bemban and mix it all together with resin.

For this ratio, they need to add a few steps in order to get a nearly perfect specimen. After pouring the mixture, use a steel roller to spread the mixture smoothly this process also helps to remove bubbles that form into the composite. This step is a bit challenging due to every movement needs to be fast and smooth because due to a mixture of resin and fibre, the mixture hardened faster.

Figure 3.23: Pouring and Rolling Process

After that, glass is stacked into the composite for the compression process. The hardening process takes time for it to become solid. After half an hour, the composite starts to form solid and proceed to the cutting process by using a Band Saw Machine.

Figure 3.24: Hardened composite and after the cutting process

For the composite ratio of 1:1 process, there a few changes are taken. The material equipment needs to replace because for this ratio needed more compression. Previous glass and Teflon are not suitable.

Mould is using a mild steel plate with a thickness of 3 mm and is cut using a laser cut machine in UTeM. The mild steel plate contains a weight of 5 kg, and it is suitable for this process. The steps are the same, pour 150 grams of resin into a cup on top of the weight machine and add 5 grams of hardening liquid and stir until the resin is completely mixed. Then measure 155 grams of Bemban and mix it all together with resin.

Figure 3.25: Mild Steel Plate (Second Mould)

This step added the film paper to cover the metal surface from sticking with the composite. A Vaseline is spread on the film paper and the frame is nicely put on top. The mixture is poured and roll the composite by using a steel roller to flatten it smoothly. The film paper that is spread with Vaseline is put on top on the composite and compressed with another mild steel plate.

Figure 3.26: Put the film paper on the mould

Figure 3.27: Hardened composite of ratio 1:1

Lastly, after the composite has been taken out from the mould. The composite is marked and cutting proceeded. Band Saw Machine is used for the cutting process.

Figure 3.28: Cut the composite by using Band Saw Machine

Figure 3.29: 3 specimens of ratio 1:1

After the cutting process for all ratios, 3 specimens of each ratio need to undergo with water absorption method. Before the specimens soak into the water, they need to be measured and weighed to see the effect of absorption.

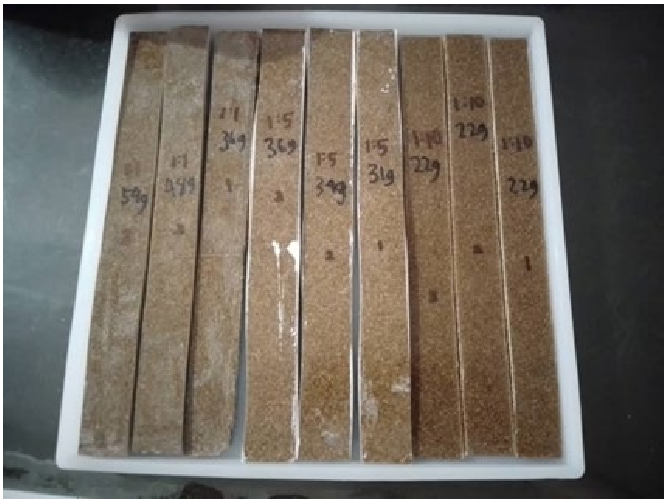

Figure 3.30: Measured and weighed the specimen

All 9 specimens, 3 specimens of each ratio were soaked in the big water bottle for 24 hours.

Figure 3.31: Soaked specimens

3.4 Testing

3.4.1 Tensile Test

Tensile testing determines the tensile strength, yield strength, and ductility of materials. It calculates the amount of force required to break a composite, as well as how far the specimen must stretch or elongate to achieve that breaking point. The specimens were tested on a universal testing machine in this study to analyse the mechanical behaviour of the composites in accordance with ASTM D3039 standards. The specimens were loaded until breaking at a constant speed of 2 mm/min.

Figure 3.32: Tensile Test Machine

There are a total of 21 specimens that need to be tested by using the Universal Testing Machine. The results and discussions of the specimens will be explained in Chapter 4.

3.5 Summary

In summary, Bemban fibre was manually extracted and grinded. There has been a lot of research and studies done on natural composites. Kenaf, Jute and Pineapple are the most commonly used natural composites for Bemban fibre. For PSM 2, the test has been done to determine the failure of the composite in order to gain the data from the tensile test.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results and analysis of the tensile test of the specimen composite before and after-effect of the water absorption test. The results obtained from composite research with variations in the ratio of 1:1, 1:5, and 1:10 on tensile strength can be seen in the results shown in this chapter.

4.2 Tensile test result

Sample with different mixing ratios. The table below shows the 3 different masses of 3 different ratios at 1:1, 1:5 and 1:10 and also Polyester Resin only as samples.

Table 4.1: Sample with different mixing ratio

Sample ratio	Natural Fibre (Bemban)	Matrix (Thermoset)
1:1	155 grams	155 grams
1:5	62 grams	245 grams
1:10	20 grams	290 grams
Matrix Only (Polyester Resin)	0 gram	310 grams

4.2.1 Sample with mixing ratio 1:1

The test was performed to determine the stress-strain curve for the mixing ratio 1:1. Data obtained from the test were shown in Figure 4.1 and listed in Table 4.2. The result of Young's Modulus, Yield Strength, Ultimate Tensile Strength, Elongation and Density of the samples will be explained in the figure and table below.

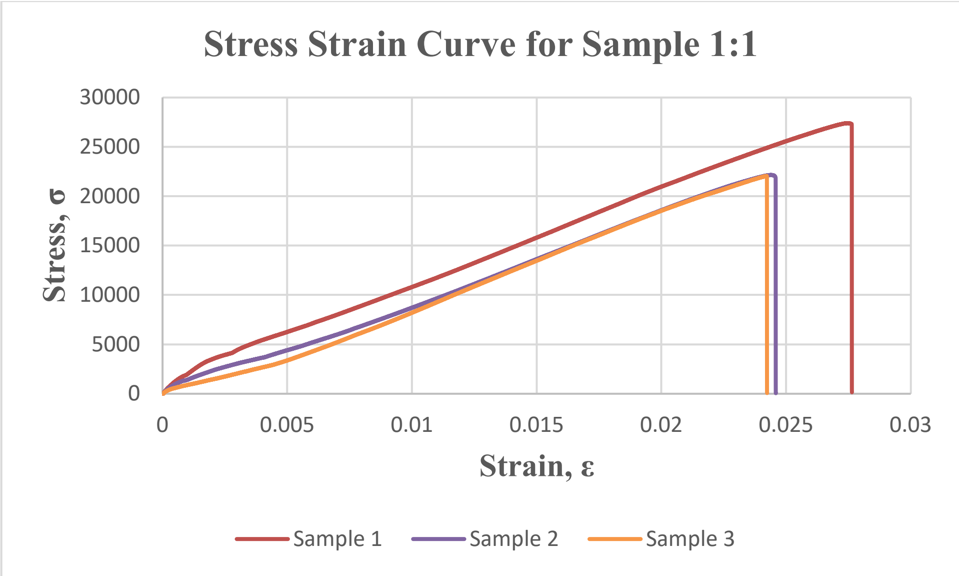

Figure 4.1: Stress-Strain Curve for Sample 1:1

Table 4.2: Result for Sample 1:1

Sample	Young Modulus, E (MPa)	σ_Y (MPa)	σ_U (MPa)	Elongation	Density (kg/m^3)
1	1006.5935	27.3931	27.3931	0.027464	8267
2	984.2121	22.1477	22.1477	0.024384	
3	1055.1692	22.0443	22.0443	0.024226	
Average	1015.3249	23.8615	23.8615	0.025358	

Figure 4.2: Result for Sample 1:1

Young's Modulus is the ratio of stress and strain in the elastic region which is also known as elastic modulus. From Young's Modulus, it can determine or predict the elongation of the sample as the result of stress is less than the yield strength of the sample. From Table 4.2, the pattern of the average specimen among the 3 specimens tested is 1015.3249 MPa.

