RESEARCH AND ANALYSIS ON MECHANICAL PROPERTIES OF JUTE / GLASS FIBER FOR GREEN PANEL APPLICATION

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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 Manufacturing Engineering Technology (Process and Technology) with Honours.

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DEDICATION

Dedicated to

my dear father, Wan Azmi Bin Wan Mohd Amin

my appreciated mother, Haslina Binti Mamat

my lovely siblings, Amsyar, Afiq and Arsyad

for give support, counsel, encouragement, and understanding on a moral level.

ABSTRACT

Nowadays, natural fibers have become one of the most widely utilized materials due to its abundance, cheaper cost, sustainability, and environmental friendliness in contrast to artificial fibers. Natural fibers are increasingly being substituted for synthetic fibers in manufacturing green panels because to the expensive cost of synthetic fiber. In this study, the manufacturing of green panels will be done in order to determine the best stacking order based on the effectiveness of the laminate hybrid made of jute and fiberglass as reinforcement and epoxy resin as the matrix. Therefore, for each distinct fiber and hybrid sequence, 4 separate stacking layers will be carried out utilizing a straightforward hand layup cold press technique. Additionally, this study will undergo testing in line with ASTM standard. The mechanical characteristics and complementary nature of fibreglass (G-24) and jute fibre (J-24), highlight their use together in green panel applications. In order to maintain the environmental benefits of hybridization, at least 50 % of the fibre content must be jute, with the remaining portion being fibreglass. J-24 is thicker than G-24 due to its inherent fibre density, as shown by the thickness comparison. The reduction in ultimate tensile strength that comes with hybridization with fewer fibreglass layers illustrates the trade-off for a composition that is more favourable to the environment. Flexural strength studies identify H-J12G12 as the most promising hybrid composite for green panels, while tensile testing reveals variable forces, with G-24 displaying the strongest force. Impact testing confirms that H-J16G8 is the most promising hybrid, providing outstanding resistance to impacts and energy absorption. In applications where strength and environmental sustainability are required, the results support the strategic use of hybridization in green composites.

ABSTRAK

Pada masa kini, gentian semula jadi telah menjadi salah satu bahan yang paling banyak digunakan kerana banyaknya, kos yang lebih murah, kemampanan, dan mesra alam berbeza dengan gentian tiruan. Gentian asli semakin digantikan dengan gentian sintetik dalam pembuatan panel hijau kerana kos gentian sintetik yang mahal. Dalam kajian ini, pembuatan panel hijau akan dilakukan bagi menentukan susunan susun terbaik berdasarkan keberkesanan hibrid lamina yang diperbuat daripada jute dan gentian kaca sebagai tetulang dan resin epoksi sebagai matriks. Oleh itu, bagi setiap urutan gentian dan hibrid yang berbeza, 4 lapisan susun berasingan akan dijalankan menggunakan teknik penekan sejuk letak tangan yang mudah. Selain itu, kajian ini akan menjalani ujian selaras dengan piawaian ASTM. Ciri-ciri mekanikal dan sifat pelengkap gentian kaca (G-24) dan gentian jut (J-24), menyerlahkan penggunaannya bersama dalam aplikasi panel hijau. Untuk mengekalkan faedah alam sekitar hibridisasi, sekurang-kurangnya 50% daripada kandungan gentian mestilah jut, dengan bahagian yang tinggal adalah gentian kaca. J-24 lebih tebal daripada G-24 kerana ketumpatan gentian yang wujud, seperti yang ditunjukkan oleh perbandingan ketebalan. Pengurangan kekuatan tegangan muktamad yang datang dengan hibridisasi dengan lapisan gentian kaca yang lebih sedikit menggambarkan pertukaran untuk komposisi yang lebih menguntungkan alam sekitar. Kajian kekuatan lentur mengenal pasti H-J12G12 sebagai komposit hibrid yang paling menjanjikan untuk panel hijau, manakala ujian tegangan mendedahkan daya berubah-ubah, dengan G-24 memaparkan daya terkuat. Ujian kesan mengesahkan bahawa H-J16G8 adalah hibrid yang paling menjanjikan, memberikan ketahanan yang luar biasa terhadap kesan dan penyerapan tenaga. Dalam aplikasi yang memerlukan kekuatan dan kelestarian alam sekitar, hasilnya menyokong penggunaan strategik hibridisasi dalam komposit hijau.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
cm^3	-	Cubic centimeter
g	-	Gram
RM	-	Ringgit Malaysia
mm	-	Millimeter
USD	-	United States Dollar
MPa	-	Mega Pascal
°C	-	Degree Celcius
J	-	Joule
J/m^2	-	Joule per meter squared
MAS	-	Multilayered Armor Systems
UPRs	-	Unsaturated Polyester resins
g/m^2	-	Gram per meter squared
kJ/m^2	-	Kilojoules per meter squared
kN	-	Kilonewton
N	-	Newton

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CHAPTER 1

INTRODUCTION

1.1 Background

Composite materials have gained in popularity recently since they are made to be high-performance materials for engineering uses. According to Barile et al. (2019), they are non-homogeneous and anisotropic materials that need particular attention when assessing their physical and mechanical properties in comparison to ones made of metal. The ability to custom-design metal alloys for a certain application is their main advantage. This characteristic is directly related to the composition of composite materials. The nature of composite materials has an undeniable relationship with these characteristics. According to Chandekar et al. (2020) and Mahir et al. (2019), they are actually composed of at least two distinct phases that interact to create the reinforcement and matrix, which are the ultimate features. Furthermore, Yi et al. (2017) noted in their study that composite materials have number of benefits, such as greater strength, endurance to fatigue, greater length of service life, high toughness and rigidity, resilience to impacts, vibration amplification or absorption, resistance to corrosion, resistant to fire, a low rate of thermal conductivity, resilience in harsh outside environments, increased dimensional stability, anisotropic properties, dimensional stability, and more. Additionally, Clyne et al. (2019) asserted that the utilization of composite materials is still growing quickly. It is difficult to estimate the current worldwide market worth, but it exceeds USD 100 billion. Consequently, more extensive benefits.

Moreover, in their research published in 2018, Akmar et al. noted that hybrid laminated composites have recently dominated the aerospace, defence, marine, and automotive industries because to their superior qualities. The strength-to-weight and elasticity-to-weight ratios of hybrid laminated composites are higher quality to those of isotropic materials. They are a popular selection among hybrid laminates due to their built-in tailoring capability. Therefore, in modern industries, optimizing the lay-up procedure of hybrid laminated composite structures is essential for reaching certain design targets. On top of that, Chen et al. (2019) discovered that the stacking sequence mostly affected the peak strain and flexural strength, but the flexural modulus kept a steady value. In order to create a multilayer structure, hybrid laminates, as described by Peng et al. (2022), must contain at least two different materials.

Corchorus olitorius, an annual herbaceous plant native to Africa and Asia, is the source of the white jute fiber (Corchorus capsularis). Whereas most food crops cannot be grown in river flats, it can, and it doesn't require fertilizer or pesticides to thrive. According to Singh et al. (2018), jute fibers are being used more frequently as reinforcement in the creation of composite materials because of the increasing environmental stress brought on by rising fuel prices, the dwindling supply of fossil fuels, and the effects of climate change. These issues have compelled researchers to focus on developing green composites. Although jute is frequently referred to as "gold fiber", Gnaba et al. (2019) noted that it is one of among the most reasonably priced natural fibers accessible.

Additionally, one of the most promising materials for the manufacture of laminate composites, according to Nassar et al. (2020), is fiberglass. It is produced by melting glass and pressing it through incredibly small holes to form ultra-thin threads. Contrarily, fiberglass is reasonably priced (USD 75 per 50 cm^3) and ideal for parts with reduced weight and strength requirements, particularly in the sports industry, enabling parts to be produced at a lower cost (Goh et al., 2018). They come in a range of materials, such as woven fabrics, yarns, and textiles.

Apart from that, fiberglass is stated to has a low moisture absorption rate and is resistant to both high and low temperatures by (Vidya et al., 2020). As a result, glass fiber reinforced materials are less brittle than carbon fiber and have better dimensional consistency. They also have superior mechanical qualities, including strong impact resistance and higher tensile strength when compared to steel.

Because of this, this research uses environmentally friendly materials to lessen the reliance on synthetic materials like fiberglass in the production of green panel applications, consequently encouraging natural fibers like jute fiber in this layered system. The proper laminated hybrid composite stacking order is one of several elements that must be taken into account while creating high-performance green panel applications. In addition, epoxy resin will serve as the matrix material in this study. Finally, in order to determine the green panel application product's ideal performance, this research will take into account the possibility of hybrid synthetic and natural materials.

1.2 Problem Statement

For the years that have passed, researchers have been studying into replacing the use of synthetic fiber in panels application due to its exorbitant cost. Besides, the majority of researchers mentioned that many natural fibers have been discovered that can be hybridized with synthetic fibers to develop new green panel compositions. Thus, Kandpal et al. (2015) explored due to the environmental issues caused by traditionally produced plastics and the growing need for fossil resource substitutes worldwide, green composites made of biodegradable renewable resources have received a lot of attention. However, there is currently a dearth of research on the consequences of combining natural jute fibres with synthetic fibres like glass fibres.

The findings support the research by Thyavihalli et al. (2019) which found that natural fibers are easily obtainable sustainable materials with benefits including being affordable, lightweight, renewable, biodegradable, and having excellent specific characteristics. To discover a replacement for synthetic fiber-enhanced composites, researchers and scientists are concentrating their efforts on natural fibre. According to them, the most effective technique for enhancing the characteristics of polymer composites is to create a hybrid composite, which modifies the final composite's properties by combining the various fiber characteristics, resulting in a material with transitional properties and potential.

In light of the problem description, this research's goal is to use a hybridization method to address the issue of employing fiberglass on green panels. Safri et al. (2018) pointed out in their research that one of the most popular and efficient techniques for enhancing and fortifying composite materials' performance in high-velocity impact applications is the hybridization method. In addition, the purpose of this research is to look at the mechanical and impact characteristics of a hybrid laminated stacking sequence comprised of jute and fiberglass using a straightforward hand layup cold press technique. To create a jute and fiberglass fiber-reinforced composite, the two materials are mixed in a thermoset binder system.

1.3 Research Objective

The primary aim of this current research is to provide the optimal sequence of a laminated hybrid utilizing jute or fiberglass for green panel application. Specifically, the objectives are as follows:

a) To fabricate the laminated green panel applications in accordance specific layer sequence for hybrid system by utilizing hand layup cold press technique.

b) To analyse the effects of the laminated and its hybrid sequence based on its mechanical properties and impact capabilities.

c) To propose the best-laminated hybrid sequence for green panel application.

1.4 Scope of Research

This study targeted the parameters of the ballistic resistance materials that correspond to the stacking sequence of the laminated hybrid composite for green panels. This research scope are as follows:

a) The sequence of stacking for natural and synthetic fiber.

b) The matrix is constructed out of epoxy resins.

c) Using hand layup process and followed by a cold press for 1 tonne using a hydraulic device.

d) For the hybrid made of fibreglass and jute, there are four distinct stacking layer sequences, each with 24 layers.

e) To carryout mechanical testing according to the American Society for Testing and Materials (ASTM) standards such as tensile test (ASTM D3039), Charpy impact test (ASTM D256) and flexural test (ASTM D790).

1.5 Rational of Research

The research indicates that there are a number of justifications for the study that are crucial to take into account, such as the following:

a) To develop further knowledge and insight into how the stacking order affects the hybrid laminated composite system.

b) Additionally, this study provides high-performance characteristics and less expensive materials. By utilising natural fibre such as jute fibre, which is more affordable and performs well, the use of synthetic fibre can be decreased. Thus, this research can lead to the development of a composite that is more economical, more efficient, and environmentally benign.

c) The results of the earlier work can offer fresh insights for creating a new type of hybrid laminated reinforced composite for use in green panel applications.

1.6 Thesis Arrangement

The focus of this research is to investigate and produce panels using epoxy resin as the matrix and jute and fibreglass as reinforcement. This report chapter consists of introduction, literature review, methodology, result, and discussion. PSM 1 will address Chapters 1, 2, and 3, while PSM 2 will address Chapters 4 and 5. The introduction of outside research is covered in Chapter 1 and includes a background study, a problem statement, objectives, the scope of the research, and a justification for additional research. An introduction to composite materials, including the kinds used in green panels and their uses, is included in Chapter 2, which also gets excited about the literature study of earlier studies. Next, in Chapter 3, the methodology for preparing the jute and fibreglass raw materials used to make the panels is thoroughly explained. The preparation, stacking, manufacture, and testing procedures utilising standard tests for tensile, flexural, and impact testing are all included in the methodology. In Chapter 4, the findings and data analysis will be covered. Every piece of information gathered from different kinds of tests will be examined and discussed in relation to the objective of this research. Finally, Chapter 5 will provide a conclusion to all of the findings and a discussion based on the goals of this study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Composite

Due to their long history of use, composite materials are not new things. The term "composite" has been in use for countless years, beginning around 1500 B.C., when early Egyptians and Mesopotamians and other craftsmen and builders created sturdy structures out of a mixture of mud and straw (Mahir et al., 2019). Moreover, as mentioned by Singh et al. (2018) composite materials are those that are created by mixing two or more constituent materials that have quite diverse physical or chemical characteristics.

In general, mostly composite materials are one component is continuous and is known as the matrix, whereas the second component which is typically discontinuous but may also be continuous is known as the reinforcement and is more powerful than the matrix. The reinforcement phase is supported by the matrix phase, which also transmits stress and protects the reinforcement from surface damage (Priyanka et al., 2017). The properties of the component materials, fibers, and resin will utilised ascertain the qualities of the composite material. The reinforcing matrix is the key factor used to categorise composite materials into three groups: metal-matrix composites, ceramic composites, and polymer composites. Because of their inherent flexibility to be customised to the needs of the customer, polymer matrix composites are the most desirable for engineering and structural applications (Shanmugarajaet al., 2019). The Figure 2.1 shows the classifier of composite for reinforcement types.

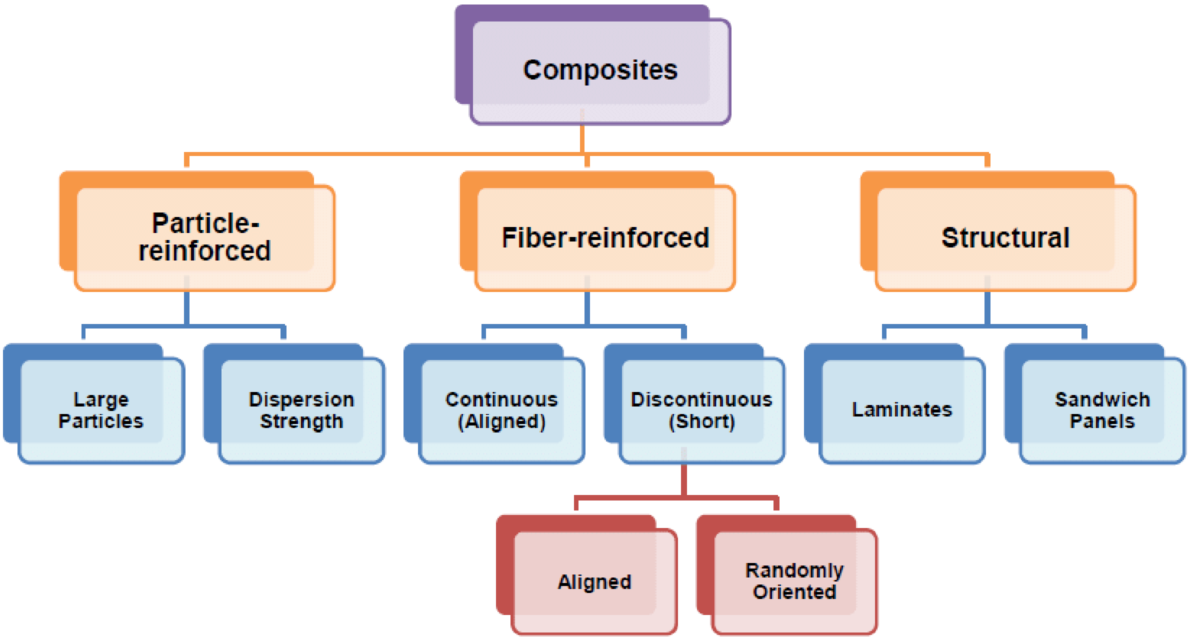


Figure 2.1 The classifier of composites (Kassa, 2018)

In another study, Amir et al. (2018) state that composite materials often have unique characteristics with a high strength-to-weight ratio. Due of the composites' ability to be moulded into complex forms, design flexibility is another benefit of composite materials. In addition, Rajak et al. (2019) also stated that to having a high strength to weight ratio, composites also have impressive durability, stiffness, damping ability, flexural strength, and resistance to corrosion, wear, impact, and fire. Composite materials have discovered utilizes in a broad range of manufacturing fields, including mechanical, construction, aerospace, automotive, biomedical, marine, and many more. Interestingly, as highlighted in Nagavally (2016) the rapid power of an explosion's blast or a bullet's burst are the example that can be absorbed by composite materials. Composites are also utilised in bulletproof jackets and panels as well as to protect buildings, military vehicles, and aeroplanes from explosions because to this feature. Furthermore, Clyne et al. (2019) claimed that the utilization of composite materials keeps to growing quickly and the prices on the global market right now is difficult to measure, but it is undoubtedly greater than USD 100 billion. One of the most widespread and most essential classifications of engineering materials nowadays are composites.

