EXPERIMENTAL STUDIES ON PLA - JUTE SANDWICH COMPOSITES

A Major Project report submitted
in partial fulfillment of the requirement for the degree of

BACHELOR OF TECHNOLOGY IN MECHANICAL ENGINEERING

by

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CERTIFICATE

It is certified that the work contained in the project report titled "**Experimental studies on PLA - Jute sandwich composites**", by **Gajwelli Sai Ashrith Kumar (B171289), Burra Manideep (B171396) , Annaldas Nikhil (B171529)** has been carried out under my supervision and that this work has not been submitted elsewhere for a degree.

Signature of the Supervisor

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May, 2023

Declaration

We declare that this written submission represents our ideas in our own words and where other's ideas or words have been included, We have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke panel action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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Approval Sheet

This project report entitled "**Experimental studies on PLA - Jute sandwich composites**", by **Gajwelli Ashrith (B171289), Burra Manideep (B171396) , Annaldas Nikhil (B171529)**, is approved for the degree of Bachelor of Technology in Mechanical Engineering.

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ABSTRACT

Honeycomb structures had found widespread applications in various fields, including architecture, transportation, mechanical engineering, chemical engineering, nano fabrication and recently bio medicine. Honeycomb structure has significant mechanical and absorption properties and widely used in various industrial fields, especially in impact scenes that need to absorb a large amount of energy. This work focuses on the manufacturing and characterization of highly environmentally friendly lightweight sandwich structures based on Poly lactic Acid (PLA) honeycomb cores and jute fabric laminate skins or facings.

This report presents the fabrication and mechanical characterization of PLA-Jute honeycomb sandwich panels. The PLA honeycomb structure was produced using 3D printing technology, and jute fibers were used as the face sheets of the sandwich panel. The jute fibers were bonded to the PLA honeycomb using an epoxy and hardener mixture in a 10:1 ratio. The mechanical properties of the sandwich panel were evaluated through 3-point bending, double lap shear, and drop impact tests. The results of the tests indicate that the PLA-Jute honeycomb sandwich panel exhibits good mechanical performance, making it a potential candidate for use in various engineering applications.

Keywords: PLA honeycomb structure, natural fiber, sandwich panel, 3-point bending,double lap shear strength and Drop impact test.

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CHAPTER 1

INTRODUCTION

The demand for low-weight and high-rigidity materials in high-performance sectors has given way to the development of composite materials. Among others, sandwich structures deserve special attention due to their use in a wide variety of sectors, which include conventional packaging with corrugated craft cores, and high-performance applications in aerospace, automotive, aeronautics, lightweight civil infrastructure, and so on. Sandwich panels are composed of a lightweight core and two (top and bottom) skins. The most common cores in sandwich panels are processed woods (i.e., balsa wood), thermoplastic and thermosetting polymer foams, and honeycomb structures. Honeycombs can be obtained from a wide variety of materials such as metals (steel, aluminum, titanium) and thermoplastic polymers such as polypropylene or aramid. The skins or faces are usually made of lightweight and stiff materials such as aluminum or fiber-reinforced polymers (FRP) . The most critical part in a sandwich structure is the skin–core interface, which plays a key role in load transfer. To enhance this interface, adhesives, fiber mats, or thin sheets are used. The final composition of a sandwich structure depends on the target application. For example, polymer foam cores are generally used in car flooring, boat parts, as well as turbine blades, as they have good rigidity, high strength and resistance to fatigue and temperature.

Despite the fact that composite panels usually combine the optimum materials for the core, bonding, and skins, some composite panels are manufactured entirely from one material such as lightweight composite panels consisting of PP skins and PP honeycombs. These composite panels have become very popular in the packaging and construction industries .

The use of high-performance composite laminates with glass fiber (GF) and carbon fiber (CF) has widened the performance of sandwich structures for applications requiring high strength at low weight, because unlike metallic materials, they offer a better strength-to-weight ratio. This work aims to develop highly environmentally friendly sandwich structures for technical applications.

Natural fibre appears to be a viable renewable and biodegradable alternative to most synthetic fibres, such as glass fibers. In composite engineering, it is commonly referred to as wood and agro-based fibre, stem, and leaf fibres. Natural fibres have a number of advantages over glass or carbon fibre, including the fact that they are renewable, low cost, lightweight, and have high specific mechanical properties. Non-bearing applications due to their lower strength compared to synthetic fibre reinforced polymer composites, despite the interest and environmental appeal of natural fibre reinforced polymer composites. The strength and stiffness limits of bio composites can be overcome by strategically placing fibres in certain regions for optimal strength presentation. In comparison to their synthetic counterparts, bio-based sandwich panels can be utilized for interior walls, doors and furniture in architectural applications with significantly less environmental impact.

CHAPTER 2

LITERATURE REVIEW

[1] The paper "**Manufacturing and characteristics of highly environmentally friendly sandwich composites from polylactide cores and Flax-polylactide faces"** by **Diego Lascano** presents a study on the development of sandwich composites using polylactide (PLA) cores and flax-polylactide faces, with the aim of producing highly environmentally friendly materials. The study includes the manufacturing process, which involves using a vacuum-assisted resin infusion technique, and investigates the mechanical properties of the composites. The results show that the sandwich composites have good mechanical properties and are highly environmentally friendly due to the use of PLA and flax, which are renewable and biodegradable materials. The study concludes that the developed sandwich composites have potential for use in various applications, including the automotive and construction industries, due to their sustainable and eco-friendly nature.

[2] The paper **"Fabrication and mechanical behaviors of an all composite sandwich structure with a hexagon honeycomb core based on the tailor - folding approach"** by **Xingyu Wei et al** (2019) is a study on the use of continuous fibers in composite sandwich structures can help to reduce stress concentration and improve the overall mechanical behavior of the structure. In the case of a carbon fiber reinforced polymer (CFRP) honeycomb core, compressive buckling and crushing are the dominant failure modes under a compression loading condition. This is because the honeycomb core is a relatively thin and fragile material, and it is susceptible to deformation and collapse when subjected to compressive loads. By utilizing a tailor-folding approach in the fabrication of the sandwich structure, it is possible to achieve a more uniform and efficient load transfer between the face sheets and the core, which can help to mitigate the risk of compressive failure. Overall, the combination of continuous fibers and a hexagon honeycomb core, along with tailored folding techniques, can result in a strong and lightweight composite sandwich structure with improved mechanical properties.

[3] In the paper "**A numerical study on the impact behaviour of natural fibers made honeycomb cores**," **Riccio et al**. (2018) explore the impact behavior of honeycomb cores made from natural fibers. Honeycomb cores are commonly used in sandwich panels due to their lightweight nature and ability to control functional capabilities such as vibration control, heat dissipation, and energy absorption. The use of natural fibers in the honeycomb cores provides an additional benefit of being environmentally friendly and biodegradable. The numerical study conducted by Riccio et al. provides insight into the impact resistance of these honeycomb cores, which is important for applications where the sandwich panels are subjected to dynamic loading conditions. The study highlights the potential of natural fiber honeycomb cores as a viable alternative to synthetic materials for use in lightweight sandwich structures, with potential applications in a range of industries, including aerospace, automotive, and construction.

[4] In the paper, "**Experimental and numerical study on honeycomb sandwich panels under bending and in-panel compression**," **Sun et al.**(2017) investigate the mechanical behavior of honeycomb sandwich panels under different loading conditions. Sandwich panels are commonly used in various industries due to their lightweight and high strength properties, and honeycomb cores are frequently employed in the construction of sandwich panels. The authors conducted experimental and numerical analyses to determine the response of honeycomb sandwich panels subjected to bending and in-panel compression loads. The study found that the mechanical behavior of honeycomb sandwich panels is influenced by the geometry of the honeycomb core, the thickness of the face sheets, and the loading conditions. The experimental and numerical results were found to be in good agreement, providing insight into the failure mechanisms and deformation behavior of honeycomb sandwich panels under different loading conditions. The findings of this study are relevant to the design and optimization of honeycomb sandwich panels for a range of applications, including aerospace, automotive, and construction industries.

