Sugarcane Bagasse Reinforced Polyester Composites

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Abstract: *A composite material is made by combining two or more materials to give a unique combination of properties, one of which is made up of stiff, short fibres and the other, a binder or 'matrix' which holds the fibres in place. The fibres are strong and stiff relative to the matrix and are generally orthotropic. More recently natural fibers have been employed in combination with plastics. The abundant availability of natural fibre in India such as Jute, Coir, Pineapple, Sugarcane, Kenaf, Bamboo, Banana etc. gives attention on the development of natural fibre composites primarily to explore value-added applications. Reinforcement with natural fibre in composites has recently gained attention due to low cost, low density, acceptable specific properties, ease of separation, enhanced energy recovery, C02 neutrality, biodegradability and recyclable nature. Recently the interest in composite materials reinforced with natural fibers has considerably increased due to the new environmental legislation as well as consumer pressure that forced manufacturing industries to search substitutes for the conventional materials, e.g. glass fibers. The objective of paper is to evaluate the mechanical properties and characterization of sugarcane bagasse reinforced polyester composite.*

Keywords: Sugarcane Bagasse Composite, Tensile Test, Bending Test, Water Absorption Test.

1. Introduction

1.1 Need of Composites:

Plastics and Ceramics have been the dominant emerging materials. The volume and numbers of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite applications from aircraft to other commercial uses has become prominent in recent years.

1.2 Definition of Composite

Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form. The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity or the laws which should given it which distinguishes it from other very banal, meaningless mixtures. The composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them.

1.3 Properties of Composites

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement or reinforcing material, whereas the continuous phase is termed as the matrix. Properties of composites are strongly dependent on the properties of their constituent materials, their distribution and the interaction among them. The composite properties may be the volume fraction sum of the properties of the constituents or the constituents may interact in a synergistic way resulting in improved or better properties. Further, the need of composite for lighter construction materials and more seismic resistant structures has placed high emphasis on the use of new and advanced materials that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures. Composites are now extensively being used for rehabilitation strengthening constituent materials; the geometry of the reinforcement (shape, size and size distribution) influences the properties of the composite to a great extent. The concentration distribution and orientation of the reinforcement also affect the properties.

1.4 Elements of Composite Materials:

A composite material is one, which is made of at least two elements working together to give material properties that are different to the properties of those elements on their own. Most composites consist of a bulk material (matrix) and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

1.4.1 Importance of matrix in a composite

Many materials when they are in a fibrous form exhibit very good strength property but to achieve these properties the fibres should be bonded by a suitable matrix. The matrix isolates the fibres from one another in order to prevent abrasion and formation of new surface flaws and acts as a bridge to hold the fibres in place. A good matrix should possess ability to deform easily under applied load, transfer the load onto the fibres and evenly distributive stress concentration.

1.4.2 Materials used as matrix in composites:

1.4.2.1 Bulk Phases

Bulk phases consist of following matrix systems:

1.4.2.1.1 Metal Matrix

Metal matrix composites possess some attractive properties, when compared with organic matrices. These include

(i) Good strength at higher temperatures,

(ii) Higher transverse strength,

(iii) Excellent electrical conductivity,

(iv) Superior thermal conductivity,

(v) Higher erosion resistance etc.

However, the major disadvantage of metal matrix composites is their higher densities and consequently lower specific mechanical properties compared to polymer matrix composites. Another notable difficulty is the high-energy requirement for fabrication of such composites.

1.4.2.1.2 Polymer Matrix

A very large number of polymeric materials, both thermosetting and thermoplastic, are used as matrix materials for the composites. Some of the major advantages and limitations of resin matrix are shown in Table 1.

Table 1: Advantages and Limitations of resin matrix

advantages	limitations
1. Low Densities	1. Low Transverse Strength.
2. Good Corrosion Resistance	2. Low Operational Temperature Limits
3. Low Thermal Conductivities	
4. Low Electrical Conductivities	
5.Translucence	
6.Aesthetic Color Effects	

1.4.2.1.3 Ceramic Matrix

Ceramic materials are inorganic, non-metallic materials made from compounds of a metal and a non-metal. Ceramic materials may be crystalline or partly crystalline. They are formed by the action of heat and subsequent cooling. Clay was one of the earliest materials used to produce ceramics, but many different ceramic materials are now used in domestic, industrial and building products. Ceramic materials tend to be strong, stiff, brittle, chemically inert and non-conductors of heat and electricity, but their properties vary widely. For example, porcelain is widely used to make electrical insulators, but some ceramic compounds are superconductors. Ceramic fibres, such as alumina and SiC (Silicon Carbide) are advantageous in very high temperature applications and also where environment attack is an issue. Since ceramics have poor properties in tension and shear, most applications as reinforcement are in the particulate form (e.g. zinc and calcium phosphate). Ceramic Matrix Composites (CMCs) used in very high temperature environments, these materials use a ceramic as the matrix and reinforce it with short fibres, or whiskers such as those made from silicon carbide and boron nitride.