In another research, Garcia et al. (2020) declared that because they are biodegradable, low weight, and other physical and mechanical properties, natural lignocellulosic fibres (NLFs) are well known examples of renewable materials that can replace synthetic fibres. NLFs also play a significant role as reinforcement in polymer composites. Construction of buildings, autos, and packaging all employ cost-effective composites made using NLFs as the reinforcing polymer matrix. Table 2.1 shows an overview of the diameters and characteristics of different types of fiber.

Table 2.1 Overview of the various different types of fiber (Clyne et al. (2019)

Fibers	**Density** ρ **(kg m^{-3})**	**Axial modulus** E_1 **(GPa)**	**Poisson ratio** V_{12}	**Axial strength** σ **(GPa)**
E-glass (*d*~10 µm)	2600	76	0.22	3 – 4
Kevlar (*d*~12 µm)	1470	150	0.35	2 – 3
HS (PAN) carbon (*d*~8 µm)	1750	250 – 300	0.20	3 – 6
HS (PAN) carbon (*d*~8 µm)	1940	400 – 800	0.20	2 – 4
SiC monofilament (*d*~150 µm)	3200	400	0.20	3
SiC whisker (*d*~0.5 µm)	3200	550	0.17	6
α Al_2O_3 long (*d*~10 µm)	3900	385	0.26	2
δ Al_2O_3 staple (*d*~3 µm)	3400	300	0.26	2
Stainless steel (304) (*d*~50–500 µm)	7800	200	0.27	1
Tungsten (*d*~50–500 µm)	19 300	413	0.28	3
Flax (~65%cellulose) (*d*~50 µm)	1500	80	0.30	2

2.1.1 Synthetic fibers

Due to their outstanding characteristics, including tenacity, abrasion resistance, resistance to chemicals and dampness, durability, and affordability, synthetic fibers predominate over natural ones in textile garments and other related uses (Karthik and Rathinamoorthy, 2017). Unfortunately, they also mentioned that because of the rising prices of raw materials, energy, and transportation, it is impossible to guarantee that synthetic fibers will remain affordable in the future by taking into account these elements.

Since their properties are acknowledged to be better to those of natural fiber, in the manufacturing and industrial sectors, the usage of synthetic fiber composites is inevitable. Synthetic fibers have been used in high-performance polymer matrix composite products such Fiber Reinforced Polymer (FRP) tanks, airplane parts, car parts, and building panels (Rahman & Putra, 2018). In 2019, Martins mentioned the synthetic fibers are widely sought-after for use in main and secondary structures of both army and commercial aircraft because of their unique qualities, which include high stiffness, high tensile strength, and low density when compared with metals. Several of the synthetic fibers that are commonly utilized in the composites sector are glass, carbon, and aramid. Figure 2.2 shows the type of the synthetic fibers.

(a) (b) (c) (d)

Figure 2.2 The fibers of (a) carbon, (b) basalt, (c) glass, (d) kevlar (Rajak et al., 2019)

By utilizing the benefits of one fiber to make up for the flaws of another, natural and synthetic fiber hybridization in the same matrix enhances mechanical properties. At the same time, this decreases the use of synthetic fibers. To increase mechanical properties that could not be reached with individual reinforcing, several forms of reinforcements are included into FRPs.

According to Shahzad et al. (2017) following hybridization, the mechanical characteristics of these composites significantly improve, particularly when synthetic fiber plies are employed as the outermost layer and natural fiber plies are utilized as the core. To enhance the interfacial bonds of natural fibers with matrices and, therefore, their mechanical characteristics, several surface treatment methods have been applied to them. Table 2.2 shows physical and mechanical properties of natural fiber compared to synthetic fiber.

Table 2.2 The physical and mechanical properties of natural fiber compared with synthetic fiber (Nurazzi et al., 2021)

Fibers	**Density** (g / m^{-3})	**Tensile strength** (MPa)	**Elongation at break (%)**	**Axial strength** (GPa)
Sugar palm	1.292	156.96	7.98	4.96
Bagasse	1.5	290	-	17
Bamboo	1.25	140 – 230	-	11 – 17
Flax	0.6 – 1.1	345 – 1035	2.7 – 3.2	27.6
Hemp	1.48	690	1.6 – 4	70
Jute	1.3	393 – 773	1.5 – 1.8	26.5
Kenaf	1.45	215.4	1.6	53
Sisal	1.5	511 – 535	2.0 – 2.5	9.4 – 22
Ramie	1.5	560	2.5 – 3.8	24.5
Pineapple	0.8 – 1.6	400 – 627	14.5	1.44
Coir	1.2	138.7	30	4 – 6
E-Glass	2.5	2000 – 3500	0.5	70
S-Glass	2.5	4570	2.8	86
Aramid	1.4	3000 – 3150	3.3 – 3.7	63.0 – 67.0
Kevlar	1.44	3000	2.5 – 3.7	60

2.1.2 Natural fibers

Natural fibers are ones that aren't artificial or synthetic. Both plants and animals can provide them. In recent decades, there has been a lot of interest in the production of composite materials using natural fibers obtained from renewable and non-renewable materials, such as flax, jute, sisal, and oil palm (Mohammed et al., 2015). According to Raju et al. (2019) and Elanchezhian et al. (2018) natural fibers may be recycled whole or in part, are affordable, renewable, and biodegradable. They are an appealing ecological substitute for glass, carbon, and synthetic fibers used to make composites because they are readily available, renewable, inexpensive, have a low density, and have acceptable mechanical properties. As shown in Figure 2.3, there are three categories of natural fibers, those made from animals, plants, and minerals.

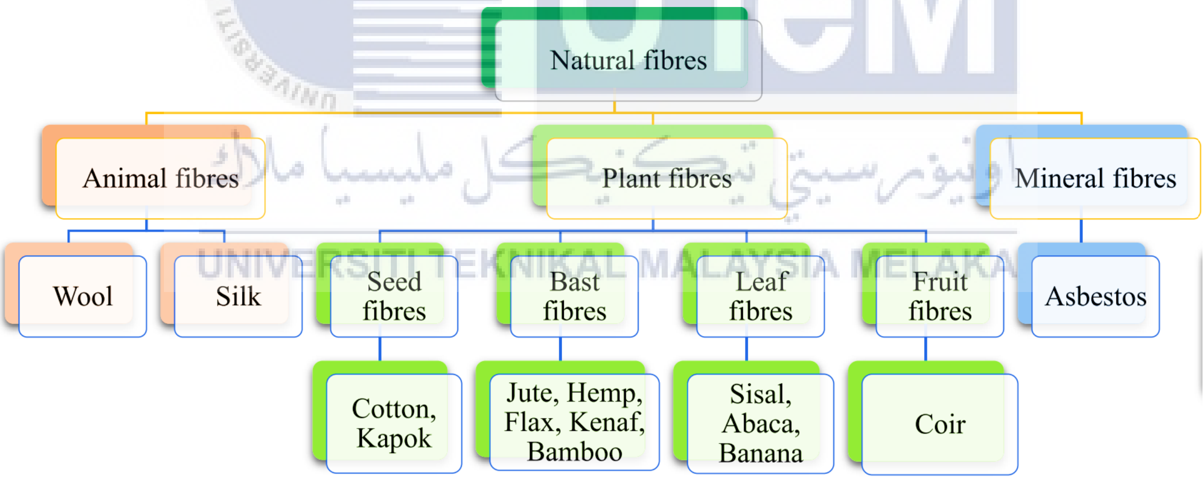


Figure 2.3 Classification of a variety of natural fibers (Awais et al., 2021)

Animal fibers are fibers made of protein that are often derived from animal hairs or animal secretions. The two most common types of animal fibers are wool and silk. Various parts of the plants are used to produce the plant fibers. In order to offer strength, nature has created a skeleton of fibers in plants (Awais et al., 2021). It was reported by Rahman and Putra

(2018) that flax, hemp, jute, sisal, kenaf, coir, kapok, banana, and henequen are examples of natural fibers that are well-known to exist. Figure 2.4 shows the list of plant-based of natural fibers. The compiled list of natural fibers is shown in Figure 2.4.

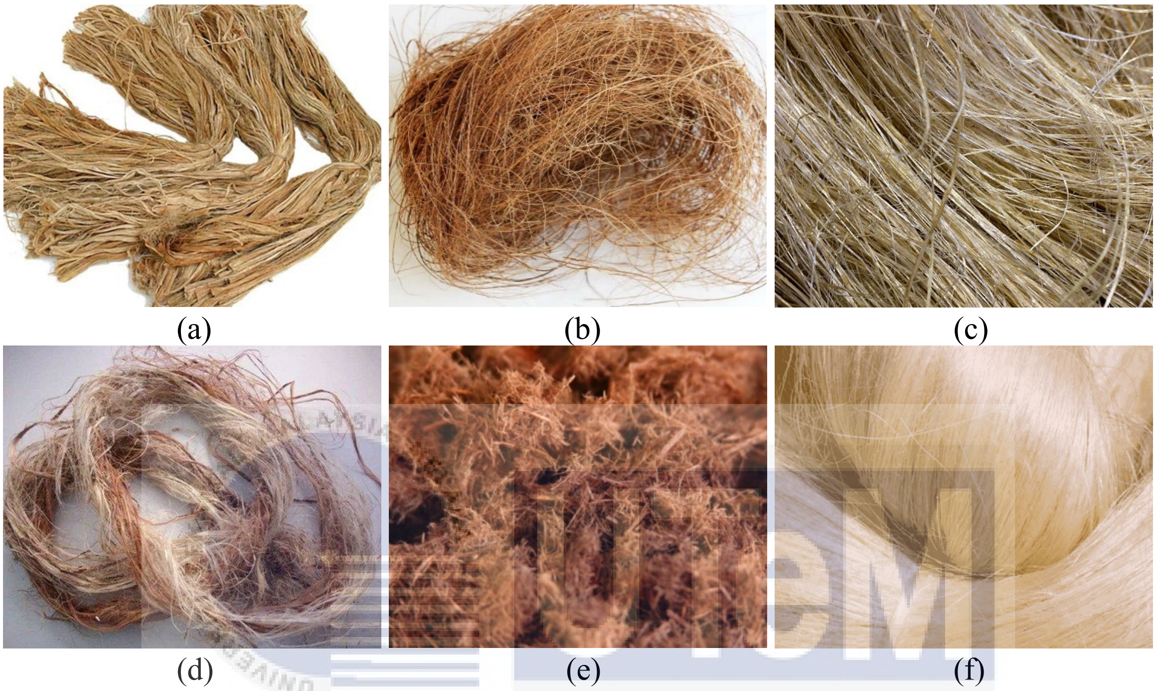


Figure 2.4 The natural fibers (a) jute, (b) coir, (c) hemp, (d) kenaf, (e) wood, (f) sisal (Syduzzaman et al., 2020)

Since natural fibers' mechanical qualities are far worse than those of synthetic fibers, it has been discovered that the majority of natural fiber composites are deficient in this area when compared to synthetic fiber composites. Natural fiber composites also have other problems, including a high sensitivity to moisture absorption, poor dimensional stability, unpredictability in characteristics, low heat resistance, and incompatibility of natural fibers with polymeric matrices, which results in poor fiber or matrix interface adhesion (Shahzad et al., 2017). In 2022, Singh et al. published an article that said natural fibers begin to deteriorate and contract after 2000 C, and because of their poor thermal stability, natural fiber composites perform worse than other materials. In addition, Safri et al. (2018) also claimed that the natural fibers' mechanical characteristics depend on the soil's conditions, the harvesting season, the harvesting region, the harvesting section of the plant that is harvested, and the maturity of the plant. The chemical properties of natural fibers are listed in Table 2.3.

Table 2.3 The listed of chemical characteristics of natural fibers (Kumar et al., 2022)

Fiber Type	**Cellulose**	**Hemicellulose**	**Lignin**
Bast fibers surrounds the central core of the plant			
Flax	64.1	16.7	2
Hemp	55 – 80.2	12 – 22.4	2.6 – 13
Remie	68.2	13.1	0.6
Kenaf	37 – 49	18 – 24	15 – 21
Jute	64.4	12	0.2
Leaf fibers that are extracted from the leaf of the plant			
Sisal	65.8	12	9.9
Cabuya	68 - 77	4 – 8	13
Abacca	56 – 63	15 – 17	7 – 10
Fruit fibers collected from the fruits			
Coir	20 – 36.7	12 – 15.4	32.7 – 53
Banana	48 – 60	10.2 – 16	14.1 – 21.6
Betelnut	35 – 64.8	29 – 33.1	13 – 26
Stalk fiers are collected from the stalk of the plant			
Rice	28 – 48	23 – 28	14
Wheat	29 – 51	26 – 32	16 - 21
Oat	31 – 48	27 – 38	16 - 19
These fibers are cells that occur in different parts of plants			
Seagrass	57	38	5
Cane fibers obtained from fiber-rich parts of plants			
Bagasse	28.4 – 56	20 – 36.4	21.4 – 24
Bamboo	48.1 – 73.8	12.5 - 73	10.2 – 21.4

Figure 2.5 illustrates the structure of the plant fiber, which has a primary cell at either end, three secondary walls within, and a lumen in the middle. According to Sanjay et al. (2019), cellulose crystalline microfibril networks that are dispersedly structured make up the primary cell wall. The crystalline cellulose microfibrils are organized helically in the secondary walls, with the fiber's primary orientation.