[5] In the paper, "**Fabrication and testing of Hybrid composites using jute and mango endover**," **Akshay Kumar and Mohan Kumar**(2017) they investigate the use of jute and mango endover fibers in the fabrication of hybrid composites. The study explores the mechanical properties of the hybrid composites and the potential of jute and mango endover fibers as reinforcement materials. Epoxy resin (LY-556) and hardener (HY-951) were used as an adhesive layer to bind the jute and mango endover fibers together. The results of the study showed that the hybrid composites exhibited improved mechanical properties, including increased tensile strength, flexural strength, and impact strength, compared to the individual materials. The study highlights the potential of jute and mango endover fibers as low-cost and eco-friendly alternatives to synthetic fibers for the production of composite materials. The findings of this study are relevant to the development of sustainable and cost-effective composite materials for a range of industrial applications, including automotive, construction, and aerospace.

[6] "**Investigation of Mechanical Properties of PLA/Jute Composite Sandwich Panels"** by **Seyed Saeed Tabatabaei et al**. (2018)
This study investigated the mechanical properties of PLA/jute composite sandwich panels. The researchers found that increasing the jute content in the composite resulted in an increase in flexural strength and flexural modulus, but a decrease in impact strength. They also found that increasing the core density of the sandwich panel increased the flexural and impact strength, but decreased the flexural modulus. Overall, the study concluded that PLA/jute composite sandwich panels have potential as lightweight and environmentally friendly structural materials.

[7] "**Characterization of PLA-Jute Fabric Composites for Structural Applications"** by **Jayaraman Srinivasan et al.** (2019)
This study characterized the mechanical properties of PLA/jute fabric composites for structural applications. The researchers found that increasing the jute content in the composite resulted in an increase in tensile and flexural strength, but a decrease in ductility. They also found that adding a small amount of maleic anhydride grafted polyethylene improved the interfacial adhesion between the PLA matrix and jute fibers, resulting in improved mechanical properties. The study concluded that PLA/jute fabric composites have potential as low-cost, lightweight, and eco-friendly materials for structural applications.

[8] “**Effect of Fiber Surface Treatment on the Mechanical Properties of PLA-Jute Biocomposites”** by **Pooja R. and Ramesh S.** (2019)
This study investigated the effect of fiber surface treatment on the mechanical properties of PLA/jute biocomposites. The researchers found that treating the jute fibers with alkali improved the interfacial adhesion between the fibers and the PLA matrix, resulting in improved tensile and flexural strength. They also found that adding a small amount of maleic anhydride grafted polyethylene further improved the mechanical properties. The study concluded that fiber surface treatment is an effective way to improve the mechanical properties of PLA/jute biocomposites.

[9] “**Development of a New Generation of PLA/Jute Sandwich Panel for Use in Automotive Applications”** by **Juan Manuel Villarreal-Gómez et al.** (2020)
This study developed a new generation of PLA/jute sandwich panel for use in automotive applications. The researchers found that using a woven jute fabric as the core of the sandwich panel resulted in improved mechanical properties compared to using a non-woven fabric. They also found that adding a small amount of maleic anhydride grafted polyethylene improved the interfacial adhesion between the PLA matrix and jute fibers, resulting in further improved mechanical properties. The study concluded that the developed PLA/jute sandwich panel has potential for use in automotive applications due to its lightweight, low cost, and eco-friendly properties.

[10] “**Manufacturing and Characterization of Biodegradable PLA/Jute Composite Laminates”** by **Nandakishore Rajagopalan et al.** (2020)
This study manufactured and characterized biodegradable PLA/jute composite laminates. The researchers found that increasing the jute content in the composite resulted in an increase in tensile strength and Young's modulus, but a decrease in elongation at break. They also found that adding a small amount of maleic anhydride grafted polyethylene improved the interfacial adhesion between the PLA matrix and jute fibers, resulting in improved mechanical properties. The study concluded that PLA/jute composite laminates have potential as eco-friendly materials for various applications, including packaging, furniture, and construction.

CHAPTER 3
MATERIALS

A composite material is one that is made up of at least two elements that interact together to provide material qualities that are distinct from those of the individual constituents. In practice, most composites are made up of matrix and some form of reinforcement, which is added to boost the matrix's strength and stiffness.The materials which have been used for the fabrication of honeycomb sandwich panel in the present work are reinforcing fiber(JUTE), matrix(EPOXY RESIN), core(PLA). The properties of the resin, fibre and PLA are discussed below.

3.1 JUTE

Jute fibers are composed primarily of the plant materials cellulose, lignin, and pectin. Both the fiber and the plant from which it comes are commonly called jute. It belongs to the genus Corchorus in the basswood family, Tiliaceae. It is one of the cheapest natural fibers. Jute is a best fiber used for sacking, burlap, and twine as a backing material for tufted carpets. It is a long, soft, shiny fiber that can be spun into coarse, strong threads.

Jute fibre is 100% bio-degradable and recyclable and thus environmentally friendly. Jute is a natural fibre with golden and silky shine and hence called The Golden Fibre. Jute is the cheapest vegetable fiber procured from the bast or skin of the plant's stem. It is the second most important vegetable fiber after cotton, in terms of usage, global consumption, production, and availability. It has high tensile strength, low extensibility, and ensures better breath-ability of fabrics.Therefore, jute is very suitable in agricultural commodity bulk packaging.

Physical Properties:
Jute fiber is a long, soft, shiny, and lustrous fiber that is primarily composed of cellulose. It is a natural fiber that has a golden-brown color and a slightly coarse texture. The fiber is about 1 to 4 meters long and has a diameter of around 20-30 microns.

Chemical Properties:
Jute fiber is composed of about 60-70% cellulose, along with lignin, hemicellulose, and pectin. It has a pH value of about 6-7.5 and is highly resistant to alkalis and acids. Jute fiber is also resistant to UV rays and is highly biodegradable.

Mechanical Properties:
Jute fiber is known for its high tensile strength, which ranges from 3.5 to 5.5 g/denier. It is also highly elastic and can stretch up to 20% of its original length. Jute fiber has a low coefficient of thermal expansion, which means that it is not easily affected by changes in temperature.

Moisture Absorption:
Jute fiber has a high moisture absorption capacity, which makes it ideal for use in products like rugs and mats. It can absorb up to 15% of its weight in moisture without becoming damp or losing its strength.

Thermal Properties:
Jute fiber has a low thermal conductivity, which means that it is a good insulator of heat. It also has a high ignition temperature of around 250°C, which makes it less prone to catching fire.

Durability:
Jute fiber is highly durable and can last for a long time without losing its strength or quality. It is resistant to abrasion and is not easily damaged by exposure to sunlight or other environmental factors.

In conclusion, jute fiber is a highly versatile and eco-friendly natural fiber that has a wide range of applications in various industries. Its unique properties make it ideal for use in products like bags, rugs, and clothing, and its low cost makes it an affordable alternative to synthetic fibers.

Properties	Values
Specific Gravity	1.3
Tensile Strength (Mpa)	393
Modulus (Gpa)	55
Specific Modulus	38
Density	1.3

Table 3.1: Properties of Jute

3.2 EPOXY RESIN

Epoxy resin is widely used in industrial application because of their high strength and mechanical adhesiveness characteristic. It is also good solvent and have good chemical resistant over a wide range of temperature. LY–556 is used as matrix in the present investigation.

The epoxy resins do not soften at a specific temperature but appear to undergo a gradual and imperceptible change. The curing of epoxy resins is an exothermic process, resulting in the production of limited-size molecules, having molecular weights of a few thousands. Epoxy resins shrink on curing. Thus density increases. The temperature, location, and magnitude of these transitions directly influence the thermo-mechanical properties of the resins.

Chemical resistance:
LY-556 epoxy resin is highly resistant to chemicals such as acids, alkalis, and solvents. This makes it ideal for use in environments where it may come into contact with harsh chemicals.

Strength and durability:
Epoxy resin is known for its exceptional strength and durability. LY-556 epoxy resin is no exception and is able to withstand significant impact and stress without cracking or breaking.

Low shrinkage:
LY-556 epoxy resin has a low shrinkage rate, which means that it will maintain its shape and size over time, even when exposed to temperature changes or other environmental factors.

Adhesion:
LY-556 epoxy resin has excellent adhesion to a variety of surfaces, including metals, ceramics, and plastics. This makes it ideal for use in bonding applications.