1.4.2.2 Reinforcement

The purpose of the reinforcement in a composite material is to increase the mechanical properties of the neat resin system. All of the different fibres used in composites have different properties and so affect the properties of the composite in different ways. For most of the applications, the fibres need to be arranged into some form of sheet, known as a fabric, to make handling possible.

1.4.2.3 Interface

It has characteristics that are not depicted by any of the component in isolation. The interface is a bounding surface or zone where a discontinuity occurs, whether physical, mechanical, chemical etc. The matrix material must wet the fiber. Coupling agents are frequently used to improve wet ability. Well wetted fibres increase the interface surfaces area. To obtain desirable properties in a composite, the applied load should be effectively transferred from the matrix to the fibres via the interface. This means that the interface must be large and exhibit strong adhesion between fibres and matrix. Failure at the interface (called debonding) may or may not be desirable.

2. Classification

Composite materials can be classified in different ways. The two broad classes of composites are (1) Particulate composites and (2) Fibrous composites.

2.1 Particulate Composites

As the name itself indicates, the reinforcement is of particle nature (platelets are also included in this class). It may be spherical, cubic, tetragonal, a platelet, or of other regular or irregular shape, but it is approximately equiaxed. In general, particles are not very effective in improving fracture resistance but they enhance the stiffness of the composite to a limited extent. Particle fillers are widely used to improve the properties of matrix materials such as to modify the thermal and electrical conductivities, improve performance at elevated temperatures, reduce friction, increase wear and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage.

2.2 Fibrous composites

A fibre is characterized by its length being much greater compared to its cross-sectional dimensions. The dimensions of the reinforcement determine its capability of contributing its properties to the composite. Fibres are very effective in improving the fracture resistance of the matrix since a reinforcement having a long dimension discourages the growth of incipient cracks normal to the reinforcement that might otherwise lead to failure, particularly with brittle matrices. Man-made filaments or fibres of non-polymeric materials exhibit much higher strength along their length since large flaws, which may be present in the bulk material, are minimized because of the small cross-sectional dimensions of the fibre. In the case of polymeric materials, orientation of the molecular structure is responsible for high strength and stiffness. Fibres, because of their small cross- sectional dimensions, are not directly usable in engineering applications. They are, therefore, embedded in matrix materials to form fibrous composites. The matrix serves to bind the fibres together, transfer loads to the fibres and protect them against environmental attack and damage due to handling. In discontinuous fibre reinforced composites, the load transfer function of the matrix is more critical than in continuous fibre composite.

2.3 Natural Fiber Composites

Natural fiber composites are made of Cotton, Flax, Jute, Sisal, Hemp and non-conventional fiber such as Coir & different EFBs (empty fruit bunches) and Wood fibers. Wood fiber thermoplastic composites are attractive, insect- and rot-resistant, and paintable that can be made to have the look of wood. In addition, they are stiffer, cheaper than plastic products, with more life-cycle coseo, Vegetable fiber thermoplastic composites are attractive to the automotive industry because of their low density and ecological advantages over conventional composites Natural fibres are lingo cellulosic in nature. These composites are gaining importance due to their non-carcinogenic and bio-degradable nature. The natural fiber composites can be very cost effective material especially for building and construction industry (panels, false ceilings, partition boards etc.) packaging, automobile and railway coach interiors and storage devices. This also can be a potential candidate in making of composites, especially for partial replacement of high cost glass fibers for low load bearing applications. However in many instances residues from traditional crops such as rice husk or sugarcane bagasse or from the usual processing operations of timber industries do not meet the requisites of being long fibers.

