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Full Length Article

An investigation into the preparation and evaluation of the physio-mechanical properties of glass-cotton, glass-jute, and glass-banana fiber-reinforced epoxy composite materials

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ABSTRACT

Fibrous composite materials are gaining popularity in various applications because of their exceptional attributes, such as high strength-to-weight ratio, high impact resistance, near-zero thermal expansion, and good corrosion resistance. These materials combine two or more fibrous materials with several physical and chemical properties to create a material with enhanced properties. The development of sustainable and environmentally friendly composite materials is increasing day by day to reduce environmental pollution and promote a more sustainable future. This research explores the physical and mechanical characteristics of cotton-glass, banana-glass, and jute-glass-reinforced epoxy composites, aiming to define their suitability for various applications. Tensile strength, flexural strength, and water absorption are the fundamental properties evaluated in this work. The hand lay-up technique was used to fabricate the composite, which involves manually layering the fiber and the matrix material. The study's findings provide significant insights into the potential application of composite materials in various industrial settings. Moreover, using sustainable and eco-friendly composite materials can help reduce environmental pollution. Although glass fiber is not biodegradable, it is easily recyclable. Other fibers used in this study are biodegradable, so it is a sustainable approach. In summary, studying the mechanical properties of composite materials provides valuable insights into their potential use in lightweight and durable diverse applications. Continued research may lead to more advanced composite materials with enhanced features for broader applications.

1. Introduction

Composite materials have been commonly used because of their exclusive mechanical and physical properties. These materials are typically composed of matrix materials, like polyester or epoxy resin, reinforced with fibres to enhance their strength and durability. Natural fibers, like cotton, jute, banana, and viscose, have recently gained attention as potential alternatives to synthetic fibers due to their renewable and sustainable nature [1–3]. The constituents of the composite usually are matrix and reinforcement, where the matrix provides a binder holding the reinforcement materials and provides strength [4,5]. Composite materials are lightweight, solid, high strength-to-weight ratio, flexible, fatigue resistant, corrosion resistant, and so on. Many natural fibers around us include jute, cotton, banana, bamboo, flax, kenaf, and so on, which fibers are extracted from nature and provide various properties [6–10]. There are also many synthetic fibers, including glass, carbon, Kevlar, Nomex, etc. Hybrid composites often provide enhanced mechanical properties for many more end uses in automobile, medical, aerospace, furniture, and construction industries [11,12]. The demand for environmentally friendly, biodegradable, sustainable materials has been increasing dramatically in recent years because today's world is now focusing on a lower carbon footprint for the betterment of the world, as the climate is changing drastically worldwide. The natural fibre is a promising alternative to traditional composites due to its abundant availability, lower production cost, and easy biodegradability [13–15].

However, hybrid fibrous composite is used intensely in the automotive industry to replace some car parts to minimize the total weight,

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reduce fuel consumption, and increase car efficiency [16,17]. In addition, aerospace is one of the sectors where composites can cope with high temperatures and have low weights. As the world is concerned about the end uses of all materials and the future impacts of the used materials, it is expected to use eco-friendly and biodegradable materials as much as possible in each sector [18]. The hybrid composite, composed of natural and synthetic fibers, could be an impactful alternative in the composite globe where the synthetic part will be responsible for the required properties and the natural part will enhance the eco-friendliness and biodegradability [19]. The abundance of natural fiber in nature makes it a more cost-effective option than synthetic fibers. Moreover, natural fiber composites are highly eco-friendly and do not harm the environment as they are biodegradable. Additionally, using natural fibers transforms agricultural bio-waste into a valuable commercial product. As a result of these distinct features, researchers and engineers are increasingly drawn to natural fiber [20]. The diminished tensile, flexural, and impact strengths of polymer composites can be addressed by incorporating natural fibres in combination with either other natural or synthetic fibres [21].

This study compares various hybrid composites made from natural and synthetic fiber regarding physio-mechanical properties. Natural fibers are used in composite, namely cotton, jute, and banana, whereas glass fiber is used as synthetic fiber. These fibers are used because of their easy availability, low price and biodegradation, and eco-friendliness of natural fiber. Composite samples with different fiber types were made to examine different physio-mechanical properties and analyze the distinct features of these composites [22]. The study aims to identify the most preferred functional composites among them as individual material exhibits weak features in these composites. By comparing all the various physio-mechanical properties of these composites made from different fibers, this research contributes to understanding the best composite in terms of functionality and environment-friendliness and their potential applications [23]. This work is conducted to find the best physio-mechanical properties showing composites produced by mixing various natural and synthetic fibers with epoxy resin. The specific fibres used in this thesis are cotton fibre, jute fibre, banana fibre, natural fibre, glass fibre, and synthetic fibre. Using the abovementioned fibers, glass-cotton, glass-banana, and glass-jute composites have been made. The various composites have been passed through several physical and mechanical tests to analyze the best performance.

Natural fibers, like cotton, jute, banana, and viscose, have recently gained attention as potential alternatives to synthetic fibers due to their renewable and sustainable nature. Cotton and jute fibers are famous for better strength, low density, and good biodegradability, while their high stiffness and low density characterize banana fiber. To manufacture composite materials epoxy, and polyester resins are commonly used due to their unique mechanical and physical properties. Polyester resin is known for its low cost, ease of processing, and good chemical resistance. Epoxy resin, on the other hand, has excellent adhesion, high strength, and good electrical properties [24,25].