Heat resistance:
LY-556 epoxy resin has a high heat resistance, which means that it can withstand exposure to high temperatures without melting or degrading.

Properties	**Values**
Density (gm/cm^3)	1.15 - 1.20
Viscosity (Mpa s)	50-100
Flash Point (°C)	>200
Storage Temperature (°C)	2-40

Table 3.2: Properties of Resin (LY-556)

3.3 HARDNER

HY-951 hardener is used as curing agent. The weight percentage of hardener used in the present investigation is in the ratio of 10:1. Araldite HY-951 is an unfilled casting resin system that is renowned for its excellent properties and possibility of a high filler addition. HY-951 low viscosity, aliphatic amine hardener for epoxies that offers incredible mechanical strength that cures at room temperature.HY-951 is also well known for its excellent resistance to chemical and atmospheric degradation.HY-951 is useful for encapsulating or potting of low voltage electric components using the vacuum casting method.

Curing time:
HY-951 hardener is a fast-curing hardener, which means that it will cure quickly once it is mixed with LY-556 epoxy resin. This makes it ideal for use in applications where a quick turnaround time is required.

Chemical resistance:
Like LY-556 epoxy resin, HY-951 hardener is highly resistant to chemicals such as acids, alkalis, and solvents.

Impact resistance:
HY-951 hardener is highly impact-resistant, which means that it will help to enhance the overall strength and durability of the epoxy resin once it is cured.

Heat resistance:
HY-951 hardener has a high heat resistance, which means that it can withstand exposure to high temperatures without melting or degrading.

Versatility:
HY-951 hardener is compatible with a variety of different epoxy resin formulations, which makes it a versatile choice for a wide range of applications.

Properties	Values
Density (gm/cm^3)	0.95
Viscosity (Mpa s)	10-20
Flash Point (°C)	110
Appearance	Clear Liquid

Table 3.3: Properties of hardener (HY-951)

3.4 PLA(POLYLACTIC ACID)

Polylactic acid (PLA) is a new kind of bio-based and renewable biodegradable material, which is made from starch proposed by renewable plant resources (such as corn and cassava). Starch raw materials obtained glucose through sacharification, and then fermentation of glucose and certain strains to produce high purity lactic acid, and then through chemical synthesis method to synthesize polylactic acid of a certain molecular weight. It has good biodegradability. After use, it can be completely degraded by microorganisms in nature under specific conditions, and finally produce carbon dioxide and water without polluting the environment, which is very beneficial to environmental protection.

PLA offers interesting properties such as biodegradability (actually, disintegration in controlled compost soil), bio-compatibility, good tensile strength, good stiffness, and shape memory. In addition, it can be manufactured by conventional processing techniques such as injection molding, extrusion, hot compression molding, and 3D printing. Due to the feasibility of 3D printer, we manufacturing the core part in 3D printer.

For these reasons, the use of PLA has remarkably grown in the last decade, mainly in the packaging industry and bio medicine. The use of PLA can

positively contribute to develop a new series of environmentally friendly composite materials or green composites. In fact, PLA is currently used as matrix in wood plastic composites with natural fibers and/or lignocellulosic fillers, and it is increasingly used in several components of composite sandwiches such as 3D-printed honeycombs, adhesion nonwovens, and skins on different composite panel configurations.

Mechanical properties:
PLA has good mechanical properties such as tensile strength, flexural strength, and modulus of elasticity. Its tensile strength is around 50-70 MPa and flexural strength is around 80-100 MPa, which makes it suitable for a variety of applications. Its modulus of elasticity is around 3 GPa, which is relatively low compared to other engineering plastics such as ABS or nylon.

Thermal properties:
PLA has a relatively low glass transition temperature (Tg) of around 60-65°C, which means that it becomes soft and pliable at relatively low temperatures. The melting temperature (Tm) of PLA is around 170-180°C, which is relatively low compared to other thermoplastics such as PET or nylon. This makes PLA more suitable for low-temperature applications.

Chemical properties:
PLA is resistant to many common solvents, including water, ethanol, and acetone. However, it is susceptible to hydrolysis and can break down in the presence of water, particularly at high temperatures or high humidity. PLA can also be degraded by some microorganisms, making it a suitable material for biodegradable applications.

Optical properties:
PLA is a transparent material that can be made into a variety of colors. It has a relatively low refractive index, which means that it has a low level of light dispersion. This makes it suitable for use in optical applications such as lenses or displays.

Electrical properties:
PLA is an insulator and has a relatively low dielectric constant, which means that it does not conduct electricity well. This property makes it suitable for electrical insulation applications.

Processing properties:
PLA can be processed using various methods such as injection molding, extrusion, or blow molding. It is also compatible with 3D printing technology, making it a popular material for prototyping and small-scale production.

Properties	**Values**
Tensile Strength (MPa)	53
Young’s Modulus	2.4
Density (gm/cm^3)	1.21-1.25
Melting Temperature (℃)	210

Table 3.4: Properties of PLA(Polylactic acid)

CHAPTER 4

METHODOLOGY

4.1 MODELLING

SolidWorks is a computer-aided design (CAD) software that is used for creating 3D models of mechanical parts and assemblies. In this case, SolidWorks was used to create a 3D model of a honeycomb sandwich panel.

The first step in creating the model is to draw a single cell of polygon shape with a 10mm diameter. The polygon shape was chosen because it closely resembles the shape of a hexagonal cell. The spacing between adjacent cells was set to 4mm, which is the distance between the center of one cell to the center of the adjacent cell.

Once the single cell was created, the linear sketch pattern tool was used to create multiple cells and form a 2D honeycomb structure. A rectangle with the dimensions of 150mm x 100mm was created with the center point of the single cell. The extrude boss tool was used to fill the gap between the cells with a thickness of 20mm, which gives a 3D model of the honeycomb structure.

The honeycomb structure that was created using SolidWorks can be analyzed further using various tools and features available in the software. For example, the software can be used to simulate the structural behavior of the honeycomb sandwich panel under different loads and conditions. This information can be used to optimize the design and improve the performance of the honeycomb sandwich panel.

In summary, SolidWorks was used to create a 3D model of a honeycomb sandwich panel. The model consists of a honeycomb core that is sandwiched between two face sheets or skins. The honeycomb core is made up of hexagonal cells that are arranged in a regular pattern, and the model was created by drawing a single cell and using the linear sketch pattern tool to create a 2D honeycomb structure. The extrude boss tool was then used to fill the gap between the cells and create a 3D model of the honeycomb structure.