Large varieties of sugar cane grow abundantly in many parts of India. Cane is crushed in a series of mills each consisting of at least three heavy rollers. Due to the crushing, the cane stalk will break in small pieces and subsequent milling will squeeze the juice out. The juice is collected and processed for production of sugar. The resulting crushed and squeezed cane stalk, named bagasse, is considered to be a by-product of the milling process. Bagasse is essentially a waste product that causes mills to incur additional disposal costs. Bagasse is a fibrous residue that remains after crushing the stalks and contains short fibers. It consists of water, fibers and small amounts of soluble solids. Percent contribution of each of these components varies according to the variety, maturity, method of harvesting and the efficiency of the crushing plant. Table 2 shows a typical bagasse composition.

Table 2: Average Bagasse Compositions

items	percentage (%)
1. Moisture	49.0
2. Soluble solids	02.3
3. Fibre	48.7

3. Fiber Reinforced Calculations

Table 3: Composition of Composite Plate

Tensile Test specimen	Bending Test specimen	% of Fiber	% of polyester
A	D	10	90
B	E	20	80
C	F	30	70

Variables Used

V_c	Volume of Composite
V_f	Volume of Fiber
V_m	Volume of Matrix
ρ_c	Density of Composite
ρ_f	Density of Fiber
ρ_m	Density of Matrix
W_c	Weight of Composite
W_f	Weight of Fiber
W_m	Weight of Matrix
w_f	Percentage Weight of Fiber
w_m	Percentage Weight of Matrix

Formulas Used

1. Volume of Composite, V_c= l*b*h

where l = length

b = breadth

h = height

2. Density of Composite,

$$\frac{1}{\rho_c} = \frac{w_f}{\rho_f} + \frac{w_m}{\rho_m}$$

3. Weight of Composite, $W_c = \rho_c * V_c$

4. Volume of Fiber, $V_f = w_f * V_c$

5. Volume of Matrix, $V_m = w_m * V_c$

6. Weight of Fiber, $W_f = \rho_f * V_f$

7. Weight of Matrix, $W_m = \rho_m * V_m$

8. Weight of Composite, $W_c = W_m + W_f$

<u>For 10% Bagasse Fiber</u>

1. Volume of die =Volume of Composite = l*b*h

= 180*90*3.5

= 56700 mm^3

2. Density of Composite,

$$\frac{1}{\rho_c} = \frac{w_f}{\rho_f} + \frac{w_m}{\rho_m}$$

$$\frac{1}{\rho_c} = \frac{0.1}{1.25*10^{-3}} + \frac{0.9}{1.37*10^{-3}}$$

$\rho_c = 1.356*10^{-3}$ gm/mm^3

3. Weight of Composite, $W_c = \rho_c * V_c$

$=1.356*10^{-3} *56700$

=76.88 gm

4. Volume of Fiber, $V_f = w_f * V_c$

= 0.1*56700

= 5670 mm^3

5. Volume of Matrix, $V_m = w_m * V_c$

= 0.9*56700

=51030 mm^3

6. Weight of Fiber, $W_f = \rho_f * V_f$

$= (1.25*10^{-3})*5670$

= 7.08 gm

7. Weight of Matrix, $W_m = \rho_m * V_m$

$= (1.37*10^{-3})*51030$

= 69.91 gm

8. Weight of Composite, $W_c = W_m + W_f$

= 69.91+7.08 = 76.99 gm

Percentage of Fibers (In %)	Weight of Composite (gm)
10	76.99
20	76.31
30	75.63

4. Results and Discussion

4.1 Tensile Test

A tensile test, also known a tension test, is probably the most fundamental type of mechanical test you can perform on a material. Tensile tests are simply relatively inexpensive and fully standardized. As the material is being pulled, you will find its strength along with how much it will elongate. Here, all tests are performed on the basis of **ASTM D638** Standards.