Several studies have investigated the properties of natural fiber-reinforced composite materials. Maadeed et al [17] investigated the effect of fiber treatment on the mechanical properties of cotton jute-reinforced polyester composites. They found that fiber treatment improved the interfacial bonding between the fibers and the matrix, resulting in improved mechanical properties. Saba et al [14] evaluated the mechanical properties of banana-epoxy composites and showed potential improvement, with higher fiber content resulting in better mechanical properties. Faruk et al [15] explored the effect of fiber content and type on the physical properties of viscose fiber-reinforced epoxy composites. They showed that the increment of the fiber content improves the physio-mechanical properties of the composite, with viscose fiber-reinforced composites exhibiting higher mechanical properties than synthetic fiber-reinforced composites. Kumar et al [16] studied the thermal stability of banana fiber-reinforced polyester composites and found that adding banana fibers improved the thermal stability of the composite. Olorunnishola and Adubi [4] have used natural jute and glass fibers to produce car bumper materials. This research used only one natural fiber, jute fibers, and one synthetic fiber, glass fibers. They didn't use cotton and banana fibers to produce the composite using glass fiber. The authors conducted the work to make only car bumper materials, excluding other possible uses of composites. Khalid et al [26] investigated the tensile properties of glass-jute composite using numerical analysis, and Pramanik et al [27] prepared jute-based polymer composites and evaluated mechanical properties. Mahmud et al [28] fabricated PLA-based jute fiber composites and investigated the effects of eggshell filler on mechanical properties.

From the above discussions, it is clear enough that different natural fibre-based composites as well as glass fibre composites have been fabricated separately; the authors do not find a combination of glass with different natural fibers at the same time. To overcome this gap and to find the impact of other easily affordable natural fibers on the composite, we have used three natural fibers: jute, cotton, and banana, in addition to a fixed synthetic fiber glass. We aim to achieve an optimal balance of mechanical properties, sustainability, lightweight design, and cost-effectiveness. The locally sourced, natural fibers helped to attain sustainability and cost effectiveness.

This study aimed to fabricate hybrid composites as well as analyze their mechanical and physical properties. It seeks to evaluate these composites' physical, mechanical, and water absorption properties to determine their potential use in various applications. This work's findings have potential practical implications for manufacturing lightweight, durable, and eco-friendly composite materials for use in the automotive, packaging, construction [26,29–31], and other industries. The work has prepared, characterized, and compared the physical and mechanical properties of the various composites and tried to find the best physico-mechanical performance of the composites among the three.

2. Experimental

2.1. Materials

Four types of fiber, jute fiber, banana fiber, cotton fiber, and glass fiber, were used to build the composites shown in Fig. 1. Glass fiber was collected from the capital market, and other fibers were collected from natural sources. The chemicals used are epoxy resin (density 1.08– 1.20 g/cm3), hardener araldite (HY951), lubricating oil, wax, pretreatment materials, etc. (collected from City Scientific, Khulna, Bangladesh). General properties of the fibre used are listed in Table 1.

2.2. Pre-treatment

In the pretreatment process, jute fiber and chemical auxiliaries were reserved inside the machine nozzle as per the recipe shown in Table 2. To ensure cleanliness, the resulting jute fiber was thoroughly washed, first using cold water, then hot water at 80°C. The pretreated jute fiber was then treated by acetic acid with a concentration of 1 g/L, at 60°C.

The samples were then thoroughly washed to remove any residual acid. Subsequently, the pretreated jute fibers were then dried using a forced dryer at 80°C for 30 min [32]. The pretreatment of banana fiber was done similarly using the recipe shown in Table 3.

No chemicals like detergent or alkali were used as scouring agents for pre-treatment cotton fiber. After collecting the fiber, it was cleaned and dried to remove moisture. Similarly, the glass fiber was thoroughly cleaned and dried to remove dirt, dust, or sizing agents on the surface.

2.3. Preparation of mold

Composite materials were created using the hand layup process, a flexible technique for customization. This method involves manually

Fig. 1. Different types of fibre for making composite (a) Glass fibre, (b) Banana fibre, (c) Cotton fibre, (d) Jute fibre.

Table 1
General properties of the used fibers [8,18,22,34-36].

Properties	Fiber			
	Cotton	Jute	Banana	Glass
Origin	Natural	Natural	Natural	Synthetic
Density(g/cm^3)	1.50 – 1.55	1.30 – 1.50	1.30 – 1.50	2.50 – 2.60
Thermal Resistance	Low	Moderate	Moderate	High
Biodegradability	Biodegradable	Biodegradable	Biodegradable	Non-biodegradable (But Recyclable)
Cost	Low	Very low	Low to moderate	Moderate to high
Availability (BD)	Available (Natural)	Available (Natural)	Available (Natural)	Available (Industrial)

Table 2
Scouring and bleaching recipe for jute fiber.

SI. No	Name of the Chemical	Amount (g/L)
1	NaOH	10
2	H2O2	12
3	Detergent	7
4	Sequestering Agent	5
5	M: L	1:20

Table 3
Scouring & bleaching recipe for banana fiber.

SI. No	Name of the Chemical	Amount (g/L)
1	NaOH	7
2	H2O2	10
3	Detergent	7
4	Sequestering Agent	5
5	M: L	1:20

layering multiple fiber sheets onto a mold, which is first treated with a release agent to prevent sticking. This process is especially useful for small batch production or prototyping, requiring specialized composite properties. The fabrication consists of several steps. Initially, the mold's dimensions are measured and marked on a sheet of glass, which is then cut to size with a cutting saw. Edges are smoothed and deburred to eliminate sharp points, and corners are rounded to avoid damaging the composite during preparation. This study used a 10 × 8-inch mold to ensure practicality and consistency in material conservation. The hand layup process blends craftsmanship and engineering, resulting in high-quality composite materials tailored for specific applications.

2.4. Fabrication of composites

To enhance the mechanical and physical properties of the final product, the fibers were cut at a desired size and arranged onto the mold in a specific pattern. Once the fibers were put together, the resin was mixed with hardener and applied onto the fibers by a brush. A ratio of 1:10 was used to properly mix the epoxy hardener and resin in a beaker [33]. The resin enters the fibers to remove any trapped air and ensure the fibers are appropriately distributed. Once the desired thickness and number of layers were achieved, additional layers of fiber as well as resin were applied. The composite was allowed to cure at room temperature and controlled pressure after it had been entirely laid up [34]. Then, the composites were cured, and ejected from the mold, and cut to the desired size and shape according to characterization requirements. All the composites were manufactured similarly following the combinations shown in Table 4. Three composites were created by using cotton fiber, banana fiber, jute fiber, and glass fiber in two layers with the same weight ratio in each layer. Fig. 2 shows the fabrication process of the banana-glass composite.