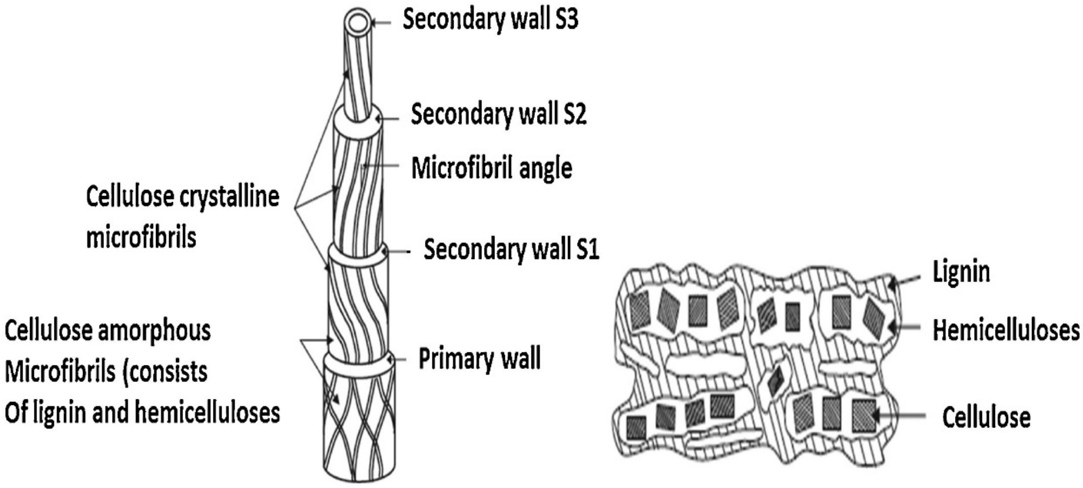
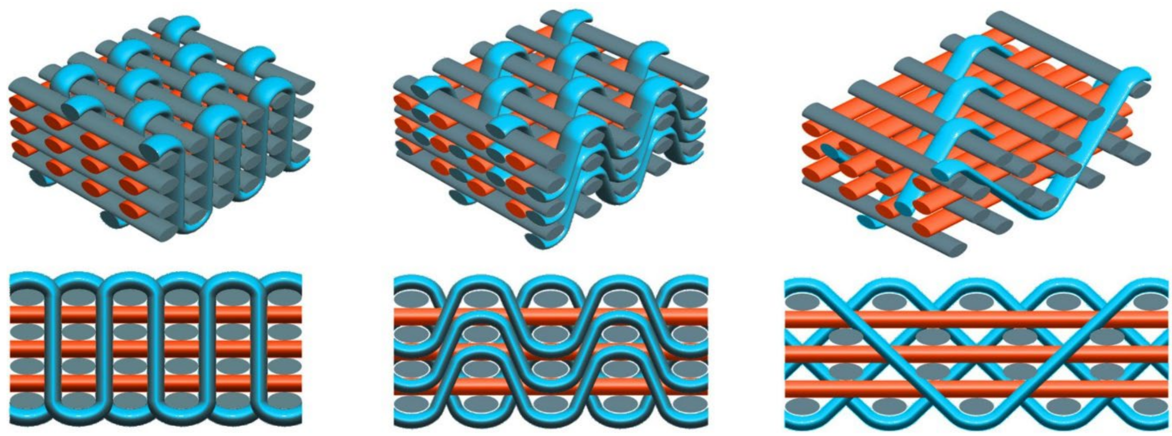


Figure 2.5 Microstructural configuration of natural fiber (Sanjay et al., 2019)

Natural Fibers Reinforced Composites (NFRCs), a component constructed from composite natural fibers, have been used in many different industries recently. The NFRCs are becoming more and more interested in both industry and education.

2.1.3 Reinforcement

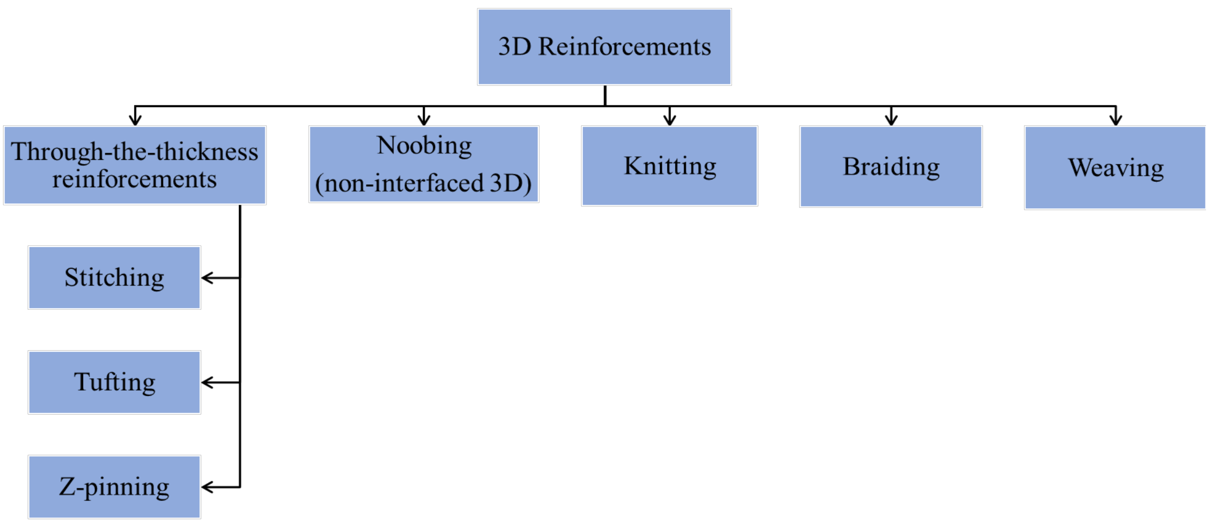
In the previous study done by Gnaba et al. (2019) through-the-thickness manufacturing techniques are an effective way to create complex-shaped structures with excellent mechanical qualities, including delamination resistance and impact damage tolerance. Additionally, these types of reinforcement could be used to create structures with high stiffness at a lower cost. In 2019, Gereke and Cherif stated that due to the avoidance of major delamination cracks, 3D weave composite components are extremely resilient to impact and cyclic loads. As therefore, they were extremely resilient to impact and cycle stress. Figure 2.6 displays numerous 3D weave variations.



(a) (b) (c)

Figure 2.6 The types of 3D weaves (a) orthogonal; (b) layer-to-layer type and (c) through-the-thickness.

In the literature, 3D structures have been classified using a variety of standards and characteristics, including the orientation of the fibers and the location of the yarns within the preform. Figure 2.7 illustrates an abridged classification of 3D reinforcements. In this sense, reinforcement can be thought of as the component of the composite that provides strength, stiffness, and the capacity to carry a load.



Figures 2.7 The abridged classification oof 3D reinforcement

2.2 Concept of Lamination and Hybridization

Composite materials that have been laminated together to form a multilayer structure are known as hybrid laminates, which are constructed of at least two different materials but at least two laminates of the same fiber-reinforced plies. Due to their superior qualities, hybrid laminated composites have taken over the automotive, marine, aerospace, and defense industries in recent years. Instead of being isotropic, hybrid laminated composites have good strength-to-weight and elasticity-to-weight ratios. Due to their innate tailor ability, they are popular hybrid laminates. Therefore, in advanced industries, optimizing the lay-up procedure of hybrid laminated composite structures is essential to obtaining specific design objectives. According to Peng et al. (2022), he stated that with a low self-weight, hybrid laminated structures may be utilized to improve strength, resilience to corrosion, endurance to fatigue, stiffness, thermal and acoustic insulation, and strength. Tornabene et al. (2018) mentioned that to effectively construct a laminate, it is essential to take into account the geometric arrangement and orientation of the fiber-reinforced layers. The outstanding mechanical performance of this laminate will result from this precaution in laminating. A laminate created by stacking a single lamina is depicted in Figure 2.8.

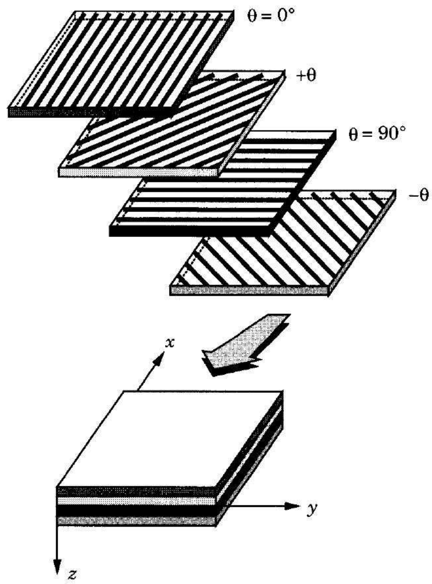
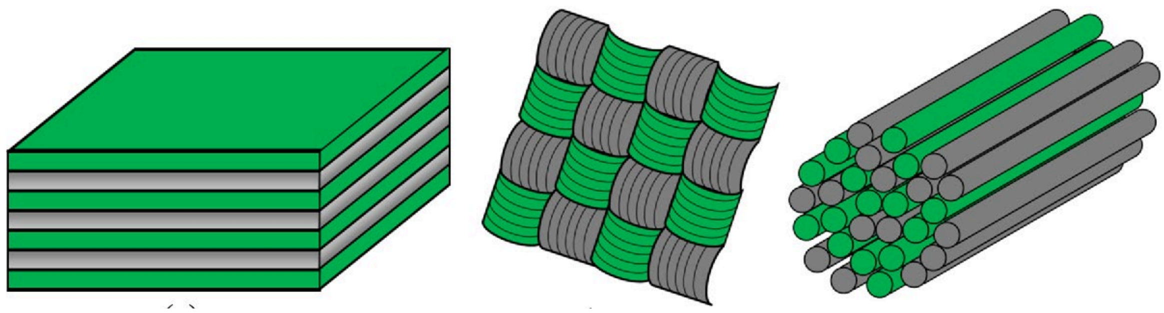


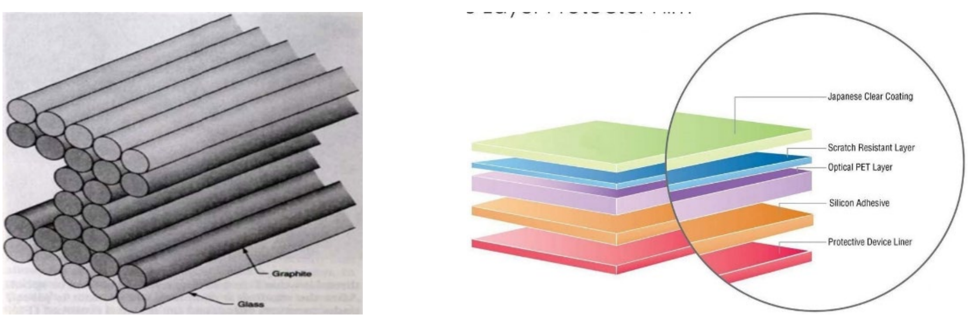
Figure 2.8 A laminated formed by stacking a single lamina (Randbaran et al., 2020)

Moreover, Nassar et al. (2020) demonstrated the advantages of implementing hybrid composites depend on the fact that additional filler can improve the properties of a single filler. In addition, Chen et al. (2019) investigated that the stacking sequence largely affected the peak strain and flexural strength, but had little effect on the flexural modulus. According to Marques et al. (2021), prepregs, or sheets, are created by pre-impregnating parallel and erect fibers with resin or rubber. In unidirectional laminates, fibers have the identical orientation in the same layer of laminate but different orientations in the separate layers.

Numerous hybrid laminated composites are available, for instance interply hybrid, intraply hybrid, intermingled mixed hybrid, selective placement hybrid, and super-hybrid laminates. The following is a definition of the hybrid laminates which are (a) interply hybrids are created by stacking two or more homogenous reinforcements, (b) intraply hybrids are tows with two or many types of component fibers in the same ply, (c) intermingled mixed hybrids are a randomly mixed combination of the constituent fiber types, with no concentrations of either kind present in the material, (d) selective placement hybrids refers to the installation of reinforcements where more strength is required on top of the base-reinforcing laminate ply and (e) super-hybrid composites are made up of specific foil or metal stacking of orientations and sequences (Akmar et al., 2018). Figure 2.9 provides an illustration of the hybrid laminated composite.



(a) (b) (c)



(d) (e)

Figure 2.9 The specific type of hybrid laminated composites system (a) interplay; (b) intraply; (c) intermingled mixed; (d) selective placement and (e) super-hybrid (Akmar et al., 2018)

2.3 Matrix

The matrix serves as a medium for the transfer of loads between fibers, and in less desirable circumstances where the loads are complex, the matrix may even need to support loads that are transverse to the fiber's axis. Since the matrix is more ductile than the fibers, it serves as a source of toughness for the composite. Before, during, and after the composite production, the matrix also protects the fibers from environmental deterioration (Elanchezhian et al., 2018). The matrix's primary role is to transmit load while holding the strands together from an external source across the interface to the reinforcing fiber and to the composite. Generally, there are three main categories of matrix: polymer, metal, and ceramic matrix composites (Yuhazri et al., 2020). Figure 2.10 serves as an illustration of the classification of composite.

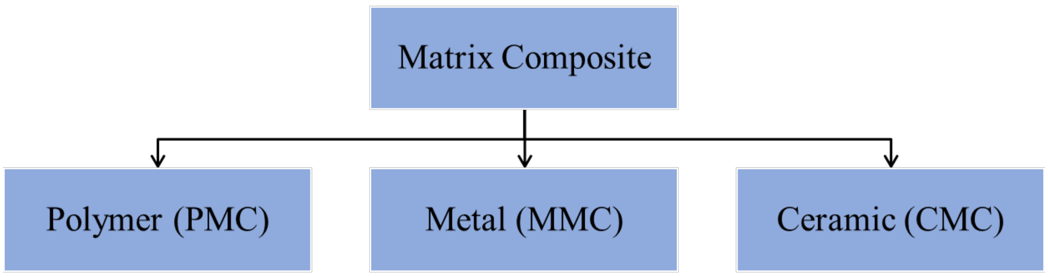


Figure 2.10 The classification of composites (Yuhazri et al., 2020)

However, Fallahi et al. (2020) and Wang et al. (2019) postulated that Polymer Matrix Composites (PMCs) in comparison to the other two, polymer matrix composites have a plenty of advantages, such as a lower volume-to-weight ratio, a greater specified strength-to-weight ratio, the ability to be moulded into a range of forms and sizes, resistance to corrosion, as well as an easy manufacturing procedure, recyclability, and a cheaper cost. Depending on the structure and characteristics of the polymer, PMCs is splitable into two primary categories: thermoset and thermoplastic, as shown in Figure 2.11.

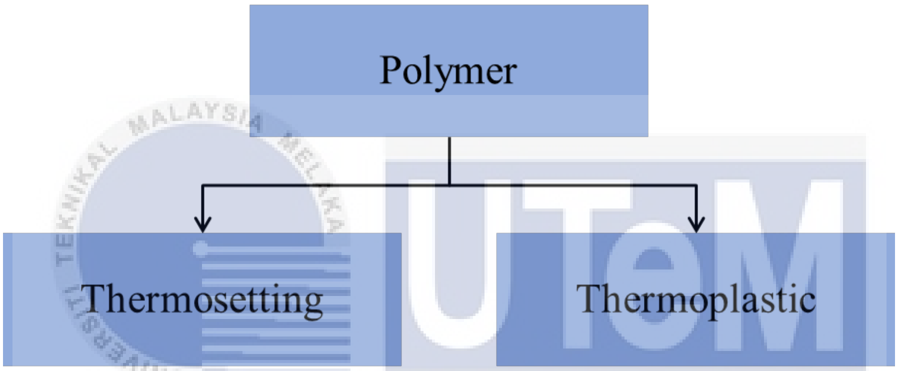


Figure 2.11 The classification of polymer matrix (Kerni et al., 2020)

Despite being used across many different industries, PMCs were mostly used in the aerospace industry last year due to their high cost. In addition, the researchers found that their applications have changed from using secondary to primary load behaviour structures as a result of remarkable advancements in manufacturing technology. Based on the kind of bonding and comprehensive description, Table 2.4 lists the two categories of PMCs that are utilized in the preparation of composites and are categorized as thermoplastics and thermosetting.

Table 2.4 Significant polymers utilized as a matrix for composites (Bahrami et al., 2020)

Thermoplastics	Thermosets
Polylactic acid (PLA)	Epoxy
Poly butylene succinate (PBS)	Phenolic
Polyhydroxyalkanoate (PHA)	Polyester
Polyamide (PA)	Polyurethane
Polyethylene (PE)	Vinyl ester
Polycarbonate (PC)	Silicone
Polyvinyl chloride (PVC)	Melamine
Polystyrene (PS)	–
Polypropylene (PP)	–
Polyurethane (PU)	–

The main distinction between thermoset and thermoplastic polymers is how they react to heat. Thermoplastics can be heated again, reshaped, and processed again without undergoing any chemical changes, while thermosets that become stronger after heating cannot be reshaped or dissolved in a solvent (Bahrami et al., 2020).

