Investigation on mechanical properties and water absorbency of jute glass reinforced epoxy composite

Abstract
Fiber reinforced composite materials are attractive because of their properties such as high toughness, water resistance and can be adapted to meet the specific needs of a variety of applications. Incorporation of natural fibers can reduce the dependency over synthetic fibers. In this work, Jute glass fiber reinforced composites are fabricated by simple hand lay-up technique using epoxy resin as a matrix and various mechanical properties like tensile strength, flexural strength, impact strength and also the water absorption properties of the composite specimens are evaluated and analysed thoroughly. It is observed that incorporation of optimum amount of jute fibre with glass fibre improved mechanical properties can be achieved. Finally cost of composites are analysed and compared.

Keywords: Jute glass woven composites, water absorption, impact loading, hand layup

Introduction
A composite is a mixed material produced from two or more components constituting reinforcing matrix and a compatible matrix in order to achieve specific properties. Composite materials are popular because of its light weight, high strength, high design and shaped freedom and are used in many sectors such as armor, bullet proof jacket, protection for vehicle, car blanket, ballistic barrier, shelter for storage under special conditions. Glass fibre reinforced composite materials are common and used for wide variety of applications. Glass fiber with epoxy resin gives the pleasing finishing and resistance to flammability. Natural fibers like jute exhibit superior mechanical properties are replacing the glass and carbon fibers recently owing to their easy availability easily bio degradable, renewable and low cost.

Kundu et al shows jute jute fibers are about seven to eight times lighter than steel and have proper tensile strength, high toughness, low extensibility and ensures better breathability of fabric. Ramesh et al. studied on sisal-jute glass fiber reinforced composites and suggested that it can improve the properties and used as an alternate material for glass fiber reinforced polymer composites. M Boopalan et al. showed that addition of banana fiber in jute-epoxy reinforced hybrid composite results good mechanical and thermal properties. Moe Moe Thew and Kin Liao used short bamboo and glass fiber as reinforcing agent to reduce the dependency of high priced glass fiber as it is not ecofriendly. Jute has the potential to be used as a replacement for traditional reinforcement materials in composites for application which requires high strength to weight ratio and further weight reduction. It has also high tensile strength, low extensibility and ensures breathability of fabrics. In this study, jute and glass fiber reinforced composites were fabricated varying different proportion by simple hand layup method and their mechanical performance has been investigated by experimentally.

Experimental
Materials
In this work, for fabricating the composites specimen 100 % Jute and Glass woven fabrics are used. The fabrics are collected from the local market. The jute and glass fiber of bi-directional woven fabrics with 280gm/m² and 400gm/m² respectively are used for the fabrication of specimen. The Bisphenol based epoxy resin and HN 2200 type hardener are used. The specifications of the materials are presented in Table 1.

Table 1 Specifications of the raw materials used

| Materials        | Specifications                                                                 | Samples                                      |
|------------------|-------------------------------------------------------------------------------|----------------------------------------------|
| Jute fibre       | Bleached, woven bi-directional jute, Weight 280gm/m²                           |                                              |
| Glass fibre      | PTFE (Polytetrafluoroethylene) coated white E-glass fiber in woven form, Weight 400gm/m² |                                              |
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Table 2 Laminate stacking sequence

| Samples | Stacking sequence | Matrix % | Weight % of fibres (reinforcement) | Thickness of composites (mm) |
|---------|-------------------|----------|-----------------------------------|----------------------------|
|         |                   |          | jute | Glass |                          |
| S1      | jjj               | 70       | 30  | 0     | 3.1                      |
| S2      | jGj               | 20       | 10  |       | 2.5                      |
| S3      | GjG               | 10       | 20  |       | 2.1                      |
| S4      | GGG               | 0        | 30  |       | 1.5                      |
| S5      | jGjG              | 15       | 15  |       | 2.8                      |

Composite fabrication process

The fabrication process of the composites is carried out by conventional hand lay-up process. Here the glass and jute fibres are used as reinforcement and epoxy resin used as matrix. The corresponding hardener (HN-2200) and epoxy resin was mixed in a proportion of 10:1 by percentage of weight. Composites of different compositions are prepared with reinforcement and matrix as 30% and 70% respectively by weight. The composite specimens were put under heavy load for about 24 hours and the curing carried out at room temperature. After the curing process the samples are cut with suitable dimensions for tests. Table 2 presents the laminate stacking sequence.

