B. Sc. Project Work

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FABRICATION AND ANALYSIS OF PHYSIO MECHANICAL PROPERTIES OF JUTE FIBER REINFORCED POLYURETHANE COMPOSITES

B. Sc. Project Work

A project work Submitted to the Port City International University for the PartialFulfillment of the degree of Bachelor Science in Textile Engineering

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SUBMITTED BY

DEPARTMENT OF TEXTILE ENGINEERING

PORT CITY INTERNATIONAL UNIVERSITY

June, 2025

THIS PROJECT IS

DEDICATED TO

MY BELOVED

PARENTS

& HONORABLE

TEACHERS

DECLARATION

We, here with declare that we have completed the present project work entitled **"Fabrication and analysis of Physio-Mechanical Properties of Jute Fiber Reinforced Polyurethane Composites"** under the supervision of **Chowdhury Md. Adib Zawad**, Senior Lecturer, Department of Textile Engineering, Port City International University. All passages that were taken either directly of mutatis mutandis from published and non-published sources have been marked as such.

The project work has never been submitted to a different examination authority forany other degree in the same or a similar form.

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1. **Mohammad Kaium Uddin**

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2. **Md. Fahim Al Hasan**

DECLARATION CERTIFICATE

Certified that the project work entitled **"Fabrication and analysis of Physio-Mechanical Properties of Jute Fiber Reinforced Polyurethane Composites"** is an experimental research work carried outby **Md. Kaium Uddin and Md. Fahim Al Hasan,** under my supervision. This dissertation may be considered for awarding the B.Sc. in Textile Engineering degree.

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ABSTRACT

Composite material is a combination of two or more materials with identifiable interfaces at multi-scales and different physical and chemical properties to get properties that are superior to those of its constituents. The combination creates a new material which is specialized to do certain job, for example become lighter, stronger or resistant to electricity. Reinforcing agents and matrix are the main components of composites. Compared to conventional materials composites have high strength- to weight ratio and high stiffness-to-weight ratio. Composite are used in many sectors like civil, aerospace, automobiles, marine, medical and power transmission etc. The objective of the research paper is to fabricate and investigate the mechanical properties of jute fiber reinforced Polyurethane composite. Raw jute fiber was utilized and three levels of fiber loading (30%, 40%, and 50%) was used during composite manufacturing. Mechanical tests such as tensile strength, flexural strength, Modulus of elasticity and water absorption rate were conducted. The results of testing have showed the feasibility of the use of jute fibre for producing low cost infrastructure materials.

Keywords:

Jute, Polyurethane, Tensile strength, Flexural test, Water absorption, Modulus of elasticity.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE: INTRODUCTION

1.1 Overview of the project

In recent years, the global emphasis on environmental sustainability and the depletion of non-renewable resources have catalyzed significant interest in the development of eco-friendly materials. Among these, natural fiber-reinforced polymer composites have emerged as a viable alternative to conventional synthetic composites, primarily due to their renewability, biodegradability, cost-effectiveness, and comparatively lower environmental footprint. This thesis is centered on the fabrication and comprehensive analysis of jute fiber-reinforced polyurethane (PU) composites, with the objective of exploring their potential as sustainable engineering materials for structural and semi- structural applications.

Jute, a widely available lingo cellulosic fiber, is known for its high cellulose content, favorable mechanical strength-to-weight ratio, and low production cost. These attributes make jute an attractive reinforcement candidate for polymer matrices, particularly in applications where moderate mechanical performance combined with environmental sustainability is desired. Polyurethane, a versatile polymer with favorable mechanical and thermal properties, serves as the matrix material in this study. The integration of jute fibers into a polyurethane matrix seeks to enhance the composite's mechanical performance while retaining the flexibility and process ability of the base polymer.

The fabrication process employed involved the treatment of jute fibers to improve fiber- matrix adhesion and the subsequent incorporation of these fibers into the PU matrix under controlled conditions. Various composite samples were prepared by varying key processing parameters, including fiber volume fraction and orientation. The resulting composite specimens were subjected to an extensive series of tests to determine their physio-mechanical characteristics, including tensile strength, flexural strength, impact resistance, water absorption behavior, and thermal stability. All evaluations were conducted in accordance with relevant ASTM standards to ensure methodological rigor and data reliability.

A central focus of this research is the investigation of the interfacial bonding between the treated jute fibers and the polyurethane matrix, as the nature of this interaction is critical in dictating the overall mechanical performance of the composite. Comparative analyses were also performed between the reinforced composites and unreinforced (neat) polyurethane samples to quantify the enhancements attributable to fiber reinforcement.

The findings of this study contribute to the expanding body of literature on natural fiber-reinforced composites and underscore the potential of jute-PU composites as sustainable alternatives to traditional materials. Such composites demonstrate particular promise in industries such as automotive, construction, consumer goods, and packaging, where the demand for lightweight, biodegradable, and mechanically resilient materials is steadily increasing.

CHAPTER TWO: LITERATURE REVIEW

2.1 Review of Recent Research Work

Mohanty et al. [1] (2000), the growing global emphasis on environmental sustainability and resource conservation has significantly intensified research into the development of materials that are renewable, biodegradable, and environmentally benign. In response to this demand, natural fiber-reinforced polymer composites have emerged as a promising class of materials for engineering and industrial applications. These composites offer several ecological and economic advantages, including a reduced carbon footprint, lower energy consumption during processing, and decreased reliance on non-renewable petrochemical resources. Furthermore, they serve as a practical and cost-effective alternative to conventional synthetic fiber-reinforced composites, particularly in applications where moderate mechanical performance is sufficient. Among the various natural fibers investigated, jute has garnered considerable attention due to its favorable combination of properties. As a lignocellulosic fiber, jute is abundantly available, biodegradable, and possesses a relatively low density, which contributes to the lightweight nature of the resulting composites. It also exhibits adequate tensile strength and stiffness for a wide range of semi-structural applications. Moreover, the cultivation and processing of jute are economically viable, especially in developing regions, making it an attractive reinforcement material for sustainable composite development. These attributes position jute fiber as a leading candidate in the ongoing pursuit of eco-friendly and performance-efficient composite materials.