2.3.1 Thermosetting

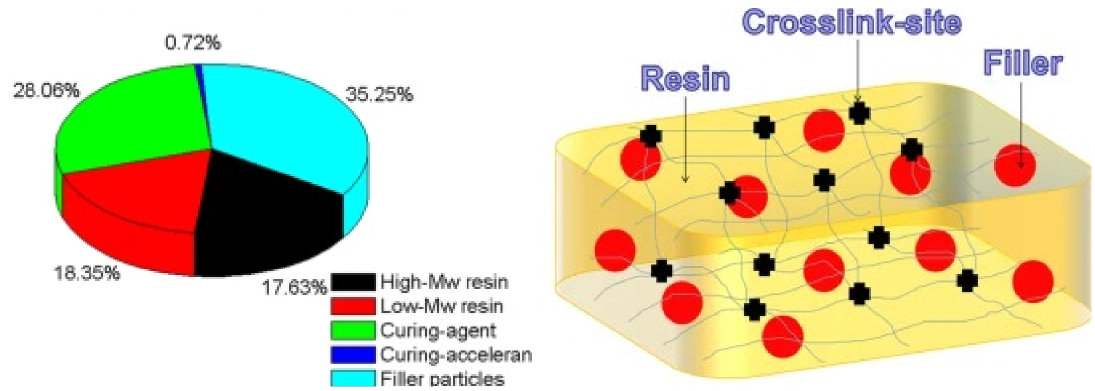
According to Mahir et al. (2019), thermosetting resins are frequently used to create composites, which perform better in a range of applications. These resins include epoxy, unsaturated polyester resin, polyester, polyurethane, and phenolic. The research carried out by Liu et al. (2021) also discovered that thermosetting resins have the capability to form strongly cross-linked networks after curing and are widely acknowledged for their Dimensional steadiness, resistance to chemical corrosion, and strong thermal and mechanical capabilities. In addition, most people who use 3D printing choose thermoplastics as their preferred polymer. This is because to the ease with which they can be handled, prepared, and remelted in contrast to thermoset plastic, which, once cured, keeps its shape and remains solid when heated.

The research paper by Firouzi et al. (2022) also asserted that a lengthy curing process is needed for thermoset-matrix FRCs. The usual time for thermoset resins to cure is 75 to 90 minutes under 4 to 8 MPa and 140 at 160 °C. The two most popular techniques for recovering thermosetting resin nowadays are mechanical crushing and chemical recycling. The thermosetting resins that have been cut or crushed are used right away as fillers or small amounts of reinforcement in new polymer compositions (X. Liu et al., 2021).

2.3.2 Epoxy resin

Epoxy is a two-part adhesive that is created by combining epoxy resin and hardener. The two elements are maintained apart and only combined when absolutely needed. Epoxy resins have numerous uses, such as adhesives, coatings, and composite matrix, according to early investigations Liu et al. (2021) by and Kerni et al. (2020). This is because of their low shrinkage, ease of moulding, relatively high toughness, excellent adhesion, and exceptional weathering resistance. Additionally, a variety of applications for epoxy thermoset resin compounds can be found in industries like aerospace, automotive, and electronics. Due to their reactivity, which allowing them to adhere to fibers well and their durability, thermoset resins have the highest quality properties of most thermosets when mixed with glass, carbon, or aramid fibers to fabricate composite materials.

Gibson (2017) claimed in his article that although there are numerous techniques for creating composite materials, the curing procedure is most important when using epoxy resins. There are two types of processes: "wet resin" and "prepreg." Epoxy resin and reinforcing fibers are combined directly by the fabricator during wet resin procedures. This can be completed by manually adding reinforcement and resin to a mold that has been properly prepared. In order to get a suitably low degree of viscosity, numerous epoxy resin precursors must be heated, as was previously described. When using the prepregs technique, the fiber reinforcement is completely impregnated from the start as a liquid. After that, the extra resin from the reinforcement is precisely removed. Yang et al. (2019) who also included this in their article that higher stability in heat and less impact on the glass transition can result from the thermoset epoxy resin that contains nitrogen, boron, and phosphorus. The weight distribution of composites while fabrication and the cured epoxy resin is seen in Figure 2.12.



(a) (b)

Figure 2.12 (a) The weight composition of composites during fabrication and (b) the cured epoxy resin (Hu, 2020)

Another study conducted by Arrillaga and Taha (2021) found epoxy resins, which are typical cationically polymerized photopolymers, in the presence of amines or anhydrides through step-growth polymerization to cure. Due to their minimal shrinkage tendency, which leads to improved dimensional precision during fabrication, this group is frequently chosen over acrylates. Epoxy also typically have better mechanical qualities overall, but they take longer times to curing. Epoxies and polyesters are frequently utilized as matrix materials, however jute or epoxy composites have superior characteristics and are more widely used (Rajole et al., 2020).

2.3.3 Unsaturated polyester resin

Due to their adaptability and affordability, unsaturated polyester resins (UPRs), which serve as the primary precursors of thermoset polyesters, are one of the most widely utilized types of polymer resins globally. UPRs are widely employed in the creation of thermoset polymer composites that may be treated at various temperatures. Furthermore, UPRs are also the preferred material for a variety of applications due to their processability and flexibility in adjusting various UPR features, including resistance to corrosion, mechanical qualities, wetting properties, and processability (Bandegi et al., 2022). Ikladious et al. (2019) claim in their literature that natural fibers are employed as reinforcing agents in UPRs composites, among other applications for them including laminates, castings, artwork, industrial constructions, insulation, and embodiments, moulding compounds, coatings, and adhesives.

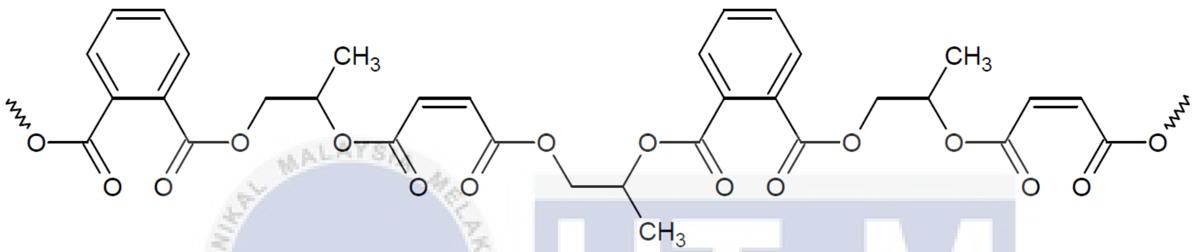


Figure 2.13 The structure of unsaturated polyester (Islam et al., 2019)

2.4 Properties and Application of Jute Fiber

Jute, which includes roughly 30–40 Capsularis species, is a member of the Tiliaceae family. The two species that are most frequently cultivated are Corchorus Capsularis (white jute) which is indigenous to Asia and Corchorus Olitorius (tossa jute) which is indigenous to Africa (Chandekar et al., 2020). The second-most natural, biodegradable, and environmentally friendly fiber is jute (Wang et al., 2019). According to (Kumar et al., 2021), the jute plant has a very quick growth rate because it may reach heights of 12 to 15 feet in just three months. The various jute fiber shapes shown in Figure 2.14, that will affect the characteristics of the composite material that is produced.

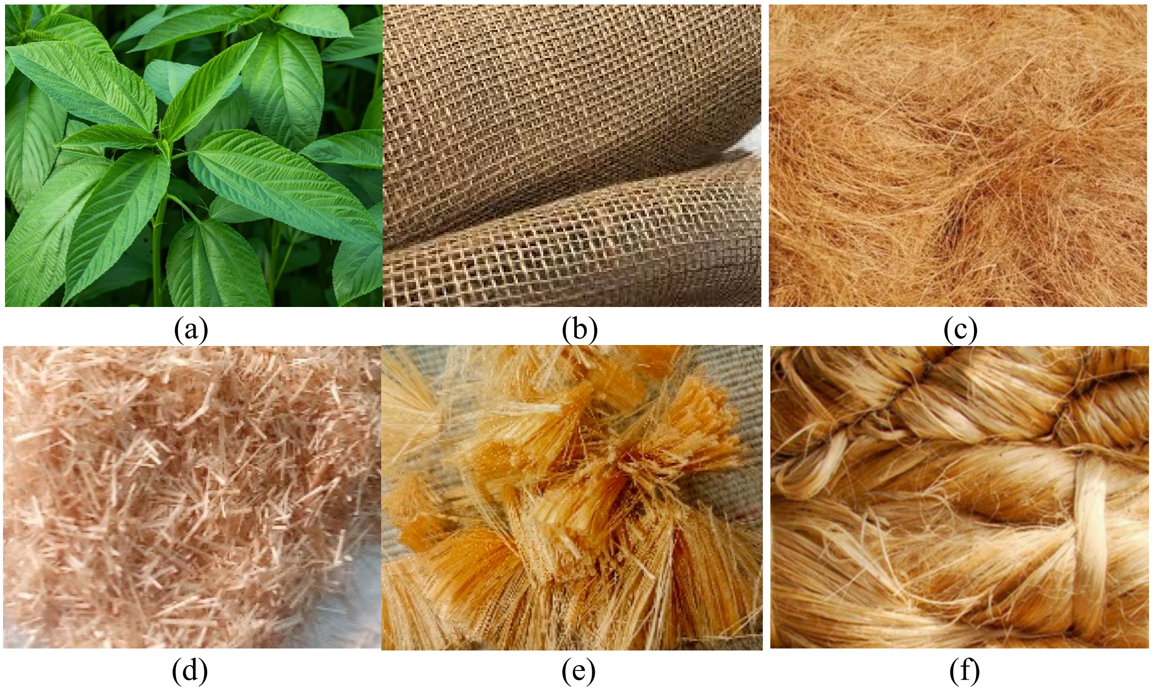


Figure 2.14 Image of jute shapes (a) plant, (b) fabric, (c) non-woven, (d) short, (e) semi-long, (f) long (Shahinur et al., 2022)

In 2021, Shelar and Narendra Kumar stated that jute fiber is used in many industries, including the automotive, military, sporting, and marine industries. They are utilized in a variety of industries because of their qualities including corrosion resistance, flexibility, and light weight. Natural fibers are utilized more frequently than synthetic ones because environmental consciousness is rising. The exceptional qualities of jute reinforcement, which are displayed in Table 2.5, have drawn the attention of numerous studies.

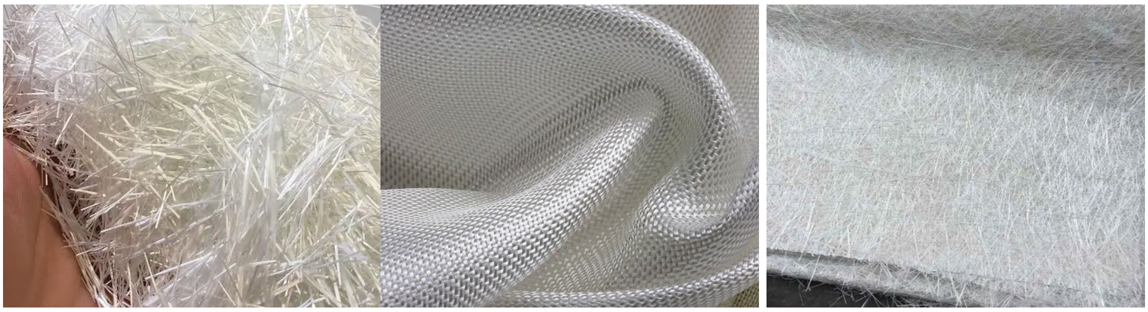
Table 2.5 The properties of jute fiber (Shelar and Narendra, 2021)

Tensile strength (MPa)	**Young's modulus (GPa)**	**Density (g / m^{-3})**	**Elongation at break (%)**
200 – 500	20 – 55	1.3 – 1.5	–
400 – 800	10 – 30	1.46	–
393 – 773	26.5	1.3	1.5 – 1.8
393 – 723	26.5	1.3	3.5 – 4.5
400 – 800	10 – 30	1.46	1.8
393 – 773	13 – 26.5	1.3 – 1.45	1.16 – 1.5

393 – 773	26.5	1.3	1.5 – 1.8
393	38	1.3	1.5 – 1.8
393 – 773	26.5	1.3	1.5 – 1.8
393 – 773	10 – 30	1.44	–
300 – 700	20 – 50	1.3	1.2 – 3
460 – 533	2.5 – 13	1.3	1.16
393 – 773	2.5 – 26.5	1.3 – 1.45	1 – 2
393 – 773	13 – 26.5	1.3 – 1.45	1.16 – 1.5
400 – 800	–	1.4	1.8
410 – 780	–	1.48	1.9
450 – 550	6.89 – 22.07	1.45	1.1 – 1.5
393 – 1035	26.5	1.15 – 1.8	1.3

2.5 Properties and Application of Fiberglass

A melted mixture of quartz sand, dolomite, limestone, and paraffin was used to make fiberglass, which is now one of the most popular composite fibers. Soda and boric acid were also included throughout the manufacturing process. Additionally, the United States (USA) Navy's battleships were the first to use fiberglass as an insulation in 1939. Fiberglass is a more preferred material by companies due to its lower cost when compared to Kevlar and carbon fiber. Polymeric composites are most frequently reinforced using fiberglass. Besides, glass fiber has a number of key benefits, including low cost, superior insulating qualities, high tensile strength, and great chemical resistance. To enhance the mechanical properties and tribological qualities of polymer composites, many types of glass fiber, including longitudinal, woven mat, chopped strand fiber, and chopped strand mat, have been created (Rahman and Putra, 2018). Nassar et al. (2020) mentioned that one of the most promising materials to produce laminate composites is fiberglass. In its production, glass is melted, then pressed through exceedingly small holes to produce fibers that are incredibly thin. Glass fibers are excellent for parts with less rigorous requirements on weight and strength (particularly for the sports industry) and exhibit pretty good mechanical qualities. As a result, parts can be made at a cheaper cost (Goh et al., 2018). The various fiber glass shapes shown in Figure 2.15 and Table 2.6 shows the mechanical and thermal properties of different type of glass fibers.



(a) (b) (c)

Figure 2.15 Various fiber glass shape (a) chopped, (b) fabric, (c) non-woven (Pandey et al., 2016)

Table 2.6 The mechanical properties of different types of glass fiber (Morampudi et al., 2021)

Type of glass	**Density (g / m^{-3})**	**Tensile strength (MPa)**	**Young's modulus (GPa)**	**Elongation at break (%)**	**Coefficient of thermal expansion**
E–glass	2.58	3.445	72.3	4.8	54
C–glass	2.52	3.31	68.9	4.8	63
S2 –glass	2.46	4.89	86.9	5.7	16
A–glass	2.44	3.13	68.9	4.8	73
D–glass	2.12	2.415	51.7	4.6	25
R–glass	2.54	4.135	85.5	4.8	33
EGR–glass	2.72	3.445	80.3	4.8	59
AR–glass	2.70	3.241	73.1	4.4	65

By including more glass fiber into the composite, GFRP composites' damping qualities will be enhanced. The fibers are handled with a variety of chemicals and matrix blends with appropriate GFRP composite processing techniques to enhance the composite qualities (Morampudi et al., 2021). According to Kumar et al. (2021), the S-Type of glass with epoxy or polyester as the matrix material are the highest grade of composites. These premium composite materials are usually utilized in aeronautical applications. The E-type glass is usually used for other household and furniture goods because it is less expensive and can be produced in large quantities despite having lower strength than S-type glass. It is evident that laminates with different orientations exhibit various characteristics. The composite material has a significant variation in strength and modulus. For GFRP composites with various environmental circumstances, various preparation processes have been applied.

2.6 Application of Green Composite

An all-renewable product or one that incorporates a discretionary percentage of synthetic and natural materials, is known as a "green composite." Moreover, the composite as a whole can be made "green" by including yearly renewable resources into its composition. This will, in part, support a more sustainable use in terms of material consumption and energy savings (Georgios et al., 2016). According to Rangappa (2020), green composite is a bio-based composite that is entirely sustainable and friendly to the environment. Green composites are made of polymers that are entirely biodegradable and sourced from plant, animal, and bacterial sources for the matrix and reinforcement, respectively. In green composites, reinforcing is provided by natural fibres such as kudzu, kenaf, cotton, coir, jute, and kapok. In accordance with Kandpal et al. (2015), green composites can be classified into three primary categories based on the type of reinforcement and polymer materials used. These categories include fully renewable composites, which derive their matrix and reinforcement from renewable resources, partially renewable composites, which obtain their matrix from renewable resources and are reinforced with a synthetic material, and partially renewable composites, which use a synthetic matrix reinforced with naturally occurring biopolymers.