Test methods

Tensile test: Tensile test also known as a tension test is one of the most common types of mechanical testing where tensile force applies on a material to measure the specimen’s response to the maximum stress. The fabricated composites are cut using a hand grinding machine to get the specific dimension (dog bone shape) for tensile testing as per ASTM:D638 standards. The schematic diagram of tensile test specimen is shown in Figure 1. The test was carried out using a universal testing machine (UTM) at a room temperature with 40% relative humidity. The tensile stress is recorded with respect to increase in strain. The specimen was placed in the grip of the tensile testing machine and the test is performed by applying tension until it undergoes fracture. The corresponding load and strain obtained are plotted on the graphs. Figure 2 presents the cut sample specimen for tensile test.

Flexural test: The flexural test is performed on the same tensile testing machine (UTM) as per the ASTM: D790 standards. According to the standard test procedure the specimens are cut into 125 mm long, 12.7mm wide and 3mm thick. In this method, the outer rollers are 64mm apart and specimens tested at a strain rate of 0.2mm/min. The test is performed at room temperature. There are three different types of specimens are used in this test which are shown in Figure 3. The specimen is subjected to a load at its center between the supports and force is applied until it breaks. Flexural test determines the maximum stress induced in the outer most fibre.

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Impact loading test: Impact strength is the capability of the material to withstand a suddenly applied load and is expressed in terms of energy. Izod impact strength test is used to measure the impact strength of composite samples by maintaining the standard ASTM D4812. The standard size of the specimen is 75x10x10mm. Figure 4 and Figure 5 present the samples of impact loading test before and after respectively.

Water absorbency test: This test measures the amount of water absorbed by a specimen or a material under specified conditions. The water absorbency test is carried out according to ASTM D570 and specimens are cut into dimensions 76.2mm in length and 25.4mm in a width by a thickness of the panel. Figure 6 shows the schematic diagram of the specimen. First the specimens are dried in an oven for a specified time and temperature (110°C) and then placed in desiccators to cool. Immediately after cooling the specimen are weighed. The material is then emerged in water for 2 and 24 hours. Finally the specimens are removed, patted dry with a lint free cloth, and weighed. Water absorption is expressed by weight percentage. The specimens for water absorbency test are shown in the Figure 7.

Results and discussion

Tensile properties

The specimen samples of different compositions are tested in the Universal Testing Machine (UTM). The typical stress–strain graphs for samples S1, S2, S3, S4 and S5 are generated directly from the machine and are presented in Figure 8, Figure 9, Figure 10, Figure 11 and Figure 12 respectively. Experimental results of tensile strength of various composites with different weight ratio of reinforcement shown in Table 3.

Figure 13 represent the comparison of tensile strength of specimens. The highest tensile strength achieved in case of hybrid composite of four layers reinforcement and when glass fiber and jute fiber content were 15%-15% of weight of total 30% reinforcement which is composite S5.
Table 3 Results of tensile strength

| Samples | Stacking sequence | Tensile Strength (MPa) | Elastic Modulus (MPa) | Energy (J) | Maximum Force (KN) | Elongation (%) |
|---------|-------------------|------------------------|-----------------------|------------|---------------------|---------------|
| S1 JJJ  | 50.7              | 2047                   | 1.031                 | 640        | 6.24                |
| S2 JGJ  | 66.3              | 3612                   | 4.174                 | 1380       | 12.78               |
| S3 GJG  | 129.8             | 1339                   | 3.557                 | 2180       | 6.24                |
| S4 GGG  | 161.7             | 1111                   | 5.91                  | 2552       | 9.54                |
| S5 JGJG | 218.1             | 1111                   | 5.91                  | 2552       | 9.54                |

Figure 8 Stress strain curve for tensile test in JJJ composite.

Figure 9 Stress strain curve for tensile test in JGJ composite.

Figure 10 Stress strain curve for tensile test in GJG composite.

Figure 11 Stress strain curve for tensile test in GGG composite.

Figure 12 Stress strain curve for tensile test in JGJG composite.

Figure 13 Representation of tensile strength of specimens.

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It is clear that the increasing amount of glass fibre increases the tensile strength of the composites. However, with the increasing of natural fiber content than synthetic fiber content, the overall tensile strength was decreased. Moreover, increasing of jute fiber reinforcement, the composite becomes more brittle as jute shows brittle behavior and overall strength decreases.

**Flexural properties**

The composite specimens for flexural test were prepared rectangular in shape and they were carried out in UTM machine in accordance with ASTM standard to measure the flexural strength of the samples. Load with respect to Cross Head Travel is plotted for the determination of flexural strength. The jute-glass fiber reinforced composite sample exhibits a significant difference in strength. The typical stress strain curve generated from machine for samples S1, S2, S3, S4 and S5 are presented in Figure 14, Figure 15, Figure 16, Figure 17 and Figure 18 respectively.

