DEVELOPMENT OF NATURAL FIBER REINFORCED COMPOSITE PREPREG

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DEVELOPMENT OF NATURAL FIBER REINFORCED COMPOSITE PPREPREG

by

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ENDORSEMENT

I, Saifulmajdy bin Ahmad Zahiri hereby declare that all corrections and comments made by the supervisor and examiner have been taken consideration and rectified by my supervisor.

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ABSTRACT

Generally, composite is a material made by mixing two or more constituent materials of different properties to enhance the advantages of the materials. Composite materials are highly utilized in lately due to their ability of tailored specified properties, such as high strength-to-weight ratio, corrosion resistance, inflammable properties, wear resistance and etc. The need for renewable fiber-reinforced composites has never been as prevalent as it currently is. Natural fibers offer cost savings and reduction in density when compared to glass fibers. Even though the strength of natural fibers is not as great as glass, the specific properties are comparable. In this study, mechanical properties of biocomposite materials of wet hand layup and prepreg using palm oil fiber, are to be analyzed and evaluated thoroughly. However, most of them will focus on the possibility to produce natural fiber prepreg composite and its characteristics. Fabrication methods includes compression molding, fiber separation and resin curing process used to manufacture the control specimens and prepreg Then, the mechanical properties of the specimens are tested using tensile test. There are a few issues encountered in this study as making prepreg is a complex process. The issues were solved through further research and development of the specimen. After the specimen produced tensile test was carried out for analysis and evaluation process. The results of specimen fabrication show that natural fiber prepreg fabrication is possible although its mechanical properties are less than fiberglass. In conclusion, natural fiber prepreg is possible to be developed. However, further research is needed to produce consistent and better natural fiber composite in the future.

ABSTRAK

Secara umumnya, komposit adalah bahan yang dibuat dengan mencampurkan dua atau lebih bahan-bahan konstituen sifat-sifat yang berbeza untuk meningkatkan kelebihan bahan. Bahan-bahan komposit sangat digunakan pada kebelakangan ini disebabkan oleh keupayaan sifat-sifat tertentu yang disesuaikan, seperti tinggi nisbah kekuatan-berat, rintangan kakisan, sifat-sifat yang tidak boleh terbakar, rintangan haus dan sebagainya. Keperluan untuk komposit bertetulang gentian yang boleh diperbaharui tidak pernah tersebar luas seperti pada masa kini. Gentian semulajadi menawarkan penjimatan kos dan pengurangan ketumpatan apabila dibandingkan dengan gentian kaca. Walaupun kekuatan gentian semulajadi tidak sama seperti gelas, sifat-sifat tertentu adalah setanding. Dalam kajian ini, sifat-sifat mekanik bahan komposit prepreg dan layang basah menggunakan gentian kelapa sawit, telah dianalisis dan dinilai dengan teliti. Walau bagaimanapun, kebanyakan itu akan memberi tumpuan kepada kemungkinan untuk menghasilkan komposit prepreg serat semulajadi dan ciri-cirinya. Kaedah fabrikasi termasuk pengacuan mampatan, pemisahan serat dan proses pengawetan resin yang digunakan untuk menghasilkan spesimen kawalan dan prepreg. Kemudian, sifat mekanik spesimen diuji menggunakan ujian tegangan. Terdapat beberapa masalah yang ditemui dalam kajian ini kerana membuat prepreg adalah proses yang kompleks. Isu-isu diselesaikan melalui penyelidikan dan pembangunan lanjut spesimen. Setelah spesimen dihasilkan, ujian tegangan dilakukan untuk analisis dan proses penilaian. Hasil fabrikasi spesimen menunjukkan bahawa fabrikasi prepreg bahan semulajadi adalah berpotensi walaupun sifat mekaniknya kurang dari fiberglass. Sebagai kesimpulan, prepreg serat semulajadi boleh dikomersialkan. Walau bagaimanapun, kajian lanjut diperlukan untuk menghasilkan komposit serat semula jadi yang konsisten dan lebih baik pada masa akan datang.

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DECLARATION

This thesis is the result of my own investigation, except where otherwise stated and has not previously been accepted in substance for any degree and is not being concurrently submitted in candidate for any other degree.

(SAIFULMAJDY BIN AHMAD ZAHIRI)

Date:

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATION

EFB	:	Empty Fruit Bunch
FFB	:	Fresh Fruit Bunch
OPF	:	Oil Palm Fiber
CSM	:	Chopped Strand Mat
GFRP	:	Glass Fiber Reinforced Composite
PFRC	:	Palm Fiber Reinforced Composite
OoA	:	Out of Autoclave
VBO	:	Vacuum Bag Only
WHL	:	Wet Hand Layup
ASTM	:	Society for Testing and Materials

LIST OF SYMBOLS

σ	:	Stress
ε	:	Strain
G	:	Toughness
E	*:*	Young's Modulus
t	*:*	Thickness
W	:	Weight
l	:	length
d	:	diameter
F	:	Force
ρ	:	Density

CHAPTER 1

INTRODUCTION

1.1 General Overview

Composite materials generally a combination of two or more materials of different properties. They are most widely used materials in the current time due to its vast range of properties[1]. Furthermore, composite materials are known for their high strength and stiffness while at lower weight due to its low density and high strength to weight ratio. They are divided into two parts which are reinforcement and bonding. Reinforcement usually in the form of fiber or particulate. In this study, palm fiber was used as they are easily available in Malaysia, low cost and has good mechanical properties in terms of flexibility, stiffness, and modulus compared with glass fiber[1]. However, natural fibers do have a few disadvantages such as poor resistance towards moisture.

Briefly, conventional materials mean the most regularly used materials. For example, high strength steel is used in manufacturing car chassis, cotton is conventional material for clothing and glass for making windows. However, conventional do pose several disadvantages, especially in material handling. Conventional materials tend to be heavy or expensive. Due to these disadvantages, composite materials are created and tailored to meet specific requirements of any particular parts.

Increasing environmental concerns has led the researcher to find a new alternative for the development of composite materials. One of them is producing biocomposite materials which incorporate natural elements into the making of composite materials. The great potential for using natural fiber composite lies in their eco-friendliness and wide potential applications for automotive, aviation and biomedical industries. Natural fiber such as pine, coir, palm as well as banana and pineapple leaves are generally extracted from renewable sources, fully biodegradable, non-toxic, and can be easily recycled to reduce materials' carbon footprint [2]. In result, the potential to create a sustainable environment is highly possible.