Yield strength occurs when the stress is the same as the amount of composite deformation. Yielding occurs during the beginning of the process of plastic deformation. Referring to Table 4.2, the average of 3 specimens of yield strength plotted at 23.8615 MPa.

Ultimate Tensile Strength is the maximum stress that can be found in the stress-strain curve as shown in Figure 4.1. From Table 4.2, the average value among the 3 specimens tested is 23.8615 MPa.

Elongation is the load maximum that occurs in the stress-strain curve as shown in Figure 4.1. The average maximum load for the composite ratio of 1:1 taken is 0.025358.

As shown in Table 4.2, the density for the composite ratio of 1:1 is 8267 kg/m^3.

4.2.2 Sample of mixing ratio 1:5

The test was performed to determine the stress-strain curve for the mixing ratio 1:5. Data obtained from the test were shown in Figure 4.3 and listed in Table 4.3. The result of Young's Modulus, Yield Strength, Ultimate Tensile Strength and Elongation of the samples will be explained in the figure and table below.

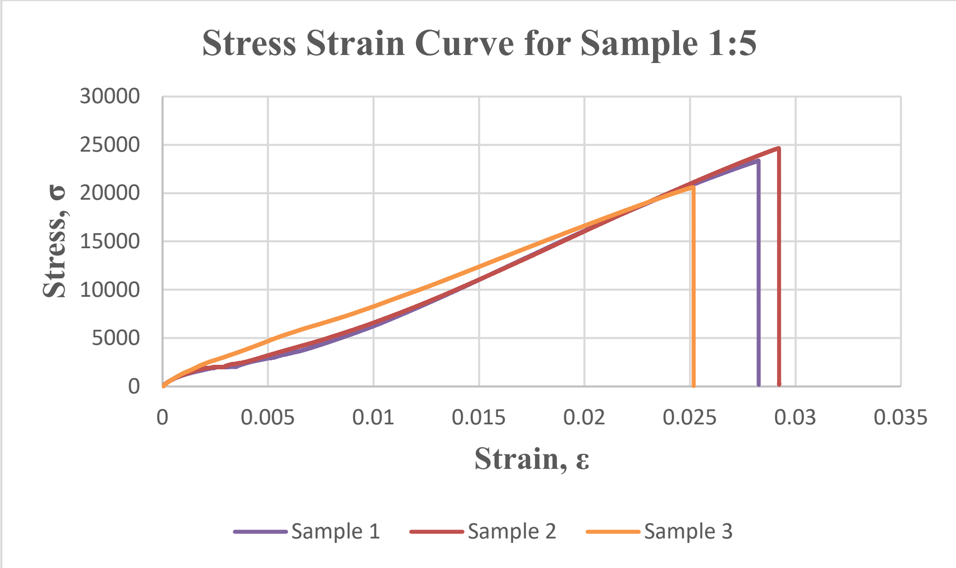

Figure 4.3: Stress-Strain Curve for Sample 1:5

Table 4.3: Result for Sample 1:5

Sample	Young Modulus, E (MPa)	σ_Y (MPa)	σ_U (MPa)	Elongation	Density (kg/m3)
1	965.9228	23.35993	23.35993	0.028246	3307
2	912.5214	24.64188	24.64188	0.029218	
3	833.0465	20.6	20.6	0.02500	
Average	903.8302	22.8673	22.8673	0.027488	

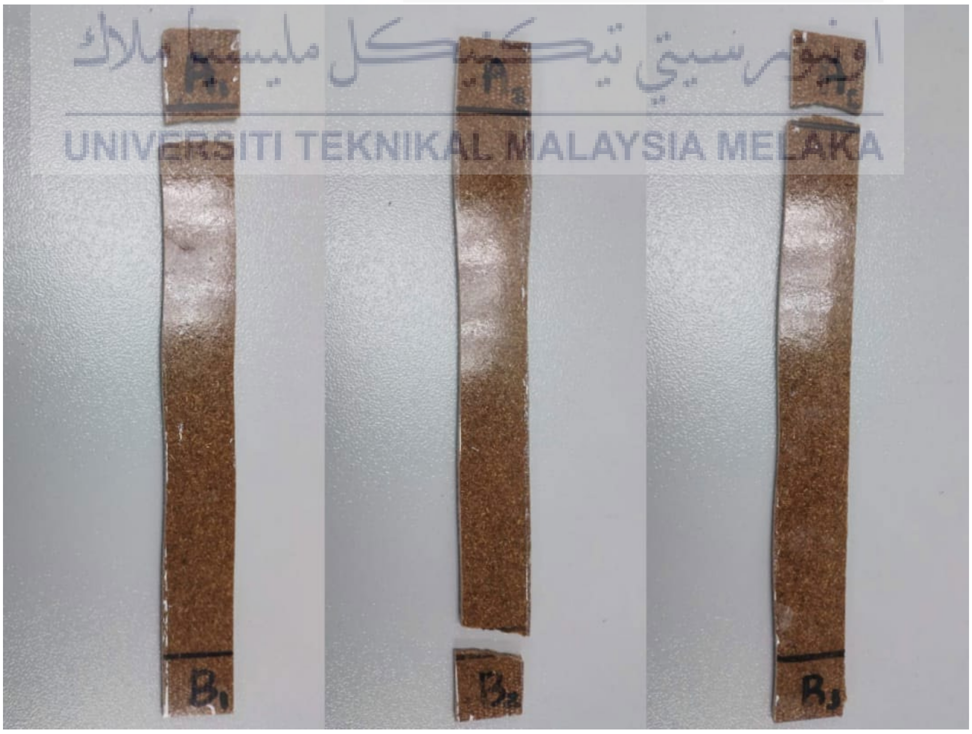

Figure 4.4: Result for Sample 1:5

Young's Modulus is the ratio of stress and strain in the elastic region which is also known as elastic modulus. From Young's Modulus, it can determine or predict the elongation of the sample as the result of stress is less than the yield strength of the sample. From Table 4.3, the pattern of the average specimen among the 3 specimens tested is 903.8302 MPa.

