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International Journal of Innovative Research in Science Engineering and Technology (IJIRTSE)
ISSN: 2395-5619, Volume – 2, Issue – 7. July 2016

Evaluation of Mechanical Properties of Banana Fiber–Jute–Glass Fiber Reinforced Polyester Composite

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ABSTRACT

Natural fiber composites are a class of materials which are currently replacing the synthetic fiber composites for practical applications. This paper deals with the fabrication and investigation of hybrid natural fiber composites and compares it with other normal natural fiber composites like fiber and jute as reinforcements used separately. Mechanical characterization of the natural composite is obtained by testing the composite lamina for tensile, flexural, shear, and impact strength. The structure of the composite is such that, the jute fiber is present at the center flanked by fiber on both sides. Glass fiber is used to laminate the composite on top and bottom, which improves the surface finish and adds strength. The natural fibers are arranged in horizontal and vertical directions to provide strength on all sides. The rate of biodegradation was also observed by placing composite samples in compost and measuring weight loss weekly. The bio composites produced using this method were shown to have increased rates of biodegradation whilst exhibiting significantly improved flexural properties.

Key word : Mechanical Properties, banana fiber , jute and glass fibre

I.INTRODUCTION

Natural fiber composites are nowadays widely used instead of synthetic fibers due to their advantages like biodegradability, low weight, low cost and high specific mechanical properties. Synthetic fiber composites have far better mechanical properties than natural fiber composites but since they are highly expensive, they are justified only for aircraft and military applications. Many authors have previously investigated composites with natural fibers reinforcement with polymer matrices[1–7].Natural fibers are extracted from plants such as fiber, oil palm, bamboo and sugarcane. These plants are extensively found in tropical and equatorial countries and hence are used as reinforcement in low-cost composites. In recent years, studies about the utilization of lingo cellulosic materials as reinforcement in polymeric composites[1–3] are increasing due to the improvements that natural s can provide to the product, such as low density and biodegradability, besides the fact that these materials are from renewable and less expensive sources.

Natural fibers are obtained from different parts of the plants, but the bastes such as hemp, flax, kenaf, and jute are frequently used due to their noteworthy mechanical properties. Along with the economic and environmental advantages, these bastes provide higher specific modulus than E-glass. [8-15]Many researchers have reported that the mechanical efficiency of the fiber reinforced polymer composites depends on fiber–matrix interface and the ability to transfer stress from the matrix to fiber. Best properties can be obtained by combining the synthetic fiber with natural fiber in the same matrix.

II.EXPERIMENTAL SETUP

A.MATERIALS

1. NATURAL FIBER

Natural fibers are materials that belong to a class of hair like materials which are in the form of continuous filaments. Natural fibers are classified into two types, as plant (vegetable) fibers and animal fibers. Plant fibers namely cotton, flax, hemp, fiber, sisal, jute, kenaf, bamboo and coconut are widely used. They are preferred mostly since they are eco-friendly, and also available in less cost.

2.BANANA FIBER

It is obtained from a plant belonging to the fiber leaf. On an average, the plant grows about 12 feet (4 m) tall and the fiber is extracted from the trunk of the plant. These fibers are generally used to make twines and ropes but nowadays it is gaining importance as a good reinforcement for composite materials. The fibers are extracted from the base of the fiber leaf.

3. *JUTE FIBER.*

Jute is one of the most affordable natural fibers. It is mainly composed of plant materials like cellulose and it can be spun into coarse or strong threads. Jute takes nearly 3 months, to grow to a height of 12–15 feet.

4. GLASS FIBER REINFORCED POLYMER.

Glass fiber is a material that contains extremely fine fibers of glass. It is light in weight, extremely strong, and robust. It is formed when thin strands of silica glass are extruded into many fibers with small diameters. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. The individual filaments are now bundled together in large numbers to provide a roving.

5. RESIN AND HARDENER

Polyester resin is used to give great binding properties between the fiber layers to form the matrix. The polyester resin used at room temperature is LY 556. Hardener (HY 951) is employed to improve the interfacial adhesion and impart strength to the composite. A resin and hardener mixture of 10:1 is used to obtain optimum matrix composition.

