Study on Mechanical Behaviour of Sugarcane Bagasse Fiber Reinforced Polymer Matrix Composites

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Abstract

Availability in natural fibers and easy of manufacturing have tempted researchers to try locally available inexpensive fibers and to study their feasibility of reinforcement purposes and to extent they satisfy the required satisfied of good reinforced polymer composite for other applications. With minimum low cost and high specific mechanical properties, natural fiber represents a good renewable and biodegradable alternative to the most common synthetic reinforcement, i.e. glass fiber. In this study, a series of epoxy based composites reinforced with sugarcane bagasse waste fiber are fabricated. Bagasse is considered to be a by-product of the milling process after production of sugar. Bagasse (fibrous residue) is essentially a waste product that causes mills to incur additional disposal costs. Bagasse is main use as a burning raw material in the sugar cane mill furnaces. The low caloric power of bagasse make a low efficiency process also sugar cane mill management encounters problems regarding regulations of clean air from the environmental protection agency, due to the quality of the smoke released in the atmosphere. Present 85% in bagasse production is burnt. Even so, there is an excess of bagasse. Usually this excess is deposited on empty fields altering the landscape.

1. INTRODUCTION

In the continuing quest for improved performance, minimize the various criteria including less weight, maximum strength, lower cost, presently used materials frequently reach the limit of their usefulness. Thus material scientists, engineers and scientists are always striving to produce either improved traditional materials or completely new materials. Composites are an example of the latter category. Within last forty to fifty years, there has been a rapid increase in the production of synthetic composites, those incorporating fine fibers in various plastics (polymers) dominating the market. With the increasing global energy crisis and ecological risks, scientists all over the world are shifting their attention towards alternative solution to synthetic fiber. Since 1990s, natural fiber composites are emerging as realistic alternative to glass reinforced composites in many applications. Natural fiber in composites claimed to offer environmental advantages such as increase dependence on non-renewable energy ratio of material sources, low pollutant emissions, low green house gas emissions, enhanced energy recovery and end of life biodegradability of components. Such superior environmental performances are important driver of increased future use of natural fiber composite.

2. CHARACTERISTICS OF THE COMPOSITES

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is use hard and strong 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 some of the properties of the constituents or the constituents may interact in a synergistic 6 way resulting in improved or better properties. A part from the nature of the constituent materials, the geometry of the reinforcement shape 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. The shape of the discontinuous phase which may by spherical, cylindrical, or rectangular cross sanctioned prisms or platelets, the size and size distribution which controls the texture of the material and volume fraction determine the interfacial area, which plays an important role in determining the extent of the interaction between the reinforcement and the matrix.

3. CLASSIFICATION

Classification based on the geometry of a representative unit of reinforcement is convenient since it is the geometry of the reinforcement which is responsible for the mechanical properties and high performance of the composites. A typical classification is presented in two broad classes of composites 1. Particulate composites 2. Fibrous composites

4. COMPONENTS OF A COMPOSITE MATERIAL

In its most basic form a composite material is one which is composed of at least two elements working together to produce material properties that are different to the properties of those elements on their own. In practice most composites consist of a bulk material the ‘matrix’ and a reinforcement of some kind, added primarily to increase the strength and stiffness of the matrix.

4.1 Role of Matrix in a Composite

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

4.2 Used Materials as Matrix in Composites

In its most basic form a composite material is one, which is composed of at least two elements working together to produce material properties that are different to the properties of those elements on their own. For practice most composites consist of a bulk material the matrix and a reinforcement of some kind added primarily to increase the strength and stiffness of the matrix.

5. BULK PHASES

5.1 Metal Matrices

Metal matrix composites possess some attractive properties, when compared with organic matrices. These include in strength retention at higher temperatures, higher transverse strength, better electrical conductivity, Superior thermal conductivity, 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.

5.2 Polymer Matrices

A large number of polymeric materials thermo setting and thermoplastic are used as matrix materials for the composites. Of The major advantages and limitations in resin matrices.

5.3 Ceramic Matrices

Ceramic fibers such as alumina and 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 fibers, or whiskers such as those made from silicon carbide and boron nitride.

