EXPERIMENTAL CHARACTRIZATION OF HYBRID COMPOSITE MATERIALS FOR TENSION, FLEXURAL AND IMPACT BEHAVIOUR

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ABSTRACT

With the growing applications of composite materials in industry, it is becoming more involved with regard to characterization of them for carrying out analysis. Especially usage of hybrid composites is finding enormous applications now days. Composite materials give freedom to stitch them to meet particular design criteria as they posses' intrinsic coupling effects. Scientists from all around the world are interested in the possibilities of natural fiber-plastic composites that use jute, wood, hemp, coir, or sisal as reinforcing fibre in a thermosetting resin matrix. Since demand for lightweight materials with high strength for specific applications grow, composites reinforced with synthetic or natural fibres are becoming more important. The major applications are found in aerospace, military and navy industries. Characterization of composite materials and the associated fabrication methods pose a big challenge to the engineers as the behavior of them is going to be anisotropic in nature because of these. In the present study, an effort has been made to characterize the hybrid composite materials experimentally through fabrication and testing using jute cloth/polyester and chopped E-glass/polyester materials. Hand layup technique is used for fabrication of specimens, followed by cutting and testing. Tensile test, flexural test and charpy tests are carried out to evaluate the young's modulus, flexural strength and impact strength respectively.

Keywords: glass fiber, jute fiber, polyester, mechanical properties.

1. Introduction

Fiber-reinforced polymer composites perform ascending functions in various applications due to their high modulus, meticulous resistance and reduced carbon footprint in the environment [1]. Rapid growth in manufacturing industry has necessitated the development of new materials with enhanced strength, stiffness, density and cost-effectiveness. Composite materials have emerged with such improved qualities, allowing them to be utilized in a wide range of applications [2-5]. Composite materials are comprised of two or more constituents, one of which is the matrix phase and the other is in the form of particle or fiber phase. Natural or synthetic fibers have found major uses within the manufacturing of composite materials in various fields like construction, mechanical, automobile, aerospace, biomedical, and marine [6-9].

The most recent study adds to the development of hybrid composites that combine different natural and synthetic fibers. Hybrid composites are composite structures that consist of more than one type of fiber. Stacking layers of fibres, intermingling fibres, and mixing two types of fibres in the same layer to create an interplay hybrid, selective positioning of fibre where it is needed for improved force, and arranging each fibre according to certain orientation are all strategies for combining these fibres. [10]. Stacking fibers is the simplest approach, while others create challenges in achieving a positive hybridization effect.

Fiber-reinforced polymer composites not only have a high strength to weight ratio, but they also have outstanding features including great durability; stiffness; damping property; flexural strength; and resistance to corrosion, wear, impact, and fire. Composite materials have found applications in mechanical, construction, aerospace, automobile, biomedical, marine, and many other manufacturing industries due to their vast range of unique properties. Natural fibers are inexpensive and biodegradable, making them environmentally friendly whereas synthetic fibers provide additional stiffness. Despite the fact that both types of fibers are effective in variety of applications, the excellent performance of hybrid fiber-reinforced composite materials has been revealed by recent studies, as they combine the benefits of both.

A fibre-reinforced composite depends also on some additional characteristics like matrix properties, filler material, fibre-matrix ratio, coupling agents and processing techniques [11]. Fiber length, fiber-matrix adhesion, fiber treatment, fiber content (loading), fiber dispersion in the matrix are all properties that affect composite performance.

Fiber reinforced composites are also widely used in the automobile industry, sporting goods industry and packaging materials, aerospace industry (tails, wings, propellers), boat hulls, storage tanks. The replacement of steel with composite materials can be saved by 60-80% of component weight and 20-50% of aluminium alloy components [12]. For an organic product, natural polymer-based packaging can also be combined with natural fibers. It has no allergic reaction and does not burn the human skin. Organic compounds based on natural fibers attack attention because of their low cost, biodegradability, low density, high specific units, and recycling capacity [13-15].

2. Materials and fabrication

2.1. Matrix material

The matrix is essentially a monolithic, homogeneous and continuous material during which a fiber system of a composite is embedded. The matrix provides a medium for holding and binding reinforcements together into a solid. Among differing types of matrix materials, polymer matrices are the foremost commonly used due to many advantages like simple fabrication with less tooling rate, cost effectiveness and they even have outstanding temperature properties.