B. FABRICATION PROCEDURE FOR SPECIMEN

The composite material is fabricated by using hand layup method. GFRP layers are placed on top and bottom on the specimen and intermediate layers are filled by natural fibers. Resin and hardener mixture (10:1) is spilled for every layer. Initially the fibers are dried in sun light to remove the moisture. The mould surface is cleaned and releasing agent (Poly Vinyl Alcohol) is applied. A thin layer of resin is also applied on the board. The woven roving (GFRP) are then completely filled with polyester resin, rolled to remove the entrapped air and to uniformly spread the mixture. In this way three layers of woven roving are placed one over the other to obtain top and bottom layers. A curing time of 3–4 h is given for the top and bottom structures to obtain good strength. Finally the fibers are closed with three layered laminate of woven roving just like the base of the laminate. Now a load (8–10 kg) is applied for a curing period of 8–12 h on the mould. This gives us the required composite laminates which can be cut to required size. Similarly the fiber–GFRP composite is prepared by replacing intermediate layers (Fig. 2). Similarly, the jute–GFRP composite is prepared by replacing intermediate layers (Fig. 3).

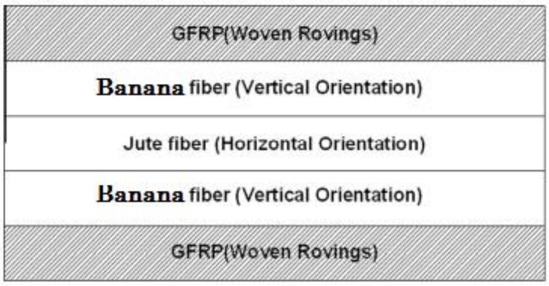

Fig. 1.Schematic diagram of banana fiber–jute–GFRP

II. TESTING OF COMPOSITES

C.TENSILE TEST

The fabricated hybrid composite is cut using a saw cutter to get the dimension of the specimen for tensile testing as per ASTM:D638 standards. The schematic diagram of tensile test specimen is shown is Fig. 5.

The test was carried out using a universal testing machine at a room temperature with 40% relative humidity. The tensile stress is recorded with respect to increase in strain. Three different types of specimens are prepared based on fibers used namely, fiber–GFRP, jute–GFRP and Banana fiber–jute–GFRP (hybrid composites). They are shown in the Fig. 1,2,3.

D. FLEXURAL TEST

The flexural test is performed on the same tensile testing machine as per the ASTM: D790 standards. The schematic diagram of flexural test specimen is shown is Fig.5.This test determines the behavior of the specimen when it is subjected to simple beam loading. Double shear test is done as per ASTM standard (ASTM: D5379). Normally shear stress is negligible when compared to the bending stress when the beam is loaded. Universal testing machine is used for performing shear test with a special fixture for double shear testing.

E. IMPACT TEST

An impact testing machine with charpy arrangement is employed to perform the test. It is done as per the ASTM: D256 standards. The schematic diagram of impact test specimen is shown is Fig.7.

The specimen is subjected to an impact blow by the pendulum until it fractures and the corresponding energy absorbed by the material is obtained.

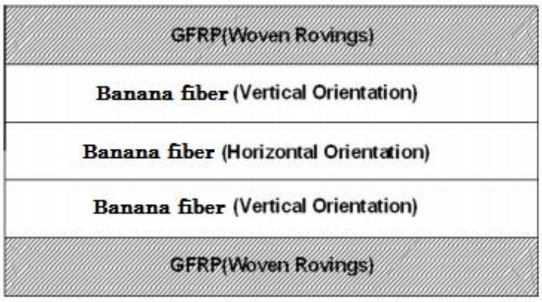

Fig. 2.Schematic diagram of banana fiber–GFRP

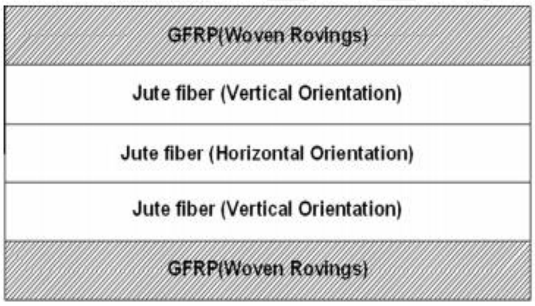

Fig. 3.Schematic diagram of jute–GFRP.