2.5. List of equipment

The fabrication and evaluation of composite materials require specialized equipment. In the hand layup method, essential tools include

Table 4
Details of the composition of all composite.

Sample no	Sample name	Sample ratio	Fabric weight (gm)	Sample size (inch)	Thickness (mm)	Resin: Hardener	Weight percentage (Fabric: Resin)
1	G: C	1:1	10:10	10*10	4	10:1	30:70
2	G: B	1:1	10:10	10*10	4	10:1	30:70
3	G: J	1:1	10:10	10*10	4	10:1	30:70

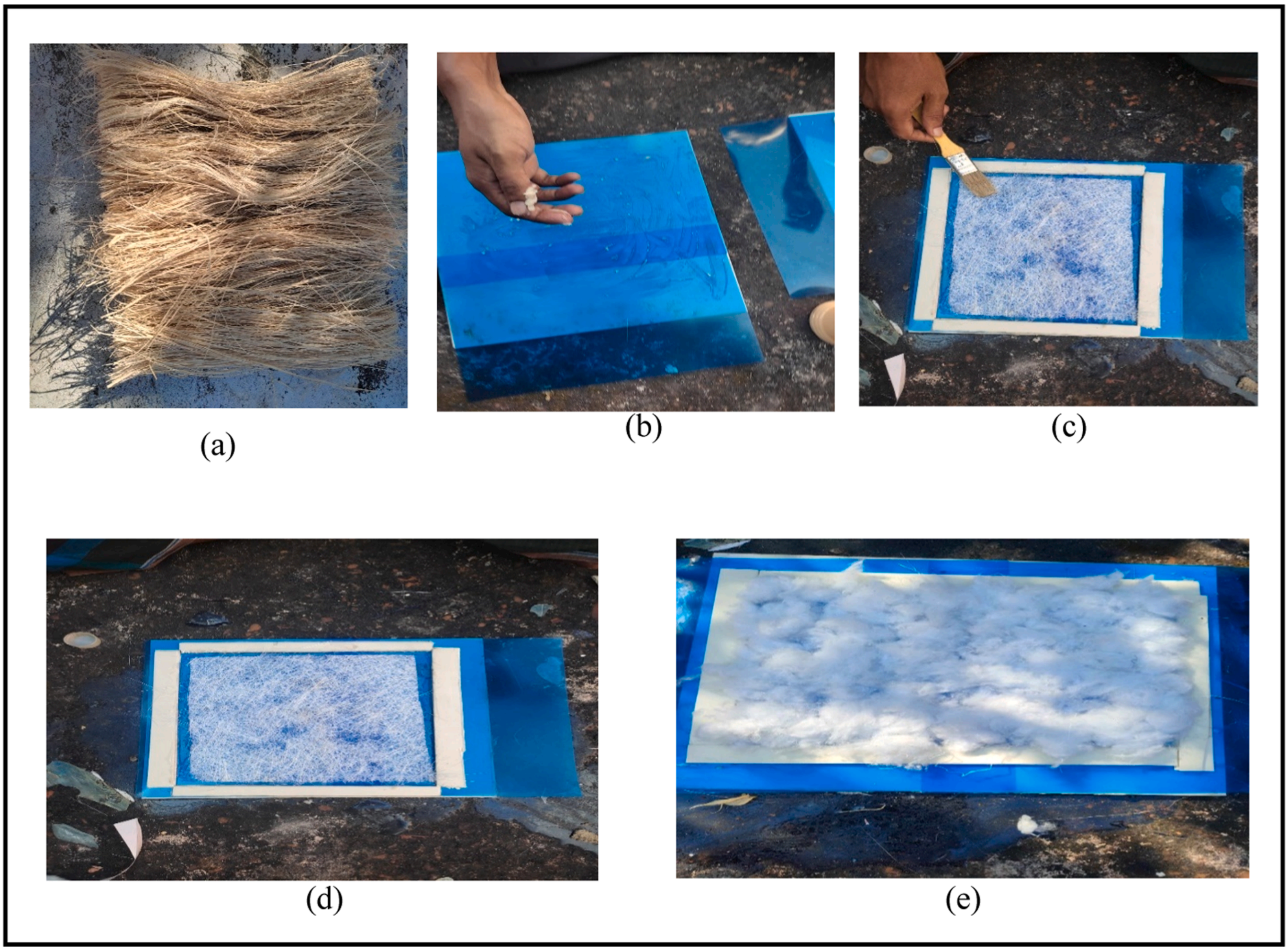


Fig. 2. Preparation technique of different composite (a)Banana fiber, (b) Mixing of wax, (c) Spreading of resin, (d) Intermediate phase, (e) Cotton fiber.

fiber reinforcement sheets, resin containers, mixing tools, and molds needed for better quality. Mechanical testing follows preparation to assess properties and structural integrity. The tools used for determining crucial parameters are listed in Table 5.

Table 5
List of equipment.

Name of Machine	Brand	Origin	Operation
UTM machine	Tinius Olsen 25ST	Germany	Tensile strength
Bending Testing Machine	Tinius Olsen 25ST	Germany	Flexural strength
Electric Balance	Ohaus	China	Weight measurement
Woven Dryer	Dhmeri	China	Drying
Lab Dyeing Machine	Gester	Germany	Pre-treatment of fibers
FTIR Machine	IR Tracer 100	Japan	Chemical bond identification
Scanning Electron Microscope	ZEISS Gemini Sigma 300	Germany	Morphological structures

3. Characterizations

3.1. Tensile test

The tensile properties of the samples were investigated using a Universal Testing Machine (UTM). The samples were cut and tested according to ASTM: D3039 standard. This test was performed at room temperature and a relative humidity of 65 %. Fig. 3 shows the samples in UTM during and after the test. The tensile stress is measured as the strain increases. Tensile strength is calculated from the equation, $\sigma = F/\text{bh}$, Where F is the maximum load at break (N), and b and h are the width and thickness of the specimen [35].

