NATURAL FIBER REINFORCED BIODEGRADABLE POLYMER COMPOSITES AND ITS PROPERTIES TESTING

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Abstract – In the past decades, the use of conventional materials is scared because of lot utilization in the industries. Nowadays the industries are searching alternate for conventional materials, as Natural Fiber Reinforced polymer composites especially for Automobile Industries because of natural fiber reinforced polymer composites have good properties like high tensile strength, stiffness, high corrosion resistance and special property as strength to weight ratio is more. This paper mainly deals with fabrication of Natural Fiber Reinforced polymer composites by had layup process using sisal, jute, glass fiber with banana fiber and pure glass fiber, hence the mechanical properties are evaluated and compared with the glass fiber to optimize the weight, cost and to improve the strength, toughness of the material for the applications of automobiles. These Natural Fibers are biodegradable, environment-friendly green composites, where the mechanical properties are investigated and analyzed. Here, the ultimate tensile strength has calculated by universal testing machine, flexural strength has calculated by universal testing machine and the toughness has calculated by Charpy pendulum impact tester.

Index Terms – Natural Fibers; Epoxy Resin, Jute Fiber, Sisal Fiber, Glass Fiber, Laminate Preparation; Tensile Test; Flexural Test; Impact Test.

1 INTRODUCTION

In the present scenario, the usages of natural fibers are predominantly increasing day by day. Hence the natural fibers are widely used as reinforcement material because of its properties as high strength, low density, easy availability, cheap cost, eco-friendly and biodegradable [1-2]. The industries are seeking new materials which are more attractive and good mechanical properties and also environmentally friendly [1-10]. These natural fibers are extracted from plants and animals which are especially grown for fibers and also extracted from agricultural organic wastes are renewable materials (Jute, Banana, rice straw, wheat straw, etc.) have creating green composites and replacing synthetic materials which are presently being used as glass fibers, carbon fibers and plastic fibers [6]. Among the other natural fibers such as sisal fiber, jute, Kenaf and banana reinforced materials place a significant role in automobile industries and aircraft industries to meet its properties like higher specific stiffness and specific tensile strength and toughness and also low absorption, low weight [1-6]. In the present investigation reports utilization of untreated sisal, banana and jute fibers as reinforcing materials for biodegradable green composite with epoxy resin LY556 mixed with hardener HY951 as the matrix material, then the laminate is prepared by hand lay-up technique [6-11]. By the same hand lay-up process, pure synthetic glass fiber reinforced and glass fiber, banana fiber sandwiched hybrid epoxy polymer matrix composite laminate are prepared. These laminates are tested as per ASTM standards and compared with the synthetic, hybrid composites.

2. MATERIALS AND METHODS

2.1 Fiber extraction

The Natural Fibers are extracted from baste of its plant (Jute), leaves of its plant (Sisal) and stem of its plant (Banana), which are rolled through rolling machines or removed by spun through hand extraction machine composed of either non-toothed or toothed knives [6].

Then the fibers are cleaned in running water as well as curing in stacked water up to 5 – 10 days at the room temperature, to remove Skins in the rolled fibers such as coating of cellulose, broken fibers, pigments, etc., are removed manually by the use of comb, after that the fibers are soaked and washed in distilled water, cleaned and sun-dried [2][5]. Once the fibers are dried, weaving is done in the handlooms. These untreated fibers have

meshed with the size, 300 mm × 300 mm manually is as shown in Figure 1.