2.7 Summary of Literature Review

For the purpose of better comprehending composites, information and knowledge from all prior research that are relevant to this study have been compiled in this chapter, together with the theory component. With the help of epoxy and hybridization of aramid, glass, and jute fibers, the information acquired will help create the green panel. Green composites are extensively utilised in many different industries, including automotive, aerospace, building and construction materials, home goods, electrical and biochemical, and packaging sectors.

This kind of application might benefit from the use of composite materials. Due of their poor density, great Young modulus, superior strength, and exceptional capacity of retaining the kinetic energy of projectiles, these materials are typically reinforced with textiles made of high-performance synthetic fibers. A significant surge in research on Composites Reinforced with Natural Lignocellulosic Fibers (CRNF) is demonstrating the advantages that these fibers have over synthetic fibers in view of the present focus on environmental issues. In particular, natural fiber composites are showing promise for the development of sustainable materials. The investigation into the use of hybrid composites used for a variety of purposes, including green composites application, may be sparked by these instances.

Natural fibers have exceptional properties as well, which may be seen in a number of industries. Natural fibers are very useful in the automotive industry, as well as for other technological purposes applications are gaining popularity due to their superior mechanical qualities and biodegradability. A lot of researchers are also working on green materials right now. In addition, the polymer composite industry has mostly used natural fibers as reinforcement for bio composite products. It is becoming more and more common to use natural fibers in place of cheaper synthetic fiber reinforced plastics due to their affordability as well as their ability to be produced from sustainable, eco-friendly, and renewable resources.

Last but not least, Table 2.7 detailed the reinforcement, matrix, fabrication technique, and stacking order that various studies have employed.

Table 2.7 Summary of prior research

No.	Reinforcement	Matrix	Fabrication process	Stacking sequence	References
1.	Ultra-High Molecular Weight Polyethylene (UHMW PE) fiber	Thermoset	Hand lay up	22 layers of UHMWPE	Firouzi et al. (2022)
2.	Fiberglass	Polyurethane resins.	Hand lay up	G-G-G-G	Nassar et al. (2020)
3.	Fiberglass Jute fiber Kenaf fiber	Zeepoxy HL002TA	Hand lay up	FG-J-J-J-FG	Nor et al. (2018)
4.	Jute fiber Kevlar fiber	Epoxy	Hand lay up	J-K-K-J	Maharana et al. (2021)
5.	Fiberglass Jute fiber	Epoxy	Hand lay up	G-J-G-J-G	Das et al. (2021)
6.	Jute fiber	Epoxy	Vaccum bagging	C-C-J-J-J-C-C-J-J-J	Sujon et al. (2020)

Furthermore, it is a naturally occurring fiber with a cheap cost and is currently the base fiber with the highest manufacturing volume. In this green panel application, jute fiber hybridization with synthetic fiberglass fibers will also be used. This new material is appropriate for green panel applications because extensive study has been done on the use of synthetic and jute fiber hybrids in green panel applications. This study will concentrate on creating green composite panels using the laminated hybrid composite method.

CHAPTER 3

METHODOLOGY

3.1 Overview of the Methodology

In Chapter 3, the proper method and planning to be used in this research to ensure that all the objectives listed are met are thoroughly discussed. This chapter will go into great detail about the research's materials, design, fabrication process, pertinent experimental testing, and analysis. In this research, every process including standard testing methodologies, instruments, and techniques, is complies with the American Society for Testing and Materials (ASTM) codes of practice guidelines.

The preparation and processing of the raw materials, associated procedures, and testing are starting first in the research. Each fiber's various stacking sequences will be used after the raw material has been processed. The current research will use epoxy resin as a matrix, jute and fiberglass as reinforcement, and a hand layup method to create a reinforced composite. The laminate then undergoes exposure to a pressure of one tonne prior to curing. Both the green panel prototype and a summary of all the research findings will be produced. Conclusions are drawn, along with suggestions for upcoming developments and enhancements. Figure 3.1 shows the methodology for the purpose of this research.

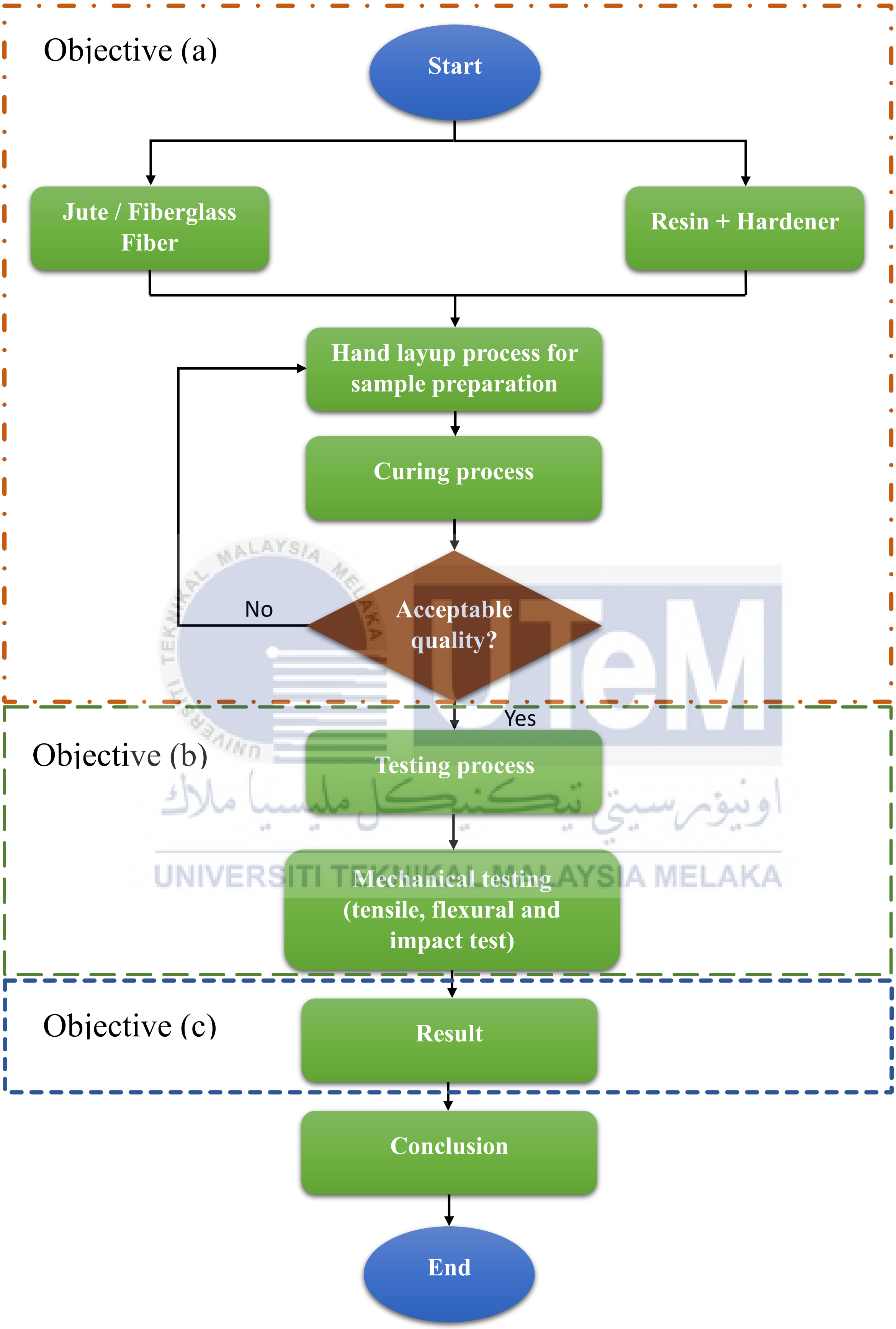


Figure 3.1 The flow chart of the research study

3.2 Preparation of Raw Material

Several raw materials must be prepared for the hand layup procedure in this experiment. The total kilogrammes of epoxy resin required for 30 specimens, including resin and hardener, are approximately 6 kilogrammes. The matrix material, which is epoxy, is bought from Zeegan Enterprise Sdn. Bhd. Besides, the materials needed for the laminated process are fiberglass fabric, which is purchased from My Tech Solution Enterprise and jute fabric, which is purchased from Himanshu Jute Fab. Jute and fiberglass fiber fabric are shown in Figure 3.2, requiring a total of 9.5 meters for each fiber. The supplier charges RM 6.00 for a meter of jute fiber fabric, RM 18.00 for a meter of fiberglass fiber fabric, and RM 48.50 for a kilogram of epoxy resin.

(a) (b) (c)

Figure 3.2 Raw materials for the hand layup process (a) epoxy resin, (b) jute fiber, (c) fiberglass

3.3 Preparation of Hand layup Process

In the current research, a laser-cut machine is used for fabricating the specimen mould, which has dimensions of 250 mm x 340 mm. The fabric will initially be cut into layers that are each 28 cm long and 19.5 cm wide, as shown in Figure 3.3.

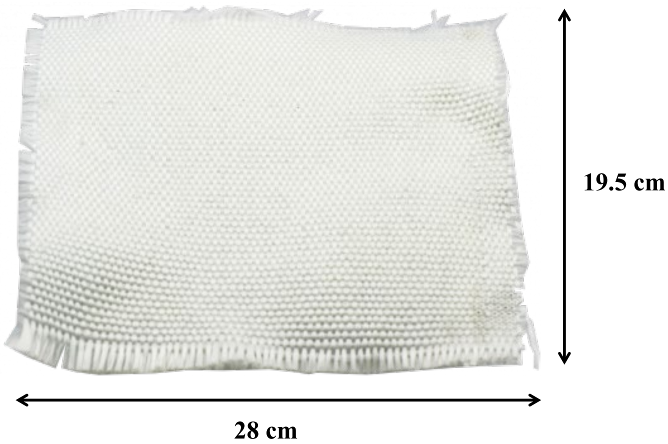


Figure 3.3 Cutting geometry for fiber fabrics

Epoxy will be mixed with natural fiber in a ratio of 1:1.7, and epoxy will be mixed with synthetic fiber in a ratio of 1:1 and 1:0.85. A cold press utilizing a hydraulic press for 1 tonne is done after computing the hand layup method, as shown in Figure 3.4. To make it easier to remove the mould after curing, the mould's surface is sprayed with silicon. This acts as the releasing agent. The specimen will undergo testing after curing.

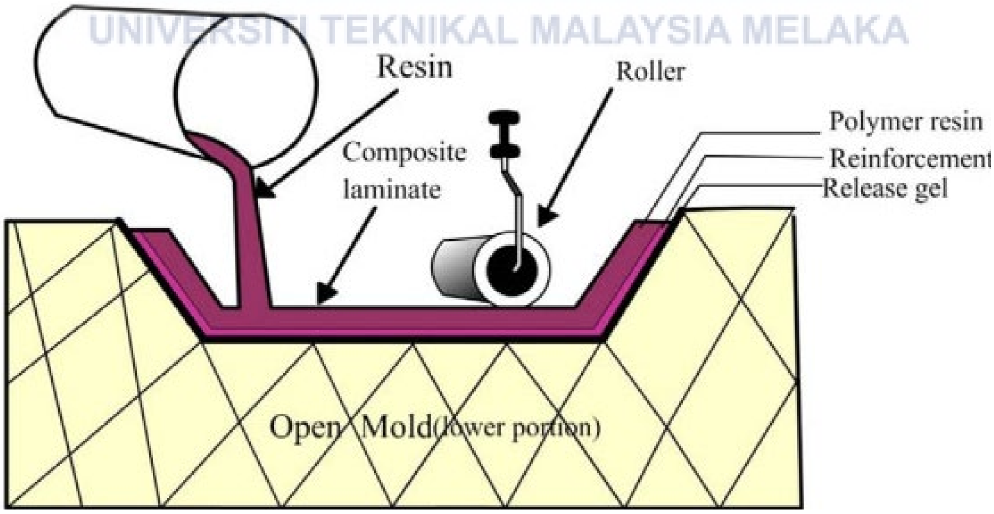


Figure 3.4 Illustration of the handlayup technique

As shown in Figure 3.5, the specimens will be categorized into two, namely jute layers and fiberglass layers containing 24 layers for each fiber. Additionally, all specimens will be oriented in the 0/90° direction.

J = Jute	G = Glass Fiber	
J1		G1
J2		G2
J3		G3
J4		G4
J5		G5
J6		G6
J7		G7
J8		G8
J9		G9
J10		G10
J11		G11
J12		G12
J13		G13
J14		G14
J15		G15
J16		G16
J17		G17
J18		G18
J19		G19
J20		G20
J21		G21
J22		G22
J23		G23
J24		G24
100%		0%
#J-J24		#G-G24

Figure 3.5 Two categorized of specimens

3.4 Development of Hybrid Laminate Stacking Sequence

Fibers made of jute and fiberglass will be employed as reinforcement in the laminated hybrid composite, while epoxy resin will serve as the matrix. The fiber will be cut into 28 cm long by 19.5 cm wide pieces before continuing with the process. The matrix mixture is then completely blended with the aid of a mixer before being applied to the fiber, ultilizing the hand layup procedure. Additionally, as seen in Figure 3.6, the specimen is layered from 24 layers down to 1 layer.

J = Jute | G = Glass Fiber

J1	J1	J1	J1
J2	J2	J2	J2
J3	J3	J3	J3
J4	J4	J4	J4
J5	J5	J5	J5
J6	J6	J6	J6
J7	J7	J7	J7
J8	J8	J8	J8
J9	J9	J9	J9
J10	J10	J10	J10
J11	J11	J11	J11
J12	J12	J12	J12
G1	G1	G1	G1
G2	J13	G2	G2
G3	G2	J13	G3
G4	J14	G3	J13
G5	G3	G4	G4
G6	J15	J14	G5
G7	G4	G5	G6
G8	J16	G6	J14
G9	G5	J15	G7
G10	J17	G7	G8
G11	G6	G8	G9
G12	J18	J16	J15
50%	75%	67%	62%
#H-J12G12	#H-J18G6	#H-J16G8	#H-J15G9

Figure 3.6 Sequence of stacking for hybrid laminated composite

3.5 Mechanical Testing

The test findings for the specimens are the most important factor in establishing whether or not their quality have changed. The outcomes of the running test can be utilized to determine whether the objective of the research study is achievable by abiding by the ASTM, which are mentioned in Table 3.1.

Table 3.1 ASTM standards for testing specifications

Testing	ASTM standard
Tensile test	ASTM D3039
Flexural test	ASTM D790
Impact test	ASTM D256

3.5.1 Tensile test

Testing or experimenting with samples can assist in gathering information for analytical needs to evaluate the efficacy of the experiment. In this study, 30 specimens' composites with different layer configurations will undergo tensile testing. As seen in Figure 3.7, the specimen will be sliced using a laser cutting machines to dimensions of 250 mm long and 25 mm wide, respectively.