III.RESULTS AND DISCUSSIONS

F.TENSILE PROPERTIES

The three different composite specimens like jute–GFRP, fiber– GFRP and fiber–jute–GFRP are tested in the universal testing machine to find the tensile properties. A sample graph showing stress vs strain of fiber–jute–GFRP is shown in Fig.9

The various mechanical properties of the fabricated composite (fiber–GFRP, jute–GFRP, fiber–jute–GFRP) are summarized in the Table 1for better comparison. It is clearly seen that the tensile strength of the fiber and jute composite is high. The stress increases linearly with respect to strain for all the composites as shown in the Fig. 10. But for the hybrid composite, the stress starts decreasing after a particular point, exhibiting ductile properties and this point resembles the yield point of a ductile material. The comparison between different composites break load, maximum displacement and percentage elongation are shown in Fig. 11. It is found that the break load of the hybrid composite is high. It is about 1.26 times that of the fiber composite and 1.14 times that of jute composite. The maximum displacement is also high for the hybrid composite. It is about 1.2 times that of the fiber composite and 1.15 times that of the jute composite It is also found that jute fiber reinforcement in a hybrid increases the strength more than any other natural fiber[29]. Thus it can be concluded that the hybrid composite is more ductile than the single type fiber composite. From the results of the tensile test, it can be concluded that the fiber–jute–GFRP composite is well performing compared with other types of composites. This has also been theoretically proved by using rule of hybrid mixtures.

G.FLEXURAL PROPERTIES

A typical load–displacement curve for three different types of composites is shown in the Figs. 15 and 16. It is seen that all the curves increase linearly with respect to displacement up to the maximum flexural load and then decreases since breakage takes place. The maximum flexural strength is observed in banana fiber. The flexural resistances shown by other composites are shown in Table 2. Banana composite has highest flexural resistance due to the presence of uniformly distributed banana fibers and its high stiffness. Moreover, the adhesion between the banana fiber and the polyester matrix is better than those other two composites.

Fig. 5.Tensile test specimen.

Fig. 6.Flexural test specimen

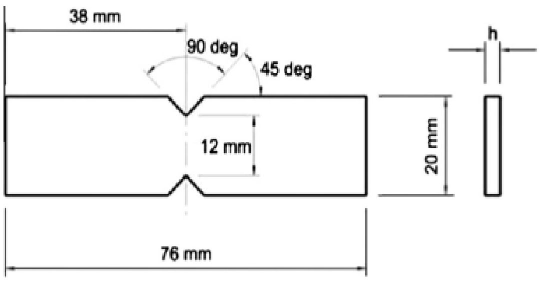

Fig. 7.Schematic figure of double shear test specimen.

The flexural modulus of the composite is found from the linear portion of the curve by determining the load and its corresponding displacement which shows banana has the highest flexural modulus when compared with the other two composites. The flexural break load of banana is 1.26 times that of jute and 1.03 times that of banana and jute hybrid composite. The maximum displacement is marginally higher for the banana fiber, which is 1.07 times that of jute and 1.05 that of banana and jute hybrid composite. The stresses induced in the composite are almost same for all as shown in Table 2.

H.DOUBLE SHEAR TEST

The double shear test results are summarized in the Table 3.A typical load–displacement curve for three different types of composites is shown in the Figs. 18 and 19. The comparison between different composite's break load and displacement are shown on Fig. 20.

The shear properties of the short laminates maybe increased by using saline treatment and matrix-resin pre-impregnation process through which the tensile and flexural moduli remain unaffected. It can be seen that as the load increases, the displacement increases linearly showing elastic nature. The maximum break load is obtained for the banana–jute hybrid composite which is equal to 8.371 kN. It is better than jute composite. The maximum displacement is also high for the banana–jute hybrid composite with a maximum stress and breaking load.