The iso-polyester Resin being a strong material commonly used for composites, boat building, autos and other repairs. This ISO-grade polyester resin is often used with fiberglass mats or cloths on surfaces because it is excellent for repairing, rebuilding and recreating damaged parts. Along with its strength, polyester resin is also simple to use. It is easily mixed using the MEKP catalyst and cobalt accelerator.

Methyl Ethyl Ketone Peroxide Catalyst (MEKP), is organic peroxide, a colourless, oily liquid, which initiates the Cross linking of polyester resins used in glass-reinforced plastic, and casting, initially causing a gel and then an entire cure. Cobalt accelerator is an efficient accelerator for polyester. It affects curing or polymerization of Polyester Resins together with catalyst likes MEKP. Resins formulated for a cure at room temperature require accelerators to increase the rate of peroxide catalysts to breakdown into free radicals. Iso-polyester resin, MEKP catalyst, Cobalt accelerator and Glass fiber is collected from Carbonblack composites website as shown in fig.1.

Fig.1. Polyester resin and fiberglass

2.2. Reinforcement material

Reinforcement material was added to the matrix material to enhance the physical properties like stiffness, high strength and other improved mechanical properties to the composite material.

A. Jute Fiber

Jute is a soft, long, shiny fiber which is obtained from the plants which is spun into coarse, strong threads. Jute fibers are primarily composed of cellulose and lignin plant components. The fibers range in colour from off-white to brown with 1–4 m long. Jute is one among the cheapest natural fibers and 100% biodegradable, eco-friendly and recyclable. Woven jute fiber having an average weight of 400GSM and average thickness of 0.96 mm is directly procured from local market as shown in fig.2.

B. Glass Fiber

Glass fibre is a material created from incredibly fine glass fibres that is lightweight, extremely strong, and exceedingly durable. The fibreglass mat is a versatile repair material that may be used on a variety of surfaces, including autos, boats, tubs, showers, sinks, pools, and hot tubs. Fiberglass mat is a non-woven fabric with a high strength-to-weight ratio that aids in the reinforcement of repairs. Fiberglass cloth has a lot of advantages includes resistance to expansion and contraction as temperatures change, moisture absorption, non-flammability, and chemical resistance. From the fig.3, the fiberglass of 0.3mm average thickness and 300GSM.

Fig.2. Jute fiber mat

Fig.3. Glass-fiber mat

2.3 Composite Fabrication

The fabrications of composite slab are carried out by conventional hand layup technique. The bidirectional jute fibre and the E-glass fibres are used as reinforcement and polyester resin is taken as matrix material. A mould of dimension 280×280 mm^2 with 10-mm thick wood flats to maintain the desired thickness and a clean, smooth surface is preferred to get the finished surface is used for casting the composite laminate. The low temperature curing polyester resin, MEKP and cobalt accelerator are mixed in a ratio of 10:1:1 by weight percentage. We provide a thin non-reactive plastic sheet on the flat smooth surface. For this study, we are varying the orientation of jute fibers in 0°and 45° respectively as presented in Table.1. After preparation of matrix material, first pour the prepared resin and place the glass fiber sheets on mold. Then, pour the resin onto the glass sheet once more and spread it evenly with rollers. Now, arrange the jute fibre in the desired orientations, such as 0° and 45°. For optimizing the results, we are taking these two orientations. The same procedure is followed for the remaining lamina to form symmetric composite. Finally, the required hybrid composites are formed as per our requirements. These composites are cured under a load for 72 hours. Then this cast is post cured in the air for another 24 hours after removing out of the mould. Figure.4 shows hybrid composite material. Specimens of appropriate dimension are cut for physical and mechanical tests.

Table.1: Designation of composite

LAMINA	ORIENTATION (Degree)	COMPOSITION
L1		Polyester resin + chopped glass fiber mat
L2		Polyester resin + chopped glass fiber mat
L3	0	Polyester resin + jute fiber mat
L4	45	Polyester resin + jute fiber mat
L5	45	Polyester resin + jute fiber mat
L6	0	Polyester resin + jute fiber mat
L7		Polyester resin + chopped glass fiber mat
L8		Polyester resin + chopped glass fiber mat

Fig.4. Jute/glass hybrid polyester composite

2.4. Specimen cutting

The specimens are cut in two different orientations namely 0° and 30° as shown in fig.5. As this hybrid composite is symmetric about axis and orientation of jute fibers are also symmetric about 0° and 45°. Thus, two specimens are cut in 0° and 30° taking 0° as reference for each test and tests are conducted.