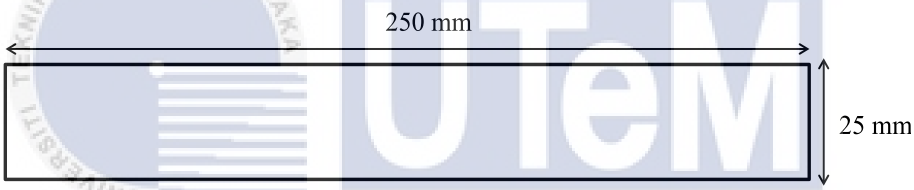
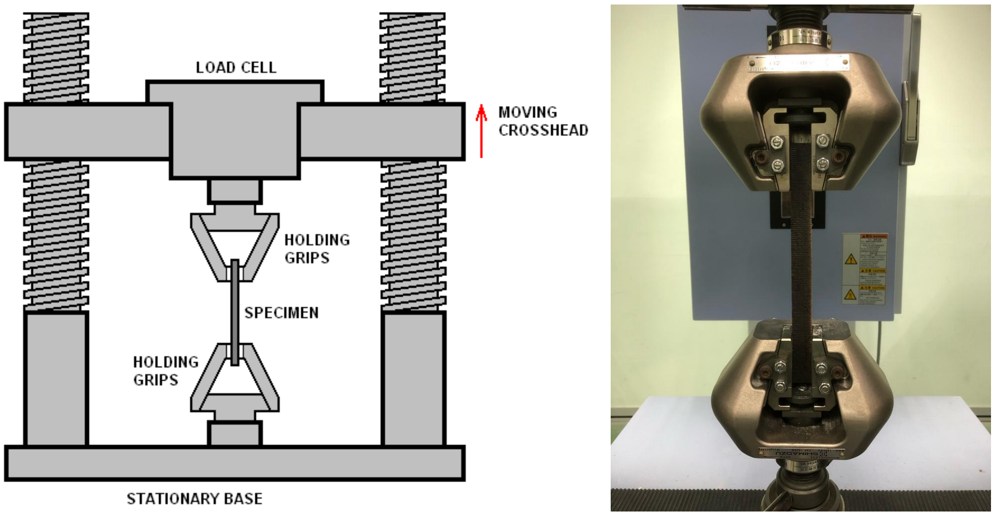


Figure 3.7 The ASTM (D3039)-based dimensions of the tensile test specimen

In accordance with the ASTM D3039 standard test procedure for the tensile strength of laminated composite specimens, as shown in Figure 3.8, the specimen will be exposed to a torsion load. A crosshead speed of 2 mm/min will be used to pull the specimen to failure in accordance with ASTM D3039 standards. The specimens will undergo a tensile strength analysis using the Shimadzu Universal Testing Machine (UTM) Instron 100 kN. Using strain gauges fastened along the specimen's longitudinal axis, the tensile strain was determined. Tensile testing is used to determine how the fibre and matrix interact. Using data from the test, the stress-strain curve will be plotted and evaluated in Chapter 4.



(a) (b)

Figure 3.8 Block diagram for the setup of a tensile test (a) illustration, (b) Shimadzu Universal Testing Machine (UTM) Instron 100 kN – Tensile Test

3.5.2 Flexural test

Testing or experimenting with samples can assist in gathering information for analytical purposes to evaluate the efficacy of the experiment. The results of this testing will show how well each layer of the laminated composite with various fibers performs. As depicted in Figure 3.9, the laminated composite will be tested using the ASTM D790 standard test procedure. Thus, the samples were tested for flexural performance in this part utilising the Shimadzu Universal Testing Machine (UTM) Instron 100 kN, as seen in Figure 3.10.

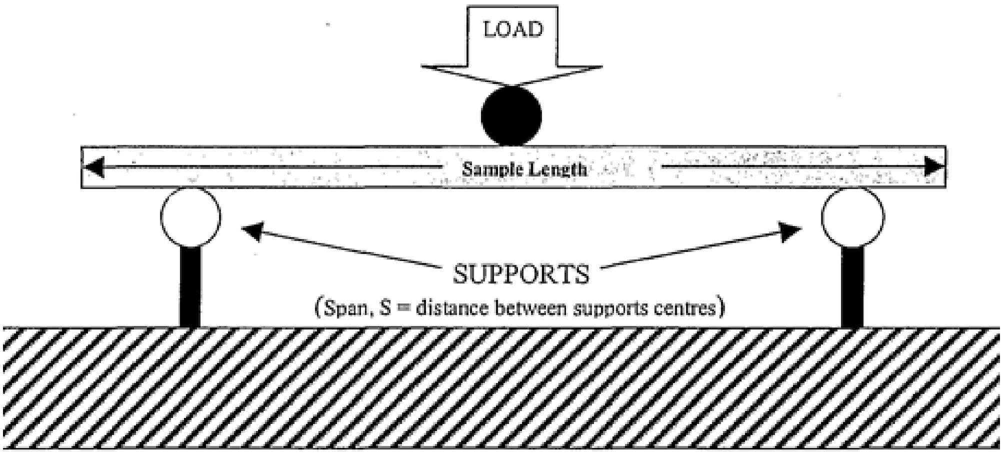


Figure 3.9 Schematic diagram for the setup of a flexural test

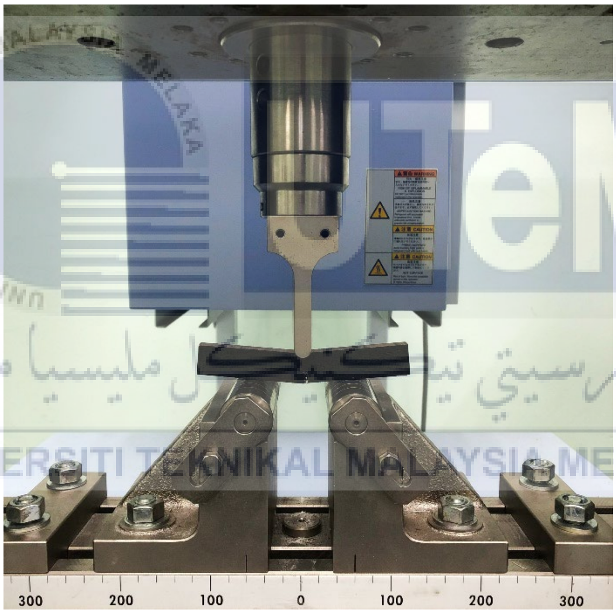


Figure 3.10 Shimadzu Universal Testing Machine (UTM) Instron 100 kN – Flexural Test

In addition, a flexural test will be performed on 30 specimens' composites made of different layers. The crosshead will therefore press at a pace of 2 mm/min, and the lower support will be 60 mm. According to Figure 3.11, the specimen will be sliced using a laser cutting equipment to measure 127 mm in length and 12.7 mm in width.

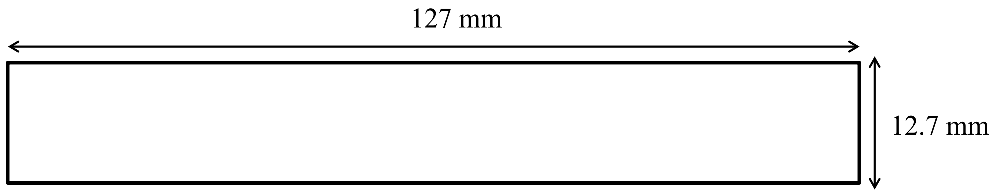


Figure 3.11 The ASTM (D790)-based dimensions of the flexural test specimen

3.5.3 Pendulum impact test

An impact test is used to determine how much energy a substance expends during fracture. A material's hardness can be determined by how much energy it has absorbed. The three most popular single impact test types are the Charpy V-notch test, the tensile impact test, and the Izod test. In this research, the Charpy impact test will be used to determine how much impact the reinforced composite can withstand. According to the ASTM D256 standard, Figure 3.12 shows the specimen's V-notch and geometry. As shown in Figure 3.13, the sample is positioned horizontally at the Charpy impact machine before the hammer is released.

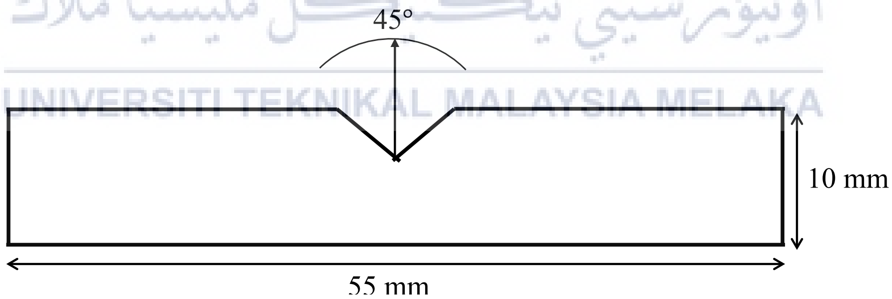


Figure 3.12 The specimen's V-notch and geometry for the Charpy impact test

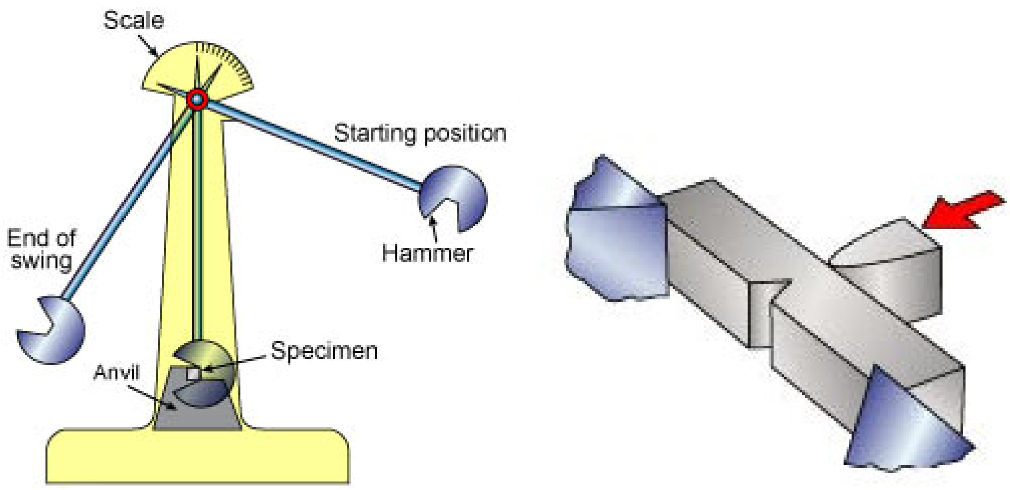


Figure 3.13 The Charpy pendulum impact test

ASTM D256 guidelines for jute, fiberglass and hybrid-reinforced composites were followed for conducting Pendulum Charpy tests. For each layer, an average of three specimens were recorded after the samples were sliced into dimensions of 10 mm x 55 mm x real thickness without notch. As shown in Figure 3.14, the EUROTECH Charpy-Izod impact tester will be used for the Charpy test. Moreover, 8.8 kg is the impact load that was utilised. A laser cut machine was used to precisely measure the samples, as shown in Figure 3.15. The Charpy Impact Test was used to ascertain the failure mechanisms of composites as well as the amount of energy absorbed by the sample following the application of force.

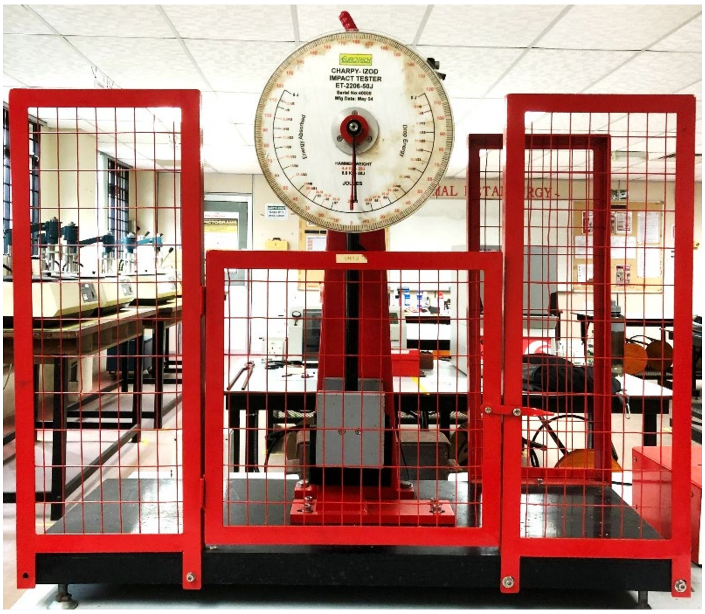


Figure 3.14 The Eurotech Charpy - Izod impact tester

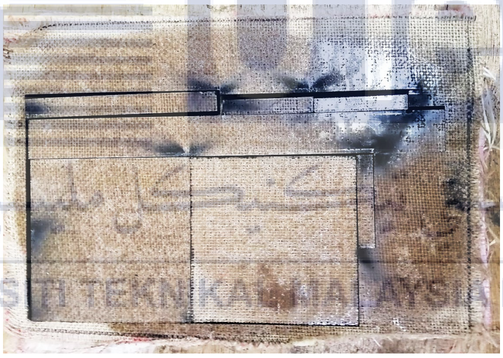


Figure 3.15 The samples after cutting using laser cut machine

CHAPTER 4

RESULT AND DISCUSSION

4.1 Fabrication and Characteristics of Laminated Composite

In this study, the lamination of the composite is a crucial step in the fabrication process that requires care. There were two types of specimens: jute and fibreglass, which were made up of 24 layers for the first category. Table 4.1 has a list of codes for the specimen.

Table 4.1 List of codes for the specimen

Layers	Fiberglass	Jute Fiber
24	G-G24	J-J24

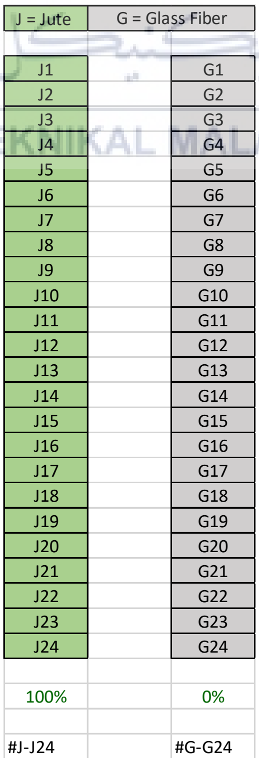


Figure 4.1 The stacking sequence

The second category dealt with creating hybrids—that is, combining the two fabrics to create a new hybrid. Initially, tensile, impact, and flexural tests will be used to evaluate the mechanical properties of the first category specimen. Next, as shown in Figure 4.1, the hybrid's sequence is determined once the test for the first category is completed. The hybrid laminated composite contains 24 layers, indicating that it has the best mechanical qualities in the first category. The code for the hybrid specimen can be found in Table 4.2.

Table 4.2 The code for the hybrid specimen

No.	Code
1	H-J12G12
2	H-J18G6
3	H-J16G8
4	H-J15G19

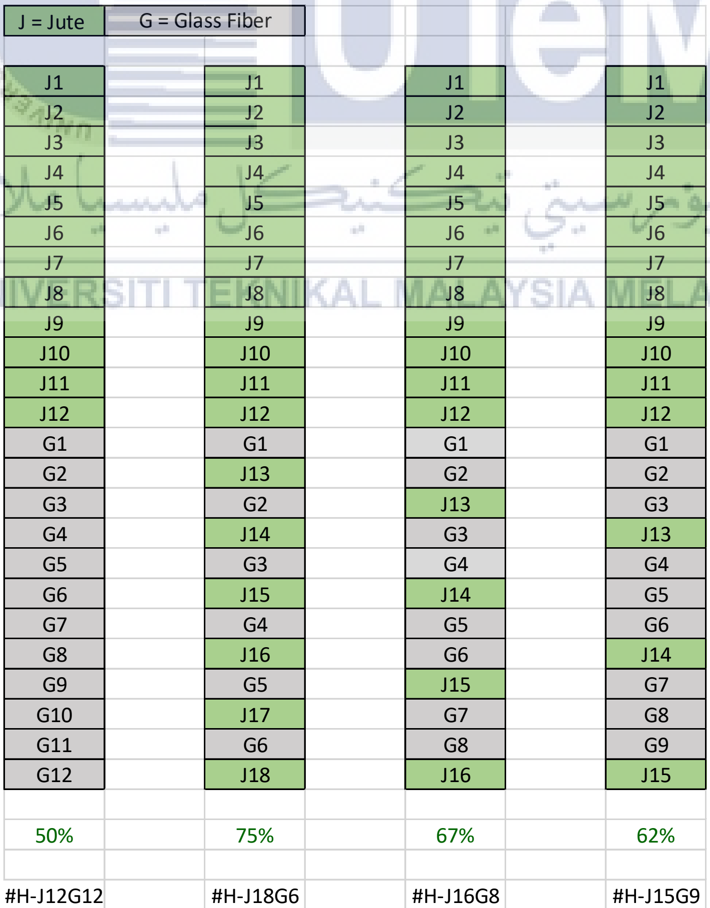


Figure 4.2 The hybrid stacking sequence

The specimen for this study was made with a one-tonne hydraulic press and the hand-layup cold press method. Initially, every fabric will be divided into 28 by 19.5 cm pieces. After that, a thermoset epoxy would be used to strengthen the specimen. Each fabric layer's weight (g) will determine how much of the matrix is used. The natural fiber matrix ratio utilised in this study was 1: 1.7, while the synthetic fibre matrix ratio was 1: 0.85, as suggested by Yuhazri et al. (2020).