Table 4 presents the overall flexural properties of specimens. The flexural strength of jute-epoxy composite is lower than that of glass-epoxy composites because jute fibers have less stiffness in comparison to glass. The composite gives better flexural strength by the addition of jute fiber with glass fibers than single reinforced composites which is shown in the Figure 19.

![Figure 14 Stress strain curve for flexural test in JJJ composite.](image1)

![Figure 15 Stress strain curve for flexural test in JGJ composite.](image2)

![Figure 16 Stress strain curve for flexural test in GJG composite.](image3)

![Figure 17 Stress strain curve for flexural test in GGG composite.](image4)

![Figure 18 Stress strain curve for flexural test in JJJ composite.](image5)

![Figure 19 Representation of flexural strength of specimens.](image6)
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**Table 4 Results of Flexural strength**

| Samples | Stacking sequence | Flexural Strength (MPa) | Strain (%) | Energy (J) | Young’s Modulus (MPa) | Maximum Force (N) |
|----------|-------------------|-------------------------|------------|------------|-----------------------|------------------|
| S1       | JJJ               | 40.72                   | 1.637      | 0.2044     | 3720                  | 60.1             |
| S2       | JGJ               | 58.1                    | 2.715      | 0.15165    | 3740                  | 55.7             |
| S3       | GJG               | 352.3                   | 2.076      | 0.925      | 13165                 | 355              |
| S4       | GGG               | 343.6                   | 1.719      | 0.3978     | 16614                 | 640              |
| S5       | JGJG              | 61.8                    | 2.285      | 0.84       | 3650                  | 72               |

**Impact strength properties**

The impact strength properties of different composites are shown in Table 5.

The results indicated that the maximum impact strength is obtained for hybrid composites followed by 15% glass and 15% jute fiber composites as in Figure 20. However, jute composite exhibit low performance compared to other composites. On increasing the amount of jute content, which is more brittle than glass fiber, the overall brittleness of material increases and impact strength decreases. But the optimum amount of natural fiber addition with glass fiber can improve the overall impact strength of the composite.

**Absorbency test result**

All the specimens were carried out for water absorbency test by maintaining ASTM Standard and calculated the absorbency test in percentage shown in Table 6 and Figure 21.

**Table 5 Impact Strength properties of specimens**

| Samples | Stacking sequence | Specimen Energy (J) | Specimen E/W (J/mm) | Pendulum energy (J) | Impact strength (J/mm²) |
|----------|-------------------|---------------------|---------------------|---------------------|-------------------------|
| S1       | JJJ               | 7.585               | 3.214               | 10.028              | 0.156                   |
| S2       | JGJ               | 6.055               | 3.52                | 10.028              | 0.166                   |
| S3       | GJG               | 8.008               | 3.742               | 10.028              | 0.169                   |
| S4       | GGG               | 5.891               | 3.386               | 10.028              | 0.16                    |
| S5       | JGJG              | 6.84                | 4.071               | 10.028              | 0.186                   |

**Table 6 Absorbency test result of the specimens**

| Immersion Time | Sample | Dried sample weight (gm) | Wet sample weight (gm) | Water absorbency (%) |
|----------------|--------|--------------------------|------------------------|----------------------|
| 2 –hours       | S1     | 3.57                     | 3.58                   | 0.28                 |
|                | S2     | 4.95                     | 4.96                   | 0.2                  |
|                | S3     | 5.08                     | 5.09                   | 0.19                 |
|                | S4     | 6.48                     | 6.49                   | 0.15                 |
|                | S5     | 6.22                     | 6.23                   | 0.16                 |
|                | S1     | 3.99                     | 4.08                   | 2.25                 |
|                | S2     | 4.37                     | 4.45                   | 1.83                 |
| 24- hours      | S3     | 4.95                     | 5                      | 1                    |
|                | S4     | 7                        | 7.04                   | 0.57                 |
|                | S5     | 6.2                      | 6.25                   | 0.8                  |

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Conclusion

This work showed that by incorporating the optimum amount of natural fibers, the overall strength of glass fiber reinforced hybrid composite can be increased. It is observed that in making composites for low load bearing applications, jute fiber can be a partial replacement of high cost synthetic fibers. Due to high stiffness and impact strength of Jute reinforced glass epoxy composite, it has good damage tolerance, lighter weight, good surface finish & appearances, weight reduction hence higher fuel efficiency, so they would enjoy wider applications in automobiles and railway coaches and sporting goods such as skis, canoe helmets. However, due to less water absorption, glass-epoxy reinforced composite can be used for door application such as insulated indoor and outdoor, underground piping, tanks, washroom door etc.

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Conflicts of interest

The authors have no conflicts of interest regarding the publication of this paper.

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