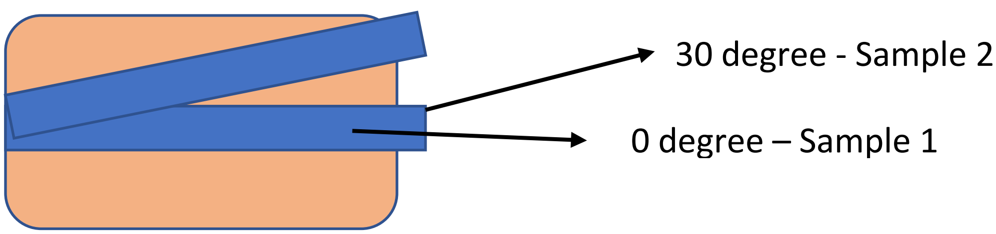

Fig.5 Orientation of specimen cutting

3. Determination of Mechanical properties

3.1. Tensile test

The tensile test is used to determine a material's ability to resist applied forces that tear it apart, as well as the extent to which the material stretches before breaking. Tensile property data is frequently used to compare different types of plastic materials such as strength, modulus, and elongation data. The tensile test specimen is prepared according to the ASTM D638-III standard as shown in fig.6.

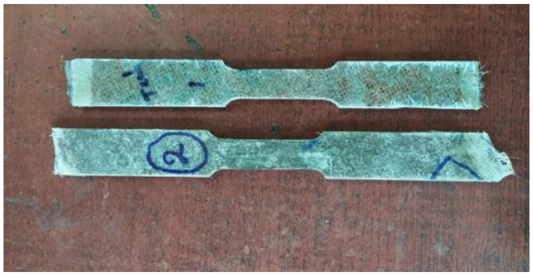

Fig.6 Tensile specimen of hybrid composite material

3.2 Flexural test

The flexural test is used to measure a material's ability to withstand bending before it reaches its breaking point. A universal testing machine is used to perform this test, which is based on the three-point bend test. As a result, we must treat it as a simply supported point load beam. By applying a bending load to the specimen, it can be sustained up to a specific point before collapsing and comes to fracture. Flexural testing specimen as shown in fig.7.

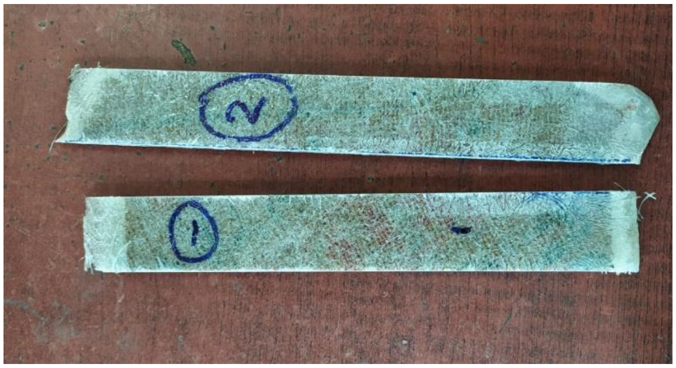

Fig.7. Flexural test specimen

3.3 Impact test

Polymeric material's impact characteristics are mostly determined by their toughness. The ability of a polymer to absorb applied energy is referred to as toughness. The impact test specimens are prepared in accordance with the standard and to the specified dimensions of ASTM-A370. The specimen must be inserted into the testing equipment, which then permits the pendulum to swing until it cracks. The different specimens used for impact testing is presented in Fig.8. the test is performed on Charpy Impact test machine.

Fig.8. Impact test specimen

4. Result and discussion

4.1 Tensile properties

The composites specimens' sample 1 and sample 2 are tested for tensile properties in UTM and obtained tensile properties are shown in Table.2. The load vs displacement curves are shown in Figure 10 and 11. The Sample 1 which is oriented at 30° shows a high tensile strength of 45.436 N/mm2 and Sample 2 which is oriented at 0° shows a lower tensile strength of 41.447 N/mm2, so comparatively Sample 2 shows better results than the Sample 1.