Table 4.3 The ratio of epoxy resin used for the specimen

Specimen	**Fabric Weight (g)**	**Epoxy Resin Ratio (A-2 : 1-B)**
J-J24	365	$365g \times 1.7 = 620.5g$ $A\ (resin)\quad : 413.66g$ $B\ (hardener) : 206.83g$
G-G24	210	$210g \times 1.7 = 178.5g$ $A\ (resin)\quad : 119g$ $B\ (hardener) : 59.5g$
H-J12G12	(J) 185 (GF) 110	$185g \times 1.7 = 314.5g$ $110g \times 0.85 = 93.5g$ $A\ (resin)\quad : 272g$ $B\ (hardener) : 136g$
H-J18G6	(J) 270 (GF) 50	$270g \times 1.7 = 459g$ $50g \times 0.85 = 42.5g$ $A\ (resin)\quad : 334.33g$ $B\ (hardener) : 167.17g$
H-J16G8	(J) 240 (GF) 70	$240g \times 1.7 = 408g$ $70g \times 0.85 = 59.5g$ $A\ (resin)\quad : 155.83g$ $B\ (hardener) : 311.67g$

H-J15G19	(J) 225 (GF) 80	$225g \times 1.7 \ = 382.5g$ $80g \times 0.85 = 68g$ $A\ (resin) \quad : 300.33g$ $B\ (hardener) : 150.17g$

4.2 Mechanical Characteristics of Composite Laminations

The tensile, flexural, and impact tests—three tests that are conducted in accordance with ASTM standards—are used to evaluate the performance of the applied research and experiment in order to ascertain the mechanical properties of the laminated composite specimen. The best results from these tests will be an ideal layer sequence for this research.

4.2.1 Specimen Properties of laminated composite materials

Based on the number of layers to be applied to the stacking sequence for the laminated hybrid composite, two different types of materials—jute and fiberglass—are being used in this research. Samples of the laminated composite properties are shown in Figure 4.3.

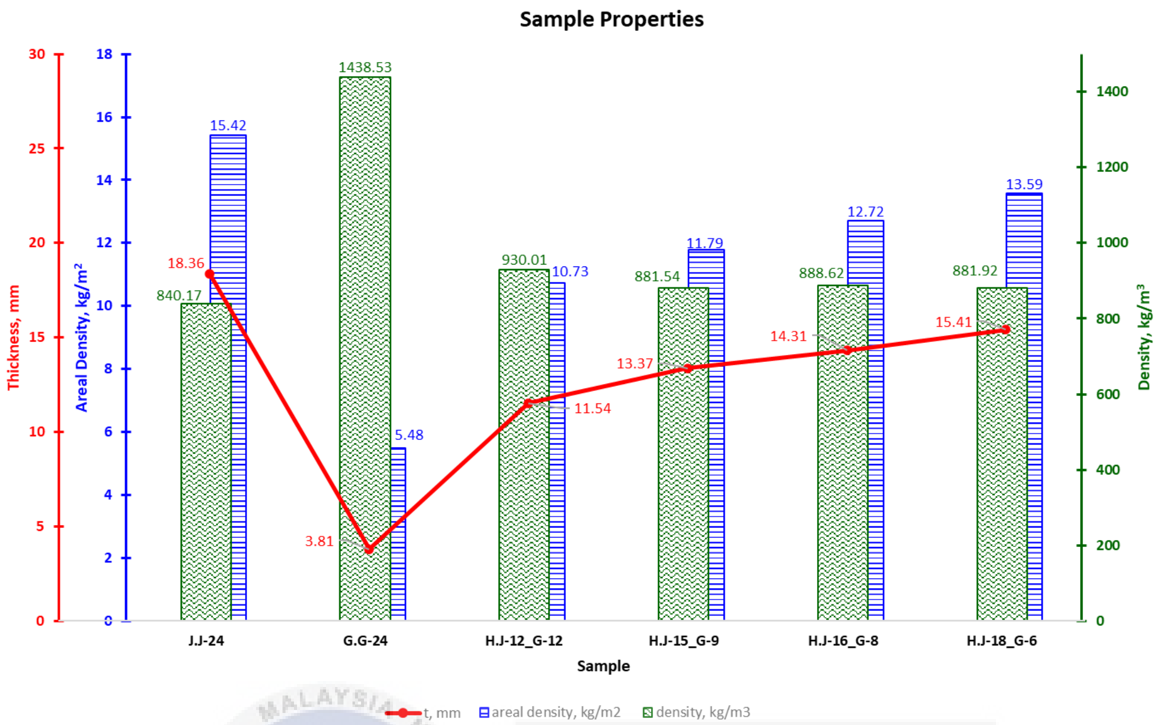


Figure 4.3 The samples of the laminated composite properties

The sample for these two materials is intended to show the mechanical strength test results as well as the relationship between the potential combination of these two materials into a single material. The graph illustrates the differences in thickness between the two non-hybrid materials, with J-24 measuring 18.36 mm and G-24 measuring 3.81 mm, as shown in Figure 4.4. The results indicate that J-24 is thicker than G-24 due to the fact that its single layer of jute fibre is thicker than its single layer of fibreglass fiber because jute fiber is natural fiber. The combination of the two materials must include at least 50 % jute fibre and the remaining portion fibreglass fibre in order to sustain the green element in the panel application. Fibreglass with fewer than 12 layers and jute fibre with 12 layers or more are mixed together to create the hybrid layer. When the hybrid panels are merged, their combined thickness ranges from 11.54 mm to 15.41 mm, which is not excessively thick.

(a) (b)

Figure 4.4 The thickness of the laminated composite (a) fiberglass fiber, (b) jute fiber

Generally speaking, materials with higher densities have more mass, which can lead to an increase in strength based on the composition of the material being used. However, areal density sheds light on the distribution of mass over a surface area. The strength-to-weight ratio of a material can be affected by the distribution of mass, which is defined by areal density. In applications where weight is a crucial factor, it is generally desirable to achieve high strength with decreased areal density. G-24 has the highest density for the non-hybrid sample while having the lowest areal density of all the others. To create a sample with a higher density but a lower areal density, hybridization is applied to the sample. When comparing the areal density from H-J12G12 to H-J18G6, it decreased from 930.01 kg/m^3 to 881.92 kg/m^3. However, the area density increased from 10.73 kg/m^2 to 13.59 kg/m^2 in H-J18G6. This demonstrates how beneficial the two materials' hybridization is despite the need to sustain the green concept.

4.2.2 Tensile performance of laminated composite materials

A critical component of comprehending the behaviour of laminated composite materials under tensile loading circumstances is their tensile performance. In order to assess how the fibre and matrix interacted within the composite material, tensile testing was used. The maximum force values for the tensile strength derived from the laminated combination of fibreglass and jute fibre are shown graphically in Figure 4.5.

Figure 4.5 The tensile properties of the laminated composite

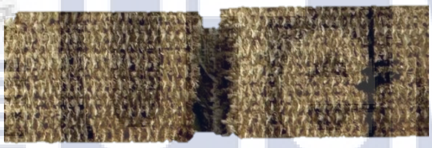
Based on the results J-24 displayed a force of 15.32 kN, but G-24 displayed the maximum force of 27.02 kN. H-J12G12, H-J15G9, H-J16G8, and H-J-18G6 showed intermediate force values, ranging from 19.87 kN to 18.64 kN, 18.93 kN, and 18.22 kN, respectively, for the hybrid composites. With an ultimate tensile strength of 283.67 MPa, G-24 demonstrated the highest value, followed by H-J12G12 with 68.87 MPa. H-J15G9, H-J16G8, and H-J18G6, the other hybrid composites, displayed final tensile strengths of 55.77 MPa, 52.91 MPa, and 47.29 MPa, in that order. With an ultimate tensile strength of 33.38 MPa, J-24 had the lowest value. The materials' deformation behaviour was revealed by the displacement that occurred during the tensile test. The findings showed that J-24 had a marginally greater displacement at 7.94 mm, whereas G-24 had the lowest displacement at 7.02 mm. The mechanical performance of the jute has been enhanced by the addition of fibreglass to the stacking sequence as depicted in Figure 4.6. That aside, it's important to note that the hybridization samples' ultimate tensile strength decreased from 68.87 MPa to 47.29 MPa, as seen in the figure. This demonstrates that using less fibreglass throughout the hybridization lamination process will result in a reduction in the samples' ultimate tensile strength.

J = Jute	G = Glass Fiber				
J1	G1	J1	J1	J1	J1
J2	G2	J2	J2	J2	J2
J3	G3	J3	J3	J3	J3
J4	G4	J4	J4	J4	J4
J5	G5	J5	J5	J5	J5
J6	G6	J6	J6	J6	J6
J7	G7	J7	J7	J7	J7
J8	G8	J8	J8	J8	J8
J9	G9	J9	J9	J9	J9
J10	G10	J10	J10	J10	J10
J11	G11	J11	J11	J11	J11
J12	G12	J12	J12	J12	J12
J13	G13	G1	G1	G1	G1
J14	G14	G2	J13	G2	G2
J15	G15	G3	G2	J13	G3
J16	G16	G4	J14	G3	J13
J17	G17	G5	G3	G4	G4
J18	G18	G6	J15	J14	G5
J19	G19	G7	G4	G5	G6
J20	G20	G8	J16	G6	J14
J21	G21	G9	G5	J15	G7
J22	G22	G10	J17	G7	G8
J23	G23	G11	G6	G8	G9
J24	G24	G12	J18	J16	J15
100%	0%	50%	75%	67%	62%
#J-J24	#G-G24	#H-J12G12	#H-J18G6	#H-J16G8	#H-J15G9

Figure 4.6 The stacking sequence of the samples

The condition of each stacking sequence following tensile testing for J-24, G-24, H-J12G12, H-J15G9, H-J16G8, and H-J18G6 is displayed in Table 4.4, which demonstrates the failure mode mechanism of laminated hybrid composites. This is due the epoxy and jute fibre had a weak bond, which is why they broke apart at different periods. It was epoxy that broke first, then jute fibre, as tensile tension increased.

Table 4.4 The failure mechanism of laminated hybrid composites under tensile testing

Specimen	**Figure**
J-J24	
G-G24	
H-J12G12	
H-J18G6	
H-J16G8	
H-J15G9	

4.2.3 Flexural performance of laminated composite materials

Based on flexural testing, the data provides a comprehensive analysis of the performance of various materials and ratios. The graph in the Figure 4.7 generally displays displacement, force, and flexural strength from the testing.

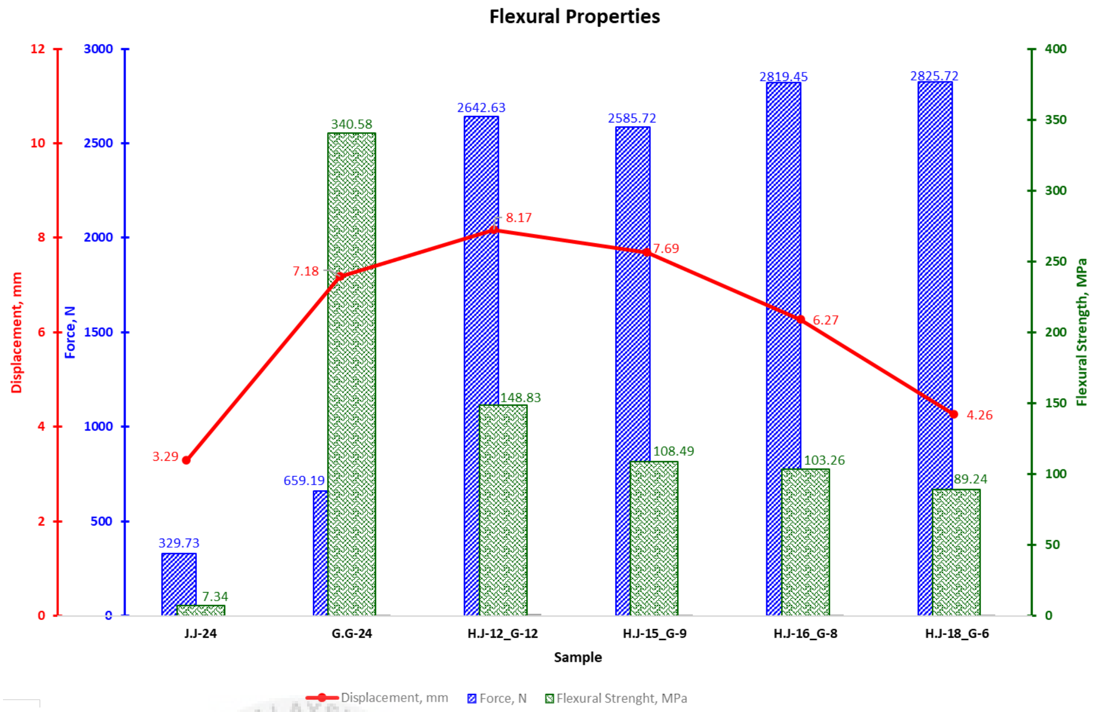


Figure 4.7 The flexural properties of the laminated composite

The G-24 demonstrated the highest force at 659.19 N, while the J-24 displayed the lowest value at 329.73 N. The results showed notable differences in the bending strengths of the materials. H-J18G6 among the hybrid composites showed the maximum force at 2825.72 N, closely followed by H-J16G8 at 2819.45 N. With a flexural strength of 340.58 MPa, G-24 was the strongest, and J-24 had the lowest value at 7.34 MPa. The hybrid composite with the highest flexural strength, H-J12G12, measured 148.83 MPa. Its strengths were closely followed by H-J15G9, H-J16G8, and H-J18G6, at 108.49 MPa, 103.26 MPa, and 89.24 MPa, respectively. The displacement data illustrates the testing-induced deformation of the materials. With an 8.17 mm displacement, H-J12G12 was the hybrid composite with the largest displacement. H-J15G9, H-J16G8, and H-J18G6 with displacements of 7.69 mm, 6.27 mm, and 4.26 mm, respectively, were the next four. The findings demonstrate the complex relationship among displacement, flexural strength, and material composition generally. In addition, there was a 27.11 % decline in H-J15G9, a 4.82 % drop in H-J16G8, and a 13.58 %

drop in H-J18G6. The results indicate that among the examined specimens, H-J12G12 is the hybrid composite with the highest flexural strength, making it the most viable option for use in green panel applications. Thus, specimens will eventually fail when debonding or cracking happens at the interface between the glass fibre and matrix, as seen in Figure 4.8.

Figure 4.8 The failure mode of hybrid composite

4.2.4 Charpy impact performance of laminated composite materials

The purpose of the impact test is to measure how much energy the sample absorbs when force is applied. Along with identifying the composite material's failure modes, this measurement offers important data into the material's durability and capacity to absorb impact energy. In order to evaluate the material's overall performance and durability, it is essential to comprehend how it reacts to impact loads. As seen in Figure 4.9, the bar chart displays an irregular pattern in the energy absorbed by the laminated hybrid reinforced composite.