Yield strength occurs when the stress is the same as the amount of composite deformation. Yielding occurs during the beginning of the process of plastic deformation. Referring to Table 4.3, the average of 3 specimens of yield strength plotted at 22.8673 MPa.

Ultimate Tensile Strength is the maximum stress that can be found in the stress-strain curve as shown in Figure 4.3. From Table 4.3, the average value among the 3 specimens tested is 22.8673 MPa.

Elongation is the load maximum that occurs in the stress-strain curve as shown in Figure 4.3. The average maximum load for the composite ratio of 1:1 taken is 0.027488.

As shown in Table 4.3, the density for the composite ratio of 1:5 is 3307 kg/m^3.

4.2.3 Sample of mixing ratio 1:10

The test was performed to determine the stress-strain curve for the mixing ratio 1:10. Data obtained from the test were shown in Figure 4.5 and listed in Table 4.4. The result of Young's Modulus, Yield Strength, Ultimate Tensile Strength, Elongation and Density of the samples will be explained in the figure and table below.

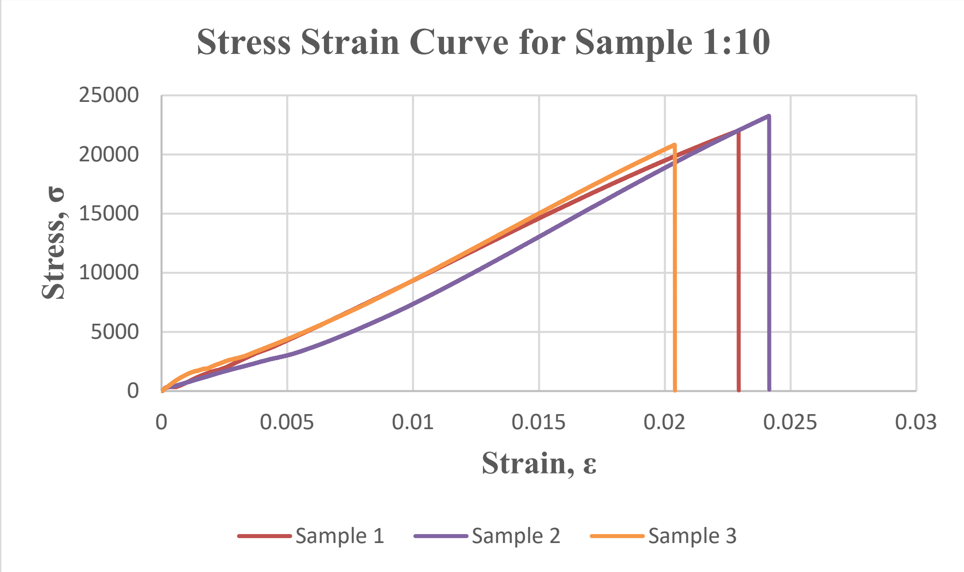

Figure 4.5: Stress-Strain Curve for Sample 1:10

Table 4.4: Result for Sample 1:10

Sample	Young Modulus, E (MPa)	σ_Y (MPa)	σ_U (MPa)	Elongation	Density (kg/m3)
1	1044.7004	22.021	22.021	0.022933125	1067
2	1138.9522	23.260	23.260	0.024145	
3	1128.1245	20.8219	20.8219	0.020398	
Average	1103.9527	22.0343	22.0343	0.02249	

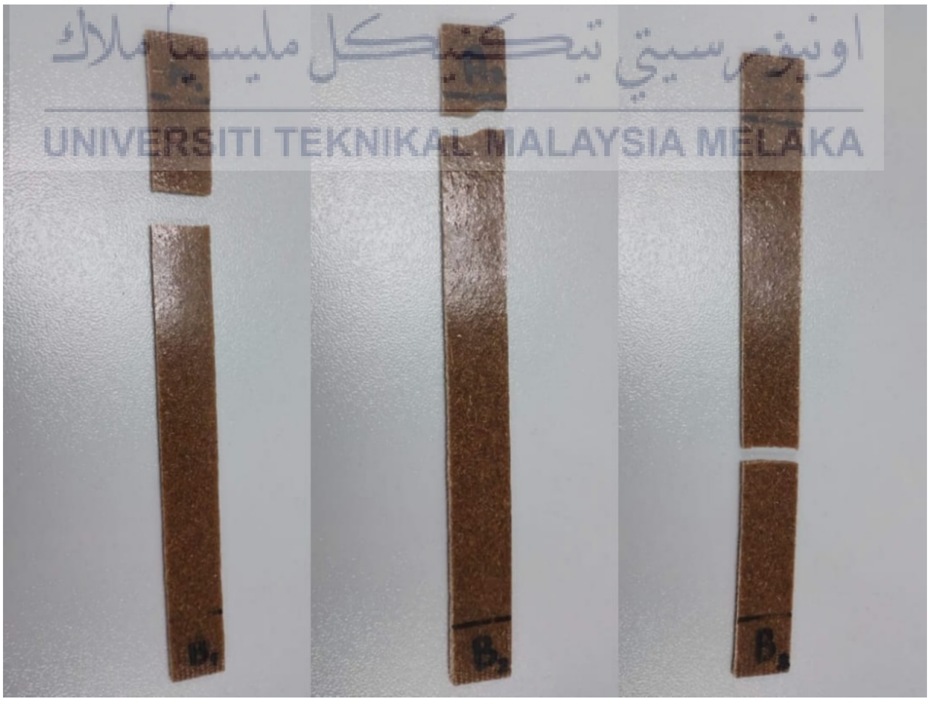

Figure 4.6: Result for Sample 1:10

Young's Modulus is the ratio of stress and strain in the elastic region which is also known as elastic modulus. From Young's Modulus, it can determine or predict the elongation of the sample as the result of stress is less than the yield strength of the sample. From Table 4.4, the pattern of the average specimen among the 3 specimens tested is 1103.9527 MPa.

Yield strength occurs when the stress is the same as the amount of composite deformation. Yielding occurs during the beginning of the process of plastic deformation. Referring to Table 4.4, the average of 3 specimens of yield strength plotted at 22.0343 MPa.

Ultimate Tensile Strength is the maximum stress that can be found in the stress-strain curve as shown in Figure 4.5. From Table 4.4, the average value among the 3 specimens tested is 22.0343 MPa.

Elongation is the load maximum that occurs in the stress-strain curve as shown in Figure 4.5. The average maximum load for the composite ratio of 1:10 taken is 0.02249.

As shown in Table 4.4, the density for the composite ratio of 1:10 is 1067 kg/m^3.

4.2.4 Sample of matrix only

The test was performed to determine the stress-strain curve for a sample of matrix only. Data obtained from the test were shown in Figure 4.7 and listed in Table 4.5. The result of Young's Modulus, Yield Strength, Ultimate Tensile Strength and Elongation of the samples will be explained in the figure and table below.