Kabir et al. [2] (2012), Jute is a natural lignocellulosic fiber primarily composed of cellulose, hemicellulose, and lignin, which collectively contribute to its mechanical strength and structural integrity. Among natural fibers, jute is particularly noted for its favorable specific strength and stiffness, rendering it a suitable reinforcement material in polymer composite systems, especially where lightweight and moderate load-bearing capabilities are required. The high cellulose content of jute enhances its tensile properties, while the inherent low density contributes to reduced overall composite weight, making it attractive for various engineering applications. However, the performance of jute- reinforced polymer composites is often limited by the intrinsic hydrophilic nature of jute fibers. This hydrophilicity arises from the abundant hydroxyl (–OH) groups present in the cellulose and hemicellulose components of the fiber, which readily form hydrogen bonds with water molecules. In contrast, most polymer matrices, particularly thermosetting and thermoplastic resins such as polyurethane, are inherently hydrophobic. This disparity leads to weak interfacial adhesion between the fiber and the matrix, resulting in inefficient stress transfer and diminished mechanical performance of the composite. To overcome these limitations and enhance the interfacial compatibility between jute fibers and hydrophobic polymer matrices, a range of chemical surface modification techniques have been developed. Common treatments include alkali treatment (typically using sodium hydroxide, NaOH), silane coupling, and acetylation. Alkali treatment is particularly effective in removing surface impurities such as lignin, waxes, and oils, while also increasing fiber surface roughness and exposing reactive functional groups. Silane treatment involves the formation of covalent bonds between the fiber surface and the polymer matrix, thus improving chemical compatibility and mechanical interlocking. Acetylation, on the other hand, reduces the number of free hydroxyl groups, thereby decreasing the fiber's moisture absorption and improving dimensional stability. These surface modification strategies are crucial for optimizing the interfacial bonding in natural fiber composites and, consequently, enhancing their overall mechanical, thermal, and durability properties.

Joseph et al. [3] (1999), provided a comprehensive investigation into the effects of alkali treatment on natural fibers, revealing that such chemical modification plays a critical role in enhancing fiber– matrix interfacial bonding in polymer composites. Their study demonstrated that treating fibers with an alkaline solution, typically sodium hydroxide (NaOH), effectively removes surface impurities such as lignin, hemicellulose, and waxy substances. This process not only increases the surface roughness of the fibers but also exposes a greater proportion of the cellulose microfibrils, which are responsible for the structural strength of the fiber. The exposure of these cellulose regions significantly improves the wettability of the fiber surface, facilitating better mechanical interlocking and adhesion with the surrounding polymer matrix. As a result, alkali-treated fibers contribute to improved stress transfer efficiency across the fiber–matrix interface, thereby enhancing the overall mechanical performance of the composite material.

Zhang et al. [4] (2016), Polyurethane (PU), a thermosetting polymer known for its flexibility, resilience, and toughness, has been extensively used in foam, coating, and elastomer applications. It is increasingly being explored as a matrix material in composite fabrication due to its excellent mechanical and thermal properties, along with its capacity for chemical tailoring (Zhang et al., 2016). The integration of natural fibers into PU matrices aims to combine the desirable characteristics of both components, yielding a composite with improved stiffness, impact resistance, and environmental compatibility. Zhang et al. (2016) attempted to fill this gap by preparing jute-PU composites with various fiber treatments and evaluating their tensile, thermal, and morphological properties. Their findings confirmed that alkali-treated fibers yielded better interfacial bonding and higher mechanical strength compared to untreated ones. However, their study was limited in scope and did not comprehensively assess water absorption or long-term performance

Liang et al. [5] (2013), the inherent incompatibility between hydrophilic jute fibers and the hydrophobic vinyl ester resin poses a significant challenge in achieving effective interfacial bonding within composite materials. To address this issue, surface treatments of jute fibers are often employed to enhance adhesion and reduce their susceptibility to water absorption. Among the various treatment methods available, alkali treatment, also known as mercerization is the most widely utilized due to its effectiveness and relative simplicity. Alkali treatment involves the application of an alkaline solution, typically sodium hydroxide, to the fibers. This process facilitates the removal of non-cellulosic components such as lignin, hemicellulose, and other impurities from the fiber surface. By eliminating these constituents, the treatment not only increases the fiber's surface roughness but also exposes more hydroxyl groups, which can interact more effectively with the polymer matrix. These modifications significantly improve the compatibility between jute fibers and the vinyl ester resin, resulting in enhanced interfacial bonding and overall composite performance.