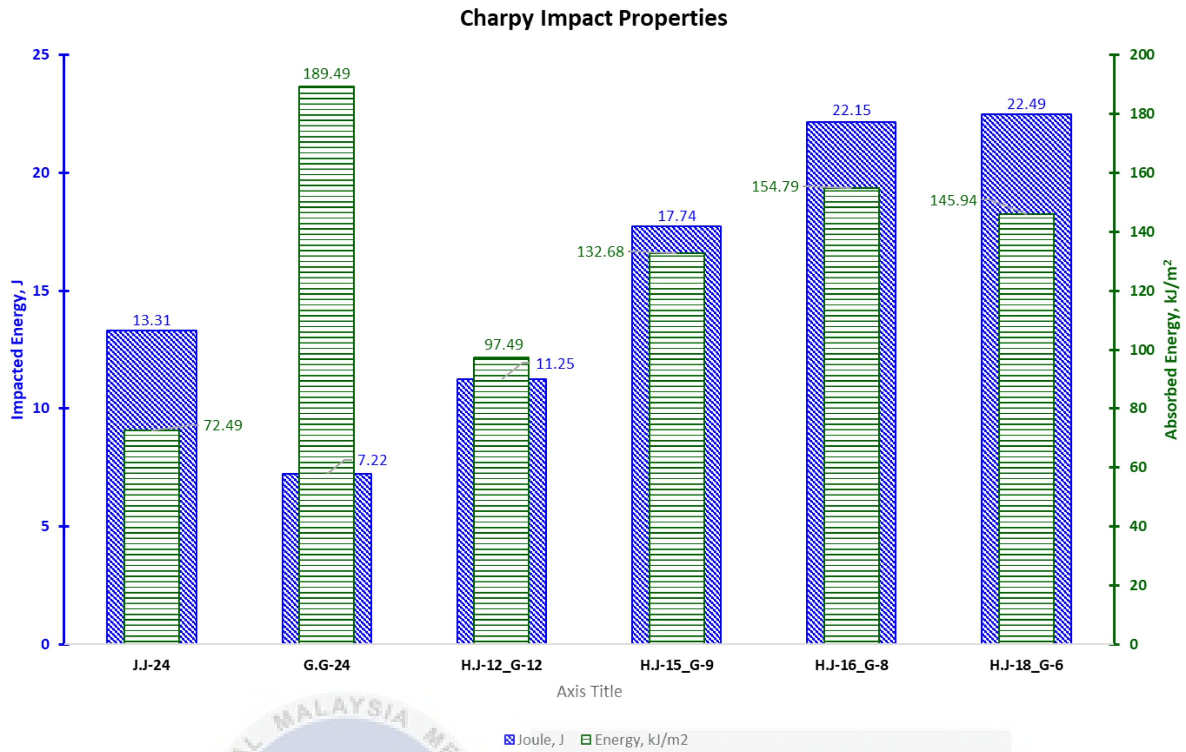
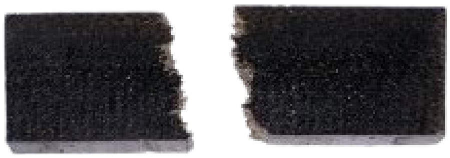
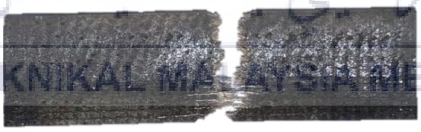


Figure 4.9 The energy absorbed of the laminated composite

With 189.49 kJ/m², G-24 had the highest absorbed energy, whereas J-24 had the lowest, at 72.49 kJ/m². The values of absorbed energy exhibited by the hybrid composites were as follows: H-J12G12 had an absorbed energy of 97.49 kJ/m², H-J15G9 was at 132.68 kJ/m², H-J16G8 was at 154.79 kJ/m², and H-J18G6 was at 145.95 kJ/m². Results show that sample H-J16G8 has the maximum energy absorbed, whereas sample H-J12G12 has the lowest. H-J18G6 is the sample with the second-highest energy absorption. This can be explained by the fact that H-J16G8 has a larger amount of energy absorbed because of the amount of fibreglass and the stacking order. With 7.22 J, G-24 showed the least affected energy, whereas J-24 showed 13.31 J. Higher affected energy values were shown by the hybrid composites, with H-J12G12 at 11.25 J, H-J15G9 at 17.74 J, H-J16G8 at 22.15 J, and H-J18G6 at 22.49 J. In light of the findings, the hybrid composite H-J16G8 sticks out as the most promising for use in green panel applications because it showed the maximum affected and absorbed energy of all the specimens put through testing. Because of its exceptional resistance to impact loads, it could be a good fit for industries like transportation and construction, where impact resistance is essential. Table 4.5 depicts the state of each stacking sequence following an impact test and provides insight into the failure mode mechanism of laminate composites. This is because the epoxy and jute fibre had a weak relationship, which is why they broke at different times.

Table 4.5 The failure mechanism of laminated hybrid composites under impact testing

Specimen	Figure
J-J24	
G-G24	
H-J12G12	
H-J18G6	
H-J16G8	
H-J15G19	

4.3 Summary of Analysis Findings

As seen in Figure 4.10, several factors were examined in the evaluation of laminated green composites' varied qualities for use in green panel applications, including force, impact energy, flexural force, modulus of rupture (MOR), and overall energy absorption. Among the specimens put to the test were J-24, G-24, and four hybrid composites with the designations H-J12G12, H-J15G9, H-J16G8, and H-J18G6, which all involved the hybridization of various fibre compositions. This investigation has demonstrated that H-J16G8 is the best stacking layer for the composites. G-24 had the highest force of any of the tested materials (100), followed by H-J12G12 (73.54), H-J16G8 (70.06), H-J15G9 (68.99), H-J18G6 (67.43), and J-24 (56.71).

Similar trends were seen in the ultimate tensile strength, where G-24 led at 100, H-J12G12 at 24.28, H-J15G9 at 19.66, H-J16G8 at 18.65, H-J18G6 at 16.67, and J-24 at 11.77. Of all the materials that were evaluated, G-24 had the maximum force (100), followed by J-24 (56.71), H-J12G12 (73.54), H-J16G8 (70.06), H-J15G9 (68.99), and H-J18G6 (67.43). Regarding the ultimate tensile strength, comparable patterns were observed: G-24 was first at 100, followed by H-J12G12 at 24.28, H-J15G9 at 19.66, H-J16G8 at 18.65, H-J18G6 at 16.67, and J-24 at 11.77. When it came to flexural force, G-24 showed the highest value at 100, closely followed by H-J18G6, H-J16G8, H-J12G12, H-J15G9, H-J51, and J-24, all of which showed values of 11.67. The results of the modulus of rupture (MOR) analysis showed that G-24 had the greatest value (100), followed by H-J12G12 (43.71), H-J15G9 (31.85), H-J16G8 (30.32), H-J18G6 (26.19), and J-24 (2.15). The maximum impact energy was found for G-24 at 32.11, followed by H-J18G6 at 100, H-J16G8 at 98.49, H-J15G9 at 78.88, H-J12G12 at 50.02, and J-24 at 59.18 of impact energy. At 100, G-24 was the leader in terms of overall energy absorption, followed by H-J16G8 (81.69), H-J15G9 (70.02), H-J18G6 (77.02), H-J12G12 (51.45), and J-24 (38.25).

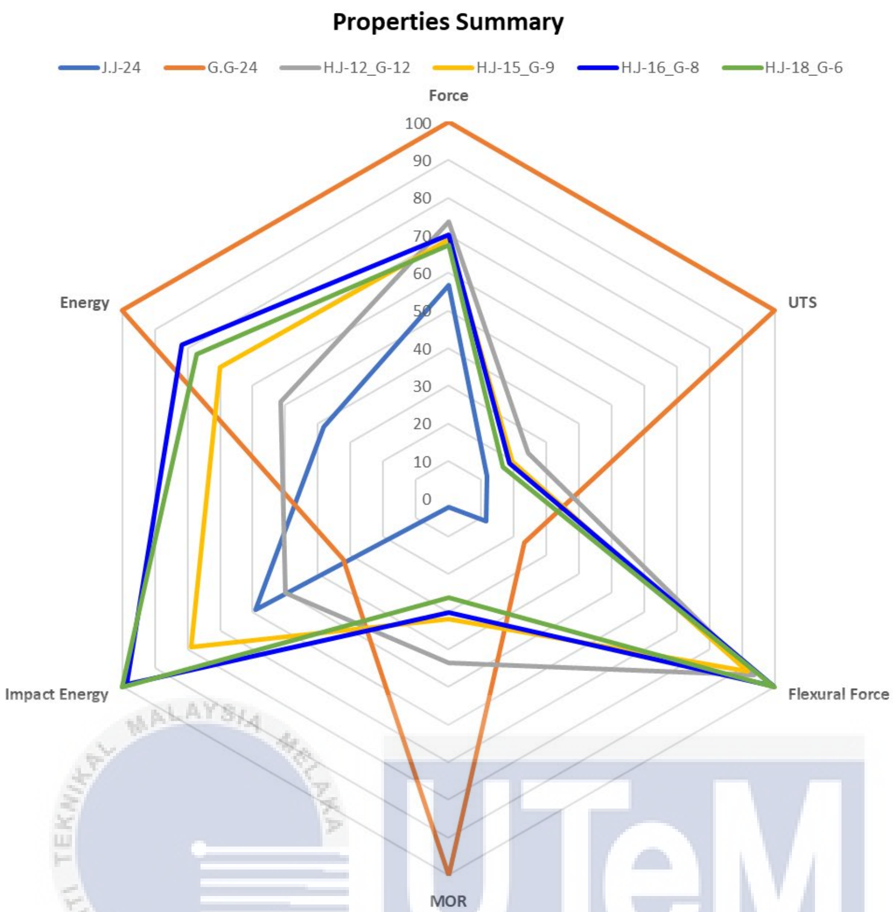


Figure 4.10 The summary of the sample properties

Based on the available information, H-J16G8 is determined to be the optimal layer. Among the evaluated specimens, H-J16G8 stands out as the most favourable; this thorough investigation of numerous features offers significant insights into the prospective applications of the hybrid composites. Analysis of all the collected experimental data leads to the conclusion that, in a laminated hybrid system, all hybridization processes contribute to improving the jute fiber-reinforced composites' characteristics. Previous studies have shown that jute fibre has a great deal of promise as a raw resource to replace the present synthetic material. A strong structure that can withstand more impact is produced by a well-planned layer sequence of jute and fibreglass. The use of replacing synthetic materials with natural materials to safeguard our climate without sacrificing our concerns for health has been experimentally verified and provides good tensile strength, energy absorption, and impact strength qualities. Thus, in accordance with the ASTM standard, the laminated composite specimens were subjected to tensile, impact, and flexural tests.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study uses a straightforward hand-layup cold press process to provide an overview of the possible uses of jute fibre in green panel applications. This research work was motivated to provide a new possibility of advanced composite by using inexpensive and lightweight materials.

The first goal of the study, to fabricate the laminated green panel applications in accordance specific layer sequence for hybrid system by utilizing hand layup cold press technique, was effectively accomplished with few notable exceptions. A new possibility for advanced composites was effectively shown with the production of laminated reinforced composite for jute, fibreglass, and hybrid employing a hand layup cold press process with a hydraulic press at 1 tonne. The second goal of the study is to analyse the impacts of the laminated and its hybrid sequence based on its mechanical properties and impact capabilities is achieved. The impact strength of the hybrid laminated composite H-J16G8 has proven that it can absorb higher energy than other hybrid laminates, which is 154.79 kJ/m^2. Plus, its flexural strength is also higher, which is 103.26 MPa. In addition, the third goal is to propose the best-laminate hybrid sequence for green panel application products. The best stacking sequence was H-J16G8, where the hybrid specimen has the most consistent results due to all of the recorded test data.

5.2 Recommendations

To make this research even better, some kinds of suggestions could be made. The recommendation that is put up is as follows:

a) Replace untreated jute fibre with treated jute fibre. This is because the contaminants in the treated jute fibre were eliminated, improving surface contact. Better interfacial bonding with the matrix is thus encouraged.

b) Diluent should be combined with hardener and epoxy. In doing so, the epoxy mixture's viscosity is decreased. In addition to providing an even wetting surface and strong interfacial adhesion between the fibre and matrix, a low viscosity of resin may also decrease voids or bubbles. This may contribute to the composite materials performing better.

5.3 Green Element

More resources have been used by humanity in the last 50 years than in all of human history combined. The "green generation" of consumers is more likely to "go green" because they value utilizing sustainable products that emit little to no pollution and making ecologically responsible actions. The rate at which this market is growing is even more astonishing. This has sparked this research's interest in green products and their advantages. Jute fiber is employed in this study as a green alternative to less environmentally friendly Kevlar fiber, which is typically used to make ballistic panels. This is due to the fact that jute is the second highest environmentally friendly, biodegradable natural fiber, whereas Kevlar fiber is a synthetic plastic created of a chemical compound called poly-para-phenylene terephthalamide. This substance is created chemically when an acid and a chemical solution that contains nitrogen and hydrogen are combined. Thus, implementing natural fiber rather than synthetic fiber will help to conserve the environment.

5.4 Sustainable Element

When over 30,000 customers from 60 countries were surveyed about their purchasing patterns, 66% of them said they would be willing to pay more for environmentally friendly companies—a 11% increase from the previous year. 73% of Millennials, one of the largest cohorts in history, are prepared to pay more for sustainable options, up from fifty percent in 2014. This growing tendency is expected to continue as Millennials enter their prime purchasing years. Given this, it is even more important for business enthusiasts and entrepreneurs to comprehend the definition, advantages, and challenges of a green product as well as the production process. It is sustainable to use natural fibre, such jute fibre, since the world produces between 2300 and 2850 tonnes of jute fibre annually. In addition, it is now the best fibre with the biggest production volume and one of the least expensive natural fibres. In just three months, the jute plant can grow to a height of 12 to 15 feet. The jute fibre that was employed as reinforcement fully complies with the sustainability criteria because it is easily accessible. Jute fibre might thereby lessen the quantity of synthetic fibre used in green panel applications.

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APPENDICES

APPENDIX A

GANTT CHART FOR PSM 1

Gantt Chart For PSM 1																	
No.	Task Project	Status	Week														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Supervisor Selection and Registered PSM Tittle.	Plan														
		Actual														
2	Briefing for PSM and project explanation by supervisor	Plan														
		Actual														
3	Drafting and writing of Chapter 2 (Literature Review)	Plan														
		Actual														
4	Presentation of draft Chapter 2 with supervisor	Plan														
		Actual														
5	Submission of Chapter 2	Plan														
		Actual														
6	Briefing of Chapter 1 with supervisor	Plan														
		Actual														
7	Writing of Chapter 1	Plan														
		Actual														
8	Submission of Chapter 1	Plan														
		Actual														
9	Discussion of Chapter 3 with supervisor	Plan														
		Actual														
10	Draft and writing of Chapter 3	Plan														
		Actual														
11	Submittion of Chapter 3	Plan														
		Actual														
12	Writing Chapter 4, expected outcome and conclusion, abstract	Plan														
		Actual														

13	Submission of report PSM 1 first draft	Plan														
		Actual														
14	Last correction of the report	Plan														
		Actual														
15	Submission of report to supervisor and panels	Plan														
		Actual														
16	Preparation slide and presentation PSM 1	Plan														
		Actual														

APPENDIX B

GANTT CHART FOR PSM 2

	Gantt Chart For PSM 2															
No.	Task Project	Status	Week													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Discussion planning task with supervisor	Plan														
		Actual														
2	Cutting mold	Plan														
		Actual														
3	Raw material preparation	Plan														
		Actual														
4	Fabrication process	Plan														
		Actual														
5	Trimming sample	Plan														
		Actual														
6	Testing sample	Plan														
		Actual														
7	Analysis of the data	Plan														
		Actual														
8	Draft and writing of Chapter 4	Plan														
		Actual														
9	Submission of chapter 4	Plan														
		Actual														
10	Draft and writing of Chapter 5	Plan														
		Actual														
11	Submission of Chapter 5	Plan														
		Actual														
12	Submission draft report PSM 2	Plan														
		Actual														

13	Last correction of the report	Plan														
		Actual														
14	Submission of report to supervisor and panels	Plan														
		Actual														
13	Preparation of slide andr presentation of PSM 2	Plan														
		Actual														

APPENDIX B

TURNITIN FOR PSM 2

WAN AMANINA

ORIGINALITY REPORT

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4	A.B. Ilyani Akmar, O. Kramer, T. Rabczuk. "Probabilistic multi-scale optimization of hybrid laminated composites", Composite Structures, 2018 Publication	1%
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