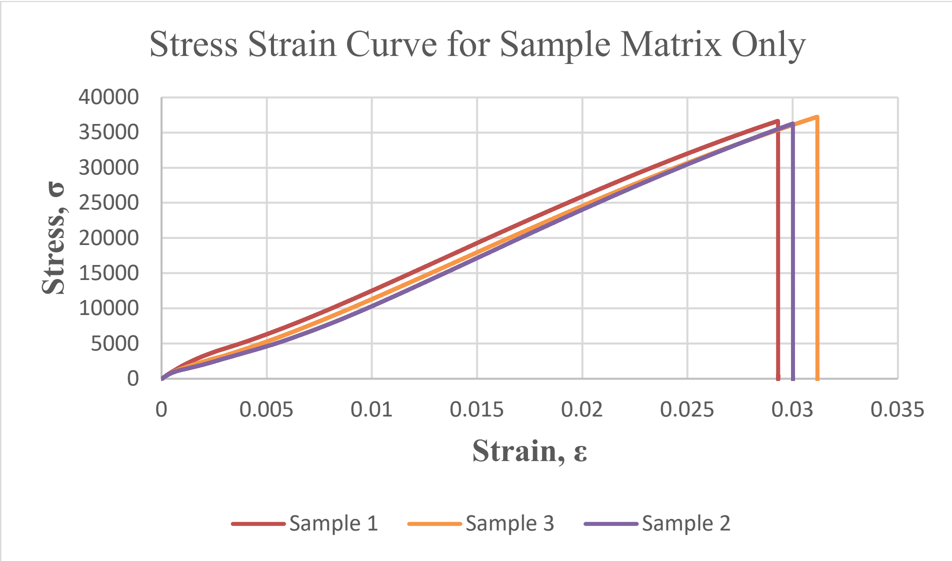

Figure 4.7: Stress-Strain Curve for Sample Matrix Only

Table 4.5: Result for Sample Pure Resin

Sample	Young Modulus, E (MPa)	σ_Y (MPa)	σ_U (MPa)	Elongation
1	1357.2384	36.6480	36.6480	0.029296
2	1372.2127	36.3	36.3	0.0300
3	1336.6210	37.23	37.23	0.03117
Average	1355.3573	36.726	36.726	0.03016

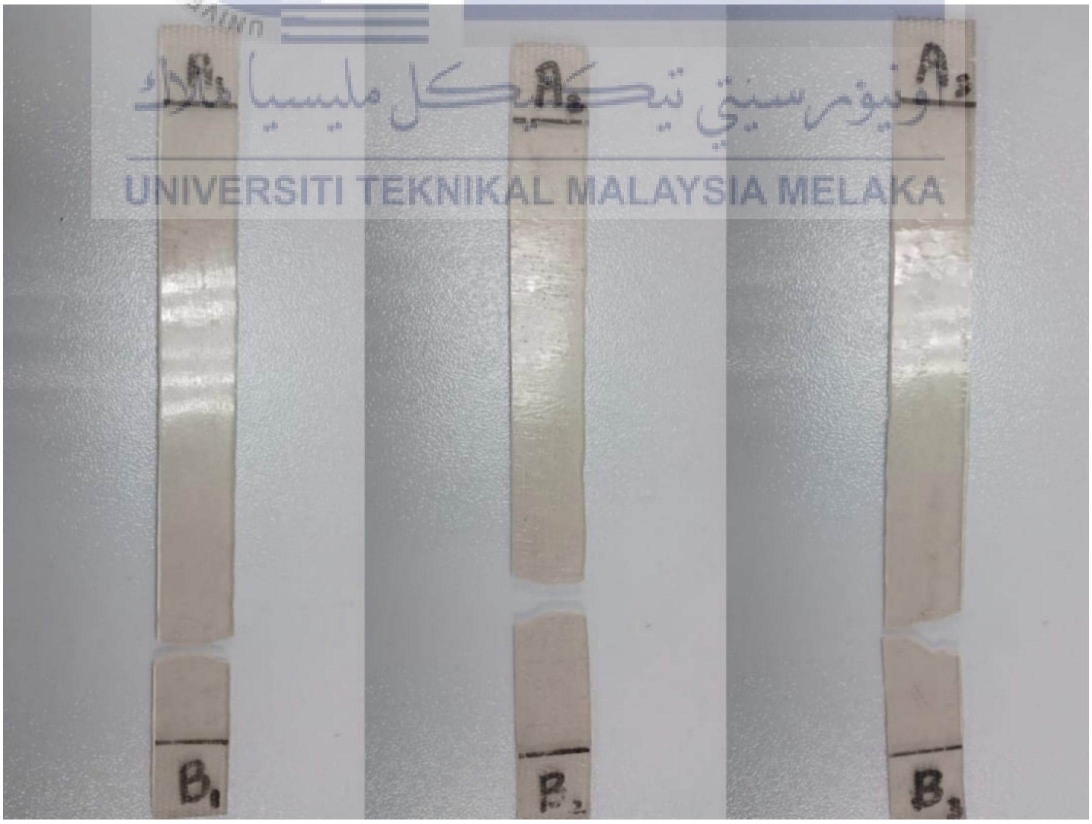

Figure 4.8: Result for Sample Pure Resin

Young's Modulus is the ratio of stress and strain in the elastic region which is also known as elastic modulus. From Young's Modulus, it can determine or predict the elongation of the sample as the result of stress is less than the yield strength of the sample. From Table 4.5, the pattern of the average specimen among the 3 specimens tested is 1355.3573 MPa.

Yield strength occurs when the stress is the same as the amount of composite deformation. Yielding occurs during the beginning of the process of plastic deformation. Referring to Table 4.5, the average of 3 specimens of yield strength plotted at 36.726 MPa.

Ultimate Tensile Strength is the maximum stress that can be found in the stress-strain curve as shown in Figure 4.7. From Table 4.5, the average value among the 3 specimens tested is 36.726 MPa.