<u>For 10% Bagasse Fiber</u>

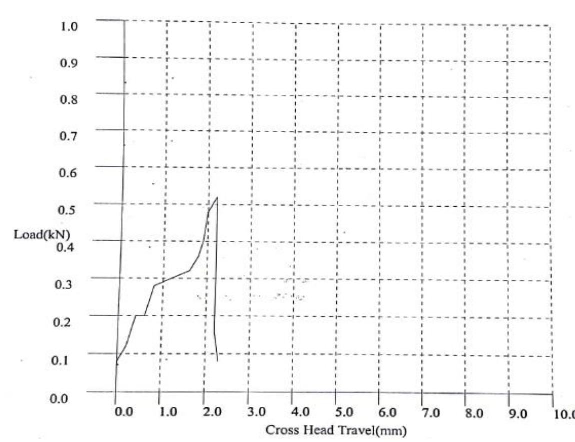

Fig 1(a) Tensile Test for Specimen A

For 20% Bagasse Fiber

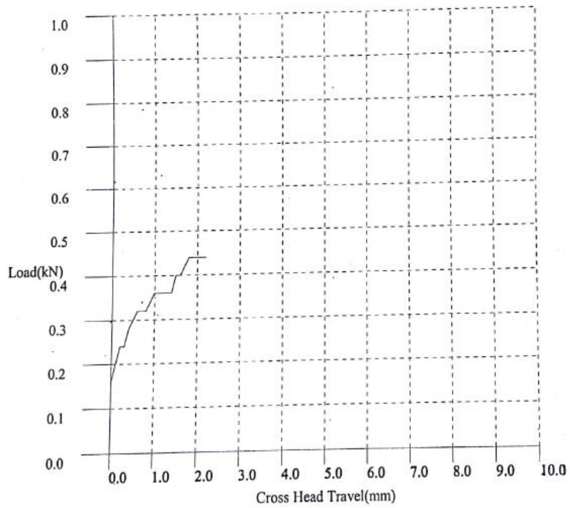

Fig 1(b) Tensile Test for Specimen B

For 30% Bagasse Fiber

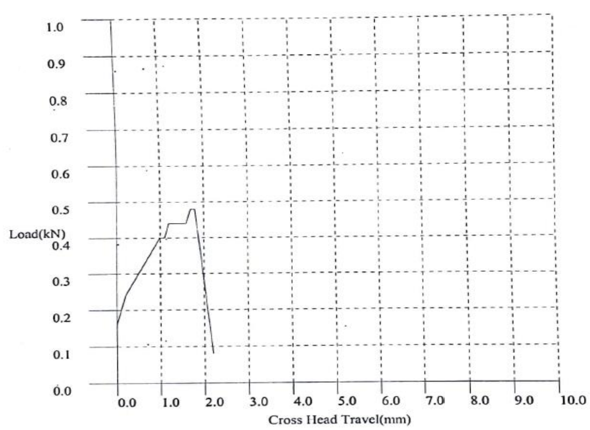

Fig 1(c) Tensile Test for Specimen C

Specimen No.	Tensile Strength (N/mm²)	Load at Yield (kN)	Yield Stress (N/mm²)	Load at Break (kN)	Peak Load (kN)
A (10%)	12.73	0.48	11.75	0.08	0.52
B (20%)	10.48	0.44	10.48	0.44	0.44
C (30%)	10.30	0.44	9.45	0.08	0.48

4.2 Bending Test

Bending test is simple and qualitative test that can be used to evaluate ductility and soundness of the material. Here **ASTM D790** test standards are used.