Table.2. Tensile properties of composite

sample	yield strength (n/mm^2)	ultimate strength (n/mm^2)	Elongation (%)
1	28.9	41.447	6.10
2	30.841	45.436	6.10

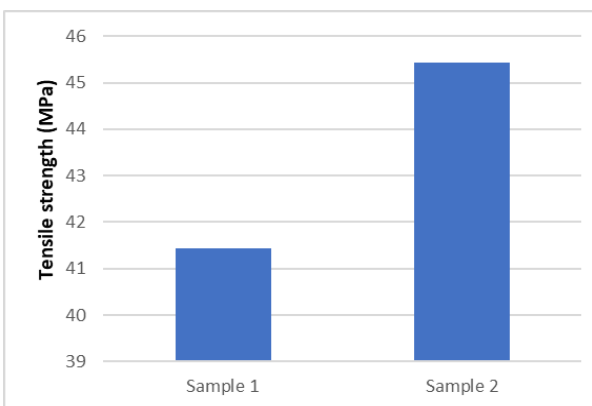

Fig.9 Comparison of tensile strength

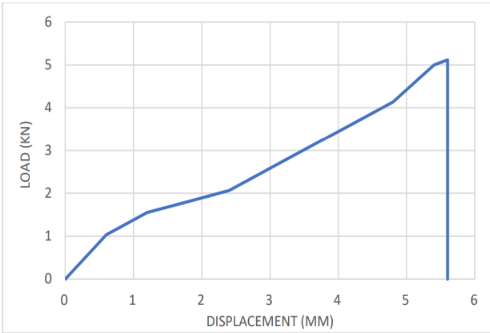

Fig.10 Load vs displacement curve of Sample 1

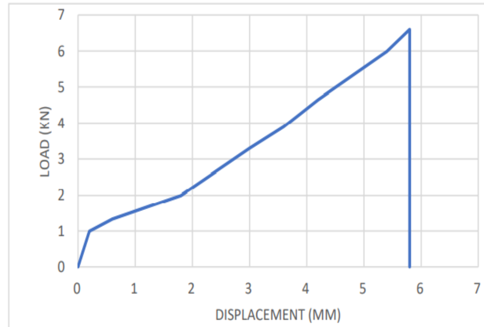

Fig.11 Load vs displacement curve of Sample 2

4.2 Young's Modulus

Young's modulus is a measurement of a material's ability to endure length changes when subjected to lengthwise tension or compression. A material's Young's modulus is a useful property to know in order to forecast how it will behave when subjected to a force. Figure 12 shows tensile modulus of Sample1 and Sample 2 were 679.459 and 744.852 N/mm^2.

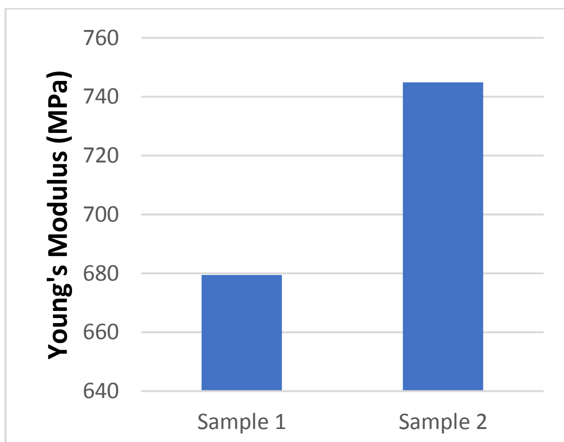

Fig.12 Comparison of Young's modulus

4.3 Failure Mechanism in Tensile test specimen

Fiber fracture and pull out, as well as fibre tearing, are visible on the tension cracked surface. We observed no stretching or pulling of polyester on the composite surface in both samples, however there is a sharp cut surface due to the brittle nature of polyester resin.

Due to tensile load, two forms of behaviour are observed on the surface of the hybrid composite in Sample 1, glass fibre stretching and jute fibre fracture without stretching. The jute fibre and matrix bonding is good, yet breaking occurs due to the brittle nature of jute fibre. Glass fibres are also debonding from one another, and transverse fibres are not carrying any load (fig.13). Because of the inadequate interfacial bonding, the fibres pull away from the resin surface, as shown in figure 14.