3.2. Flexural test

The flexural test was conducted to evaluate the bending strength of the prepared composites. The specimens were prepared and tested as per ASTM D790 standard in a UTM [36]. Five specimens were assessed from each type. The span length was 60 mm, and the crosshead speed was 12

Fig. 3. Fig. of UTM tensile testing machine and broken tensile test sample (a) UTM machine, (b) Tensile test sample.

mm/min. The samples of flexural tests before and after are shown in Fig. 4.

3.3. Water absorption test

The water-absorption test was performed to ascertain the moisture in a composite material as a percentage of its dry weight, as specified by the (British Standard 1377:1967). A material sample is initially weighed and then dried in an oven to conduct the test. Subsequently, the sample is weighed again under predetermined standard conditions. The difference in weight between the initial and final measurements is then used to calculate the percentage of moisture content in the specimen.

3.4. FTIR test

The FTIR Machine (IR Tracer 100) was used to identify the chemical composition of the samples. FTIR is based on the principle that each type of chemical bond in a sample vibrates at a unique frequency known as its vibrational frequency. The machine used attenuated total reflection (ATR) mode to identify the transmittance between 500-4000 cm^{-1} wavelengths.

3.5. Scanning electron microscopy (SEM)

To investigate the morphological structures of the glass-cotton, glass-jute, and glass-banana composites, an SEM machine (ZEISS Gemini Sigma 300) was used. For the imaging process, the landing voltage was 5.0 kV, the working distance varied between 12-15 mm, and the mode was vacuum (HighVac).

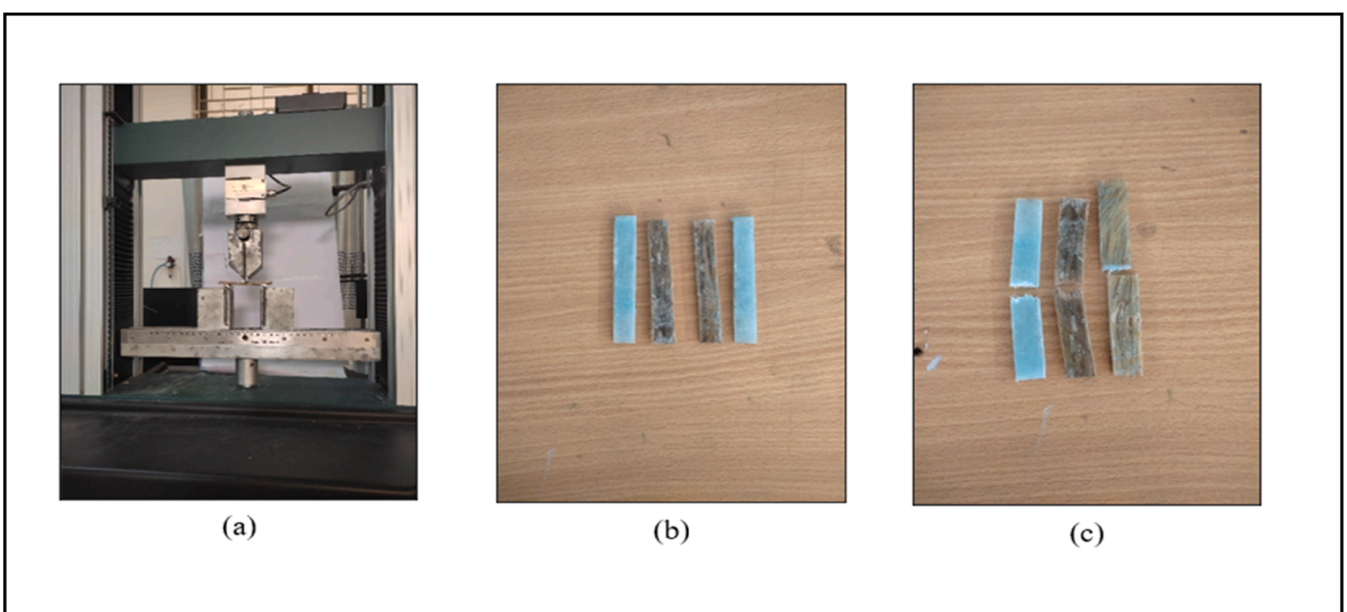


Fig. 4. Flexural test machine and sample (a) Flexural test, (b) before sample, (c) after sample.

3.6. Innovation of the methodology

This study presents a novel hand lay-up method for creating hybrid composites using glass-jute, glass-cotton, and glass-banana fibers. The aim was to achieve an optimal balance of mechanical performance, sustainability, light weight and cost-effectiveness by combining synthetic and natural fibers. An alkaline treatment was applied in the pretreatment process to enhance the bonding between natural fibers and the resin matrix, improving overall quality. This approach includes lightweight compression techniques and manual assistance, improving laminate uniformity without costly machinery. Using locally sourced, affordable natural fibers supports sustainability. Finally, a comparative analysis of the hybrid composites was conducted to assess the influence of different fiber types on mechanical and functional properties, contributing to advancements in composite development.

4. Results and discussion

4.1. Tensile properties

Initially, the tensile test of the samples was measured to determine the strength and stretchability of the composite before failure. The results provide insight into the tensile behavior of the composite materials. The produced hybrid composites were cut using a saw cutter to meet the dimensional requirements for tensile testing. During the tensile test, tensile stress was measured as the strain increased. The ultimate force was observed for different composites, including cotton-glass, banana-glass, and jute-glass composites. Due to its rigidity and stiffness [37], the jute-glass composite demonstrated the highest ultimate force of 3790 N. The cotton-glass composite exhibited a noteworthy ultimate force of 210 N, whereas the banana-glass composite had the lowest ultimate force at 1770 N.