In manufacturing fiber-reinforced-plastic composite components, the use of prepregs reduces the work involves and provides stronger, stiffer and more reliable parts than equivalent components produced by wet lay-up processes [3]. Prepreg is the common term for a reinforcing fabric which has been pre-impregnated with a resin system. This resin system (typically epoxy) already includes the proper curing agent. As a result, the prepreg is ready to be lay into the mold without the addition of any more resin. In order for the laminate to cure, it is necessary to use a combination of pressure and heat[4].

Thermoset prepregs are produced by saturating a fiber reinforcement with a liquid thermoset resin. Excess resin is removed from reinforcement and the resin undergoes a partial curing, changing from a liquid to pliable solid state. This is known as the "B-stage". Prepregs in the B-stage require refrigerated storage conditions. The curing process is then activated with the application of heat. Meanwhile, thermoplastic prepregs are produced by coating fiber reinforcement with a thermoplastic matrix. This gives it advantages by its ability to reheat and reform the material multiple times by heating above the melting point of the specific thermoplastic matrix. Unlike thermoset prepregs, thermoplastic prepregs can be stored at room temperature[5].

1.2 Motivation and Problem Statements

Prepregs are designed to reduce work in manufacturing fiber-reinforced plastic composite components and provide stronger, stiffer and more reliable parts than equivalent components produced by wet layup process if done properly[3]. This project will explore the possibility of using natural fiber as a replacement for conventional fiber used in prepregs such as carbon or glass.

Wet hand layup of fiberglass and natural fiber are possible due to the flexibility of material selection. However, wet hand layup has disadvantages due to inaccurate matrix content, material handling and health and safety consideration.

When mixing the matrix with the fiber, wet hand layup usually requires higher matrix content because low matrix content cannot be achieved without the incorporation of excessive quantities of voids. Besides, materials are quite hard to handle as the matrix is in its raw state which means it must be mixed from the resin and hardener and requires calculation every time. Moreover, the layup process requires experienced individuals as there is a huge learning curve to master the layup skill.

In health and safety consideration, wet hand layup process that deals with lower molecular weights of wet hand layup resins generally means that they have the potential to be more harmful than higher molecular weight products. The lower viscosity of the resins also means that they have an increased tendency to penetrate clothing etc [6].

Prepreg has benefit to control accurate fiber volume content, possible to achieve high fiber content and not necessarily used liquid molding process[6]. Because of this, the majority of composite materials manufacturing today use this approach but using conventional fiber as reinforcing material introduce a few problems such as availability, cost, and environmental issues. Therefore, an approach of substituting the fibers by using natural fibers would be more convenient if prepreg composite can be made from natural fibers and surpass current existing material, eventually providing an alternative for prepreg composite manufacturer.

Therefore, it is a huge advantage to develop a prepreg composite from natural fibers as they are high advantages gained from the fiber and its process perspective. The properties of the prepreg will be equal if not better than its wet hand layup specimen if the composites are made properly. In this study, characterization of the specimens' mechanical properties will be carried out by tensile test. The specimen that will be produced will be chopped mat glass fiber composite(E-glass) and palm fiber composite.

1.3 Objectives of research.

The research work described in this thesis is performed based on the following objectives:

I. To fabricate palm fiber biocomposites wet hand layup(WHL) specimen.
II. To fabricate palm fiber biocomposites prepreg specimen
III. To study and analyze the mechanical properties of palm fiber reinforced prepreg composite and compare it with wet hand layup fabrication method.

1.4 Thesis Layout

This thesis composed of 6 chapters. Chapter 1 gives a general overview of the definition of composites, bio-composites, and prepreg composites. The advantages and disadvantages of prepreg composite and natural fiber composite were discussed as well. Then, the motivation of this project, which is to create a more sustainable environment by replacing conventional reinforcing materials with the vast resources of natural fiber such as palm fiber. Then, the objectives of the research are defined.

Chapter 2 reviews all literature related to this work. The focus is on the fabrication and characterization methodology. This is required to help in process of fabrication using or implying method from previous research and looking into any area of improvements. Chapter 3 briefly describes all the fundamental theories involved in analyzing the properties of the specimens as well as the fabrication and characterization procedures. Chapter 4 will discuss the results and discussions obtained from this project. Chapter 5 will be conclusion and recommendations for any further research. Finally, chapter 6 is the references collection used in the making of this project.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction to composite material

Composite material is a material comprised of two or more materials differing in composition or form. The constituents retain their identities in the composites and they do not dissolve or otherwise merge completely into each other although they act together. In other words, a composite structure is a material system consisting of 2 or more phases (material) with an increase in mechanical performance and properties. The 2 most required material would be reinforcing material and matrix.[7]

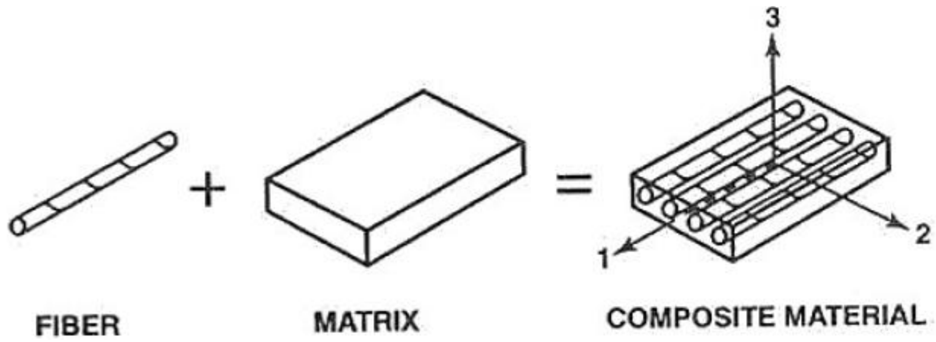


Figure 2.1.1: Fiber and matrix element made up composite material [7]

The strength and stiffness are provided by reinforcing phase. Usually, reinforcement is harder, stronger and stiffer than the matrix. The reinforcement usually comes in particulate or fiber. Particulate composites tend to be much weaker and less stiff than continuous fiber composites, but they are mostly less expensive.

A fiber has a length that is much greater than its diameter. The length to diameter(l/d) ratio is known as the aspect ratio and can vary greatly. Continuous fibers have long aspect ratio while discontinuous fibers have short aspect ratio. Continuous fiber composites have a preferred orientation, while discontinuous fibers in random orientation.