I. IMPACT TEST

The impact test is conducted for analyzing the impact capability of three different composites. The loss in energy is found using charpy impact test machine. The energy absorbed by the each specimen when it is impacted by a heavy blow is summarized in the Table 4. The comparison of the impact test results of different composites are shown in Fig.8.

Fig. 8.Impact test specimen.

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The reason for such high strength is due to the presence of single type in the matrix in alternating directions. Thus when the crack propagates, it travels through the matrix and the s of the composite

Table 1
Result of tensile test of different com posites

Sample	BreaK load (kN)	Maximum displacement (mm)	Elongation %	Tensile strength		Tensile modulus	
				In Kn/mm²	In Mpa	In Kn/mm²	In Mpa
GFRP+Banana	5.825	8.56	15.05	0.0445	44.5	0.27	270
GFRP+Jute	6.23	9.12	15.72	0.0465	46.5	0.25	250
GFRP+Banana+Jute	7.1075	10.0	18.182	0.057	57.0	0.29	290

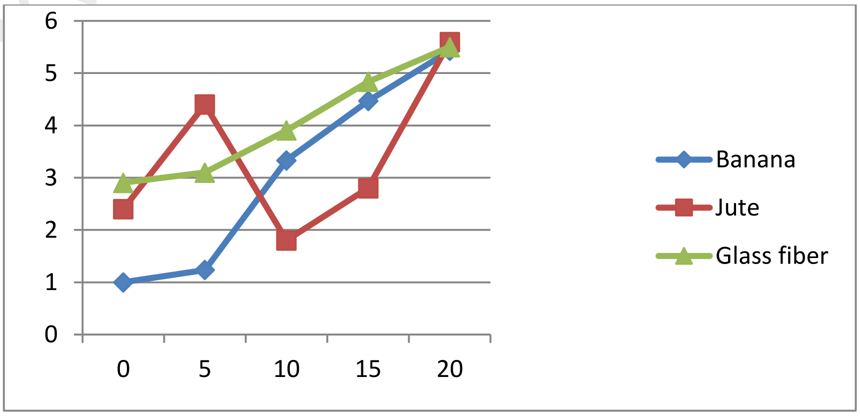

Fig. 9.Stress vs strain curve for tensile test

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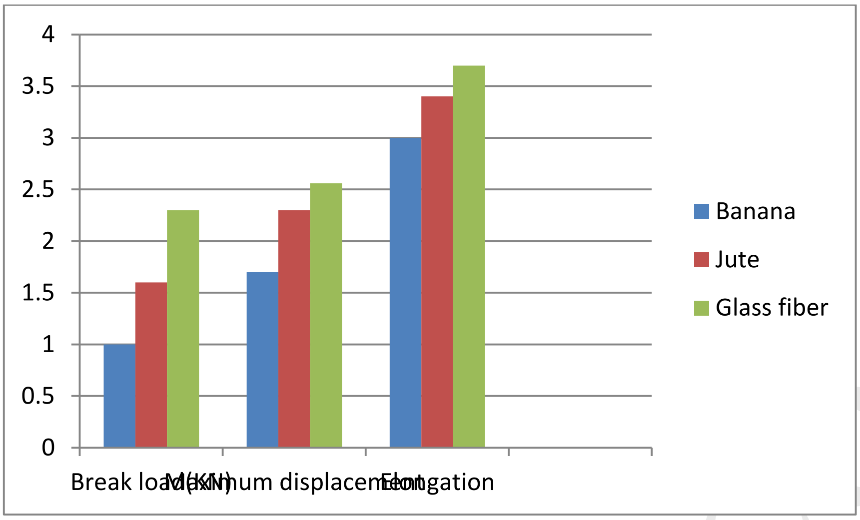

Fig. 11.Comparison between different composites: break load, displacement and % elongation