The results for ultimate stress across various composites indicated that the jute-glass composite had the highest ultimate stress at 28.2 MPa, as shown in Fig. 5(a), attributable to its unique physical and chemical structure. The banana-glass composite showed the lowest ultimate stress, 1.2 MPa less than the cotton-glass composite. Due to its rigidity and stiffness [38], the jute-glass composite displays the highest ultimate force at 3,790 N, shown in Fig. 5(b). The cotton-glass composite follows with a notable ultimate force of 1980 N, while the banana-glass composite has the lowest ultimate force at 1,770 N among the three materials. The test results indicate that the jute-glass composite also possesses the highest ultimate stress, measuring 28.2 MPa, because of its inherent physical and chemical properties. So, the jute-glass composite exhibits best tensile properties among the three composites.

4.2. Flexural properties

The flexural test measured the ultimate force and stress of the composite materials, which can withstand before rupturing. It is seen from the result that, the cotton-glass composite had the highest ultimate force, shown in Fig. 6(b), measuring 372.45 N. In contrast, the banana-glass composite exhibited the lowest ultimate force of 229.60 N, which can be attributed to its physical and chemical characteristics [39]. The jute-glass composite had a moderate ultimate force of 312.70 N.

In analyzing the data and graph from the bending test, the ultimate stress was measured in megapascals (MPa) for the three composites. The cotton-glass composite also demonstrated the highest ultimate stress, shown in Fig. 6(a), with a value of 105.6 MPa. The jute-glass composite had the second-highest ultimate stress, approximately 16 MPa greater than the banana-glass composite. The experimental data further indicated that when force is applied, the banana-glass composite tends to fail more quickly than both the jute-glass and cotton-glass composites.

4.3. Water absorption

During the water absorption test, the water absorption percentage of various composites were calculated for all composites. Fig. 7 shows the results of water absorption of cotton-glass composite having the highest percentage, measuring 5.8 %. The banana-glass composite had the second-highest absorption at 3.15 %. In contrast, the jute-glass composite exhibited the lowest water absorption, with a value of 2.5 %.

Epoxy resins are generally more hydrophobic, repelling water molecules [40]. Their molecular structure is more compact and tightly packed compared to polyester resins, which makes it difficult for water molecules to penetrate and diffuse into the material [41]. In contrast,

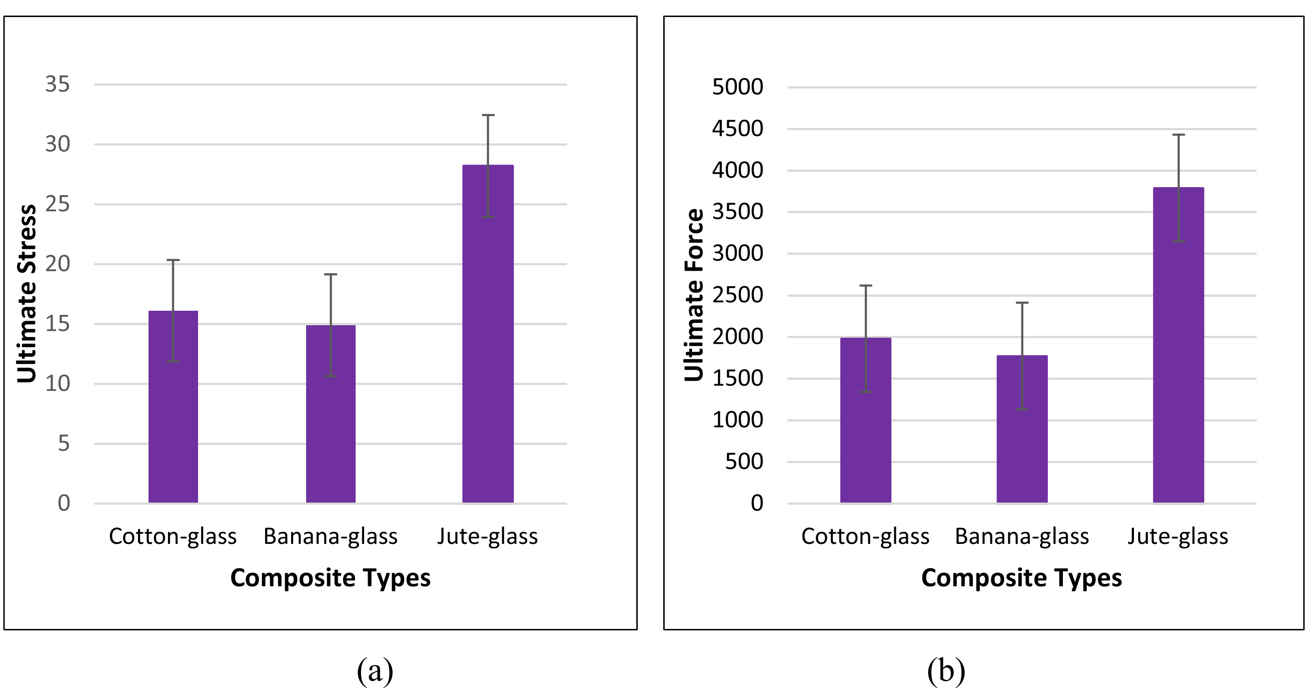


Fig. 5. Tensile test a) ultimate stress b) ultimate force.