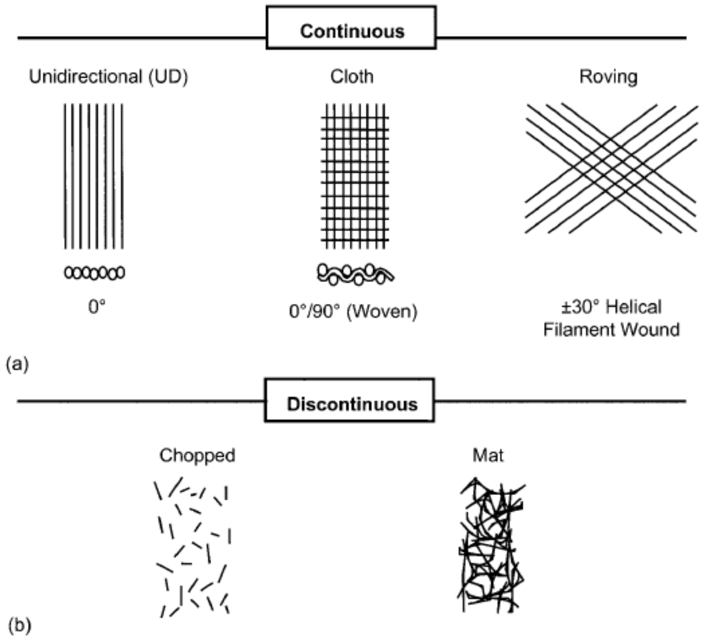


Figure 2.1.2: Typical reinforcement type [7]

The continuous phase is the matrix, which is a polymer, metal or ceramic. Polymers have low strength and stiffness, metals have intermediate strength and stiffness but high ductility, and ceramics have high strength but are brittle. The matrix (continuous phase) functions as maintaining the fibers in its orientation, spacing and protecting them from abrasion and environment. Besides, in polymer matrix composites, the matrix transmits the load from the matrix to the fibers through shear loading at the interface. [1]

2.2 Matrix

The matrix is basically a homogenous and monolithic material in which a composite is embedded. It is completely continuous. The matrix provides a medium for binding and holding reinforcements together into a solid. It offers protection to the reinforcements from environmental damage, transfer load between reinforcements and provide color, texture and surface finish of a composite product.[8]

There are 3 types of composite matrix materials: Ceramic matrix composites, which consist of ceramic fiber embedded in a ceramic matrix. Metal matrix composites are composite materials that contain at least 2 constituent parts, a metal and another material of another metal. The metal matrix is reinforced with the other material to improve strength and wear. Polymer matrix composites can be divided into 3 subtypes, namely, thermoset, thermoplastic, and rubber. Polymer is a large molecule composed of repeating structural units connected by covalent chemical bonds.

In using polymer matrix, the specification can be obtained from the manufacturer. Depending on the type of matrix, the specification are different with different types of application. Besides, the matrix came in two parts which is resin and hardener. The rate of cure for the matrix is specified by the hardener type used. In this project, pot life and thin film working time is the crucial part where the B-stage required to produce a prepreg is determined based on the specified time.[9]

2.3 Natural Fibers

Natural fibers are generally classed as either vegetable or animal. [10]. The most common type of fibers used is vegetable-based. The cell structures of natural fibers are relatively complicated, with each fiber being a composite of rigid cellulose micro fibrils embedded in a soft lignin and hemicellulose matrix.[11]

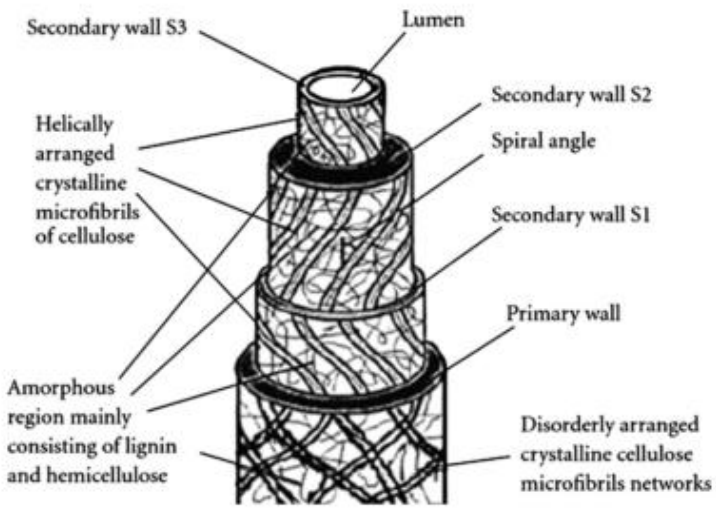


Figure 2.3.1: Structural constitution of a natural vegetable fiber cell [11]

2.3.1 Oil Palm Fibers

From oil palm tree, lignocellulose fibers can be extracted from trunk, frond, fruit mesocarp and empty fruit bunch (EFB). Empty fruit bunch is the fibrous mass left behind after separating the fruits from sterilized (steam treatment at 294kPa for 1h) fresh fruit bunches (FFB).[12]

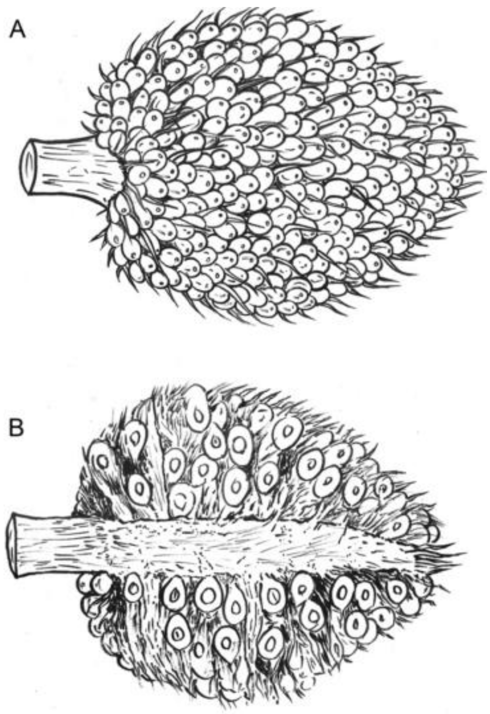


Figure 2.3.1.1: Sketch of (A)oil palm FFB (B) Cross section of EFB showing fiber arrangement. [12]

The fibers can be extracted from EFB by retting process such as mechanical retting(hammering), chemical retting (boiling with chemicals), steam/vapor/dew retting and water/microbial retting. Mechanical retting is environmentally friendly as other method does not because they pollute water bodies. One of the mechanical retting is using decorticator machines that decorticates EFB.