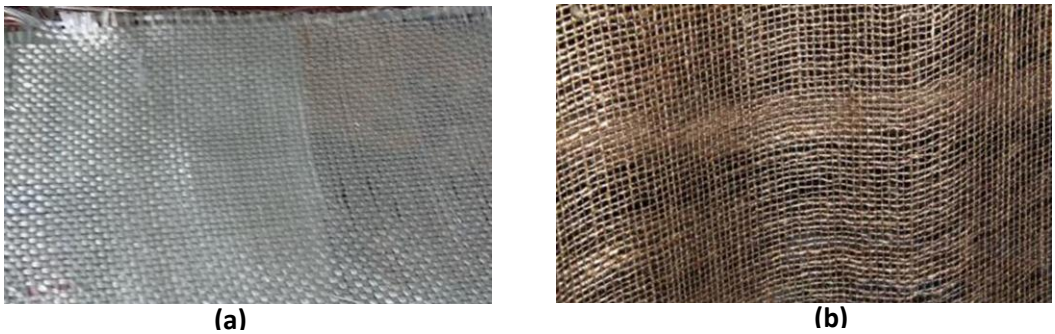


Fig. 1. Meshed Fibers. (a) Meshed Glass Fiber (b) Meshed untreated Natural Jute Fiber

2.2 Matrix

The matrix materials were prepared in the ratio 10:1, 10 parts of epoxy resin LY556 and 1 part of hardener HY951 by volume [5]. These epoxy resin and hardener were thoroughly mixed with the help of stirrer and it becomes uniform.

3. PREPARATION OF COMPOSITE

In this investigation, the composite laminates are prepared by hand lay-up process [4][5][8]. The Meshed fibers of 300 mm length were impregnated to form a fiber layer and used to prepare the specimen. Here the composite specimen consists of total five layers in which meshed fiber layers are placed one after another on the Mylar sheet1.2 mm thick and then the resin is coated on the sheet and also coated in between the fiber layers. Then this technique was continual up to entire five layers and Resin coated further evenly scattered in the fiber using a roller. The composite laminate was placed in between the press or by placing weights uniformly on it and cured further at room temperature until it was dry and gets required standard thickness. The cured and dried composites are as shown in Figure 2.

Fig. 2. Laminate Preparation by Hand lay-up Process. (a) Glass Fiber Reinforced Polymer Composite Laminate, (b) Glass Fiber with short Banana Fiber Reinforced (Hybrid) Polymer Composite Laminate, (c) Natural Jute Fiber Reinforced Polymer Composite Laminate,

4. SPECIMEN PREPARATION:

The specimens are prepared from the composite laminates according to ASTM standards of mechanical testing by using the saw cutter or abrasive disc cutter into the required number of pieces. Tensile test specimen was prepared according to the ASTM D638 (250 ×25× 5mm) standard; Flexural (3 point bending) test specimen was prepared as per the ASTM D790 (250 ×25× 5mm) standard and the impact test specimen was

prepared as per the ASTM A370 (80 × 10 mm) standard[7-11]. The specimens prepared according to ASTM standards are as shown in Figure 3 (a), (b), (c) and the specimens after testing are as shown in Figure 3 (d).

