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A Study on Mechanical Properties and Water Absorption Behaviour of Jute Composites

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Elimination of huge waste produced by mankind has become a sensitive issue in the present scenario. To preserve our earth and to make it pollution free, it becomes necessary to reduce the garbage causing pollution. Plant fibers are the best and abundant sources of natural reinforcement readily available. These fibers can be used for fabrication of composites which can reduce the problem of pollution (garbage). In this study composites of jute are fabricated by hand layup and compression molding using reinforcement material of jute and matrix material as epoxy resin of different areal densities (4, 5, 5.5 and 7.5 kg/m^2) or layers and produced jute epoxy composites are tested for physical, mechanical and water absorption behaviour to meet the demands of the fiber based jute composites. It was observed that the different mechanical properties of the fiber based jute epoxy composites were significantly influenced by the areal density and number of layers It was obtained that there was an increase in mechanical properties like tensile and flexural strength of jute-epoxy composite with areal density up to 5.5 kg/m^2 and further these properties decreases with increase in areal density. On the other hand, the impact strength and water absorptivity increases with increase in areal density and number of layers of composite.

Keywords: jute-epoxy composite, composite fabrication, areal density, mechanical properties

1 Introduction

Elimination of huge waste produced by mankind has become a sensitive issue in the present scenario. Most of the waste consists of plastics, metals, glass *etc.* and are responsible for various types of environmental pollution in urban areas[1]. To preserve our earth and to make it pollution free, it becomes necessary to reduce the garbage causing pollution. Problem can be solved by the use of environmental friendly or biodegradable materials (green composites)[2]. Green composite materials are produced from natural fibers[3-6]. These fibers offer excellent properties related to environmental safety such as easiness in recycling, biodegradability lower density, low cost, strength, stiffness and high specific properties[7-12]. Plant fibres are one of the most easily and widely available natural sources of reinforcement which can be used for fabrication of bridgeable composites. Composites made from natural fiber have inferior impacts on environment in comparison to glass fiber[13,14]. In the present scenario, fibrous materials like wood and bamboo have found wide applications in construction industries[15]. Similarly automotive and aerospace industries use fibres found in pineapple, sisal, jute, banana and coir for manufacturing of various components[16] packaging industries[17-19] and bio-medical science[20]. Due to their typical benefits composites prepared from natural fibres have wide applications in today's market[21-25].

Jute fiber has received rapid attention by various researchers on its immense applications and material design of the composite decides its performance and quality[26,27]. In jute composites high strength jute fibers are surrounded by or fused to a matrix with separate boundaries or interfaces in between them although, both fibers and matrices maintain their original properties (physical and chemical) and they yield a blend of improved properties which cannot be produced with any of the elements acting separately. Jute is considered as a preferred reinforcing material for composites due to its nature, cost and processing requirements. Fibers of jute are strong, rigid and coarse with limited extensibility which improves its reinforcing properties[28]. Jute fibers are the main load

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absorbing member in these composites, whereas it is kept in its necessary condition and orientation by the surrounding matrix, this matrix also plays the important role in transferring the load and protects the fibers from damage due to environment like that of high temperature and humidity[29].

Various researchers have discussed on characterization and different mechanical properties of fiber based composites of jute laminates[30-36]. Although an enormous amount of work has been done on the fiber based jute composites yet very limited amount of work is available on the mechanical properties and water absorption behaviour of jute composites considering the variation of areal density or number of layers of composites. Hence the present study is conducted to measure the effects of areal density or number of layers on the mechanical and water absorption behaviour of jute epoxy composites. In this study jute composites of different areal densities are fabricated by hand layup and compression molding. Fabricated composites were subjected to test the various mechanical properties such as tensile, impact and flexural strength. Moreover water absorption behaviour properties were also evaluated to meet the demands of jute based fiber composites.

2 Methodology

2.1 Materials

In this study the specimen of composite is fabricated using jute as reinforcement and epoxy as matrix material. Both reinforcement and matrix materials are purchased from local suppliers. The physical properties of reinforcement and matrix material used in fabrication of composites are provided in Table 1 and Table 2 respectively.

Table 1 — Physical properties of natural jute fiber (reinforcement)

Physical Property	Jute fiber
Breaking strength (Wrap)	278 Kgf
Breaking strength (Weft)	121.8 Kgf
Mass	473.5 gsm

Table 2 — Physical properties of epoxy (matrix)

Physical Property	Epoxy
Aspect (visual)	clear pale yellow liquid
Colour (Gardner, ISO 4630)	≤ 2
Viscosity at 25 °C (ISO 9371B)	10000 - 12000 [MPas]
Density at 25 °C (ISO 1675)	1.15 - 1.20 [gms/cm^3]
Epoxy index (ISO 3000)	5.30 - 5.45 [Eq/kg]

2.1.1 Composite Fabrication

Hand layup process followed by compression molding is used for the manufacture of jute composite material used in the study. Procedure of fabrication of the jute composite used in this study is provided in Fig. 1. After preparation of the specimen the edges of the fabricated composite are carefully cut by saw to meet the requirement of standard dimensions. The composite samples of four different compositions JE-1 to JE-4 having matrix material as epoxy resin and reinforcement as jute were prepared and shown in Fig. 2. The amount of jute and epoxy used in the manufacture of composites with different areal densities are provided in Table. 3.