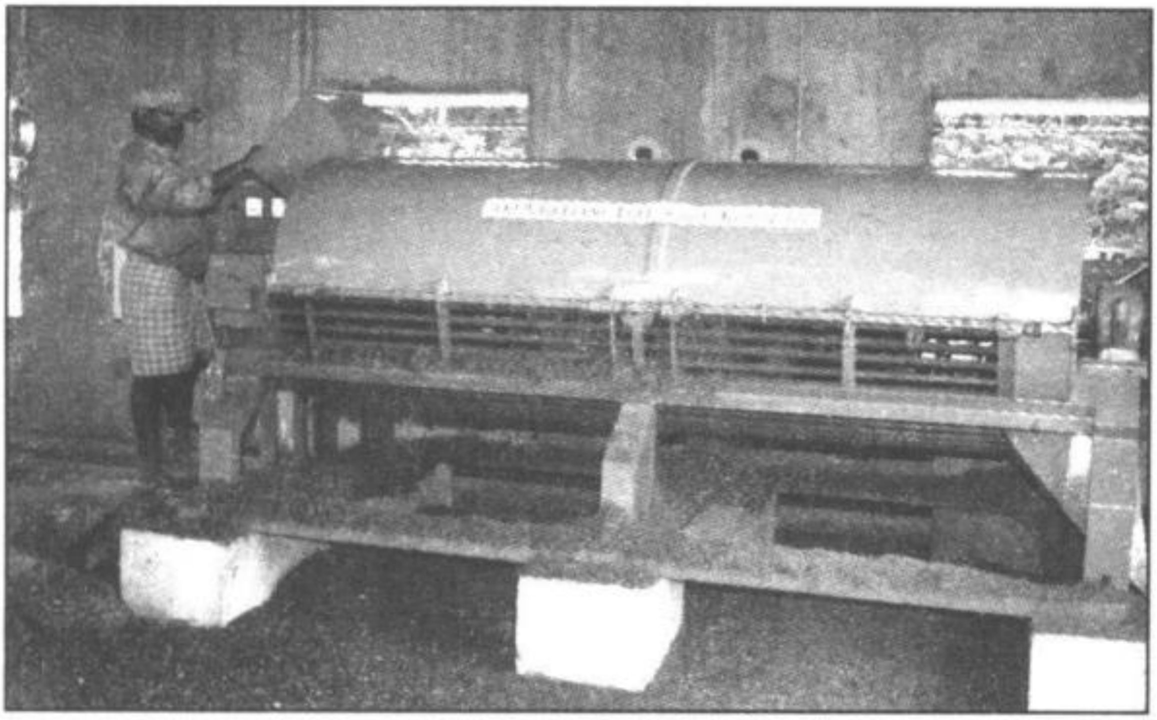


Figure 2.3.1.2: Decorticator machine[13]

2.3.2 Advantages of Natural Fiber

There are advantages of using natural fiber as reinforcement material in composite materials than any conventional material such as glass fiber, carbon fiber and many more. However, they also possess several disadvantages. The table below shows the advantages and disadvantages of natural fiber:

Table 2.3.2.1: Advantages and disadvantages of natural fiber [14]

Advantages	Disadvantages
Environmentally friendly	Bad compatibility with hydrophobic polymer matrix
Fully biodegradable	The fibers degrade after being stored for a long time
Non-toxic	High moisture absorption
Easy to handle	Low thermal stability

Non-abrasive during processing and use	Hygroscopic
Low density/lightweight	Forms aggregate during processing[15]

2.3.3 Mechanical Properties

From study done, the mechanical properties that shown by the fibers are as follows:

Table 2.3.3.1: Characterization comparison between E-Glass with OPF [5]

Fiber name	Density (kg/m^3)	Diameter (μm)	Tensile Strength (MPa)	Tensile Modulus (GPa)	% Elongation	Reference
E-Glass	2.55	<17	3400	7.3	3.4	[16]
Oil Palm (OPF)	0.7-1.55	150-500	80-248	0.5-3.2	17-25	[17]

Further OPF characterization was done in terms of tensile strength, Young's modulus, elongation at break, density and so forth. The table below showed the characterized value properties made using a different type of polymer matrix and different type of fiber content:

Table 2.3.3.2: Physical and mechanical properties of OPF from various research

Property	Value	Sources
Density(g/cm^3)	0.7-1.55	[19]
	1.15	[20]
	1.15	[21]
	1.03	[22]
	0.895	[23]
	0.7-1.55	[24][25]
	1.4	[26]
	1.51	[27]
Tensile strength(MPa)	71	[21]
	377	[22]
	24.9	[23]
	100-400	[19]
	50-400	[24]
	240-550	[27]
Young's Modulus(GPa)	1.7	[21]
	1-9	[24], [19], [25]
	2.75	[22]
	3.2	[26], [27]
Elongation at break(%)	4	[23]
	13.71	[22]
	11	[21]
	8-18	[24], [19], [25]
	14	[26], [27]

OPF major chemical components consist of 65% cellulose, 19% lignin and 2% ash. To determine OPF composite properties, tensile properties are made as it is considered as major properties of materials. In the table below are some tensile properties made using different types of polymer matrix and different type of fiber content:

Table 2.3.3.3: Tensile properties of OPF composites [18]

Property	Fiber content	Polymer	Value
Tensile Strength (MPa)	5% OPF	Epoxy	29.9
	10% OPF	Polypropylene	19
	30% OPF	Polypropylene	12
	40% OPF	Polypropylene	7
	35% OPF	Epoxy	47.8
	55% OPF	Epoxy	46.1
	5% OPF	Polyester	36.3
	10% OPF	Polyester	29.38
	15% OPF	Polyester	31.5
	20% OPF	Polyester	28.59
	30% OPF	Polyester	29.24
	5% OPF	Epoxy	1433
	20% OPF	Epoxy	1335
	10% OPF	Polypropylene	560
Tensile Modulus (MPa)	30% OPF	Polypropylene	615
	40% OPF	Polypropylene	725
	35% OPF	Epoxy	1010
	55% OPF	Epoxy	1020
	5% OPF	Polyester	1497
	10% OPF	Polyester	2542
	15% OPF	Polyester	2358
	20% OPF	Polyester	2170
	30% OPF	Polyester	2308

2.4 Prepreg

Prepreg is the common term used to define a composite system where a reinforcing fabric which has been pre-impregnated with a resin. The resin is staged or advanced (B-staged) to the point where the resin in the prepreg is tacky semisolid, which allows the layers to be layed up to form a laminate that can be cured. [1] This resin where typically used epoxy already mixed with a proper curing agent is ready to lay into the mold without any addition of any more resin [4].