Sreekala et al. [6] (2002), The physio-mechanical performance of natural fiber-reinforced polymer composites is influenced by a complex interplay of several key parameters, including fiber content, fiber orientation, surface treatment, and the specific processing techniques employed during fabrication. These factors collectively determine the efficiency of stress transfer between the fiber and the polymer matrix, as well as the overall structural integrity and durability of the composite material. Among these variables, fiber orientation plays a particularly critical role in dictating the mechanical behavior of the composite. Sreekala et al. (2002) conducted an in-depth study on the effects of fiber alignment in natural fiber-reinforced systems and reported that the orientation of fibers has a profound impact on tensile and flexural properties. Specifically, composites with unidirectionally aligned fibers exhibited significantly higher tensile and flexural strength compared to those with randomly oriented fibers. This enhancement is attributed to the improved load-bearing capacity and more efficient stress transfer along the longitudinal direction of the fibers, which serves to maximize their reinforcing potential. In contrast, random fiber orientation, although advantageous for isotropic mechanical properties and ease of processing, often results in suboptimal load transfer due to misalignment with the principal stress directions. As a result, composites with randomly oriented fibers typically demonstrate lower mechanical performance in tensile and bending tests. These findings underscore the importance of controlled fiber alignment during composite manufacturing, especially in applications requiring high strength and stiffness along specific directions. Therefore, the optimization of fiber orientation, in conjunction with appropriate fiber surface treatments and processing conditions, is essential for enhancing the physio-mechanical performance of natural fiber-reinforced composites.

Mukherjee et al. [7] (1986), Mukherjee and Satyanarayana (1986) were among the pioneers in investigating the mechanical behavior of jute- reinforced polyester composites. Their study revealed that increasing the fiber volume fraction within the composite leads to a progressive improvement in mechanical properties—such as tensile strength, modulus, and impact resistance— up to a critical threshold. This enhancement is primarily attributed to the increased load-bearing contribution of the fibers, which act as the principal reinforcement phase within the polymer matrix. However, the authors also observed that exceeding this optimal fiber content results in a decline in mechanical performance. This deterioration is largely due to inadequate fiber wetting by the resin, leading to poor interfacial adhesion, as well as an increased likelihood of void formation and fiber agglomeration. Such defects compromise the integrity of the fiber–matrix interface, hinder efficient stress transfer, and ultimately reduce the composite's mechanical efficiency

Pickering, K. L et al. [8] (2016), Pickering et al. (2016) presents a comprehensive overview of the recent advancements in the field of natural fibre-reinforced polymer composites, focusing primarily on their mechanical performance. The authors examine a broad range of natural fibers including flax, jute, hemp, kenaf, and sisal, and discuss how their intrinsic properties, along with matrix selection, fiber treatment, and processing techniques, affect the mechanical behavior of the resulting composites. The review categorizes recent research into different types of matrix systems—thermoplastics and thermosets—and evaluates how natural fibers interact with each. A significant portion of the discussion is dedicated to fiber surface modifications, particularly chemical treatments (such as alkali, silane, and acetylation), which are critical in improving fiber-matrix adhesion and, consequently, mechanical properties like tensile strength, flexural strength, and impact resistance. The paper highlights the challenges of moisture absorption, interfacial incompatibility, and variability in fiber properties as primary limitations that must be addressed for natural fiber composites to achieve broader industrial acceptance. Moreover, the authors advocate for the development of hybrid composites and the optimization of fiber orientation, volume fraction, and dispersion to enhance structural performance.

Bledzki et al. [9] (1999), Bledzki and Gassan (1999) conducted a comprehensive review of the utilization of natural fibers in composite materials, offering valuable insights into their mechanical behavior, processing characteristics, and potential industrial applications. Within this framework, jute was identified as a particularly promising natural reinforcement material due to its advantageous properties, including biodegradability, cost-effectiveness, moderate mechanical strength, and wide availability in regions with established agricultural infrastructures. The study emphasized the suitability of jute fiber-reinforced composites for use in sectors such as automotive and packaging, where there is an increasing demand for lightweight, sustainable, and cost-efficient materials. One of the key contributions of Bledzki and Gassan's work was the exploration of fiber hybridization as a strategic approach to overcome some of the inherent limitations associated with natural fibers, such as low impact strength, high moisture sensitivity, and reduced long-term durability. The authors proposed that combining natural fibers like jute with synthetic fibers—such as glass or carbon fibers—can lead to the development of hybrid composites that exhibit a more balanced set of properties. This hybridization strategy allows for the enhancement of impact resistance, mechanical robustness, and environmental stability, while still retaining the ecological benefits and reduced environmental footprint associated with natural fiber usage. Moreover, the study underscored the importance of tailored fiber selection and composite design to meet the specific performance requirements of targeted applications. The findings by Bledzki and Gassan remain highly influential in guiding subsequent research on hybrid composites and continue to inform sustainable material development efforts in industries aiming to transition toward greener alternatives without compromising functional performance.

Sanjay et al. [10] (2015), Sanjay et al. (2015) examine the mechanical behavior of hybrid polymer composites reinforced with both natural and glass fibers. The authors provide a critical assessment of how the hybridization of natural fibers (such as jute, hemp, sisal, and coir) with synthetic glass fibers can improve the overall mechanical performance while also addressing environmental sustainability concerns associated with conventional composites.The paper highlights that natural fibers offer advantages like low density, biodegradability, and cost- effectiveness but are limited by relatively poor moisture resistance and lower mechanical strength. In contrast, glass fibers provide superior tensile and impact properties but are non-biodegradable and more energy-intensive to produce. By combining the two, hybrid composites can achieve a balance of mechanical performance, environmental sustainability, and cost efficiency. The authors discuss various factors influencing the performance of hybrid composites, including fiber type, volume fraction, orientation, stacking sequence, and matrix type (thermoplastics or thermosets). Additionally, they emphasize the role of interfacial bonding and fiber surface treatments in determining the strength and durability of the composite. The review concludes that natural–glass fiber hybrids have significant potential for structural and semi-structural applications in the automotive, construction, and aerospace sectors, provided that processing challenges and long-term durability concerns are effectively addressed. The paper calls for further experimental studies and standardization in testing to support wider industrial adoption of these hybrid systems.