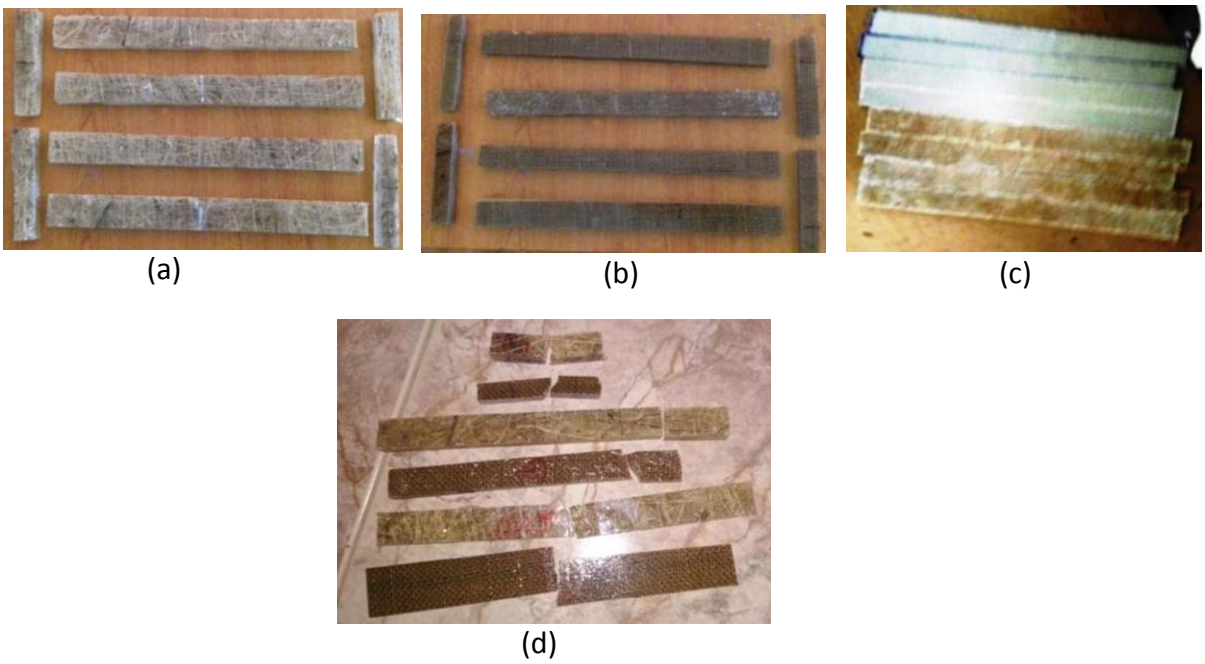


Fig. 3. Preparations of Specimens as per ASTM Standards for Tensile, Flexural, Impact test. (a) Natural Sisal Fiber Reinforced Composite Specimens for testing, (b) Natural Jute Fiber Reinforced Composite Specimens for testing, (c) Glass Fiber reinforced and Hybrid (Glass Fiber with short Banana Fiber) Composite specimens for testing, (d) Shows the all the Specimens After Testing

5. EXPERIMENTAL PROCEDURE

5.1 Tensile Test

The tensile test specimens are prepared according to ASTM D 638 standard and the machine specifications are also chosen according to the ASTM D638 [7, 9]. This tensile test conducted on Universal Testing Machine (UTM) [8] by placing the specimen in the jaws as shown in Figure 4.

Fig. 4. Universal Testing Machine (UTM). The tensile test Specimen fitted in the jaws of Universal Testing Machine.

The specimen is subjected to the tension according to the specific load until it gets fractures and the loads are recorded. The stress-strain curve was plotted during the test for evaluating the ultimate tensile strength and elastic modulus. The Young's modulus or elastic modulus was determined by drawing the straight line from the slope of the stress-strain curve [12].

5.2 Flexural Test

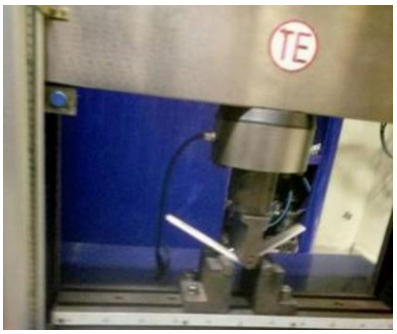
The flexural test specimens are prepared as per the ASTM D790 standard [4-11] and the machine specifications are also chosen according to the ASTM D790. The flexural test conducted on Universal Testing Machine (UTM) by placing the specimen on the table such that as simply supported and applying force on it until it gets the fracture is as shown in Figure 5 (a). The specimen deflection is measured by the crosshead position. Test results include flexural strength and displacements are tabulated.

5.3 Impact Test

The impact test specimens are prepared according to the ASTM-A370 standard [9, 10]. During the testing process, the specimen must be loaded into the testing machine and allows the pendulum until it fractures by using the (Charpy) impact test setup as shown in Figure 6. The energy required to break the material can be measured easily and can be used to measure the toughness of the material and the yield stress. The impact

strength (Toughness) values were calculated by dividing the energy by the cross-sectional area of the specimen [13-15].