6. TYPES OF COMPOSITE MATERIALS

The composite materials are broadly classified into the following categories as

6.1 Fiber-Reinforced Composites

Reinforced composites are popularly being used in many industrial applications because of their inherent high specific strength and stiffness. Due to their excellent structural performance, the composites are gaining potential also in tri-biological applications. This type composite the second phase is in the form of fibers dispersed in the matrix which could be either plastic or metal. The volume fraction varies from a few percentages to as high as 70%.use the fiber reinforcement is done to obtain high strength and high modulus. Hence it is necessary for the fibers to posse’s higher modulus than the matrix material so that the load is transferred to the fiber from the matrix more effectively.

6.2 Dispersion Hardened Material

In this type of material fine particles of sizes range from 0.01μm to 0.14μm are dispersed in matrix. Their concentration varies from 1% to 15% by volume. These fine particles impede dislocation movement in the material and therefore result in very high strength. Also these materials posses improve high temperature strength and creep resistance.

6.3 Particulate Composite

This type of composites range 1μm to 200μm size particles are dispersed in the matrix and volume fraction is generally between $0.01V_f$ to $0.85\ V_f$.

6.4 Natural Fiber Composites

Now-a-days, research and engineering interest have been shifting from traditional synthetic fiber composite to lingo-cellulosic natural fiber composite due to their advantages like high strength to weight ratio, non-carcinogenic and bio-degradability. The term “natural fiber” covers a broad range of vegetable animal and mineral fibers. However in the composite industry, it is usually refers to wood fiber and agro based blast, leaf, seed, and stem fibers. These fibers often contribute greatly to the structural performance of plant and, when used in plastic composites, can provide significant reinforcement.

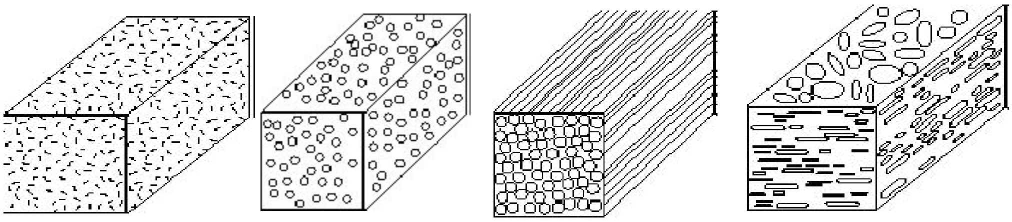

Fig.1 (a) Fig. 1 (b) Fig.1 (c) Fig.1 (d)

Fig.1 (a) Random fiber (short fiber) reinforced
Fig.1 (b) Particles as the reinforcement Composites
Fig.1 (c) Continuous fiber (long fiber) reinforced
Fig.(d) Flat flakes as the reinforcement Composites

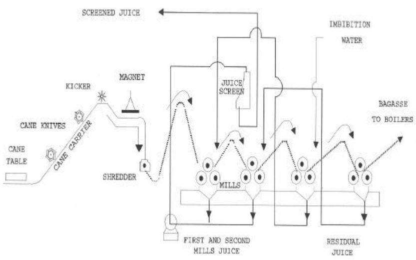

Fig.2: Current technological process for extraction of sugar juice from cane in a sugarcane mill

Fig.3: Bagasses

This is also considered as a fibrous residue (Figure 3) that remains after extraction of juice from the sugar cane stalks. It consists of water, fibers, and small amounts of soluble solids. Percentage contribution of each of these components varies according to the variety, maturity, method of harvesting and the efficiency of the crushing plant.

Table-1 : Average Bagasse Compositions

ITEM	**PERCENTAGE**
Cellulose	46
Hemicelluloses	**24.5**
Lignin	**19.95**
Fats and waxes	**3.5**
Ash	**2.4**
Silica	**2**
Other elements	**1.7**