Prepreg can be done by hot melt impregnation, resin filming and solvent impregnation[1]

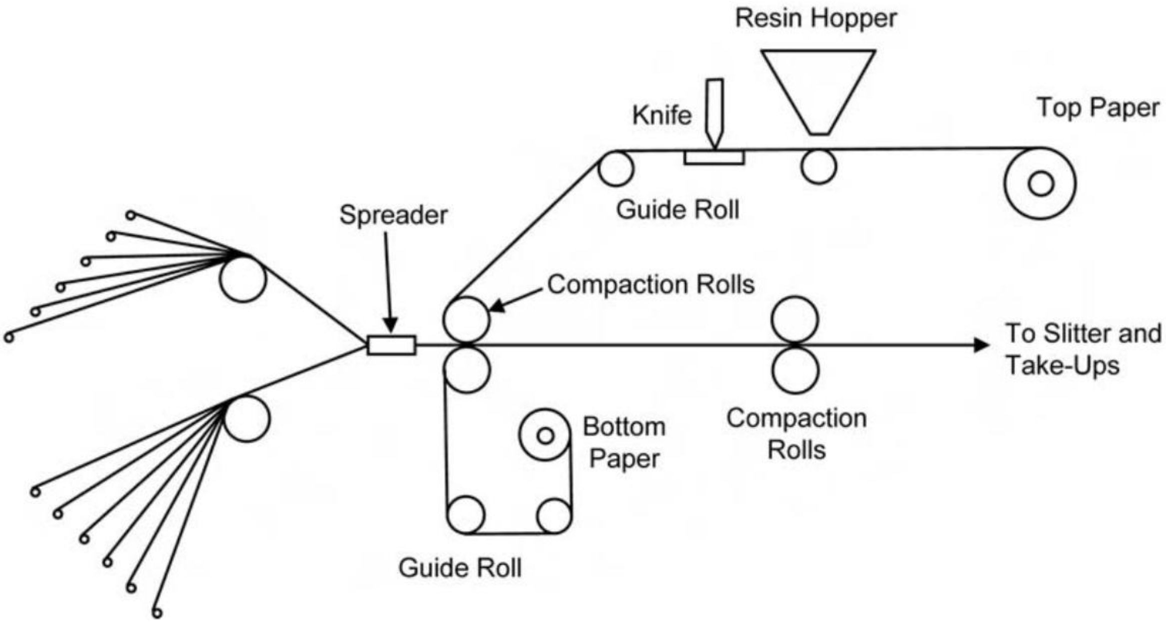


Figure 2.4.1: Hot melt resin impregnation process [1]

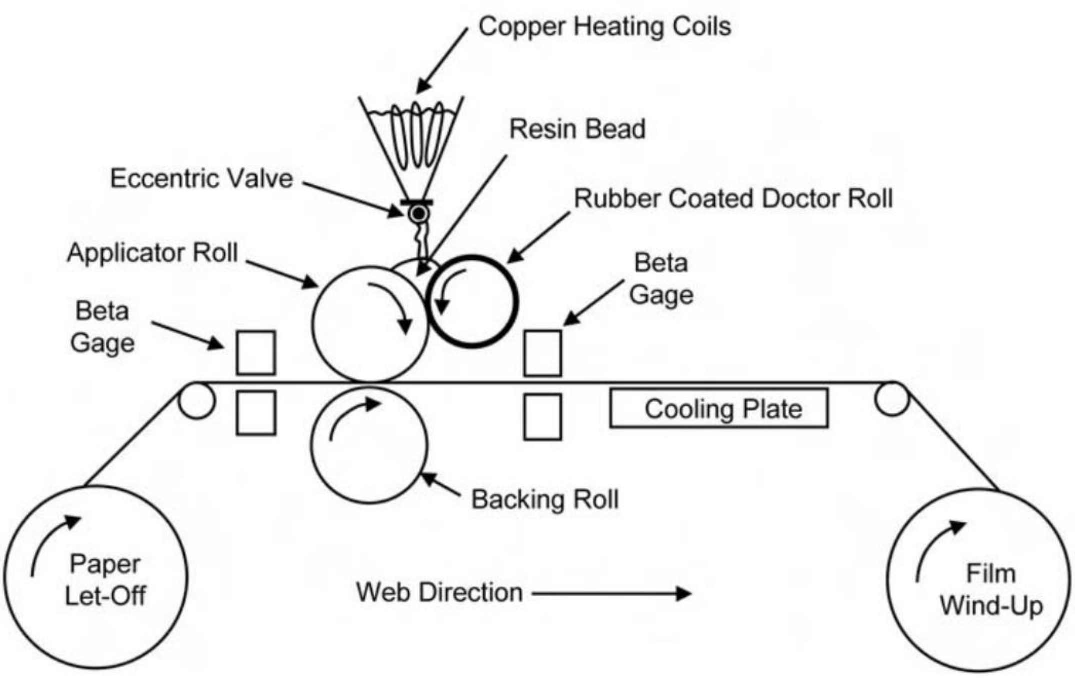


Figure 2.4.2: Resin filming process[1]

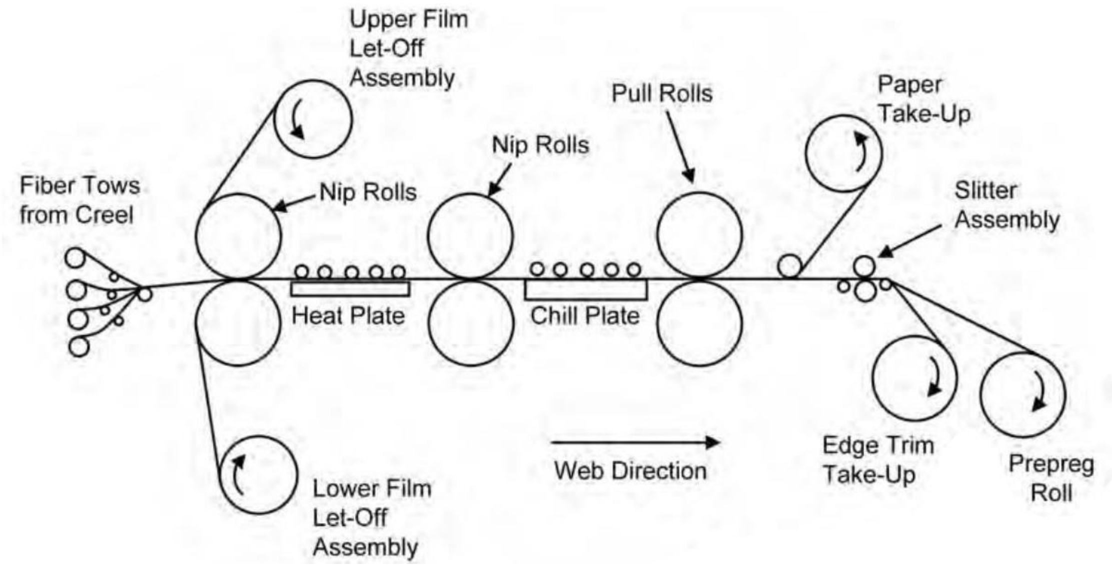


Figure 2.4.3: Process for producing hot melt tape from resin film[1]