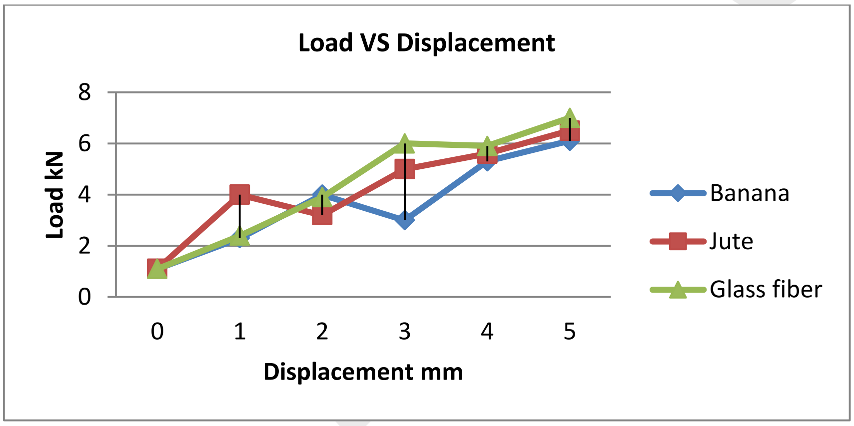

Fig. 10.Load vs displacement curve for flexural test

Table 2
Result of flexural test for different composites.

Sample	Flexural break load (kN)	Maximum displacement (mm)	Flexural strength		Flexural modulus	
			In kN/ mm^2	In MPa	In kN/ mm^2	In MPa
GFRP +Banana	1.55	4.6	0.0125	12.5	1.380	1380
GFRP + jute	1.23	4.28	0.0119	11.9	1.216	1216
GFRP +Banana+ jute	l.496	4.36	0.0121	12.1	1.452	1452

VI. MORPHOLOGICAL ANALYSIS (SCANNING ELECTRON MICROSCOPY ANALYSIS)

Morphological analysis was done using scanning electron microscope. The surface characteristics of the composite material were studied through SEM after conducting tests.

The SEM micrograph of the banana–jute–GFRP composite is shown in Fig. 14. Even though the manufacturing of the composite was done with care, it is seen that there is intra fiber delimitation predominantly present in the banana fibers which reduces the strength of the composite. The top portion of the image shows the banana fibers in vertical direction and the center part shows the fiber in horizontal direction. Since the loading for tensile test is done in horizontal direction, the fibers are found to be damaged in that direction more than the other direction.

Fig. 13shows the point of fracture of glass fibers in the banana– GFRP composite subjected to impact testing. The fibers are fractured due to the sudden impact and no trace of fatigue failure is observed. Moreover due to the woven nature of the glass fiber, it is clear that there is uniform distribution in the matrix and interfacial adhesion is also present to a decent level.

Fig. 13 shows the adhesion of fiber and resin in 0.6 volume fraction jute composite which is subjected to tensile testing. In general, the adhesion is good although there are a few defects like air bubbles and fiber draw-out. The smooth surface seen is the resin and the irregular surface is fiber. Due to the high strength of jute fibers, they have undergone individual breakage, giving it very high strength. Fig 14 shows the arrangement of fibers in the composite which shows one layer of fiber perpendicular to the other layer.

Fig.15 shows the SEM micrograph of a flexural fractured specimen. Inter-phase delimitation is found at the cross-section of applied load. Presence of voids in the specimen is found to be minimal due to uniform load applied on it. The crack propagates through the natural fibers rather than the glass fiber and causes failure

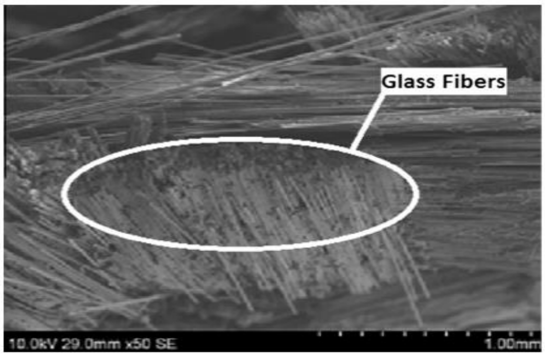

Fig. 12 .SEM image of banana–GFRP after impact testing.