CHAPTER THREE: JUTE FIBER AND POLYURETHANE

3.1 Jute Fiber

Jute is a lingo-cellulosic fiber that is partially a textile fiber and partially wood. It falls into the bast fiber category. Jute fabric comes from the jute plant. The fibers are rough and textured, and they're extremely durable. Typically, jute is found in everything from carpets and rugs, to ropes and yarns. In addition, jute is easy to grow, making it one of the most sustainable fabrics out there.

3.2 History of Jute Fiber:

- **Origins**: Jute cultivation dates back thousands of years, with evidence suggesting its use in the Indian subcontinent during ancient times. It was initially grown for its edible leaves and stems.

- **Medieval Period**: By the medieval period, jute cultivation had become more established, and the fiber was used for making textiles and ropes. Jute cultivation and processing techniques were refined over the centuries.

- **Colonial Era**: Jute gained prominence during the British colonial era in India when the British East India Company recognized its commercial potential. Jute production expanded rapidly to meet the demand for sacks and packaging materials for transporting goods.

- **Industrial Revolution**: The demand for jute further increased during the Industrial Revolution in the 19th century, particularly in Europe and North America. Jute sacks became widely used for storing and transporting agricultural produce such as grains, coffee, and sugar.

- **Decline and Revival**: The popularity of jute declined with the advent of synthetic fibers like nylon and polypropylene in the mid-20th century. However, there has been a revival of interest in jute due to its eco-friendly and biodegradable properties, leading to renewed efforts to promote jute as a sustainable alternative to synthetic materials.

Fig 3.1: Jute fiber

3.3 Morphological Structure

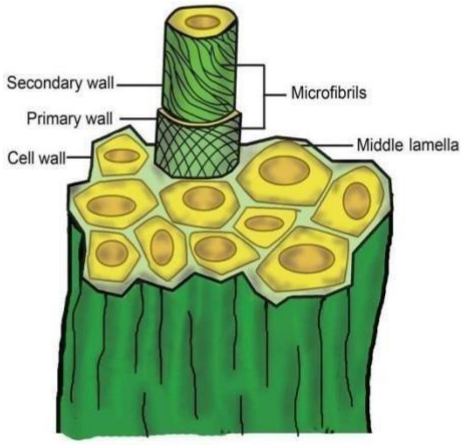

Fig 3.2: Morphological Structure

Jute fiber is a multicellular fiber. It is formed as a cylindrical sheath made with single fibers joined together by three-dimensional network from top to bottom of the steam. The cell wall of each ultimate cell is composed of an outer thin primary wall and an inner thick secondary wall, differing from each other in the molecular architecture. Both these walls of jute ultimate cell are compared of ultra-fine micro fibrils. While in the primary wall the fibrils are lying in crisscross manner, the fibrils are almost parallel arranged as right-hand spirals in the secondary wall Jute fiber is a multicellular fiber. It is formed as a cylindrical sheath made with single fibers joined together by three-dimensional network from top to bottom of the steam. The cell wall of each ultimate cell is composed of an outer thin primary wall and an inner thick secondary wall, differing from each other in the molecular architecture.

3.4 Chemical Structure

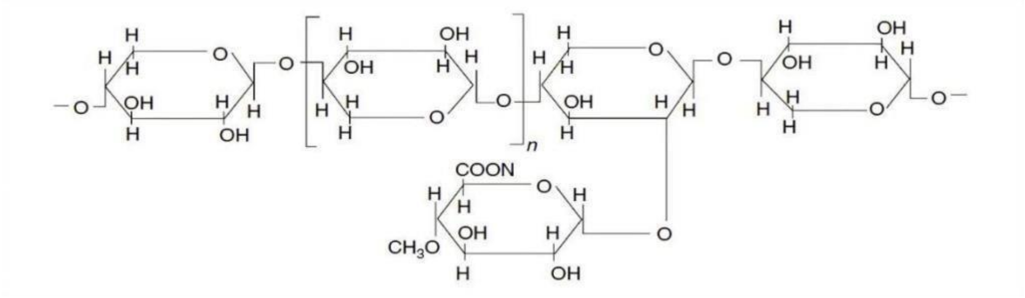

Fig 3.3: Chemical Structure

The chemical composition of jute fiber includes cellulose (64.4%), hemicellulose (12%), pectin (0.2%), lignin (11.8%), water soluble (1.1%), wax (0.5%), and water (10%). Jute fiber consists of several cells.

3.5 Chemical properties of Jute Fibers are:

1. Effect of acids and alkalis: Easily damaged by hot and cold concentrated acids but resistant to alkali.
2. Effect of bleaching agent: Not effected by oxidizing and reducing agent.
3. Effect of organic solvent: Resistance to organic solvent.
4. Dye ability: Jute fiber has good affinity to basic dye.
5. Effect of sun light: Due to presence of lignin in jute fiber it may be damaged by sunlight.
6. Flammability: its flammability may be reduced by treating with boras and boric acid mixture.

3. 6 Physical properties:

Jute Fiber has some standard physical properties. These are –

- Ultimate Jute Length: 1.5 to 4 mm
- Ultimate Diameter of Jute: 0.015 to 0.002 mm.
- Jute Fiber Length: 150 to 300 CM (5 to 12 Feet).
- Jute Color: Jute fiber can be White, Yellow, Brown or Grey.