(a)



(b)

Fig. 5. Flexural Test Experimental Setup on UTM. (a) Flexural test specimen placed on the Universal Testing Machine, (b) Flexural Test Performed on the Universal Testing Machine

Fig. 6. Charpy Impact Test Experimental Setup

6. RESULT AND DISCUSSION

In the future automobile and aerospace industries are facing difficulties in the scarcity of conventional materials and also with the restriction of global conditions. They are searching for green and biodegradable alternative materials with good mechanical properties like Ultimate Tensile strength; Ultimate Compressive strength and Impact strength are tested and tabulated as shown in the Table. And also stress-strain, load-displacement curves are drawn for different composites are glass Fiber Reinforced Composite, Hybrid Composite (glass fiber with short banana fiber), Jute fiber reinforced Composite and Sisal fiber reinforced composite.

Table 1 Tested Result of Specimens

	Type of Composite	Ultimate Tensile Load in KN	Ultimate Flexural Load in KN	Ultimate Tensile Strength in MPa	Ultimate Flexural Strength in MPa	Impact Energy in Joules	Impact Strength or Toughness in J/mm^2
1.	Glass Fiber reinforced Composite	22	1	243	8.5	8	0.2
2.	Glass Fiber with short banana fiber reinforced Hybrid Composite	23.8	1.6	180	10	9.33	0.16
3.	Jute Fiber reinforced Composite	25.7	1.98	200.8	15.43	10	0.2
4.	Sisal Fiber reinforced Composite	24.4	1.8	190.4	14.03	8	0.16

6.1 Comparison of Tensile Test Properties:

The tensile test was conducted in Universal Testing Machine (UTM) for different specimens, Glass Fiber Reinforced, Glass Fiber with short Banana Fiber Reinforced (Hybrid), Jute Fiber reinforced and Sisal Fiber Reinforced composite. Here the test is conducted up to fracture and the Ultimate Tensile Strength are evaluated and compared as shown in Figure 7. The specimen of pure Glass Fiber has the highest tensile strength of 243 N/mm^2 and hybrid composite has lowest tensile strength of 180 N/mm^2, the natural jute fiber reinforced composite has tensile strength 200.8 N/mm^2 similar to pure glass fiber reinforced composite and the sisal fiber reinforced composite has 190.4 N/mm^2 [11] is similar to the hybrid composite.

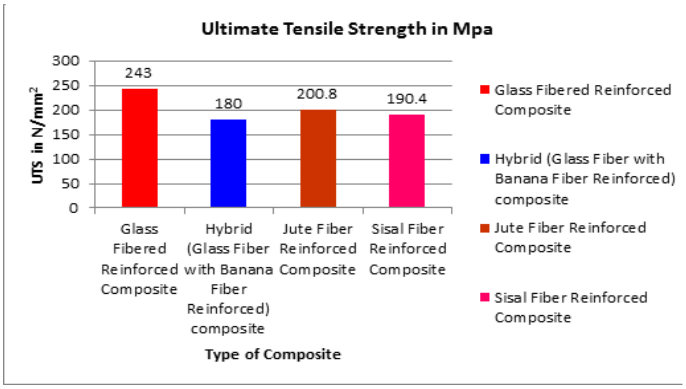


Fig. 7. Comparison of ultimate Tensile strength. Graphical representatio of Observed values, ultimate tensile strength for glass fiber composite 243 MPa, Jute fiber reinforced composite 200.8 MPa, Hybrid Composite 180 MPa and Sisal Fiber reinforced Composite 190.4 MPa. The tensile strength of Jute fibered reinforced composite is 200.8 MPa is similar to that of Glass fibered reinforced composite.