2.3.1 Advantages of Prepreg

Rather than using traditional wet hand layup, prepreg has several advantages.[4] Firstly, it has maximum strength properties. This is because in wet hand layup, it is difficult to achieve 50% resin content where the finished laminated weight is 50% fabric and 50% resin. Excess resin increases brittleness and reduces overall properties. However, most prepregs can achieve around maximum 35% resin. Besides, the prepregs parts uniforms and repeatable. There will be almost no resin-rich areas or dry spots caused by human lack of lamination skills technique. Moreover, it will be less mess and less waste. Prepregs will bleed excess resin but the need for cups, messy rollers and drips are no longer a problem. In fact, prepreg has better cosmetics. Prepregs virtually eliminate air bubbles and a smooth, glossy surface is easily achievable.

2.3.2 Disadvantages of Prepreg

Even though prepreg has advantages than conventional method, it also possesses a few disadvantages[4]: The first one would be cost. Due to its complexity, prepregs are pricey even when added up the cost of the resin. Besides, prepreg has limited shelf life before it cures. To prevent curing in storage, the resin needs to be stored in low temperature. Moreover, it is necessary to be heat cured. This is true only to resin that cures in elevated temperature. However, most of the resin used in prepreg is heat cured.

2.4 Characterization

Characterization of the specimen will be done using ASTM D3039. This will require the specimens to undergoes simple tensile testing. The force required to break the specimen will be calculated and a graph of stress vs strain will be produced. The graph is analyzed from raw data of the tensile test. This graph is used to determine the tensile modulus. In order to do the tensile test, it is recommended to test specimens at a temperature that simulate the intended end use environment.[28]

Besides, the tensile test will require the rate of extension to be 2mm/min. In the ASTM D3039 specification sheet, the specimen dimension is given based on the orientation of the fibers. In this project, the orientation used is random-discontinuous.

Table 2.4.1: Tensile specimen geometry recommendations [28]

Fiber Orientation	Width, (mm)	Overall length, (mm)	Thickness, (mm)	Tab length, (mm)	Tab thickness, (mm)	Tab bevel Angle, (°)
0°	15	250	1.0	56	1.5	7 or 90
90°	25	175	2.0	25	1.5	90
Balanced and Symmetric	25	250	2.5	Emery cloth	-	-

Random-discontinuous	25	250	2.5	Emery cloth	-	-

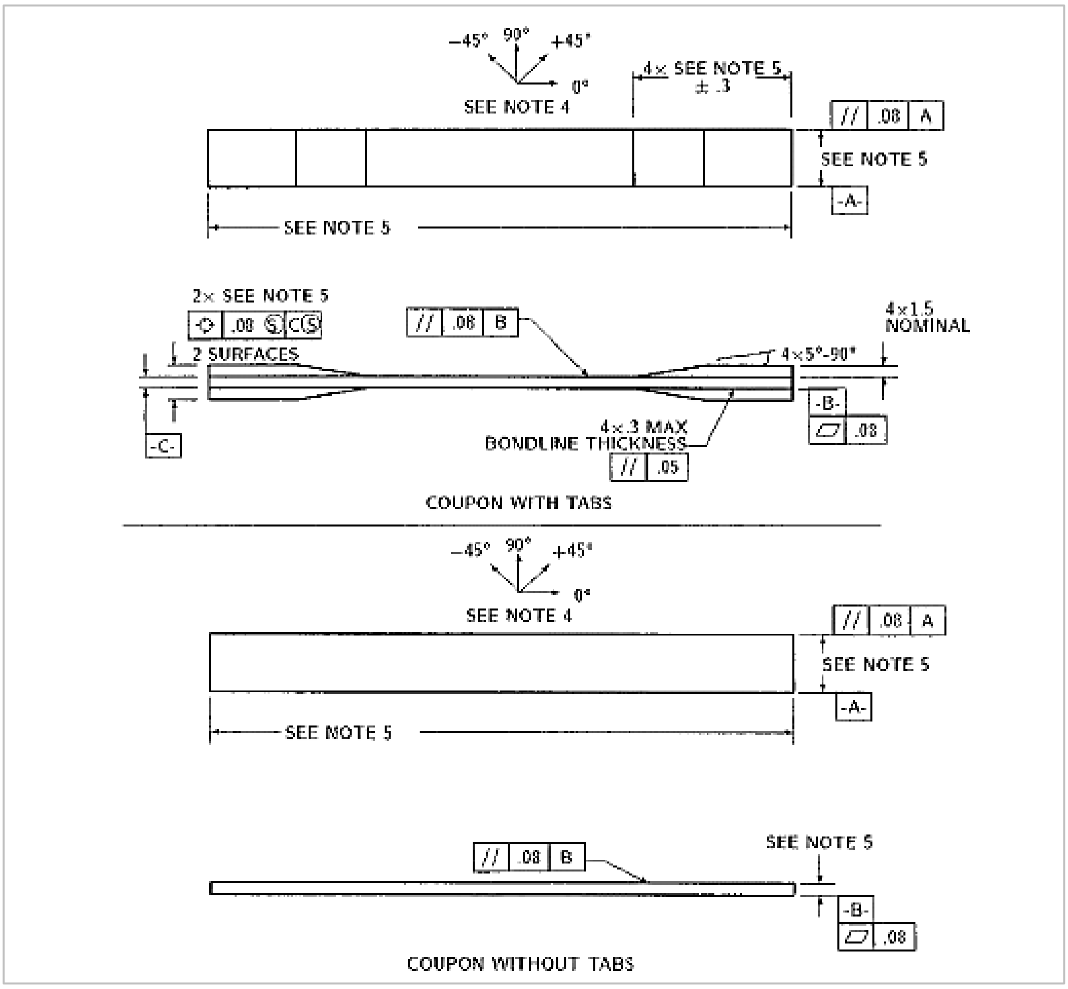


Figure 2.4.1: Tensile test specimen drawing [28]

CHAPTER 3

METHODOLOGY

This chapter presents all the steps and calculation used for development of fiberglass and natural fiber composites for both wet hand layup and prepreg specimen along with their characterization.