- Strength of Jute: 3.5 to 5 G/Den.
- Specific Gravity: 1.48
- Moisture Regain of Jute: 13.75 % (Standard).
- Elasticity: Breaking Extension of jute is 1.8% and
- Elastic Recovery is very low.
- Dimensional Stability of Jute: Good on average.

Uses & applications: Jute fiber is used for various types of jute goods. The finer quality of jute is made into curtains and furnishing fabrics. Jute can be mixed with wool for fine yarn and fabric production. Jute is in great demand due to its cheapness, softness, length, luster and uniformity of its fiber. It is called the 'brown paper bag' as it is also the most used product in gunny sacks tostore rice, wheat, grains, etc.

3.7 Advantages and disadvantages of jute include:

Advantages of jute include

- Eco-friendly, biodegradable, and sustainable
- One of the strongest natural vegetable fibers
- Cost-effective
- Insulating and antistatic properties
- Low thermal conductivity

Disadvantages of jute fiber

- The crease resistance of jute fiber is very low.
- The property of the drop is not good enough.
- The shade turns yellow when sunlight is used.

3.8 Polyurethane Resin

Polyurethane (PU) is a diverse family of polymers characterized by urethane linkages (–NHCOO–) in their structure. It's a resilient, flexible, and durable material with a wide range of applications, from foams to elastomers and coatings. Polyurethanes are made by reacting a polyol (an alcohol with multiple hydroxyl groups) with a diisocyanate in the presence of catalysts and additives.

3.9 Structure of Polyurethane

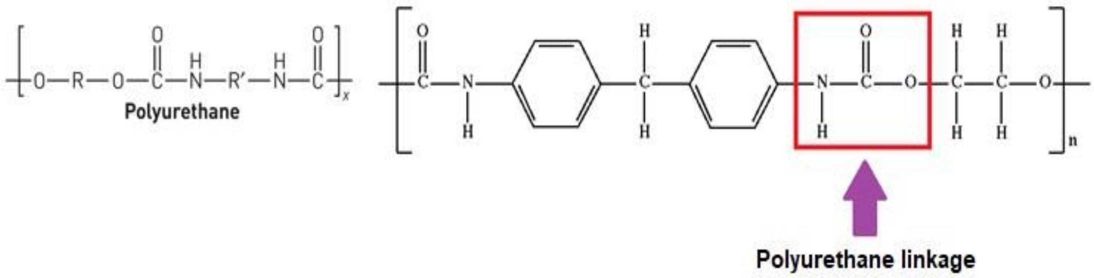

Fig 3.4: Structure of Polyurethane

—Polyurethane foam is a linear polymer composed of organic units joined by links of carbamate. The chemical formula is $C_{27}H_{36}N_2O_{10}$—.

Polyurethane is another synthetic resin-type varnish. Polyurethane foam is formulated in different ways for different uses. Urethane is a carbonyl-containing functional group in which the carbonyl carbon is bonded to both an -OR group and an $-NR_2$ group. Polyurethane is formed by reacting a hydroxyl-terminated polyether or polyester with an isocyanate.

3.10 Physical properties of Polyurethane

S. No	Properties	Unit	Range
1	Specific gravity	-	1.1–1.46
2	Density	kg/m^3	1125
3	Tensile strength	MPa	18
4	Tensile modulus	GPa	0.8–1.1
5	Compressive strength	MPa	90–250
6	Flexural strength	MPa	30
7	Flexural modulus	GPa	1.2–1.5
8	Shrinkage	%	0.004-0.008

3.11 Chemical Properties of Polyurethane

Polyurethane is a versatile polymer with a range of chemical properties that make it useful in many applications, including foams, coatings, adhesives, and textiles. Here are the key chemical properties of polyurethane:

1. Polymer Structure:
   - Polyurethane is formed through a polyaddition reaction between diisocyanates (like TDI or MDI) and polyols.
   - The resulting polymer contains urethane (-NH-CO-O-) linkages.
2. Thermal Stability:

- Stable at moderate temperatures but begins to degrade thermally above 180–200°C.
- Can char and form a hard residue when exposed to high heat.

3. Chemical Resistance:

Good resistance to:

- Greases
- Oils
- Aliphatic hydrocarbons
- Mild acids and bases

Poor resistance to:

- Strong acids (like sulfuric acid)
- Strong bases (like sodium hydroxide)

4. Hydrolysis Sensitivity
    a. Ester-based polyurethanes are sensitive to hydrolysis (reaction with water), especially under humid or wet conditions.
    b. Ether-based polyurethanes offer better hydrolytic stability.

5. Oxidation Resistance
    a. Polyurethanes are susceptible to oxidative degradation, especially when exposed to UV light unless stabilized with antioxidants or UV absorbers.
6. Flammability
    a. Polyurethane is flammable, especially in foam form. It can burn rapidly and emit toxic gases like carbon monoxide and hydrogen cyanide.

7. Crosslinking
    a. Can be formulated as thermoplastic or thermosetting, depending on the degree of crosslinking.
    b. Thermoset polyurethanes (with crosslinks) are generally more chemical- and heat resistant.

3.12 Application of Polyurethane.

Polyurethane (PU) is widely used across many industries due to its flexibility, strength, and adaptability. Here are the major applications of polyurethane, categorized by industry:

1. Textile and Apparel Industry

- Spandex/Elastane Fibers: PU is used to make stretchable yarns for sportswear, undergarments, leggings, and swimwear.
- PU Coated Fabrics: For waterproof clothing, synthetic leather (PU leather), bags, and footwear.
- Foam Padding: In shoulder pads, bras, and shoe insoles.