2.2 Mechanical Properties of Composites

The prepared specimens of fabricated composites were subjected to testing of different mechanical properties according to ASTM standards and statically significant results were recorded.

2.2.1 Tensile tests

INSTRON 5900 (Instron, USA) universal testing machine was used for measurement of tensile strength of jute composite specimens with varying areal densities. The test was conducted using a load cell of 5 kN with a cross head speed of 5 mm/min and various values were recorded as a result. The dimensions 250mm x 25 mm x t (length x

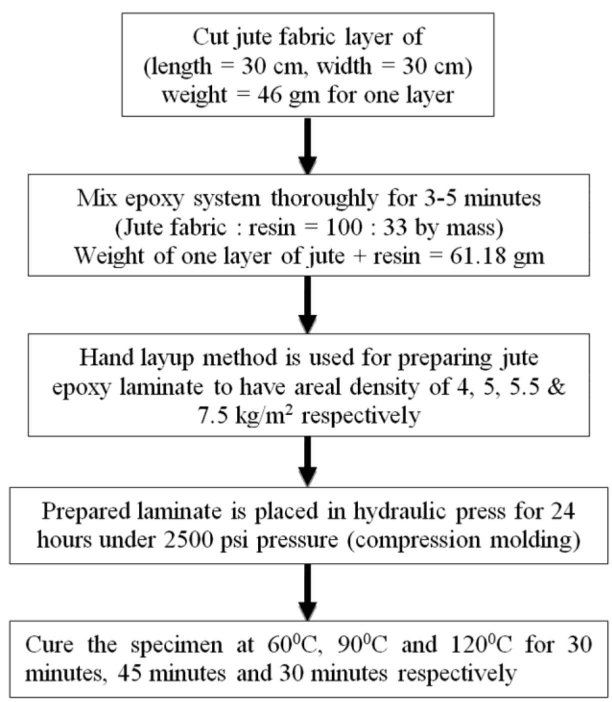

Fig. 1 — Preparation of the jute composite.

width x thickness) were selected according to ASTM D3039 standards the value of *t* varies for different samples as provided in Table 3.

2.2.2 Flexural tests

The ability of the bending of material before the bending point is known as the flexural strength of the material. STAR TESTING SYSTEM 77 on a universal testing machine was used for the flexural test on the composite specimen. The flexural test was conducted using 3-point flexure test and the testing specimens were prepared taking into considerations of ASTM D790 - 81 standards. The dimensions of specimens for the flexural test were 100 x 15 x *t* (mm^3) the value of *t* varies for different samples as provided in Table. 3. The test was conducted at room temperature at constant speed of 10 mm/min.

Fig. 2 — Fabricated composites.

2.2.3 Impact tests

Impact testing machine Zwick Roell RKP450 was used for Charpy test in this study. The specimens were made according to the dimensions of ASTM D256 in which the dimensions are 63.5 x 12.7 x *t* (mm^3) where t is the thickness and varies for different samples as provided in Table. 3.

2.2.4 Water Absorption tests

ASTM 570 standards were used for testing of water absorption capacities of fabricated jute composites with different areal densities. Dimensions of the specimens 50 x 50 (mm^2) were used for testing of water absorption test; the specimens were placed in a microwave oven at 50°C for half an hour and weighted immediately using precise balance. Specimens were then submerged in a distilled water bath at room temperature for a day and weighed immediately after wiping away water from the surface; specimens were again measured on the same precise balance. The equation using difference in weight provided below is used for the calculation of water absorption capacity of the jute composites with different areal densities.

$$\text{Water absorption (\%)} = \frac{W_2 - W_1}{W_1} \text{x } 100$$

W_1 and W_2 represent the weights of the dry and wet samples

3 Results and Discussions

3.1 Tensile strength

Tensile test was performed to evaluate the influence of areal density on the fabricated jute-epoxy composite. The tensile strength of four test specimens with varying areal densities is provided in Table. 4. It

Table 3 — Characterization of prepared samples

Sample	Areal density (kg/m^2)	Number of layers (for 33 % of epoxy resin)	Thickness (t) (mm)	Fiber content (gm)	Epoxy calculated (gm)
JE 1	4.0	5.88 ≈ 6	3.20	276	91.08
JE 2	5.0	7.35≈ 7	3.85	322	106.26
JE 3	5.5	8.08≈ 8	4.75	368	121.44
JE 4	7.5	11.02≈ 11	6.35	506	166.98