3.1 Material used

The reinforcement used for this project are palm fiber and Chopped Strand Mat (CSM) E-Glass fiber. The density of palm fiber is 1.0 gcm^{-1} while the E-Glass fiber is 2.5gcm^{-1}. CSM E-Glass is chosen to be control specimen for this project that would be compared with natural fibers in characterization. The non-homogenous alignment of fibers in CSM E-Glass made it almost similar to natural fibers. As such, CSM E-Glass is the most suitable control specimen.

Meanwhile, the matrix used for both fibers are the similar type where resin used in this project is EpoxAmite 100 that cures at room temperature and require catalyst hardener which is 103 medium hardener.

Materials	Figure
Palm Fiber	

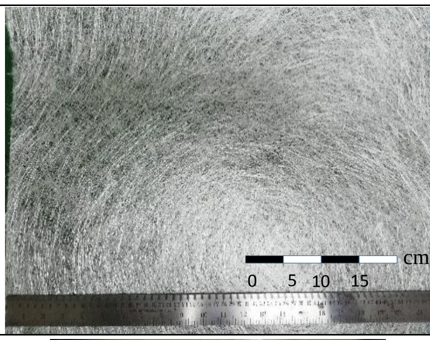
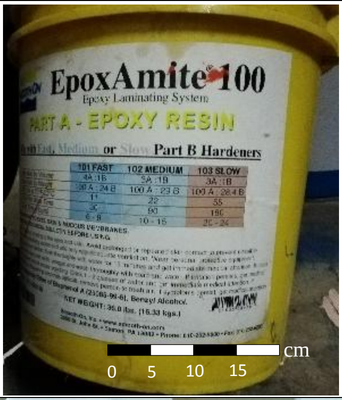
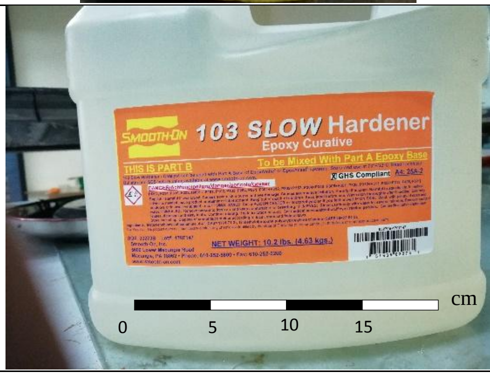
CSM E-Glass Fiber	
Epoxy Resin	
Hardener	

Figure 3.1.1: Materials used

3.2 Design and producing a mold for wet hand layup method.

To produce a wet hand layup specimen, a mold is required to retain shape and dimension of the specimen. The mold suggested for the specimen would be 160mm×160mm×3mm. Besides that, the mold should be robust to retain pressure that will be exerted to compress the specimen in the making progress. Therefore, a design was created. Using available material and tools from the aerospace laboratory and workshop, aluminium plate base with retainer on the side is made with a Perspex plate as a compression plate. The set up will be compressed using a hydraulic press to pressure at approximately 30 tons since that is the highest pressure can be exerted from the hydraulic jack.

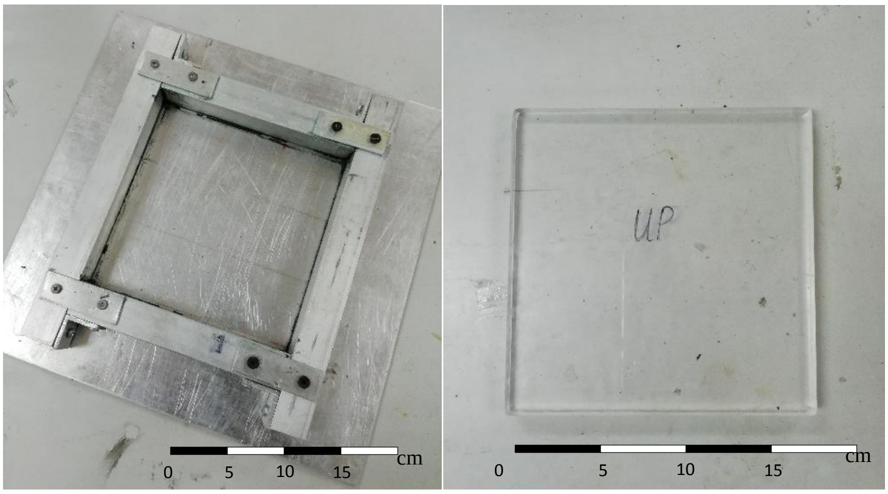


Figure 3.2.1: Aluminium mold and Perspex plate

Figure 3.2.2: Hydraulic press

3.3 Preparation of the fibers and matrix

The CSM fiberglass was cut from a fiberglass roll in the Composite lab of Aerospace School. Since the fiberglass was already in a layered form, the preparation of fiberglass only included cutting and weighing of the fiberglass layers. However, OPF comes in bulk where it is mixed with other parts of palm fruit. These impurities will prevent the specimen from being compressed properly in later steps. So, the OPF need to be cut and filtered to remove any undesired material. To fasten things up, after the fiber was cut, it was sifted through a basket into a bucket

Figure 3.3.1: The setup to remove any large contaminant

3.4 Producing wet hand layup specimen

Using conventional method of wet hand layup method, a fiberglass chopped mat layer was cut into the desired size which is 160mm×160mm. The total glass fiber layers used to achieve 40% fiber volume in a 160mm×160mm×3mm size would be 9 layers. The fibers will be stacked up inside the aluminium mold with resin, compressed and let to cure in 24 hours. Using the rule of mixture, the density is used to find the weight required. The density for matrix is 1.38g/cm^3, density of fiberglass is 2.54 g/cm^3 and density of OPF is 1 g/cm3. The matrix is calculated to be 60% of total volume of the composite and weighted about 63.59g. The matrix is composed of resin and hardener. Using recommended mixing ratio from the manufacturer, the resin to hardener weight ratio will be 28.4:100. After mixing the resin with hardener, the matrix undergoes de-gassing stage where it was vacuumed in a chamber to remove any trapped bubbles that were induced during the mixing stage. The removal of air bubbles will prevent massive voids inside the composite after it was finished.