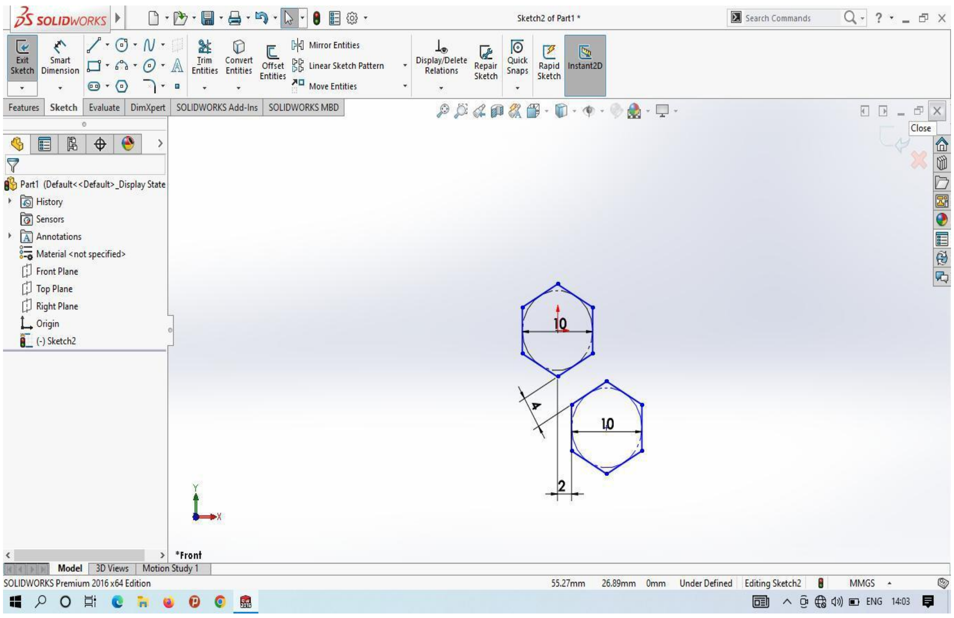

Fig 4.1 : Honeycomb core cell dimensions

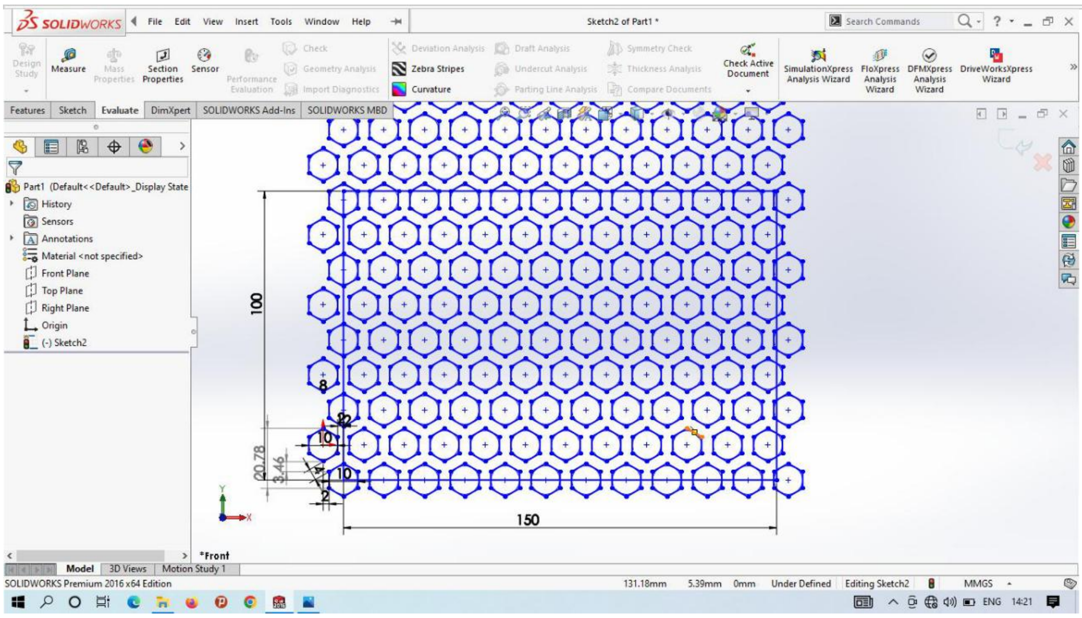

Fig 4.2 : Linear sketch pattern of multiple cells

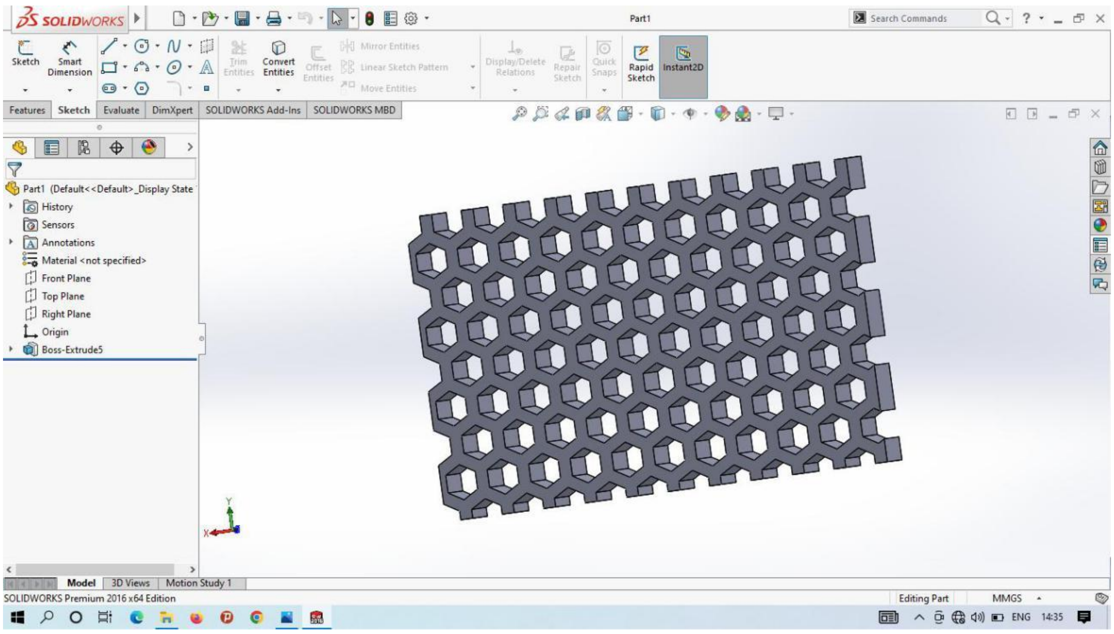

Fig 4.3 : 3D model of honeycomb core structure

4.2 PRINTING OF HONEYCOMB CORE IN 3D PRINTER

3D printing or additive manufacturing is the construction of a three-dimensional object from a CAD model or a digital 3D model. It can be done in a variety of processes in which material is deposited, joined or solidified under computer control, with material being added together (such as plastics, liquids or powder grains being fused), typically layer by layer.

The 3D model core part made in solidworks is used for printing of it in 3D printer using pla material. The modelled part is opened in simplify 3D software and converted into G-codes as input for the 3D printer. Then select the part and choose type of medium mode and go for printing. Insert the pla material into the printer and start the process of printing the object.