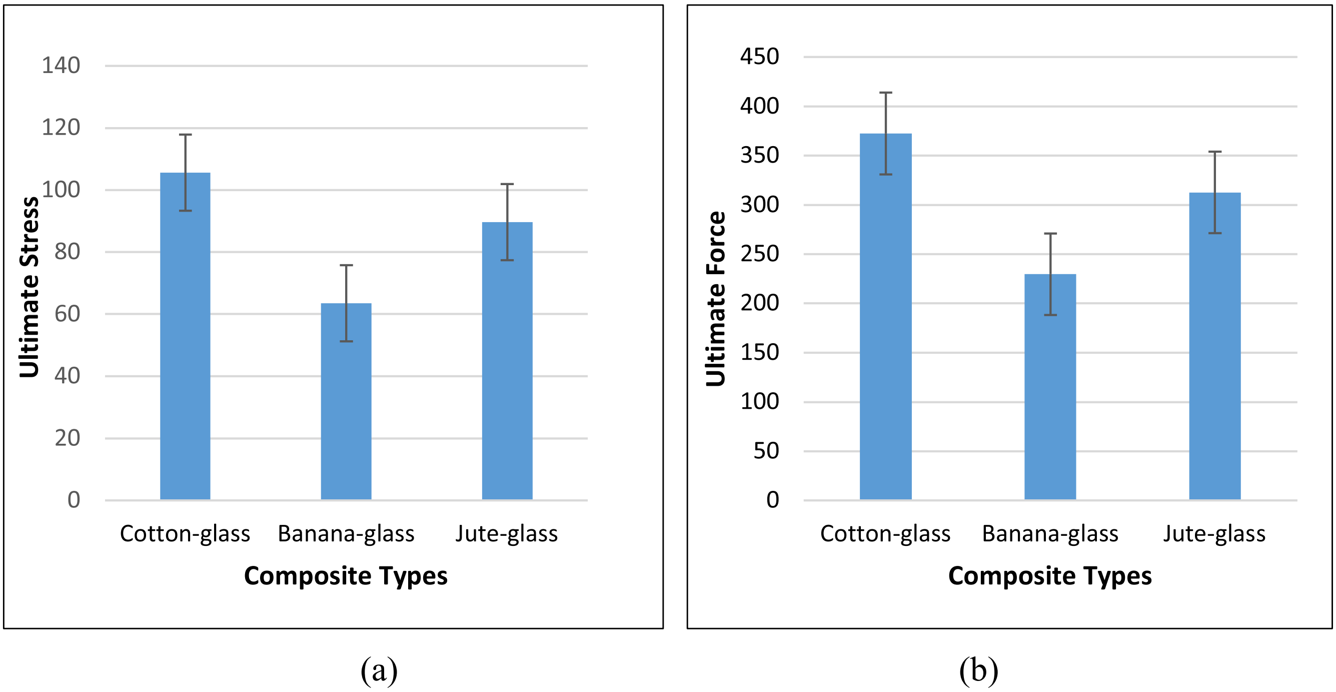


Fig. 6. Bending test a) ultimate stress b) ultimate force.

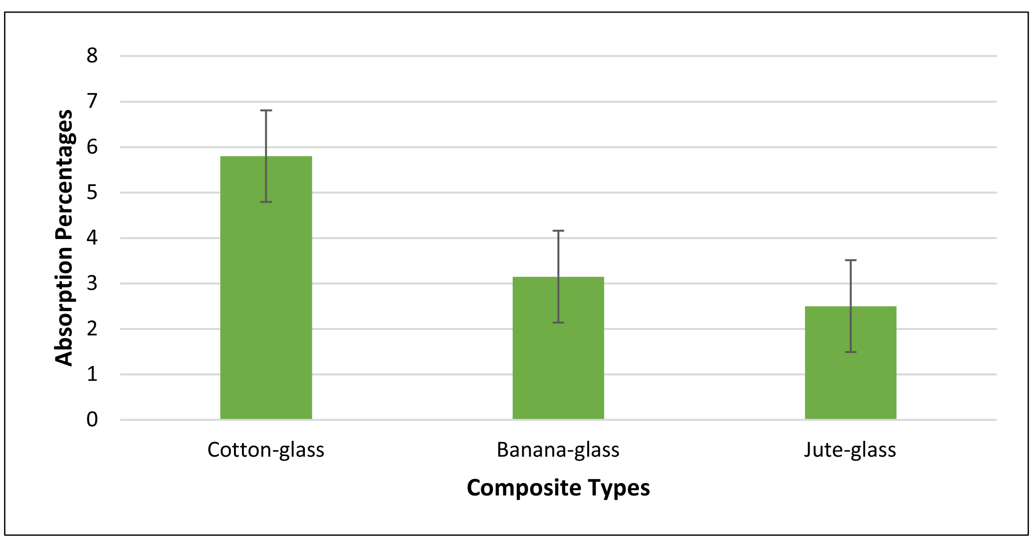


Fig. 7. Water absorption percentage bar chart.

polyester resins contain polar groups, such as ester linkages, that can interact with water molecules through hydrogen bonding. Polyester resins have a more open molecular structure, allowing water molecules to penetrate and diffuse easily into the material.

4.4. SEM test

SEM examination was conducted to visualize the morphology and microstructure of epoxy resin composites reinforced with cotton, jute, and banana fabric. The surface morphology of Banana-glass composite is shown in Fig. 8(a) at different magnifications from 100X to 1200X. SEM analysis provides a visual understanding of these composite materials' surface morphology and microstructure and offers crucial insights into their performance and durability. From the Fig., the adhesion of fibers is clear, which enhances bonding capacity and increases strength [23,29]. Fig. 8(b) visualizes the surface morphology of the Cotton-glass composite at different magnifications, from which the bonding of fiber and resins is visible. A good fibre matrix adhesion is noticeable, which ensures less void space, which is efficient for better stress transfer and mechanical properties [30]. Similarly, the surface structure of Jute-glass composite at various magnifications between 100X and 1200X is shown in Fig. 8(c). Here, minimal fibre pullout is visible, which ensures moderate adhesion and decent mechanical properties [4,26].

By revealing the intricacies of fibre-matrix interactions and identifying potential weaknesses or areas for improvement, SEM analysis guides the refinement of manufacturing processes and formulation of composite materials with enhanced mechanical properties and structural integrity. This meticulous examination at the microscale empowers researchers and engineers to tailor the composition and fabrication techniques for cotton, jute, and banana fiber composites, unlocking their full potential across diverse industrial sectors.