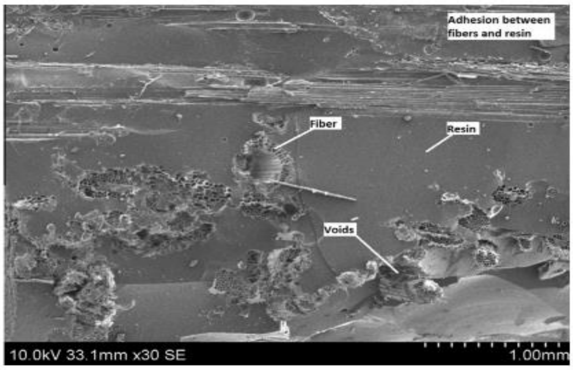

Fig. 13.SEM image of jute–GFRP composite after tensile test

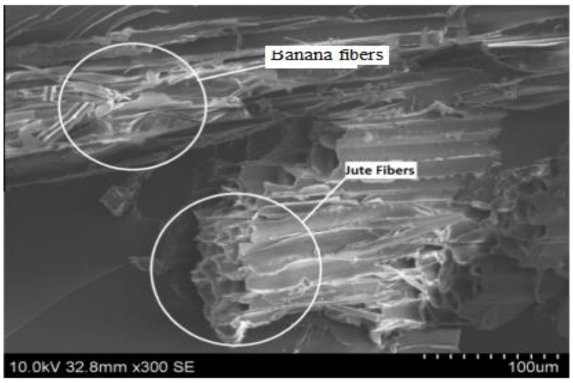

Fig. 14.SEM image of banana–jute–GFRP composite after tensile test

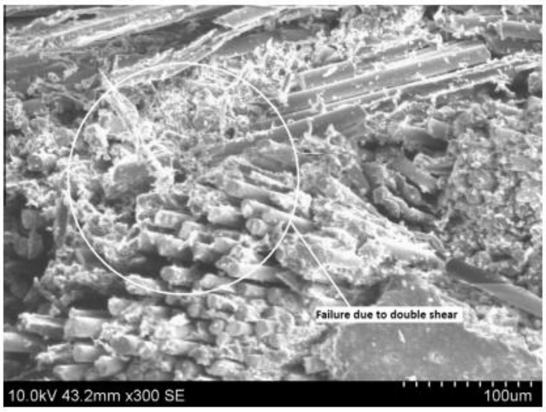

Fig. 15.SEM image of jute–GFRP composite after double shear test.

V.CONCLUSION

In this work, different natural fiber composites are fabricated with fibers like jute, banana and combining them as well. All the composites have the highest volume fraction of 0.40 along with GFRP. Their mechanical properties like tensile strength, flexural strength, shear strength and impact strength are investigated and from the results obtained, the following conclusions were drawn.

- The tensile strength of banana and jute composite is the relatively more than jute composite and much higher when compared with banana composite. It has a value of 7.1075 kN.
- The percentage elongation of single fiber in tensile testing is found to be less than that of the hybrid composite. Therefore, the hybrid composite withstands more strain before failure in tensile testing than the single fiber composite.
- The flexural strength of the composite is in decreasing order from banana, banana and jute hybrid, jute composite. Banana has the highest flexural strength since its strength increases with increase in interfacial adhesion. Flexural modulus is also found to be highest for the banana–jute–GFRP composite. From the above results, the hybrid composite is found to the best option for all general application. Banana composite can be used in applications where high impact strength is necessary. Banana and jute fibers are abundantly available from agricultural resources; they are cheaper than the conventional natural fibers like bamboo, sisal, etc. Moreover they have high mechanical properties as discussed above and hence can be used for a variety of applications like housing, automobile and packaging industry, etc.

This work can be further extended to real time replacement of automotive components such as mudguard and engine cover. The composites mechanical characteristics can be analyzed under different working conditions and better design may be suggested which will provide a way for green environment concept.

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