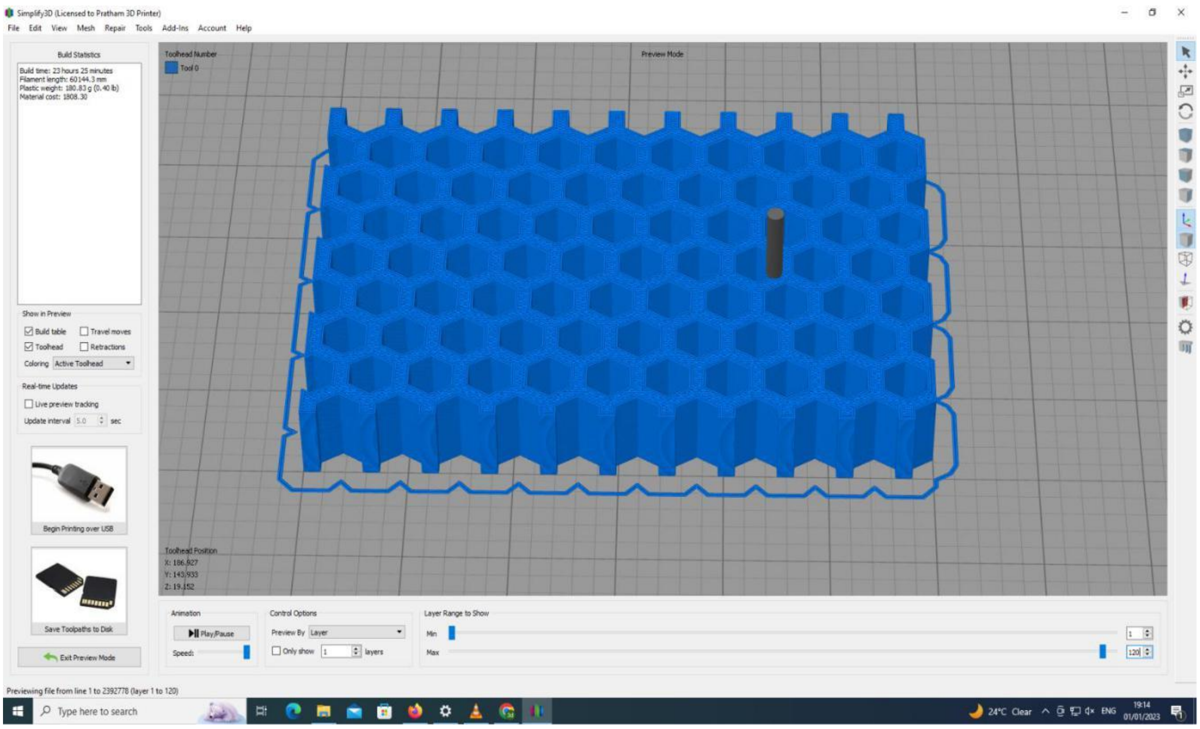

Fig 4.4: Honeycomb core in simplify3D software

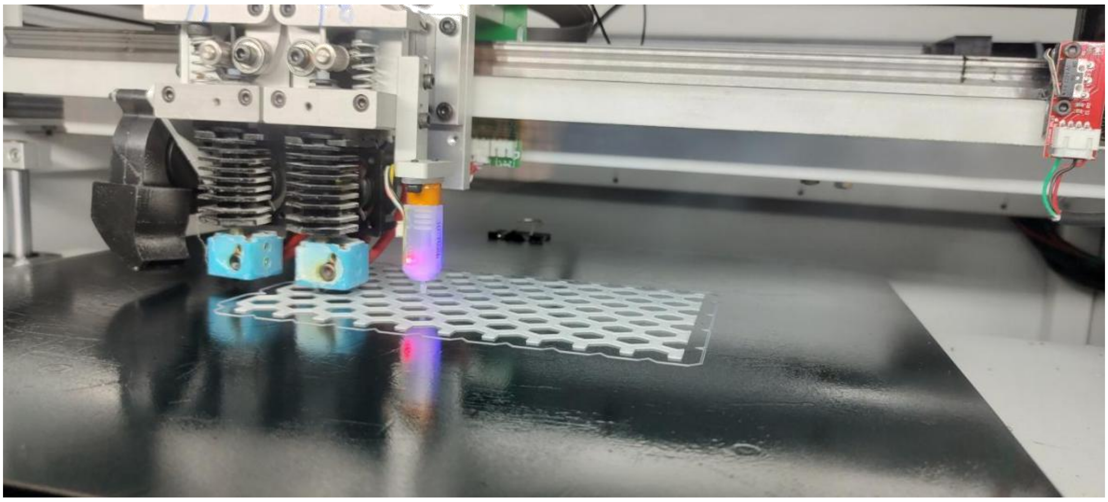

Fig 4.5:Printing in 3D printer

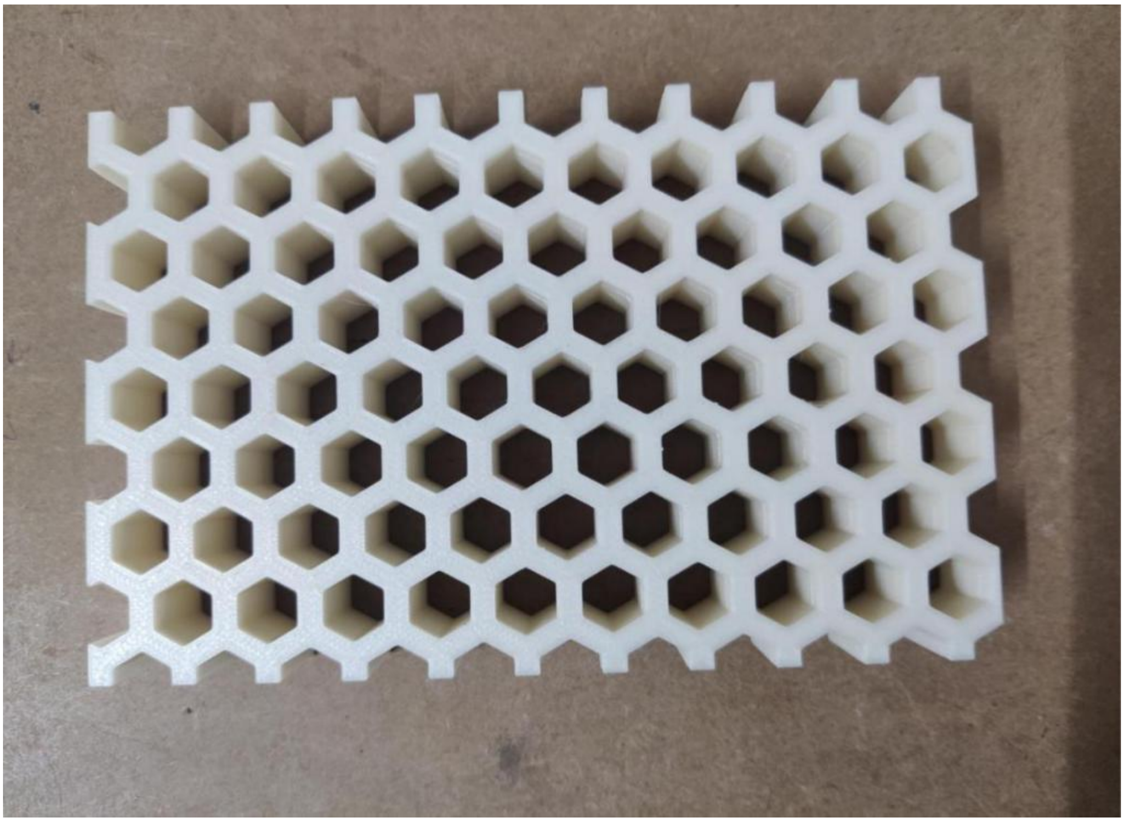

Fig 4.6 : PLA honeycomb core dimensions of 150mm*100mm*20mm

4.3 HAND LAY - UP METHOD

The hand lay-up method is a common manufacturing process used for producing composite materials, including PLA jute sandwich panels. Here's how the hand lay-up method can be used to produce a PLA jute sandwich panel:

1. Prepare the mold: The first step is to prepare the mold by applying a release agent to prevent the composite material from sticking to the mold.

2. Prepare the PLA resin: Mix the PLA resin with a hardener in the correct ratio, as specified by the manufacturer. The hardener will initiate the curing process of the PLA resin.

3. Prepare the jute fabric: Cut the jute fabric to the correct size and shape to fit the mold.

4. Lay up the jute fabric: Place the jute fabric in the mold, ensuring it is positioned correctly and smoothly.

5. Apply the PLA resin: Using a brush or roller, apply the PLA resin to the jute fabric. Make sure that the resin is applied evenly and thoroughly saturates the jute fabric.

Fig 4.7: Preparation of sandwich panel using hand lay-up method

6. Repeat the process: Repeat the process of layering the jute fabric and applying the PLA resin until the desired thickness is achieved. It is typical for PLA jute sandwich panels to have multiple layers of jute fabric and PLA resin.

7. Add the core material: Once the desired number of jute fabric and resin layers have been added, insert the core material into the mold. The core material can be any lightweight material that adds strength and stiffness to the sandwich panel.

8. Apply pressure: Apply pressure to the sandwich panel using a vacuum bagging process, which involves placing the panel in a vacuum bag and using a vacuum pump to remove the air. This compresses the panel and removes any excess resin.

9. Cure the panel: Allow the panel to cure for the specified time as per the manufacturer's instructions. This typically involves leaving the panel in the mold at room temperature for a certain period.

Fig 4.8: Curing of the specimen

10. Demould the panel: Once cured, remove the panel from the mold and trim any excess material.

11. Finish the panel: Sand and finish the panel to achieve the desired appearance and dimensions.

Overall, the hand lay-up method is a cost-effective and relatively simple process for producing PLA jute sandwich panels with a variety of thicknesses and properties.