4.2.5 Comparison with different mixing ratio

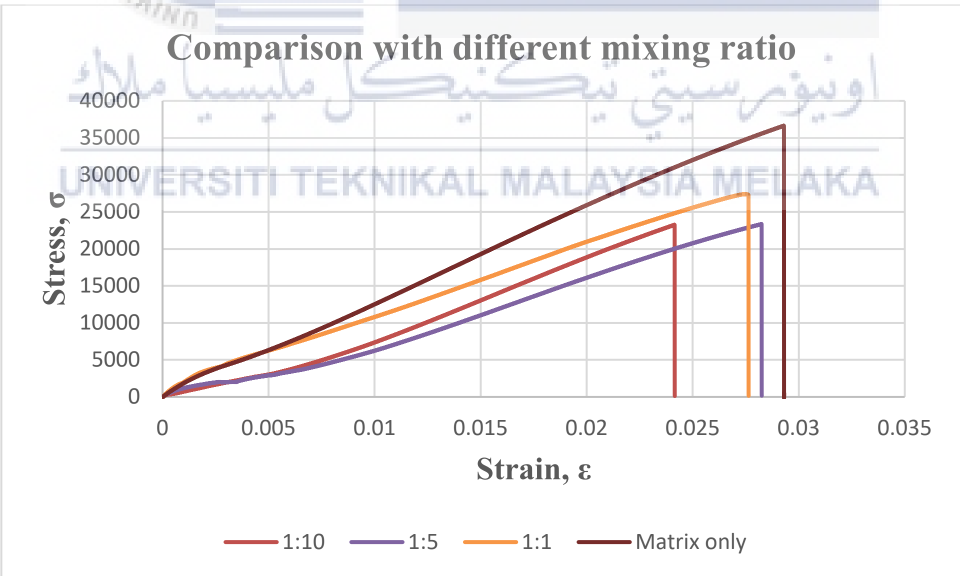

Figure 4.9: Comparison with different mixing ratios

Table 4.6: The best result for different mixing ratios

Sample	Young Modulus, E (MPa)	σ_Y (MPa)	σ_U (MPa)	Elongation	Density (kg/m3)
1:1	1006.5935	27.3931	27.3931	0.027464	8267
1:5	833.0465	20.6	20.6	0.02500	3307
1:10	1138.9522	23.260	23.260	0.024145	1067
Matrix only	1357.2384	36.6480	36.6480	0.029296	-

Based on the graph above, there are 4 best samples tested on the tensile test. The matrix (Polyester Resin) has the best result for tensile strength. Among the ratios of 1:1, 1:5, and 1:10, ratio 1:1 has the best result for tensile strength compared to other ratios. As a result, the Bemban composite with a ratio of 1:5 was prone to show poor tensile strength and modulus than a ratio of 1:1.

The result for Young's Modulus for all best ratios has almost the same average from 833. 0465 MPa to 1357.2384 MPa. The Matrix of Polyester Resin has the highest data of Young's Modulus which is 1357.2384 MPa and the composite ratio of 1:5 has the lowest data which is 833.0465 MPa.

As shown on the graph obtained, yield strength and ultimate yield strength has the same value because there is no plastic region. These 4 samples have a brittle failure result. The highest result for both yield strength and ultimate yield strength is from Polyester Resin which is 36.6480 MPa. While a composite ratio of 1:5 has the lowest result for both yield strength and ultimate yield strength which is 20.6 MPa.

For the result of Elongation, it can be observed that Polyester Resin has the highest value which is 0.029296 and a composite ratio of 1:10 has the lowest value which is 0.024145.

As shown in Table 4.6, the density for a composite ratio of 1:1 has the highest value of 8267 kg/m^3. Followed by a composite ratio of 1:5 is 3307 kg/m^3 and a composite ratio of 1:10 is 1067 kg/m^3.

Generally, natural fibres have lower elongation and yield strength compared to synthetic fibres like glass or carbon. However, when combined with Polyester Resin, the overall properties of the composite are improved.

In terms of natural fibres, Bemban reinforced Polyester Resin composites have different elongation and yield strength than other natural fibres like Pineapple Leaf Fibre reinforced Polyester Resin composites (S. Y. Nayak, 2017). A study published in 2017, by S. Y. Nayak (2018) showed that the use of natural fibre of Pineapple Leaf fibre in Polyester Resin composites resulted in yield strength of 65 MPa. Another study published in 2020, by S. Sudhaghar (2020) showed that the use of Sisal, Jute and Banana fibre in Polyester Resin composites resulted in elongation at a break of 8.3 mm and yield strength of 194.92 MPa. Both of the studies have higher tensile strength than Bemban reinforced Polyester Resin.

The graph shows that the relationship between elongation and yield strength for the mixing ratios of composites would likely show that as the elongation of the material increases, the yield strength decreases. This is because as the specimens are stretched or deform, the Bemban fibres that are mixed with Polyester Resin are pulled apart and lose their ability to support the load.

In summary, Bemban reinforced Polyester Resin composites typically have lower elongation and yield strength compared to Pineapple Leaf Fibre reinforced Polyester Resin and a combination of natural fibres of Sisal, Jute and Banana reinforced Polyester Resin, but they can be improved by using a higher fibre content and better-quality fibres. The more fibre content in the composites, the more they tend to break. The more resins in the composites, the more it tends to flex.

4.3 Effect of water absorption

In this experimental research, the composites' ratio undergoes testing for water absorption. Tap water was used as the medium to test the composite specimens' ability to absorb water. The percentage of water intake was determined from the difference between the final and beginning weights before and after 24 hours of soaking in the water. 9 specimens were tested for each test and kind of composite, and the average results were presented. The calculation was based on the table below.

Table 4.7: Calculation of Increase in Weight, %

Increase in weight, %	$\frac{W_t - W_0}{W_0} \times 100$

4.3.1 Effect of water absorption for mixing ratio 1:1

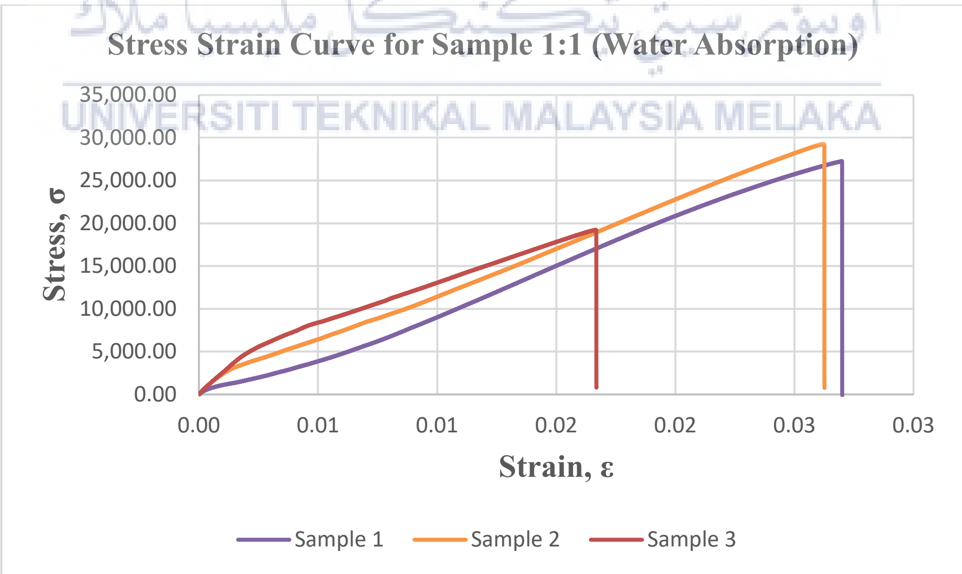

Figure 4.10: Stress-Strain Curve for Sample 1:1 (Water Absorption)

Table 4.8: Result for Sample 1:1 (Water Absorption)

Sample	Young Modulus, E (MPa)	σ_Y (MPa)	σ_U (MPa)	Elongation	Density (kg/m3)	Increase in weight (%)
1	1204.8193	27.3	27.3	0.0270	9264	2.13
2	1122.7824	26.7	26.7	0.0262		
3	947.7336	29.259	29.259	0.0166		
Average	3275.3353	27.753	27.753	0.0233		

Figure 4.11: Result for Sample 1:1 (Water Absorption)

Young's Modulus is the ratio of stress and strain in the elastic region which is also known as elastic modulus. From Young's Modulus, it can determine or predict the elongation of the sample as the result of stress is less than the yield strength of the sample. From Table 4.8, the pattern of the average specimen among the 3 specimens tested is 3275.3353 MPa.