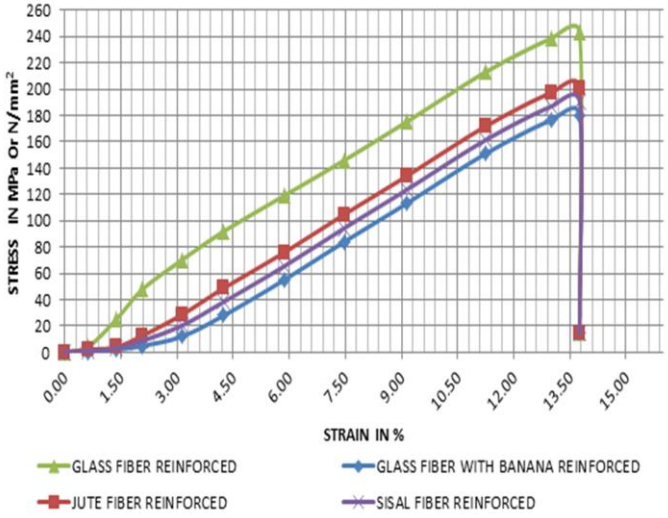


Fig. 8. Comparison of Tensile Test Stress – Strain curve. From the slope of stress strain curve the Modulus of Elasticity are evaluated and the elasticity of pure Glass Fiber has highest value of 1986.42 N/mm^2 and hybrid composite has lowest elastic modulus of 1219.45 N/mm^2, the natural jute fiber reinforced composite has elastic modulus of 1818.18 N/mm^2

In this test, the Stress-strain curves are plotted for all the specimens and compared as shown in Figure 8. The Modulus of Elasticity of each specimen is calculated from the slope of the Stress-Strain curves and discussed. The Modulus of Elasticity or elastic modulus for the specimen of pure Glass Fiber has the highest value of 1986.42 N/mm^2 and hybrid composite has lowest elastic modulus of 1219.45 N/mm^2, the natural jute fiber reinforced composite has elastic modulus of 1818.18 N/mm^2 similar to pure glass fiber reinforced composite and the sisal fiber reinforced composite has 1666.66 N/mm^2 is similar to the hybrid composite.

6.2 Comparison of Flexural Test Properties

The flexural tests were conducted in Universal Testing Machine (UTM) for different specimens. Here the test is conducted up to fracture and the Ultimate Flexural Strength are evaluated and compared as shown in Figure 9. The specimen of Natural Jute Fiber has the highest flexural strength of 15.43 N/mm^2 and pure glass fiber composite has the lowest flexural strength of 8.5 N/mm^2, the natural sisal fiber reinforced composite has flexural strength 14.03 N/mm^2 and the hybrid composite has 10 N/mm^2.

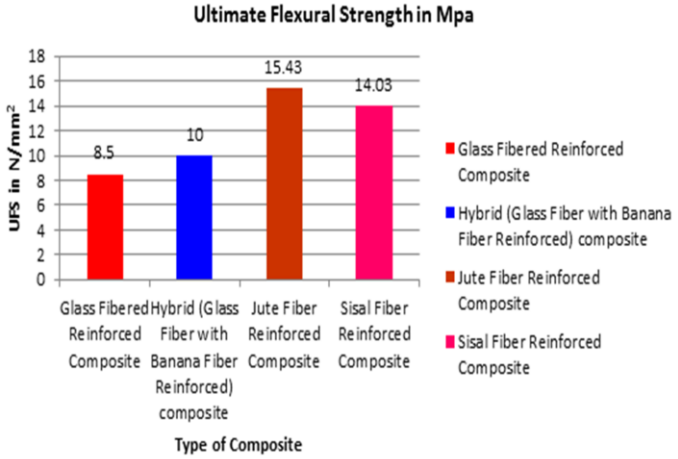


Fig. 9. Comparison of Ultimate Flextural strength. Graphical representatio of Observed values, ultimate flexural strength for glass fiber composite 8.5 MPa, Jute fiber reinforced composite 15.43 MPa, Hybrid Composite 10 MPa and Sisal Fiber reinforced Composite 14.3 MPa. The flexural strength of Jute fibered reinforced composite is 15.43 MPa is greater than that of Glass fibered reinforced composite.