4.4 SPICEMEN TESTING

4.4.1 THREE POINT BENDING TEST

For finding the bending properties of composite specimen by Zwick Roell Z100 (test standard ASTM C393, Bench model 3-point bending testing machine, capacity: 10 KN) was used. specimens with varying wt% were tested with 10mm/min test specimen

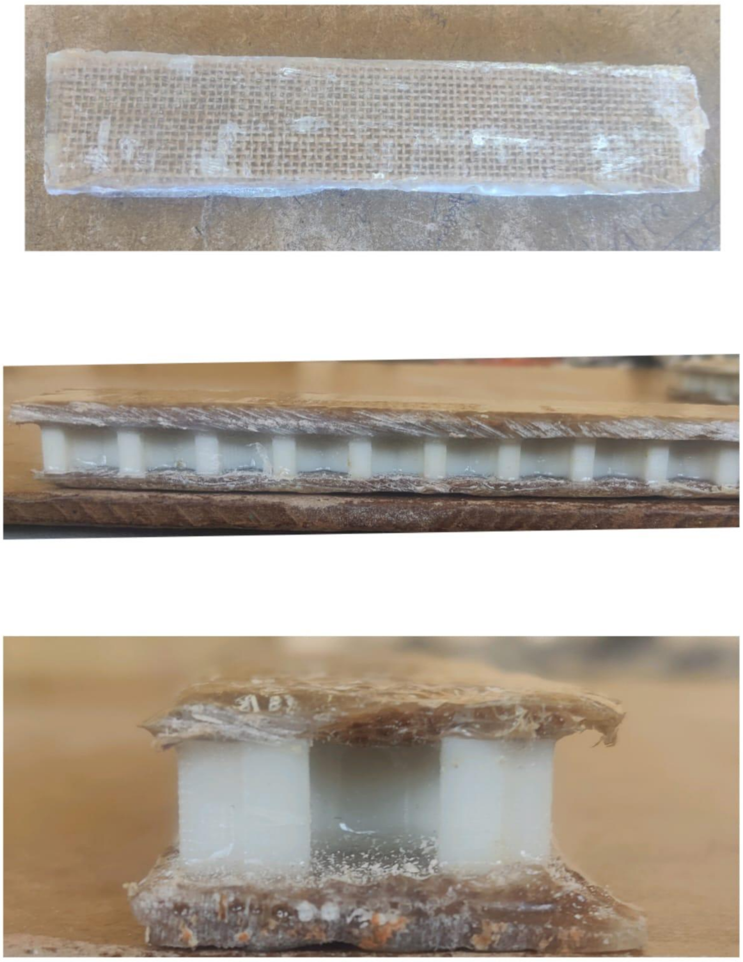

Fig 4.9: Specimen for 3-point bending test

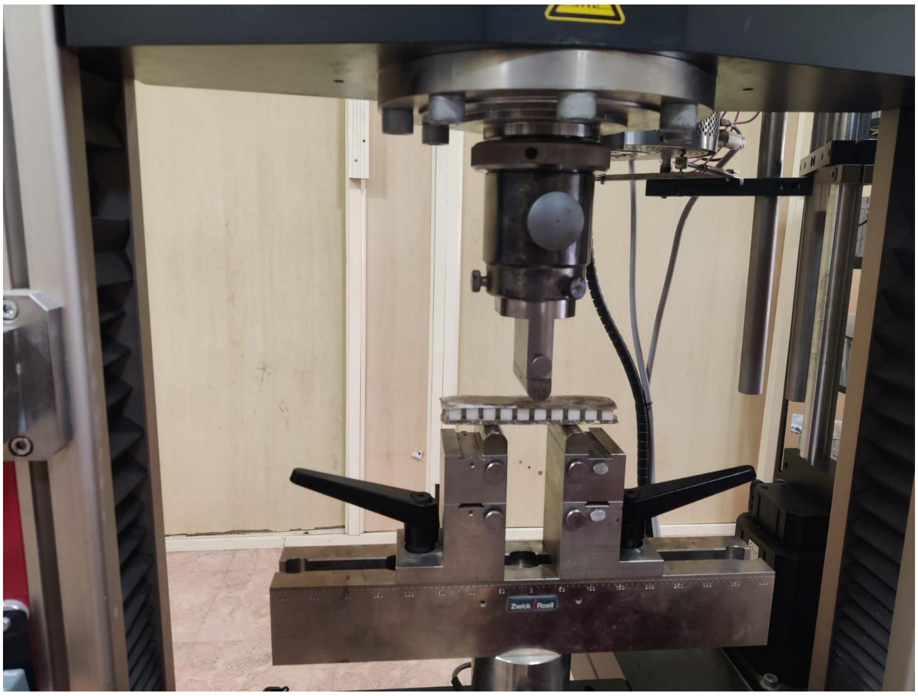

Fig 4.10: Testing of specimen on Zwick Roell Z100

4.4.2 DOUBLE LAP SHEAR TEST

The honeycomb sandwich panel is field according to the ASTM D3528. The length and width of the specimen for the double lap shear test is 253.2mm and 25.4mm.