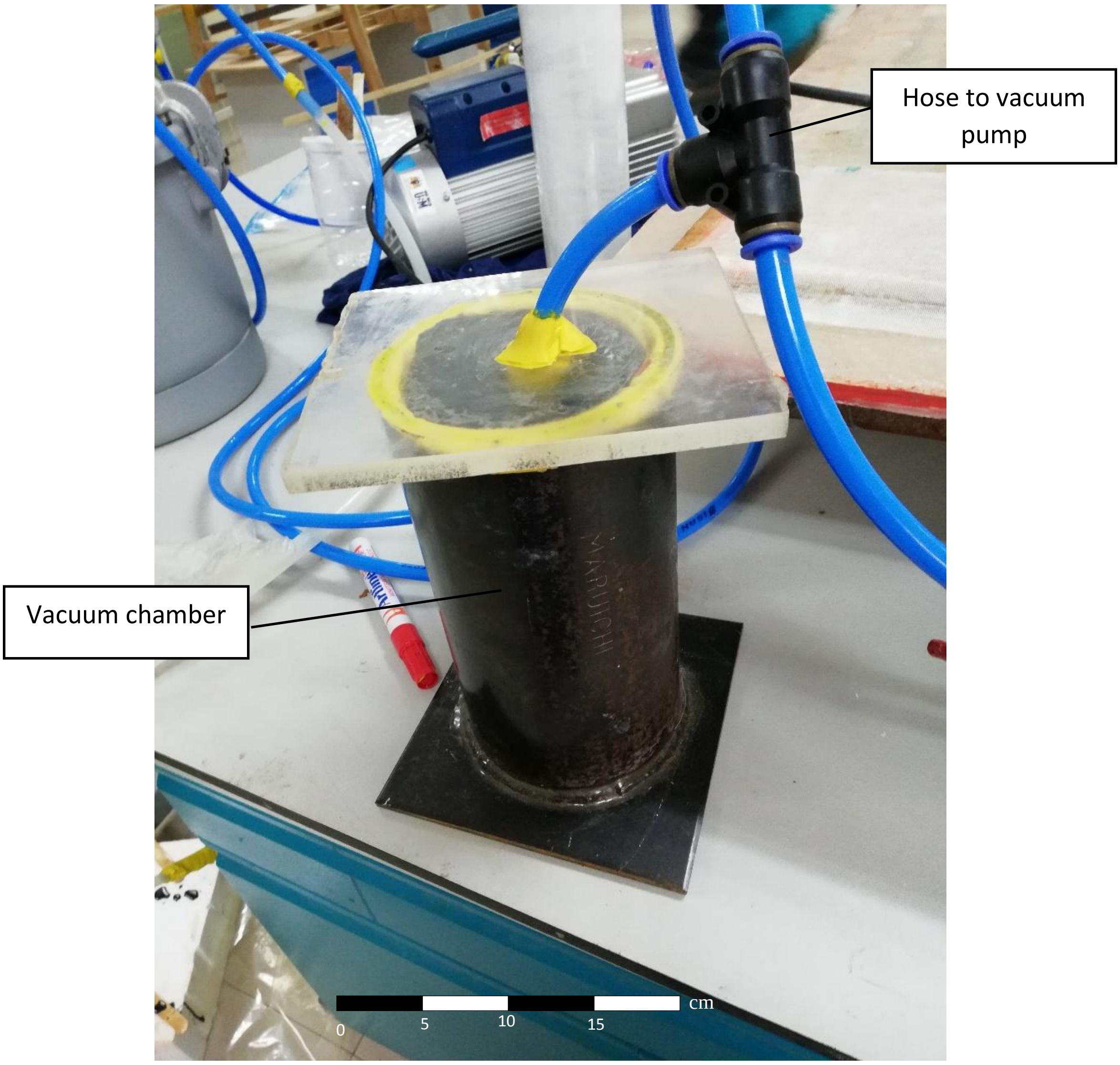


Figure 3.4.1: Setup for the de-gassing stage. The mixed resin is in the chamber.

Then, the matrix was applied to each layer of fiberglass and stacked into the mold. Then, a Perspex layer is used to cover the layup to be compressed into panel. Shown below are the calculation done for developing glass fiber reinforced composite(GFRP):

$$\text{Volume of composite} = \text{Length} \times \text{Width} \times \text{Height}$$

.13.4

Volume of composite = 160mm×160mm×3mm

$=76800mm^3$

Volume of matrix = 60% of total volume

$= 46080mm^3$

$$\text{Mass} = \text{Density} \times \text{Volume}$$

3.4.2

Mass of matrix $= 46080mm^3 \times 1.38\ g/cm^3 \times 1/1000$

$= 63.59g$

Since epoxy: hardener is 100:28.4, matrix mix will be:

Mass of resin = 100/128.4 × 63.59g

= 49.52g

Mass of hardener = 28.4/128.4 × 63.59g

= 14.06g

Volume of GFRP fiber = 40% of total volume

$= 30720mm^3$

Mass of GFRP fiber $= 30720mm^3 \times 2.54g/cm^3 \times 1cm^3/1000mm^3$

= 78.03g

The resultant fiber weight totaled up to 9 layers of CSM fiberglass. Using similar method, the wet hand layup (WHL) natural fiber based composite specimen was made. However, the fiber required extra steps in preparing them to be usable. The fibers need to be compressed to retain its shape so that it can be used to lay it up with the matrix. There are 6 layers of natural fibers and each of them is weighted around 5 to 6 grams. These layers are made to ensure equal distribution of fibers in the mold. Just like glass fiber method, the layers are stacked up with the matrix in between and compressed. Below are the calculations done for palm fiber reinforced composite(PFRC):

Since the volume of the composite is maintained:

Mass of matrix = Mass of matrix GFRP

= 63.59g

Volume of PFRC fiber= 40% of total volume

= $30720mm^3$

Mass of PFRC fiber = $30720mm^3 \times 1g/cm^3 \times 1cm^3/1000mm^3$

= 30.72g

3.5 Producing Glass Fiber Prepreg

In order to achieve same specifications of prepreg specimen with wet hand layup specimen, the method requires using the same material with the previous method. Using the same fiberglass type and matrix, the fiberglass is soaked with matrix each layer and covered with peel ply on top and underneath the layers. The set-up of fiberglass with resin is let to partially cure until it reached B-stage which require 2.5 hours. After that, it was sealed in a plastic vacuum bag and refrigerated to prevent the matrix from fully cured. After 24 hours, the prepregs are taken out from the refrigerator and cut into size to compensate with the preferred panel dimension. The prepreg layers are stacked up in the mold and compressed to remove air bubbles and to achieve the desired thickness.