In this test, the Stress-strain curves are plotted for all the specimens and compared as shown in Figure 10. The Modulus of Rigidity of each specimen is calculated from the slope of the Stress-Strain curves and discussed. The Modulus of Rigidity or Shear Modulus for the specimen of Natural Jute Fiber has the highest value of 307.7 N/mm^2 and pure glass fiber composite has lowest shear modulus of 112 N/mm^2, the sisal fiber reinforced composite has a shear modulus of 285.71 N/mm^2 and

the hybrid composite has 266.13 N/mm^2. The load-displacement curves are plotted as shown in Figure 11. And from the slope of the curves, the stiffness of the specimens are calculated [13, 14]. The specimen of jute fiber composite has the highest stiffness of 857.14 N/mm, 800 N/mm for sisal fiber, 77.96 N/mm for hybrid composite and 422.5 N/mm for pure glass fiber reinforced polymer composite.

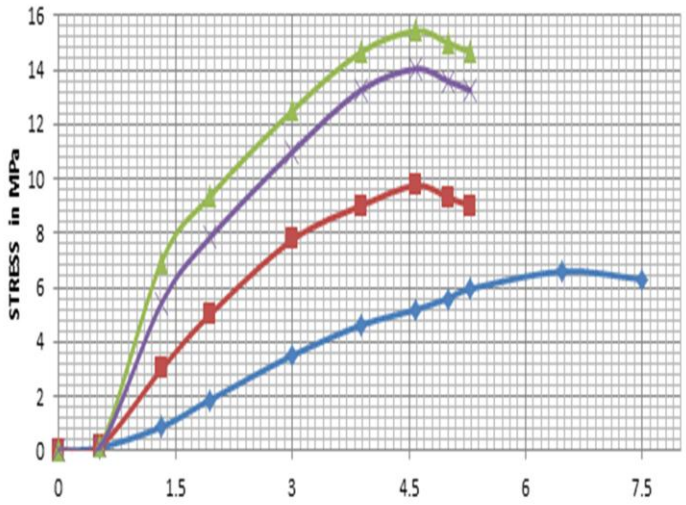


Fig.10. Comparison of Flexural Test Stress – Strain curve, From the slope of stress strain curve the Modulus of Rigidity are evaluated and the Modulus of Rigidity of Natural jute Fiber has highest value of 307.7 N/mm^2 and Glass Fiber

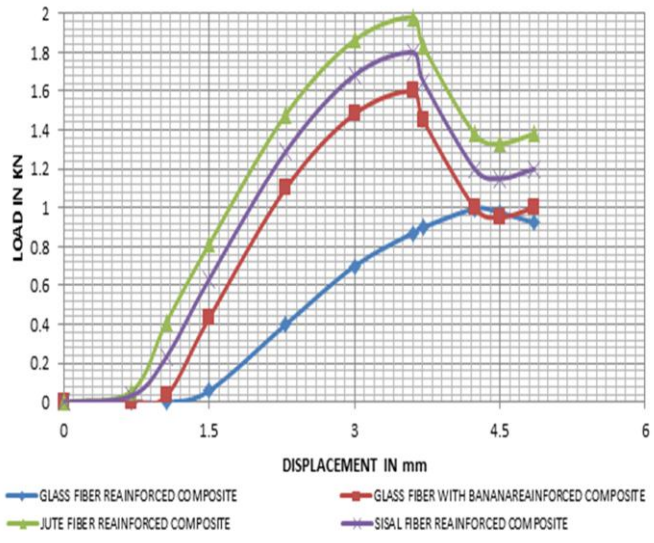


Fig. 11. Comparison of Flexural Test Load – Displacement curve. From the Load – Displacement curve stiffness are evaluated, Natural Jute fiber has highest stiffness 857.14 N/mm and Hybrid composites has lowest value of 422.5 N/mm.