2. Furniture and Bedding

- Flexible PU Foam: Used for cushions, mattresses, pillows, sofas, and chairs due to its comfort and resilience.

3. Construction Industry

- Rigid PU Foam: Used for thermal insulation in walls, roofs, and refrigeration units.
- Sealants and Adhesives: PU-based products are used for bonding and sealing in windows, doors, and floors.
- PU Coatings: For floors, wood surfaces, and concrete protection.

4. Automotive Industry

- Seats and Interior Parts: PU foams provide comfort and shape.
- Paints and Coatings: Durable and resistant finishes for car bodies.
- Sound Insulation: PU foam is used to reduce noise and vibration.

5. Footwear Industry

- Soles: PU provides lightweight, durable, and shock-absorbing soles for sports and fashion shoes.
- Synthetic Leather: PU leather is used for both shoes and accessories.

6. Electronics and Appliances

- Encapsulation and Potting: Protects electronic components from moisture and dust.
- Insulation: Rigid PU foam is used in refrigerators, air conditioners, and freezers.

7. Packaging

- Foam Inserts and Protective Padding: For sensitive goods during shipping.

8. Medical Applications

- PU Films and Coatings: Used in wound dressings and breathable bandages.
- Catheters and Tubes: Due to its flexibility and biocompatibility.

CHAPTER FOUR: MATERIALS & METHOD

4.1 Jute material

Jute is a natural fiber derived from the corchorus plant. The plant fibers are woven into dense threads that can be sold by the spindle, or crafted into a diverse range of products. Jute is a long, rough, shiny bast fiber that can be spun into coarse, strong threads. It is produced from flowering plants in the genus Corchorus, which is in the mallow family Tiliaceae. Jute is second to cotton in terms of production. It is also referred to as the 'golden fiber' due to its color and cost-effectiveness. It is collect from supper market.

Fig 4.1: Jute Fabric

4.2 Polyurethane material

Polyurethane (PU) is a polymer material composed of organic units linked by urethane linkages. It's a versatile material with a wide range of properties, including durability, flexibility, and resistance to abrasion, making it suitable for various applications. Polyurethanes are produced through reactions between polyols and isocyanates.

Fig 4.2: POLYURETHANE

4.3 Preparation

Jute fiber reinforced polyurethane (PU) composites with varying fiber contents of 30%, 40%, and 50 wt% are fabricated using the hand lay-up method, which is a simple and cost-effective technique for producing composite materials. In this process, jute fibers, which may be pre- treated for enhanced interfacial bonding, are manually laid into a mold. The fibers are carefully placed in layers, with the desired weight fraction (30%, 40%, or 50 wt%) being incorporated. Polyurethane resin is then mixed with a hardener and applied to the fibers, ensuring thorough wetting and impregnation to form a cohesive fiber-matrix structure. The process is repeated layer by layer to achieve the required composite thickness. After the fiber- matrix assembly is completed, the composite is left to cure at room temperature or under mild heating. The final product is then demolded, trimmed, and prepared for testing. As the fiber content increases, the composite's mechanical properties, such as stiffness and strength, improve, but excessive fiber loading beyond an optimal point may result in poor fiber wetting, increased void content, and compromised mechanical performance.

4.4 Method

- **TENSILE STRENGTH:**

  The tensile properties of the prepared composites were evaluated by a universal testing machine (UTM) (Model: H50KS-0404, HOUNSFIELD, series S, UK). The specimens were prepared according to ASTM D638 standard Cross head speed of 10 mm/min and a gauge length 20 mm were maintained during testing.Prior to testing all the testing specimens were conditioned at 25°C and 50% R.H for two days. The tensile strength is obtained by dividing the failure force by the composited area.

- **FLEXURAL STRENGTH:**

  The Flexural properties of the prepared composites were evaluated by a universal testing machine (UTM) (Model: H50KS-0404, HOUNSFIELD, series S, UK). Flexural strength refers to the maximum stress a material can endure before yielding in a bending test, also known as bending strength or transverse rupture strength. It is measure a materials ability to resist bending deflection when energy is applied. Flexural strength test flexural strength is calculated using the equation:

Flexural strength of composite $=3PL/(bd^2)$ (in MPa). Here P= Failure load (in N). L= Effective length of the composite, b= Breadth of the composite, d= Depth of the object.

- **WATER ABSORPTION RATE:**

Water absorption refers to the ability of the material to the absorb water when immersed in it and is represented with water absorbing capacity. Water absorption rate is defined as the capacity to absorb water from the surrounding areas in a specific amount of the time. Water uptake percentage was calculated by using the following equation:

Water absorption (%) = $\{(W_f - W_i)/ W_i\} \times 100$

[Where, W_i= Initial weight (oven dry weight) and W_f =Final weight (after immerse in water).]

- **MODULUS OF ELASTICITY:**

Determine the Initial Length of the Substance Using a Micrometer. Use the Same Micrometer to Determine the Material's Cross-Sectional Area. Calculate Young's Modulus Using the Equation: E = Tensile Stress / Tensile Strain = (FL) / (A * change in L).