Yield strength occurs when the stress is the same as the amount of composite deformation. Yielding occurs during the beginning of the process of plastic deformation. Referring to Table 4.8, the average of 3 specimens of yield strength plotted at 27.753 MPa.

Ultimate Tensile Strength is the maximum stress that can be found in the stress-strain curve as shown in Figure 4.10. From Table 4.8, the average value among the 3 specimens tested is 27.753 MPa.

Elongation is the load maximum that occurs in the stress-strain curve as shown in Figure 4.10. The average maximum load for a composite ratio of 1:10 taken is 0.0233.

As shown in Table 4.8, the density for a composite ratio of 1:10 is 9264 kg/m^3. There is an increase in weight observed of 2.13 %.

4.3.2 Effect of water absorption for mixing ratio 1:5

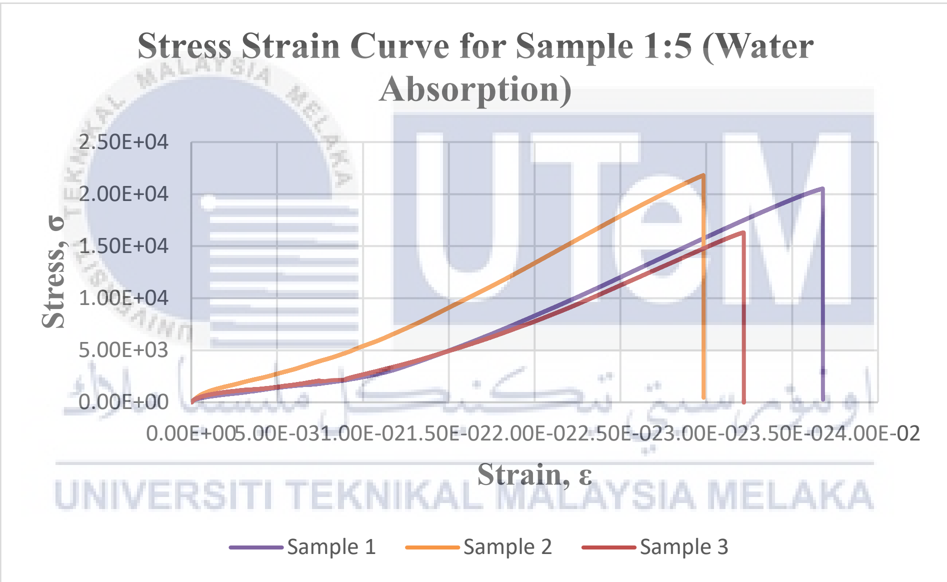

Figure 4.12: Stress-Strain Curve for Sample 1:5 (Water Absorption)

Table 4.9: Result for Sample 1:5 (Water Absorption)

Sample	Young Modulus, E (MPa)	σY (MPa)	σU (MPa)	Elongation	Density (kg/m3)	Increase in weight (%)
1	521.5146	20.5	20.5	0.0368	4304	3.03
2	750.6895	21.8095	21.8095	0.029826		
3	463.9503	16.3148	16.3148	0.032159		
Average	578.7181	19.5414	19.5414	0.03293		

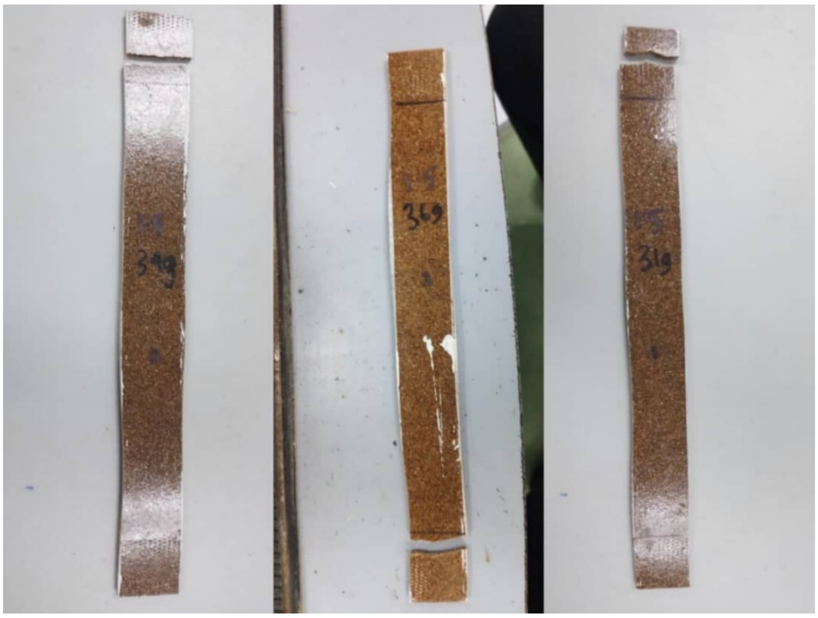

Figure 4.13: Result for Sample 1:5 (Water Absorption)

Young's Modulus is the ratio of stress and strain in the elastic region which is also known as elastic modulus. From Young's Modulus, it can determine or predict the elongation of the sample as the result of stress is less than the yield strength of the sample. From Table 4.9, the pattern of the average specimen among the 3 specimens tested is 578.7181 MPa.

Yield strength occurs when the stress is the same as the amount of composite deformation. Yielding occurs during the beginning of the process of plastic deformation. Referring to Table 4.9, the average of 3 specimens of yield strength plotted at 19.5414 MPa.

Ultimate Tensile Strength is the maximum stress that can be found in the stress-strain curve as shown in Figure 4.12. From Table 4.9, the average value among the 3 specimens tested is 19.5414 MPa.

Elongation is the load maximum that occurs in the stress-strain curve as shown in Figure 4.12. The average maximum load for a composite ratio of 1:5 taken is 0.03293.

As shown in Table 4.9, the density for a composite ratio of 1:5 is 4304 kg/m^3. There is an increase in weight observed of 3.03 %.