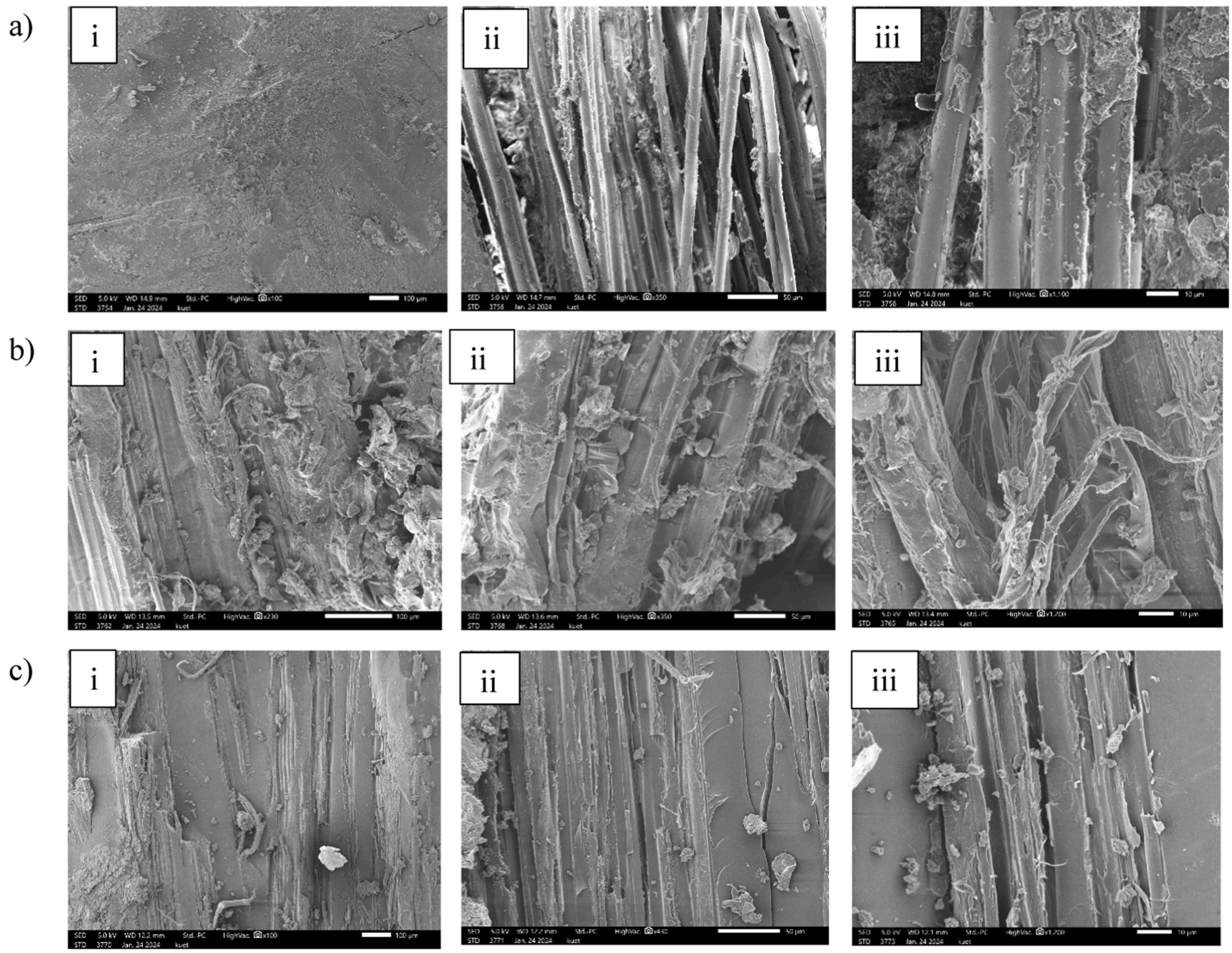


Fig. 8. Surface morphology by SEM of (a) Banana-glass composite at a magnification of i) 100X ii)350X iii) 1100X (b) Cotton-glass composite at a magnification of i) 230X ii)350X iii)1200X (c) Jute-glass composite at a magnification of i) 100X ii) 430X iii) 1200X.

4.5. FTIR test

The FTIR spectra for glass-banana composite, glass-cotton composite, and glass-jute composite samples are shown in Fig. 9, which range from a wave number of 4000 cm^{-1} to 500 cm^{-1}. The wavelengths at 825 cm^{-1}, 820 cm^{-1}, and 824 cm^{-1} correspond to the bending vibrations of Si-O-Si bonds in the glass component of the composites. These siloxane bridges create bonds with fibers, which increases the composites' binding capacity and greatly impacts mechanical properties [42]. Furthermore, the wavelengths at 1030 cm^{-1}, 1035 cm^{-1}, 1240 cm^{-1}, and 1246 cm^{-1} are associated with the stretching vibrations of C-O bonds, indicating the presence of cellulose or other organic components from the cotton fibers. The C-O groups are polar and create hydrogen bonding with resin materials, increasing tensile and flexural strength [43].

Similarly, the wavelengths 1500 cm^{-1}, 1510 cm^{-1}, and 1505 cm^{-1} are linked to C=C bonds, suggesting the presence of unsaturated hydrocarbons or other organic materials. This bond is the backbone of the cellulose fibrous material and has a strong covalent bond, which is important for structural stability [29,30]. The wavelengths at 2320 cm^{-1}, 2850 cm^{-1}, and 2855 cm^{-1} typically indicate the stretching vibrations of C-H bonds in aliphatic hydrocarbons, which signifies the presence of organic components. Finally, the wavelengths at 2920 cm^{-1}, 2917 cm^{-1}, and 2923 cm^{-1} indicate the stretching of C-H bonds, particularly in methyl (-CH_3) or methylene groups.