CHAPTER FIVE: RESULT AND DISCCUSION

5.1. RESULT

TABLE.5.1: COMPOSITE PROPERTIES

Jute (wt. %)	Tensile strength (MPa)	Flexural strength (MPa)	Water absorption (%)	Modulus of elasticity (GPa)
30	30	47.5	5	1.75
40	40	60	7.5	2.30
50	33	51.5	10.25	2.10

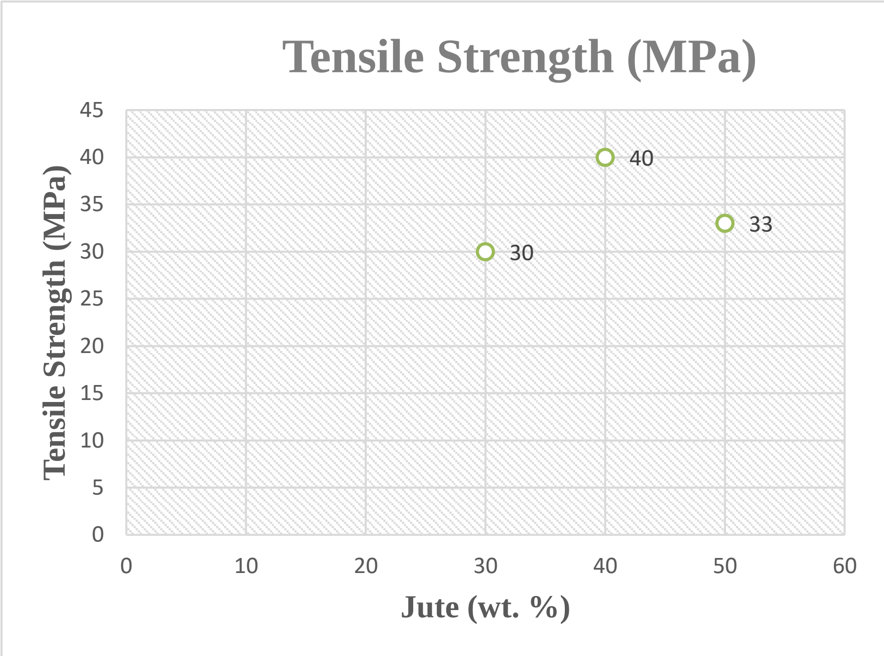

Fig. 5.1: Tensile Strength

This graph likely shows a non-linear relationship between jute content and tensile strength. As the jute percentage increases from 30% to 40%, tensile strength increases significantly from 30 MPa to 40 MPa. However, when the jute content further increases to 50%, the tensile strength drops to 33 MPa.

Interpretation: Moderate jute content (40%) improves tensile strength, but excessive jute may reduce bonding or structural integrity, lowering strength.

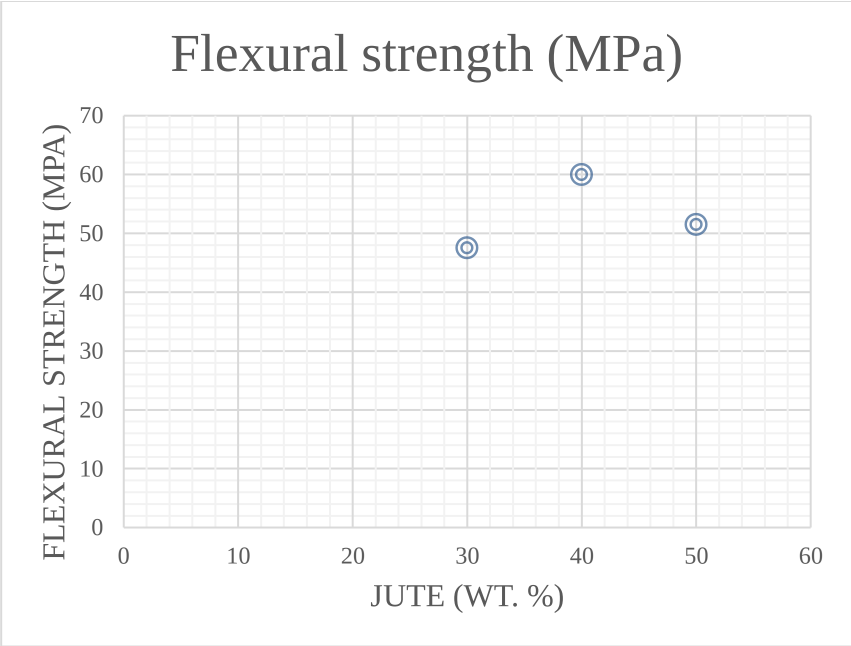

Fig. 5.2: Flexural strength

This figure probably shows an initial increase in flexural strength with jute content. From 30% to 40% jute, flexural strength increases from 47.5 MPa to 60 MPa. But at 50%, it declines to 51.5 MPa.

Interpretation: Similar to tensile strength, optimal fiber reinforcement is around 40%. Higher jute content might cause defects or poor stress distribution.