Table 4 — Tensile strength of jute fiber with different areal density

Specimen	Areal density (kg/m^2)	Span length (mm)	Tensile strength (MPa)	Modulus of elasticity (GPa)
JE 1 (6 layers)	4	150	84.08	5.13
JE 2 (7 layers)	5	150	85.65	3.96
JE 3 (8 layers)	5.5	150	86.28	3.16
JE 4(11 layers)	7.5	150	72.86	2.69

Table 5 — Flexural strength of jute fiber with different areal density

Specimen	Areal density (kg/m^2)	Max. load (kg)	Max. displacement (%)	Flexural strength (MPa)
JE 1 (6 layers)	4	19.05	54.33	109.49
JE 2 (7 layers)	5	27.80	44.33	110.41
JE 3 (8 layers)	5.5	45.33	25.0	118.25
JE 4 (11 layers)	7.5	73.66	33.15	109.18

Table 6 — Impact strength of jute fiber with different areal density

Specimen	Areal density (kg/m^2)	Impact strength sample-1 (Joule)	Impact strength sample 2 (Joule)	Mean Impact strength (Joule)
JE 1 (6 layers)	4	1.2	1	1.1
JE 2 (7 layers)	5	1	1	1
JE 3 (8 layers)	5.5	1.8	1.8	1.8
JE 4 (11 layers)	7.5	1.9	2	1.95

is concluded by Table 4 that the tensile strength and modulus of elasticity of the specimen increases with the increase in the areal density of the jute composite and its maximum value is obtained at areal density of 5.5 kg/m^2. After that the tensile strength decreases with the increase of areal density since the wettability of the jute layer decreases and possibility of presence of voids in the laminate increases. If the number of layers in the composite increases then the number of voids increases and it becomes very difficult to wet all the layers accurately with epoxy and this leads to decrease in the tensile strength of the jute composite.

3.2 Flexural strength

The flexural strength of four test specimens with varying areal density is shown in table 5. It is predicted from table 5 that the flexural strength of jute composites increases with the increase in the areal density and its maximum value is obtained at areal density of 5.5 kg/m^2. Further flexural strength decreases with increase of areal density as the wettability of the jute layer decreases and possibility of presence of voids in the laminate increases. The flexural strength of the jute decreases after reaching optimum limit and there is no further increase is observed in flexural strength with increase in the value of areal density or with the increase in number of layers of jute composites as number of voids rises with number of layers and it becomes very challenging to wet all the layers perfectly with epoxy and this is responsible for decrease in the flexural strength of jute composites.

3.3 Impact strength

Impact test of five test specimens were conducted as per ASTM standard. The impact strength of four test specimens with varying areal density is shown in table 6. It was observed that specimen with areal density 7.5 kg/m^2 showed the maximum impact strength. Therefore, the results revealed that the incorporation of layers had shown significant improvement in the impact strength of all 4 test specimens.

Table 7 — Water absorption of jute fiber with different areal density

Specimen	Areal density (kg/m^2)	% Water absorption
JE 1 (6 layers)	4	5.12
JE 2 (7 layers)	5	5.35
JE 3 (8 layers)	5.5	5.64
JE 4 (11 layers)	7.5	6.04

3.4 Water Absorptivity

Table 7 shows the effect of areal density on the water absorption of jute composites. It is observed from table 7 that water absorption of jute fibre is less and it increases with the areal density. The water absorption behaviour of jute composites does not have significant variation with varying areal density. Water absorption for all samples is less than 10% which suggests that these are excellent materials for flowing problems and artificial roofing. Therefore these composites can be used in underground insulating pipe materials because of their low thickness and insulating property. Further these composites have high strength and low density hence they will be useful in making fan blades.

Conclusions

Jute-epoxy composites were fabricated and evaluated for various mechanical properties and water absorption behaviour as these are equally important parameters for the selection of composite, the condition which enables maximum mechanical properties and minimum water uptake is considered as the best for application purpose. It was observed that there is a significant influence of areal density and number of layers on the properties of the fabricated jute epoxy composite. The strength like tensile and flexural properties of composite increases with areal density up to 5.5 kg/m^2 and further it decreases. On the other hand, the impact strength and water absorptivity increases with increase in areal density and number of layers of composite. Jute composites can be selected as a potential alternative in various applications in an alternate to wood, car dashboards, as an insulator over pipes, electric switch boards etc. and it can also be used in case of low loading conditions. Thus, it is recommended for many more applications to decrease the dependence on synthetic fibers and metals as India has an advantage over other countries in jute production.

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