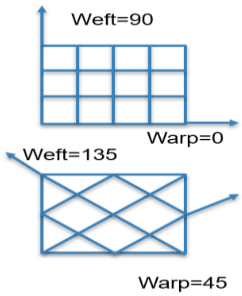

Fig.13 Orientation of jute fibers in sample 1

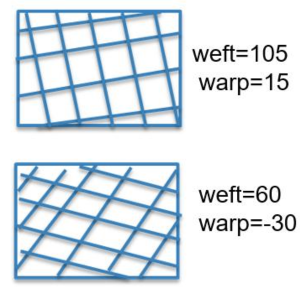

Fig.15. Orientation of jute fibers in sample 2

a b c

Fig.14. (a), (b), and (c) are Images of tensile fractured composite of sample 1

a b c

Fig.16. (a), (b), and (c) are Images of tensile fractured composite of sample 2

For sample 2, the integration of glass fibre with polyester increased the polymer's strength, as seen by the stretching of glass fibre. From the surface of the composite shown in fig.16, little jute fibre stretching and fibre breakage can be seen. The reason that there is no visible fibre pull out on the surface may be attributed to increased adhesion between the fibre and the matrix, which leads to improved composite strength qualities. This is due to brittle nature of the composites. It was observed that, pull out of both weft and warp fibers (fig.15), thus strength increases and all orientation fibers will contribute to stress carrying. This can be correlated to interlaminar shear strength.

4.4 Flexural properties

The different composite specimen samples are tested in the universal testing machine and the samples are takes displacement till the break occurs. The composite specimens sample 1 and sample 2 are tested for flexural properties in UTM and obtained flexural properties are shown in Table 3. The load vs displacement curves are shown in Figure 17 and 18. Load vs displacement curve of Sample 1 is plotted in fig.17.

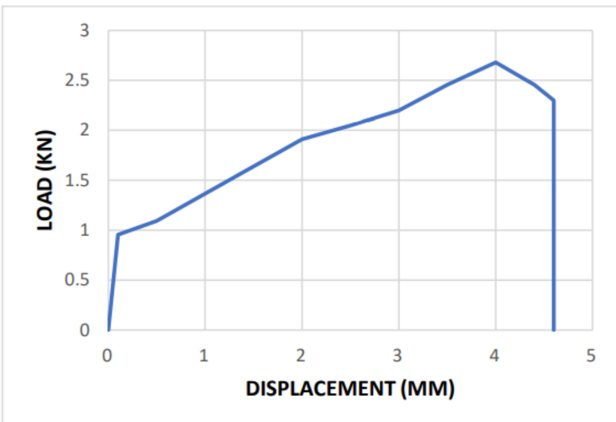

Fig.17. Load vs Displacement curve of flexural test specimen of Sample1

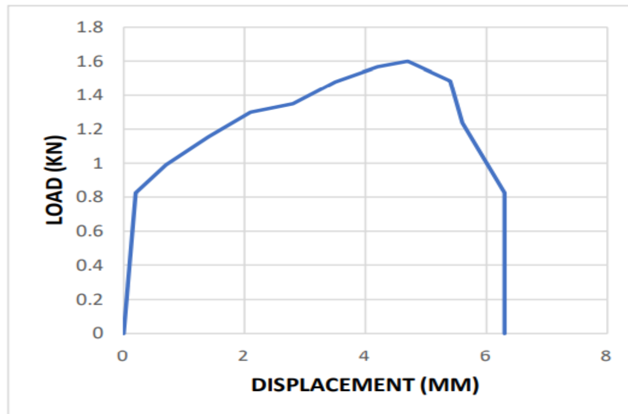

Fig.18. Load vs Displacement curve of flexural test specimen of Sample2

The displacement increases with increasing applied load up to a point about 2.68KN, beyond which it tends to decrease. Breaking occurs, in other words. Sample 1 has a maximum displacement of 4.6mm. Load vs displacement curve of Sample 2 is plotted in fig.18.

The results showed that when the load increases, the displacement increases as well. There is a break after the 6.3mm displacement. The maximum displacement observed in Sample2 is 6.3 mm.

Table.3. Flexural properties of composite

SAMPLE	ULTIMATE STRENGTH (N/mm2)	ULTIMATE LOAD (KN)	MAXIMUM DISPLACEMENT (mm)
1	10.984	2.68	4.6
2	5.626	1.6	6.3

4.5 Failure Mechanism in Flexural test specimen

In flexural test, the greater extensibility of glass fibers resulting in large fiber pull out and matrix failure was observed. For flexural specimen, there is no delamination between the jute and glass plies. Here transverse stress is acting on the specimens. Two types of behaviour are observed, one is the brittleness of jute fiber and another is the bending of glass fiber. Cracks are also formed due to flexural load. For sample 1, bending and pulling out of fibers are observed. In which, horizontal fibers getting elongate and transverse fibers show no effect. Figure 13 and 19 shows its behaviour.