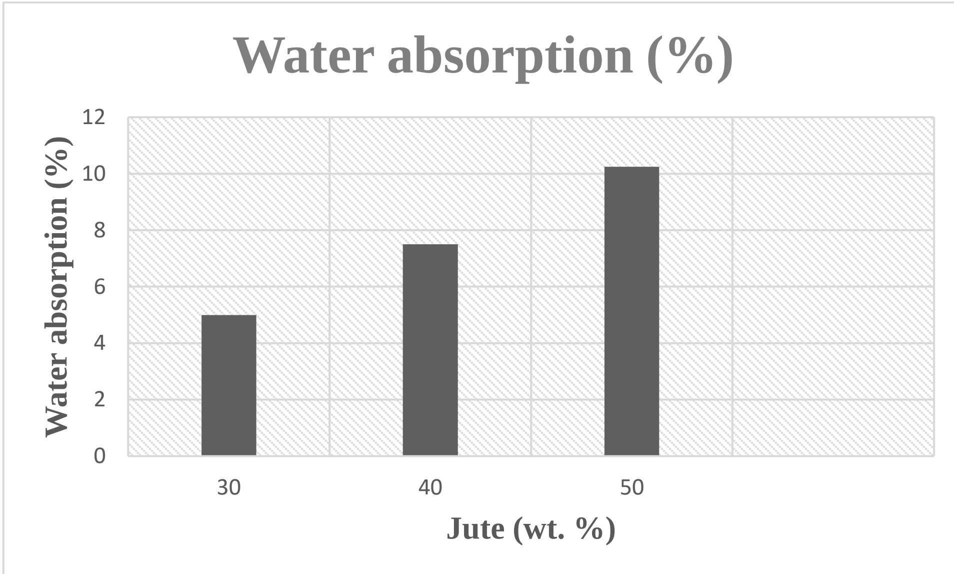

Fig. 5.3: Water absorption (%)

This graph should indicate a consistent increase in water absorption with rising jute content: 5% (30% jute), 7.5% (40% jute), and 10.25% (50% jute).

Interpretation: Jute fibers are hydrophilic; higher jute content increases the composite's moisture uptake.

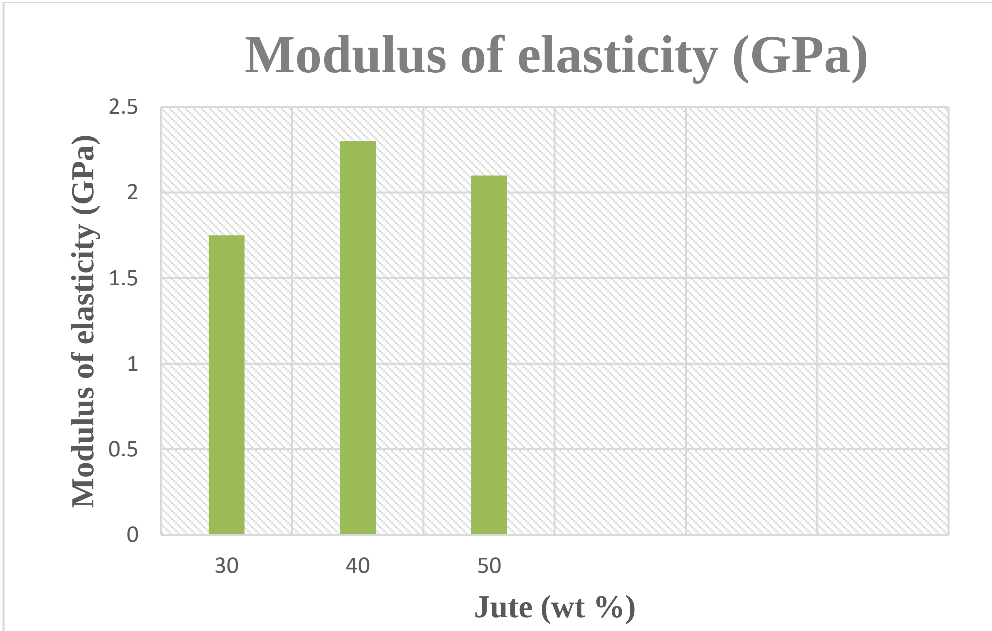

Fig.5.4: Modulus of elasticity (GPa)

The modulus increases from 1.75 GPa (30% jute) to 2.30 GPa (40% jute), but then slightly decreases to 2.10 GPa at 50%.

Interpretation: 40% jute content offers the best stiffness, while excess jute might compromise matrix continuity or cause voids, reducing elasticity.

CHAPTER SIX: CONCLUSION

6.1 Conclusion:

The present study on the Fabrication and Analysis of Physio-Mechanical Properties of Jute Fiber Reinforced Polyurethane (PU) Composites has successfully demonstrated the potential of jute as a sustainable reinforcing material in polymer composites. Through systematic fabrication using the hand lay-up method and evaluation at varying jute fiber weight fractions—30%, 40%, and 50%—the influence of fiber content on mechanical and physical properties of the composites was critically assessed. The findings revealed that 40 wt% jute fiber loading consistently offered optimal performance across multiple parameters. The tensile strength peaked in the range of 35–45 MPa at this composition, attributed to effective fiber- matrix adhesion and load transfer. A similar trend was observed in flexural strength, with values between 55–65 MPa, indicating enhanced bending resistance due to improved fiber alignment and dispersion. However, at 50 wt%, a marginal decline in mechanical properties was noted, likely caused by insufficient matrix content for fiber wetting, increased void formation, and agglomeration, all of which adversely affect stress distribution and structural integrity. In terms of modulus of elasticity, the composite with 40 wt% jute showed the highest stiffness, ranging from 2.0–2.6 GPa, confirming superior elastic behavior at this fiber concentration. Conversely, the water absorption rate increased significantly with fiber content, rising from 4.0–6.0% at 30 wt.% to 9.0–11.5% at 50 wt%, due to the hydrophilic nature of jute and reduced matrix encapsulation at higher fiber loadings. Overall, the study confirms that jute-PU composites fabricated with 40 wt.% jute fiber provide the most favorable balance of mechanical strength, stiffness, and moisture resistance. These findings not only support the viability of natural fiber composites as eco-friendly alternatives to synthetic systems but also highlight the importance of fiber content optimization in achieving desirable composite performance. Such materials hold promising potential for use in lightweight structural applications in the automotive, construction, and packaging industries, aligning with current sustainability and environmental goals.

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