Jute Fiber, sisal fiber) Reinforced Polymer Composites [14]. The impact strength or toughness is calculated and discussed as shown in Figure 12. The Impact Strength for pure glass fibered reinforced and natural jute fiber reinforced composites has equal to 0.2 J/mm^2, and for hybrid, sisal fiber reinforced composites has equal to 0.16 J/mm^2. Here the natural jute fiber reinforced composite has the highest impact strength of 0.2 J/mm^2.

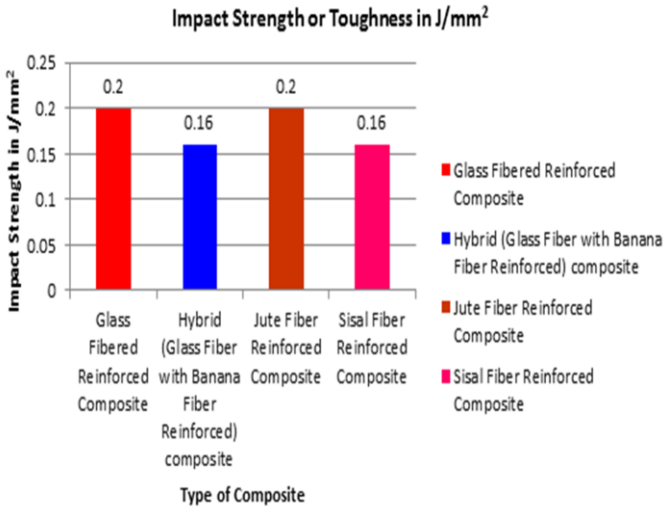


Fig. 12. Comparison of Impact strength. Graphical representatio of Observed values, Impact strength for glass fiber and Natural Jute fiber reinforced composite has equal to 0.2 J/mm^2, Hybrid Composite and Natural Sisal fiber composite has equal to 0.16 J/mm^2. Here the natural jute fiber reinforced composite has highest impact strength of 0.2 J/mm^2.

7. CONCLUSION

In the future automobile and aerospace industries are facing difficulties in the scarcity of conventional materials and also with the restriction of global conditions. They are searching for green and biodegradable alternative materials with good mechanical properties so that the mechanical properties are tested for different composites discussed above and the discussion results and conclusions are

- The ultimate tensile strength for pure Glass Fibered reinforced and Natural jute fiber reinforced epoxy polymer composite has 243N/mm^2, 200.8 N/mm^2 respectively and the modulus of elasticity 1986.42 N/mm^2, 1818.18 N/mm^2 respectively.
- The ultimate Flexural strength for pure Glass Fibered reinforced and Natural jute fiber reinforced epoxy polymer composite has 8.5N/mm^2, 15.43 N/mm^2 respectively and the modulus of rigidity 112 N/mm^2, 307.7 N/mm^2 respectively. And the stiffness for jute fiber composite has 857.14 N/mm, for glass fiber has 422.5 N/mm.

- The Impact strength for pure Glass Fibered reinforced and Natural jute fiber reinforced epoxy polymer composites are equal, and the impact strength has 0.2 J/mm^2.

By comparing the mechanical properties required for automotive and aerospace structural applications and the tested results of above mechanical properties for pure glass fiber reinforced, glass fiber with short banana fiber reinforced hybrid composite, natural jute fiber reinforced and natural sisal fiber reinforced polymer composites are compared and concluded that Ultimate flexural strength, modulus of rigidity, impact strength or toughness are more for natural jute fiber reinforced polymer composite and the Ultimate tensile strength, modulus of elasticity for natural jute fiber reinforced polymer composite has nearer and equal to glass fiber reinforced polymer composite.

From these results, we have finally concluded that the natural jute fiber reinforced composite has more strength to weight ratio and this natural fiber reinforced polymer composite is the best substitute for glass fibered reinforced composite and this composite was used for automobile and aerospace structures, biodegradable, environment-friendly and best green alternative composite material.

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