4.3.3 Effect of water absorption for mixing ratio 1:10

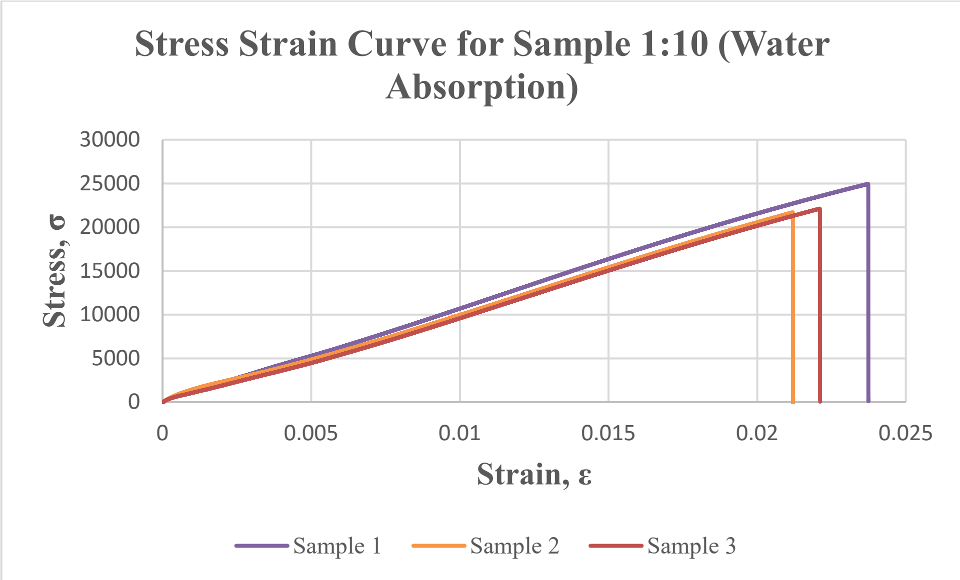

Figure 4.14: Stress-Strain Curve for Sample 1:10 (Water Absorption)

Table 4.10: Result for Sample 1:10 (Water Absorption)

Sample	Young Modulus, E (MPa)	σ_Y (MPa)	σ_U (MPa)	Elongation	Density (kg/m3)	Increase in weight (%)
1	1126.6724	24.9587	24.9587	0.023723	2064	4.5
2	1086.5403	21.7094	21.7094	0.021196		
3	1089.5009	22.1	22.1	0.021000		
Average	1100.9045	22.9227	22.9227	0.021973		

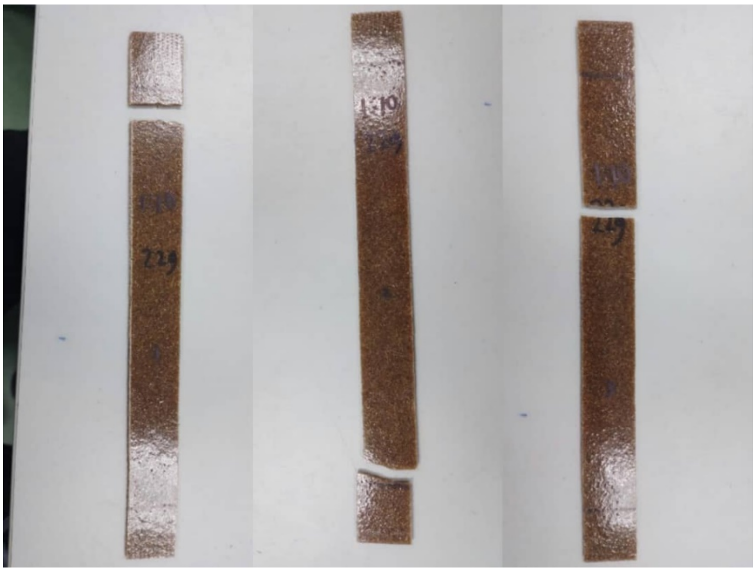

Figure 4.15: Result for Sample 1:10 (Water Absorption)

Young's Modulus is the ratio of stress and strain in the elastic region which is also known as elastic modulus. From Young's Modulus, it can determine or predict the elongation of the sample as the result of stress is less than the yield strength of the sample. From Table 4.10, the pattern of the average specimen among the 3 specimens tested is 1100904.5178 kPa.

Yield strength occurs when the stress is the same as the amount of composite deformation. Yielding occurs during the beginning of the process of plastic deformation. Referring to Table 4.10, the average of 3 specimens of yield strength plotted at 16484.7 kPa.

Ultimate Tensile Strength is the maximum stress that can be found in the stress-strain curve as shown in Figure 4.14. From Table 4.10, the average value among the 3 specimens tested is 22922.7 kPa.

Elongation is the load maximum that occurs in the stress-strain curve as shown in Figure 4.14. The average maximum load for a composite ratio of 1:10 taken is 0.021973.

As shown in Table 4.10, the density for a composite ratio of 1:10 is 2064 kg/m^3. There is an increase in weight observed of 4.5 %.

4.3.4 Comparison of the effect of water absorption with different mixing ratios

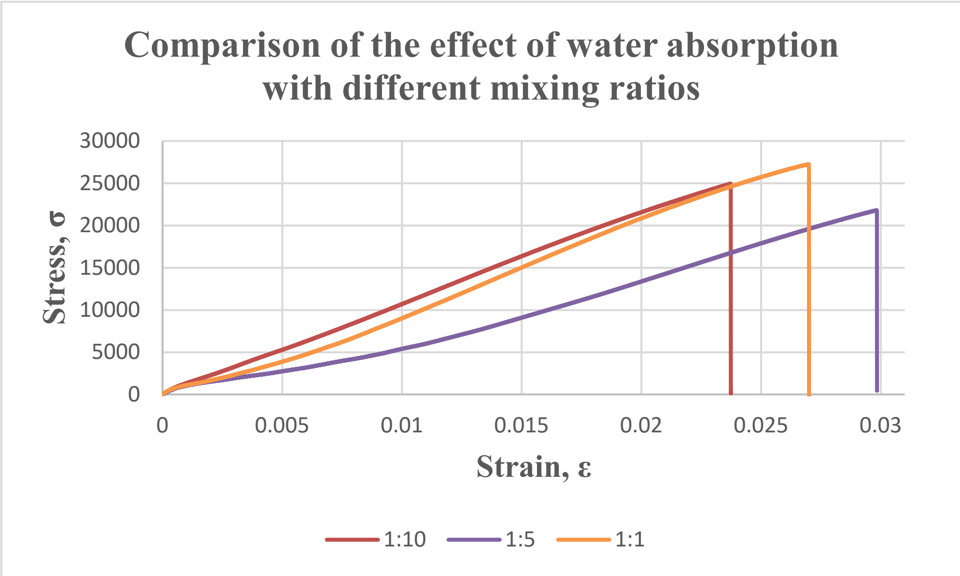

Figure 4.16: Comparison of the effect of water absorption with different mixing ratios

Table 4.11: The best result for the effect of water absorption

Sample	Young Modulus, E (MPa)	σ_Y (MPa)	σ_U (MPa)	Elongation	Density (kg/m3)	Increase in weight (%)
1:1	1204.8193	27.3	27.3	0.0270	9264	2.13
1:5	750.6895	21.8095	21.8095	0.029826	4304	3.03
1:10	1126.6724	24.9587	24.9587	0.023723	2064	4.50

Based on the graph above, there are 4 best samples tested on the tensile test for the effect of water absorption. A composite ratio of 1:1 has the best result for tensile strength. Among the ratios of 1:1, 1:5, and 1:10. As a result, the Bemban composite with the ratio of 1:5 was prone to show poor tensile strength but good ductility than other ratios for the effect of water absorption.