For 10% Bagasse Fiber

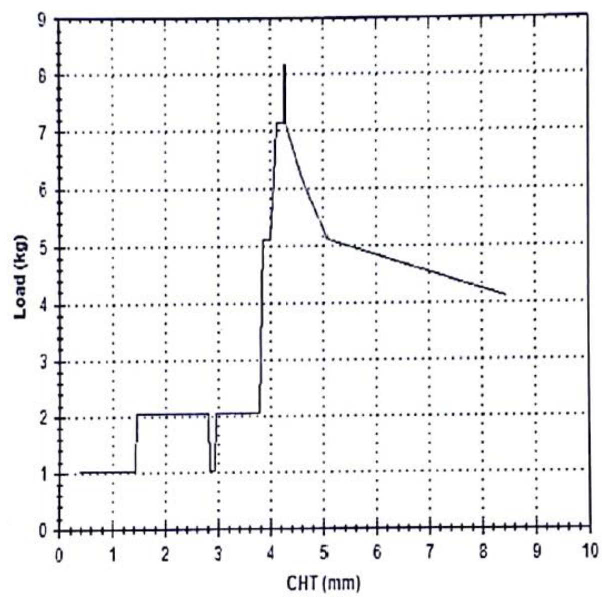

Fig 2(a) Bend Test for Specimen D

For 20% Bagasse Fiber

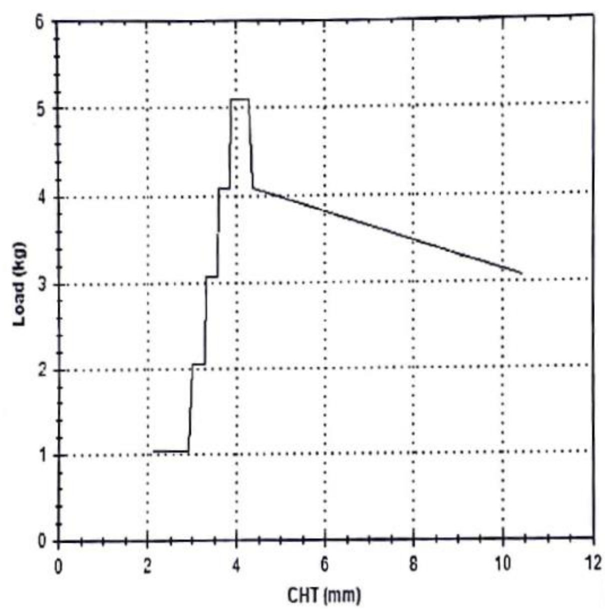

Fig 2(b) Bend Test for Specimen E

For 30% Bagasse Fiber

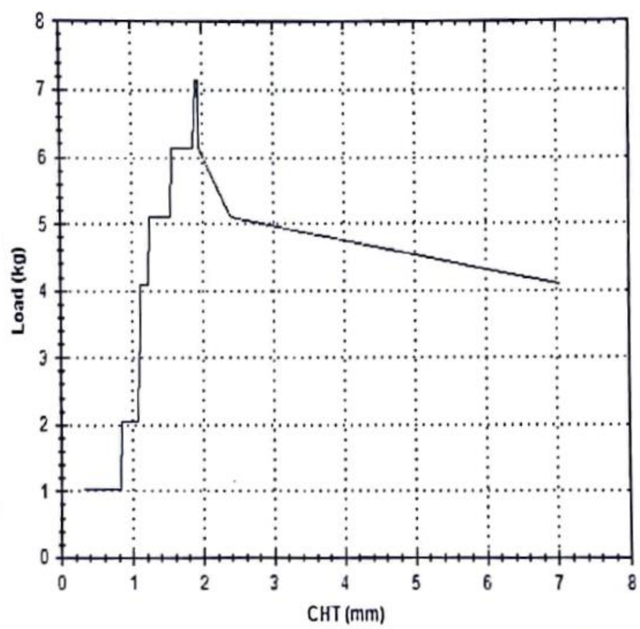

Fig 2(c) Bend Test for Specimen F

Specimen No.	Peak Load (N)	Compression Strength(N/mm^2)
D (10%)	80.0299	2.315
E (20%)	50.02119	1.079
F (30%)	70.0237	1.3739

4.3 Water Absorption Test

Observation

Weight before dipping

10% Bagasse fiber, $W_{i(10)}$= 19.582 gm

20% Bagasse fiber, $W_{i(20)}$ = 19.429 gm

30% Bagasse fiber, $W_{i(30)}$ = 18.719 gm

Weight after dipping

10% bagasse fiber, $W_{f(10)}$ = 25 gm

20% bagasse fiber, $W_{f(20)}$ = 26 gm

30% bagasse fiber, $W_{f(30)}$ = 27 gm

Calculation

$$\text{Weight gained, } W_G = \frac{W_f - W_i}{W_i} \times 100$$

For 10% bagasse ,

$$W_{G(10)} = \frac{W_{f(10)} - W_{i(10)}}{W_{i(10)}} \times 100$$

$$= \frac{25 - 19.582}{19.582} \times 100$$

$$= 27.668\ \%$$

Percentage of Fiber (%)	Weight of composite before dipping (gm)	Weight of composite after dipping (gm)	Percentage of Water Absorption (%)
10	19.582	25	27.66
20	19.429	26	33.82
30	18.719	27	44.238

Hence, from the above calculations we can conclude that the composite plate with the most composition of bagasse fiber (30%) gains weight or absorbs the water quickly. It is because sugarcane bagasse has the ability to soak water quickly. So, more the composition of bagasse faster is the water absorption.

5. CONCLUSION

The following points are the conclusion drawn from the above tests on Sugarcane Bagasse Reinforced Polyester Composite.

- If the percentage of fibre increases, the tensile and bending strength decreases.
- 10% Bagasse Fiber Composite has the highest tensile and bending strength compared to 20% and 30%.
- If the percentage of fibre increases, the water absorption increases.
- 30% Bagasse Fiber Composite has the highest water absorption.

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