Fig.19. (a) and (b) shows Images of flexural fractured specimen of sample 1

For sample 2, due to flexural load, some fibre splitting may be seen on the surface of the composite, as well as sharp cuts in some areas. The brittle nature of the jute fibre in composite is defined by this. Both fibers of different orientation are participating, but shearing between fibers is taking place. Also, we can observe out of plane compression, i.e., buckling is happening from figure 15 and 20.

Fig.20. (a) and (b) show Images of flexural fractured specimen of sample 2

4.6 Impact property

The impact test carried out for the present investigation is Charpy impact test. Figure 21 shows a comparison between energy absorbed by the various composite samples. The Sample 1 shows very high impact energy compare to another sample. The Sample 2 shows very poor impact strength of 2J.

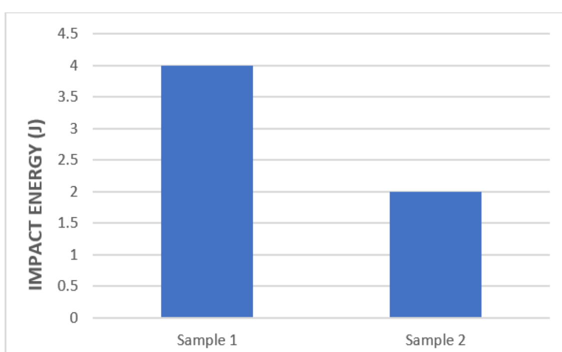

Fig.21. Comparison of impact energy .

The results indicated that the maximum impact energy is obtained for Sample 1 composite followed by Sample 2 composite. When the amount of jute, which is more brittle than glass fibre, is increased, the overall brittleness of the material increases and impact strength decreases.

4.7 Failure Mechanism in Impact test specimen

Delamination is constrained by through-thickness compression stress. Common thing observed is glass fiber fracture and pull out, considerable damage to jute fibers due to splitting from the strands. Transverse cracks can be seen at the impact point in both cases, with the sample 1 impacted specimen having a longer crack.

In fig.22, the damage appears to be primarily in the form of matrix cracking and interlayer delamination for sample 1. A progressive bending of the central part and, as a result, local buckling of the compressed specimens occurs as the impact energy increases, suggesting increasing internal damage and involving an increase in delamination. The propagation of delamination is caused by out of plane deflection and local buckling, which mostly impacts the compressive performance of the damaged specimens.

Fig.22. (a) and (b) show Images if impact fractured specimen of sample 1

For sample 2, this part shows a specimen failure due to the effect of delamination and a serrated fracture surface from fig.23. The specimen has a flat fracture surface, with the fibre pull-out, fibre breaking and matrix cracking having a dominant effect on the composite failure.

Fig.23. (a) and (b) show Images of impact fractured specimen of sample 2.

5. Conclusion

The experimental investigation on the fabrication and mechanical behaviour of jute/glass fibre reinforced polyester based hybrid composites lead to the following conclusions:

1. The successful fabrication of hybrid jute/glass fibre reinforced polyester composites by simple hand lay- up technique.

2. The present investigation revealed that effect of stacking and orientation of jute and glass mat on mechanical properties of jute/glass fibre reinforced polyester composites have been experimentally studied and the variation in mechanical properties are explained by studying the fracture features and crack profiles. Mechanical properties

of the composites were improved with the increase of stacking sequences and different specimens oriented w.r.t reference axis successfully.

3. For zero degree orientation (Sample1):

    i. Ultimate strength= 41.447N/mm^2
    ii. Yield strength=28.9N/mm^2
    iii. Young's modulus=679.459 N/mm^2
    iv. Maximum flexural strength = 10.984N/mm^{2,}
    v. Maximum impact energy = 4 J is predicted.

4. For 30 degree orientation (Sample 2):

    i. Maximum ultimate strength = 45.436N/mm^2
    ii. Maximum yield strength= 30.84N/mm^2
    iii. Young's modulus=744.852 N/mm^2
    iv. Flexural strength=5.626N/mm^2
    v. Impact energy = 2J is predicted.

5. The use of jute fibre in glass fibre composites improves mechanical properties and increases the use of natural fibres in many applications, resulting in a cost savings.

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