The result for Young's Modulus for composite ratios 1:1 and 1:10 has almost the same value, averaging from 750.6895 MPa to 1204.8193 MPa. While a composite ratio of 1:5 has the lowest data of 750.6895 MPa. The results indicate that the moisture content has a significant effect on the tensile strength and Young's Modulus in case of effect water absorption.

As shown on the graph obtained, yield strength and ultimate yield strength has the same value because there is no plastic region. These 4 samples have a brittle failure result. The highest result for both yield strength and ultimate yield strength is a composite ratio 1:5 of 21.8095 MPa. While a composite ratio of 1:5 has the lowest result for both yield strength and ultimate yield strength which is 21.8095 MPa.

For the result of Elongation, it can be observed that the composite ratio of 1:5 has the highest value which is 0.029826 and the composite ratio of 1:10 has the lowest value which is 0.023723.

4.4 Summary

To summarise, the natural fibre which is Bemban cannot improve the ductility and strength of the matrix of Polyester Resin. Because Bemban is cheap in the market, it saves costs to do this process and the hand layup method is also one of the methods that are save-cost methods.

But it does not mean the natural fibre is not good. To compare the ratio of 1:1 1:5 and 1:10, the composite ratio of 1:1 is the most ductile and strength than other ratios. Young's Modulus of the ratio 11 is 1006.5935 MPa. The yield strength and ultimate tensile strength are 27.3931 MPa. The elongation at break is 0.027464. So, the graph shows that the more fibres, the higher the tensile stress and ductility of the composites.

For the effect of water absorption, it can be observed that there are not many changes in terms of density and the increase of weight of the specimens. For a composite ratio of 1:1, the actual density is 8267 kg/m^3 and after being soaked in water is 9264 kg/m^3. The increase in weight after soaking is by 2.13 %. For a composite ratio of 1:5, the actual density is 3307 kg/m^3 and after being soaked in water is 4304 kg/m^3. The increase in weight after soaking is by 3.03 %. While for a composite ratio of 1:10, the actual density is 1067 kg/m^3 and after being soaked in water is 2064 kg/m^3. The increase in weight after soaking is by 4.5 %.

The result shows that it was attributable due to the lower content of Bemban's density than the Polyester Resin. The tensile properties of the composites slightly changed on exposure to water absorption because there was not much difference between Bemban with Polyester Resin.

The stress-strain curve of the composites from the graph shows how the material behaves under different levels of stress and strain. The curve typically has three distinct regions: the linear elastic region, the plastic region, and the failure region.

In the linear elastic region, the material behaves linearly, meaning that the stress and strain are directly proportional to each other. As the stress increases, the strain also increases, but at a constant rate. The modulus of elasticity or Young's Modulus of pure Polyester Resin is typically higher than the presence of the Bemban fibres. The fibres provide reinforcement to the polymer matrix, which increases the material's stiffness and strength.

In the plastic region, the material begins to deform permanently. The stress-strain curve becomes nonlinear, and the material can no longer return to its original shape when the stress is removed. But in this research, there is no plastic region for mixing Polyester Resin composites.

In the failure region, the specimens reach their breaking point and can no longer withstand any more stress. The stress-strain curve steepens, and the specimen has a brittle failure.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Bemban fibre is one of the types of natural fibre that has good mechanical behaviour. The objectives of this research are achieved especially the effect of different mixture combinations on the mechanical properties of thermoset with Bemban. The effects of water absorption on the mechanical properties (tensile test) of the composites have been studied. The composites were prepared on the ratio of 1:1, 1:5 and 1:10 by using the hand layup method.

As expected, Young's Modulus increases against the increasing content of natural fibre and the resin viscosity. Before the specimen of composite ratio 1:1 soaked in the water, the highest data of Young's Modulus is 1006.5935 MPa. The lowest data of Young's Modulus is from a composite ratio of 1:5 of 833.0465 MPa. For the data of Yield Stress and Ultimate Yield Strength, the highest data is from a ratio of 1:1 of 27.3931 MPa and the lowest is a ratio of 1:5 of 20.6 MPa. This shows that the composites ratio of 1:1 is the most strength compared to other ratios. For the data of Elongation, the highest data is from ratio 1:1 of 0.027464 while the lowest is from ratio 1:10 of 0.024145. This shows that ratio 1:1 is the most ductile compared to other ratios.

The result of the effect after water absorption is not much different even if it has been soaked for 24 hours. After the specimens of all ratios are soaked in the water, the data has not changed. The highest data of Young's Modulus is still from a composite ratio of 1:1 which is 1204.8193 MPa and the lowest data of Young's Modulus is from a composite ratio of 1:5 is 750.6895 MPa. For the data of Yield Stress and Ultimate Yield Strength, the highest data is from a ratio of 1:1 of 27.31 MPa and the lowest is a ratio of 1:5 of 21.8095 MPa. This shows that the composites ratio of 1:1 is the most strength compared to other ratios. For the data of Elongation, the highest data is from ratio 1:1 of 0.0270 while the lowest is from ratio 1:10 of 0.023723. This shows that ratio 1:1 is the most ductile compared to other ratios. By doing the experiment research, the most successful ratio in terms of strengthening the matrix is 1:1 where the Bemban and Polyester Resin are equally the same weight and compact for water absorption.

From the results obtained between the two graphs, it may be influenced by fibre bonding and proper composite hand layup methods.

5.2 Recommendations

For future improvements, there are some recommendations to increase the usability of natural fibres, especially Bemban and matrix especially Polyester Resin that may produce a better result.

1. Make more types of tests.

   To see the best results of natural fibre especially Bemban, can suggest making an Impact Test and Flexural Test. Impact strength is to be performed to determine the impact resistance or toughness of materials by calculating the amount of energy absorbed during fracture. Flexural testing measures the force required to bend a beam of plastic material and determines the resistance to flexing or stiffness of a material.

2. Use other types of methods.

   Currently, for this experimental research, the method used is Open Mould Process which is a hand layup method. They are many types of process methods that can be used for future research which are the spray layup method, tape layup method and autoclave method. While for other than open mould processes can be used are compression moulding, injection moulding, transfer moulding, pultrusion and filament winding.

3. Use the end tab for tensile testing.

   From the experimental research result, can see that the specimens tested on Universal Testing Machine were broken at the clamped area. For future studies, suggesting using the end tab to see a better result.

4. Combined with other natural fibre.

   Combination of Bemban with other natural fibre such as Kenaf to strengthen the Polyester Resin of natural fibre reinforced matrix.

5. Testing for water absorption for more than 24 hours.

   To see the difference between the before and after effects of water absorption, the composite may have to be soaked for more than 24 hours to get a better result.

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APPENDICES

APPENDIX A: Gantt Chart for PSM 1

Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Introduction														
Literature Review														
Research Methodology														
Preliminary Result														
Pre-Submission														
Correction														
Final Submission														
Presentation														

Planning	
Completed	

APPENDIX B: Gantt Chart for PSM 2