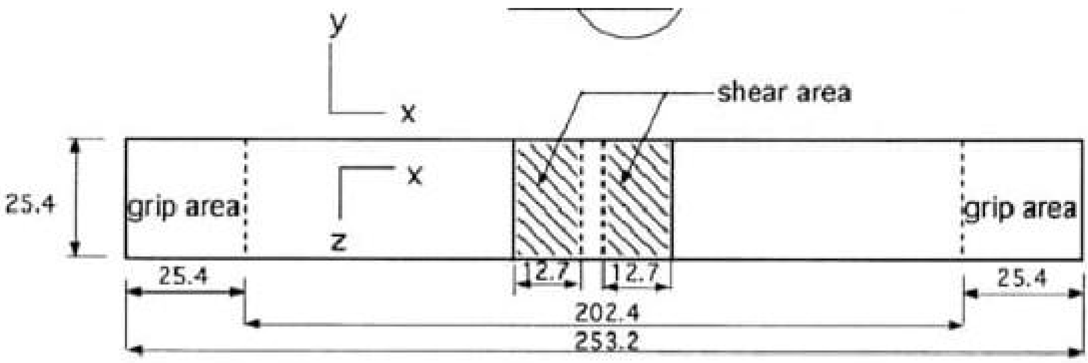

Fig 4.11: Specimen Dimension for Double Lap Shear Test

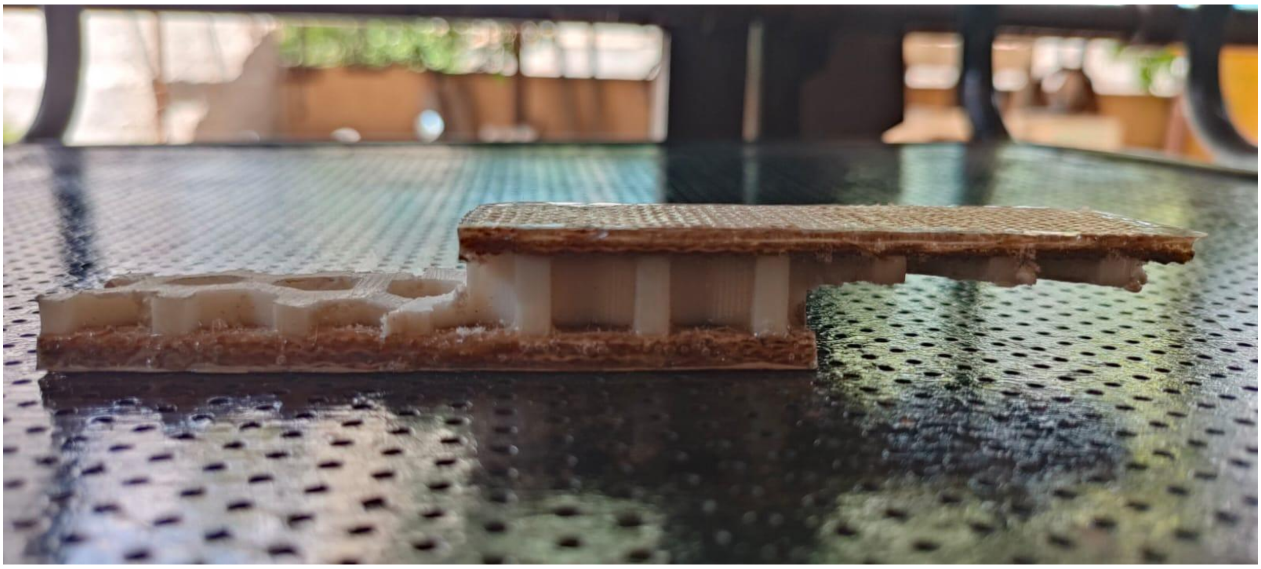

Fig 4.12: Specimen for Double Lap Shear Test

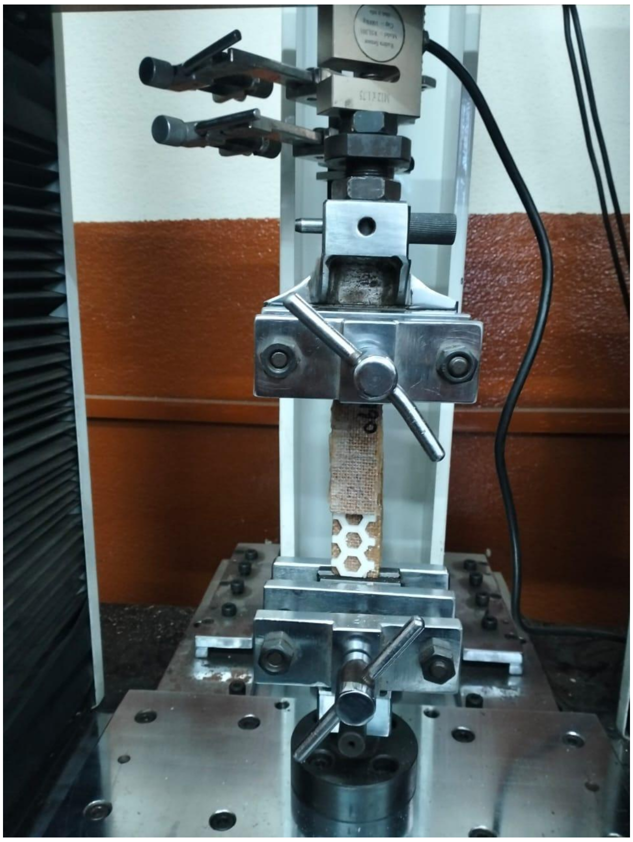

Fig 4.13: Testing of Specimen on MCS / UTE - 1T Machine

4.4.3 DROP WEIGHT IMPACT TEST

The drop weight impact test is a commonly used method to evaluate the impact resistance of PLA-Jute honeycomb sandwich panels by measuring the energy absorbed during impact.

The honeycomb sandwich panel is field according to the ASTM D7136. The length and width of the specimen is 150mm and 100mm.

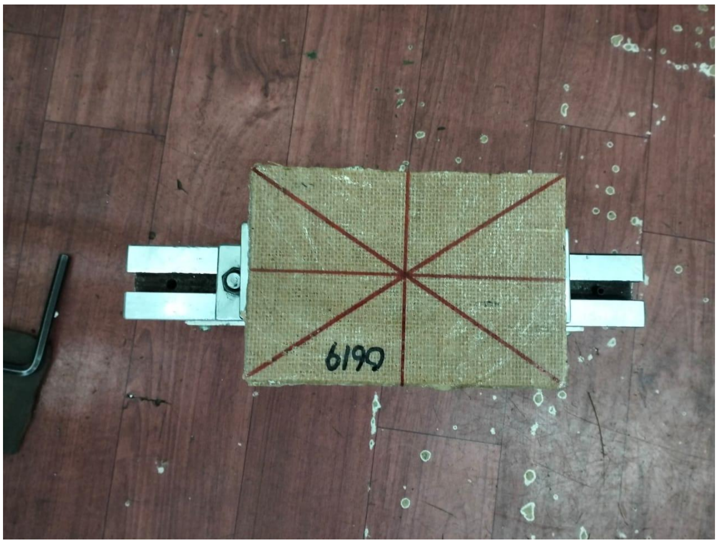

Fig 4.14: Specimen for Drop Weight Impact Test

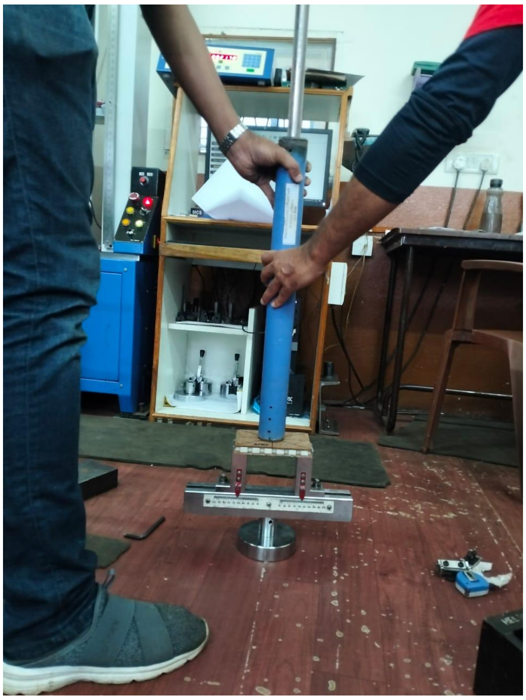

Fig 4.15: Manual Drop Weight Testing of Specimen

CHAPTER 5

RESULT AND DISCUSSION

5.1 THREE POINT BENDING TEST RESULT

The response of the specimen to three point bending test is shown in fig 16 and fig 17.

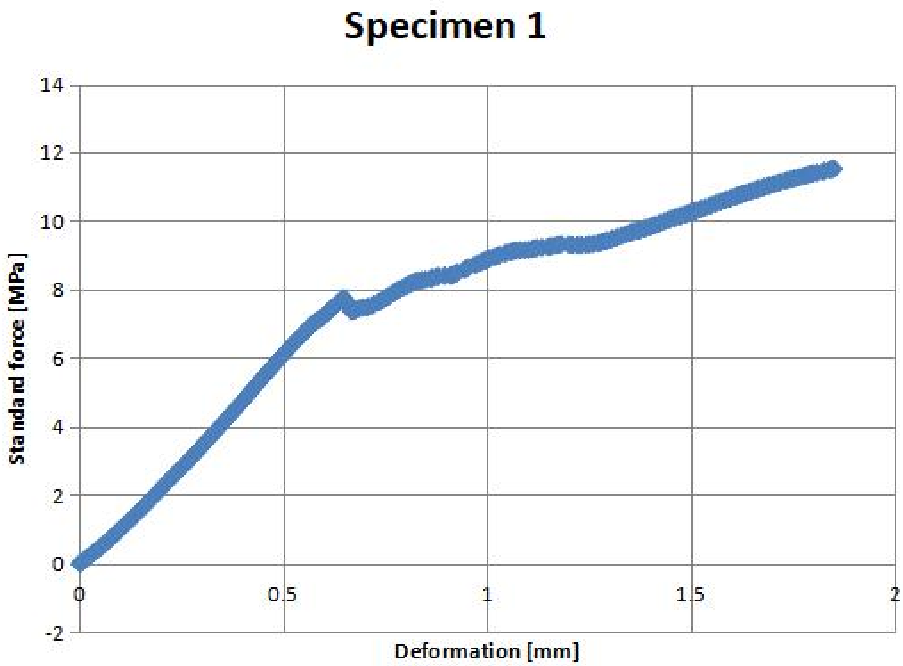

Fig 5.1: Three point bending test graph of specimen 1

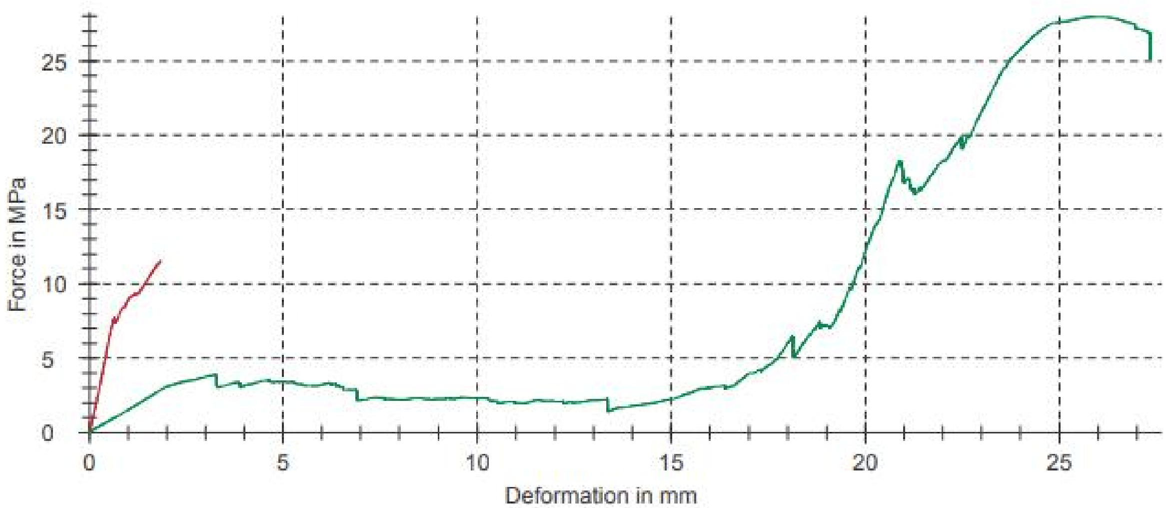

Fig 5.2: Three point bending test graph of specimen 1&2

S.No	Ultimate load(N)	Core shear stress, (MPa)	Facing bending stress, (MPa)	dL at F_{max} (mm)
1	1110	1.64	23.49	1.9
2	2700	1.64	23.49	26.0

Table 5.1: Flexural(three point bending) properties of specimens

During three point bending test the bending of the material was observed. With the increase in the applied load, the core part tends to break in the sandwich panel. After the peak strength a region with a gradually drop occupied in the deflection after 1.9mm under the maximum load of 1110N.