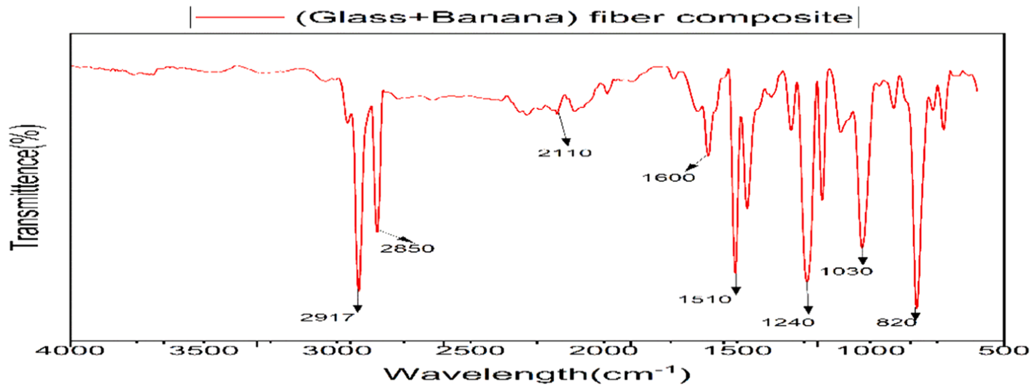
4.6. Comparison of the composites

Table 6 compares the three composites. The ultimate force values for the cotton glass composite, banana glass composite, and jute glass composite are 1980 N, 1770 N, and 3790 N, respectively. This data shows that the jute glass composite displayed the highest ultimate force among the three, while the banana glass composite demonstrated the lowest value.

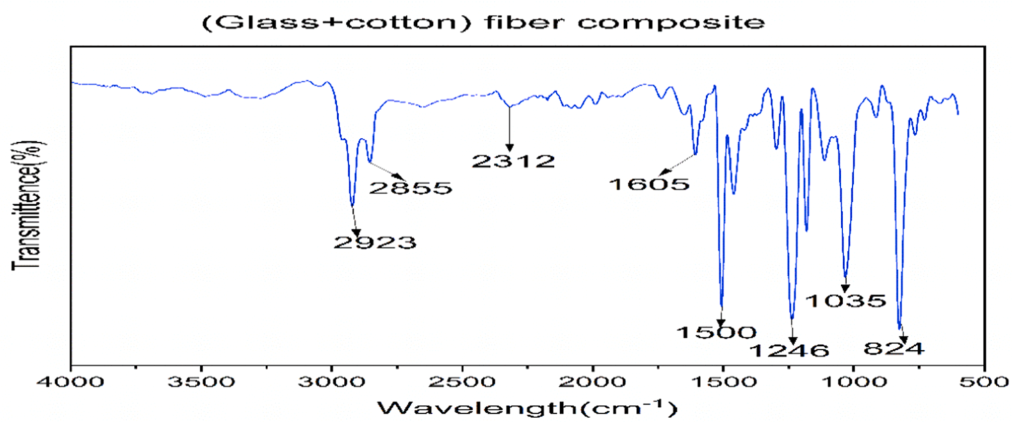
The cotton glass composite achieved the best performance in the bending test with a maximum force of 372.45 N. In contrast, the banana glass composite recorded the lowest value at 229.60 N. The cotton glass composite showed the highest water absorbency at 5.8 % by weight. In contrast, the jute glass composite showed the lowest water absorbency at 2.5 % by weight.

5. Conclusion

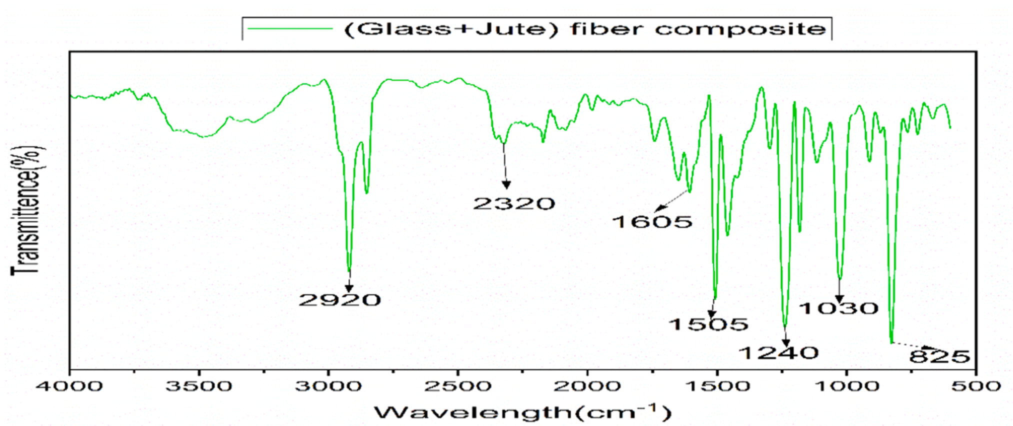
The study investigates the development of natural fiber and synthetic fiber-reinforced epoxy composites with excellent tensile and flexural strength. Mechanical tests, including tensile strength, flexural strength, FTIR, water absorption, and SEM, were conducted on composites created through a hand lay-up process. Among these, the cotton-glass composite showed the highest flexural and bending strength in comparison with jute-glass and banana-glass composites. To improve the



(a)



(b)



(c)

Fig. 9. FTIR result of (a) glass-banana composites, (b) glass-cotton composites, (c) glass-jute composites.

properties of these composites, the study suggests a more uniform fiber lay-up and the application of automatic pressure during preparation. These environmentally sustainable composites are easy to manufacture which have the potentiality for replacing various traditional materials while reducing the use of hazardous substances. The study also notes that the composites are made with a single type of resin: epoxy. Exploring other polyester resins could lead to even more effective composites and help identify the best options.

CRediT authorship contribution statement

Alberuni Aziz: Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Farjana Parvin:** Writing – original draft, Visualization, Formal analysis, Data curation. **Md. Kajol Hossain:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization.

Table 6
Comparison of Cotton-glass, Banana-glass, and Jute-glass composite.

SI. No	Test		Cotton-glass composite	Banana-glass composite	Jute-glass composite
1	Tensile	Ultimate Force	1980	1770	3790
		Ultimate Stress	16.1	14.9	28.2
2	Bending	Ultimate Force	372.45	229.60	312.70
		Ultimate Stress	105.61	63.56	89.67
3	Water Absorption		5.8 %	3.15 %	2.5 %

Declaration of competing interest

The authors declare that there are no known competing interests in the work reported in this paper.

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