5.2 DROP WEIGHT IMPACT TEST RESULTS

When the sample was subjected to an impact load 23.4J by the drop weight impact test, it was observed that the diameter of indentation on the sample was 16.86mm.

S.No	**Identification**	**Indenter Diameter**	**Energy Applied**	**Observed Diameter**
01	Specimen	20mm	23.4 Joules	16.86mm

Table 5.2: Result for drop weight impact test

5.3 DOUBLE LAP SHEAR TEST RESULTS

The test is typically used to evaluate the strength and bond quality of a sandwich panel, as it can provide information on the material's resistance to shear stress and deformation. The test results can be used to determine the ultimate shear strength of the panel, the maximum load that it can withstand before failure, and the deformation behavior of the panel under different loading conditions.

5.3.1 DOUBLE LAP SHEAR IN TENSILE LOADING

Input Data		**Results**	
Specimen Width	28.15mm	Ultimate Load	1295 N
Specimen Thickness	10mm	Ultimate Strength	4.6 N/mm^2
Area	281.50mm^2	% Elongation	ꝏ

Table 5.3: Test results of double lap shear in tensile loading

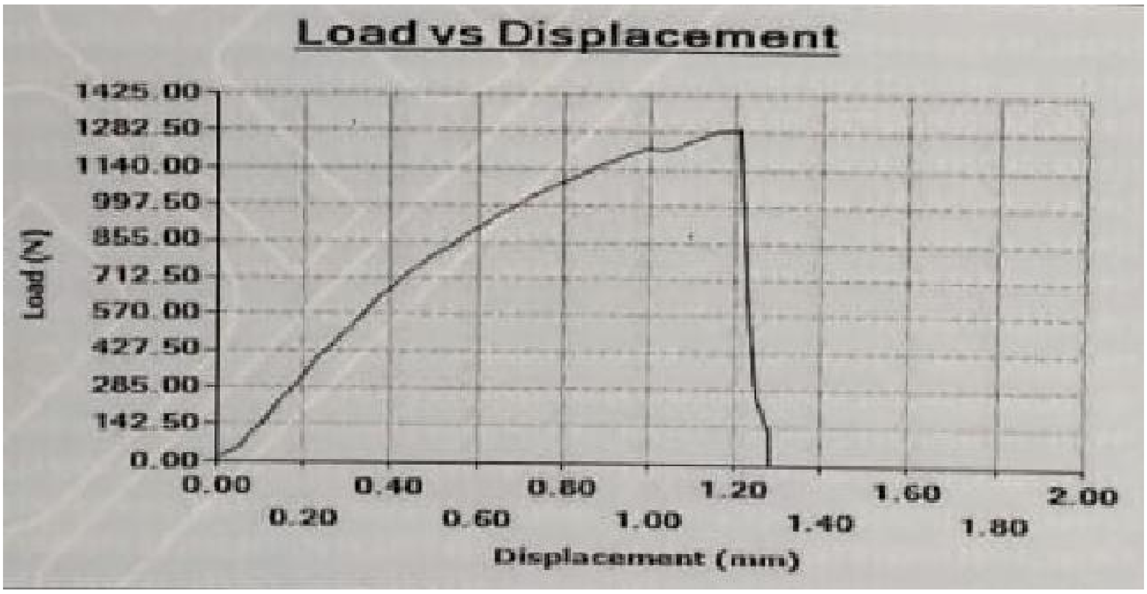

Fig 5.3: Double Lap Shear in Tensile Loading

By the load vs displacement graph the Maximum Load is 1295 Newton, the Displacement is 1.27mm, and the Maximum Shear Stress of the Specimen is 4.6 MPa

5.3.2 DOUBLE LAP SHEAR IN COMPRESSION LOADING

Input Data		**Results**	
Specimen Width	28.15mm	Ultimate Compressive Load	297 N
Specimen Thickness	10mm	Ultimate Compressive Strength	1.06 N/mm^2
Area	281.50mm^2		

Table 5.4: Test results for double lap shear in compression loading

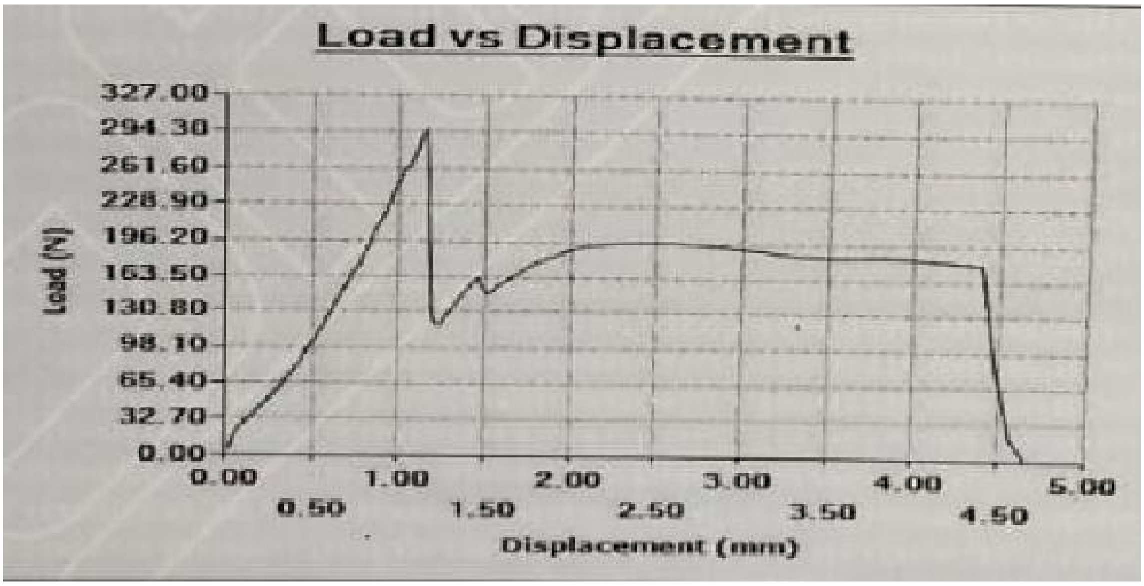

Fig 5.4 : Double Lap Shear in Compression Loading

By the load vs displacement graph the Maximum Load is 297 N, the Displacement is 4.7 mm, and the Maximum Shear Stress of the Specimen is 1.05 MPa.

CHAPTER 6

CONCLUSION

The 3-point bending, double lap shear, and drop impact tests showed that the PLA-Jute honeycomb sandwich panel created for this study had good mechanical properties. The Bending stress was discovered to be 23.49 MPa. The maximum tensile and compressive loads in double lap shear test were determined to be 4.6 MPa and 1.06 MPa, respectively, while the drop impact test's energy absorption was 23.4 J. These findings point to the PLA-Jute honeycomb sandwich panel as a potentially useful material for a range of engineering applications, particularly when robust and lightweight materials are needed. Since natural fibers are renewable and biodegradable, using them as reinforcement in composites also benefits the environment. However, additional study is required to improve the fabrication process and look at the stability and long-term durability.

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