Bagasse is main use as a burning raw material in the sugar cane mill furnaces. The low caloric power of bagasse makes this a low efficiency process. Also the sugar cane mill management encounters problems regarding regulations of “clean air” from the environmental protection agency, due to the quality of the smoke released in the atmosphere. Present in 85% of bagasse production is burnt. Even so, there is an excess of bagasse. Usually this excess is deposite on empty fields altering the landscape. Approximately 9% of bagasse is use in alcohol (ethanol) production. Ethanol is not just a good replacement for the fossil fuels, but it is also an environmentally friendly fuel. Apart from this, ethanol is a very versatile chemical raw material from which a variety of chemicals can be produced but again, due to the low level of sucrose left in bagasse, the efficiency of the ethanol production is quite low. With increasing emphasis on fuel efficiency, natural fibers such as bagasse based composites enjoy wider applications in automobiles and railway coaches & buses for public transport system. There exist an excellent opportunity in fabricating bagasse based composites towards a wide array of applications in building and construction such as boards and blocks, reconstituted wood, flooring tile. Different volume fraction by weight of bagasse fiber has been mixed with matrix material and specimen were prepared. The present work is undertaken to develop a new class of natural fiber epoxy on the sugarcane bagasse waste composite materials. Physical and mechanical properties such as tensile, flexural, impact (with varying ratio of sugarcane bagasse waste) were studied. Storage modulus, loss modulus and damping characteristics of varying sugarcane bagasse waste with epoxy composites have been studied in dynamic mechanical analysis. Sugarcane bagasse waste with epoxy composites have been studied in dynamic mechanical analysis.

7. MATERIALS AND METHODS

7.1 Composite Preparations

To prepare the composite, following materials are required.

1. Sugarcane Bagasse fibers
2. Epoxy
3. Hardener

7.2 Preparation of Sugarcane Bagasse Fiber

In this sugarcane stalk is composed of an outer rind and inner pith. The upper layers of bagasse consist of a hard fibrous substance called rind while inside is soft material called pith. The pith contains small fibers and the majority of the sucrose, while the rind contains longer and finer fiber, After approximately two weeks, the long bagasse fibers (rind portion only) were shortened into a length of 10mm to 40 mm (optimum fiber length found from single fiber pull out test) and width of 1mm to 4 mm with a pair of scissor. Due to the low moisture content of the bagasse samples, no fungi grew during the storage. The bagasse samples were then cleaned via pressurized water for about one hour. This procedure removes fine bagasse particles, sugar residues and organic materials from the samples. Then the fibers were dried with hair drier.

7.3 Epoxy Resin and Hardener

Epoxy resins are relative low molecule weight pre polymers capable of being process under a variety of conditions. Two important advantages of these over unsaturated polyester resins are first, they can be partially cured and stored in that state and second they exhibit low shrinkage during cure. However, the viscosity of conventional epoxy resins is higher and they are more expensive compared to polyester resins. The cured resins have high chemical, corrosion resistance, good mechanical and thermal properties, outstanding adhesion to a variety of substrates, and good and electrical properties. Approximately 45% of the total amount of epoxy resins produced is used in protective coatings while the remaining is used in structural applications such as laminates and composites, tooling, moulding casting, construction, adhesives.

7.4 Preparation of Composite Laminates

Two wooden molds of dimension 150x150x3.5 mm and 130x80x3 mm were use for casting the composite sheet. First mold size is use for preparing the samples for tensile strength and second mold size is used to prepare the samples for flexural testing. The first group of samples was manufactured with 5, 10, 20, 25 and 30 % volume fraction of fibers**.** Usual hand lay-up technique was used for preparation of the samples. For different volume fraction of fibers, a calculated amount of epoxy resin and hardener ratio of 10:1 by weight was thoroughly mixed in a glass jar and placed in a vacuum chamber to remove air bubbles that got introduced. This procedure was performed for 10 minutes initially. The mixture was re-stirred and the vacuum procedure was performed again for 10 minutes for further removal of bubbles. For quick and easy removal of composite sheets, mold release sheet was put over the glass plate and a mold release spray was applied at the inner surface of the mold. After keeping the mold on a glass sheet a thin layer 1mm mm 39 thickness of the mixture was poured. Then the required amount of fibers was distributed on the mixture. The remainder of the mixture was then poured into the mold. Care was taken to avoid formation of air bubbles. Pressure was then applied from the top and the mold was allowed to cure at room temperature for 72 hrs. During application of

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pressure some amount of mixture of epoxy and hardener squeezes out. Care has been taken to consider this loss during manufacturing of composite sheets. After 72 hrs the samples were taken out of the mold. The photograph of the composite and some of the specimen cut for further experimentation. After cutting they were kept in airtight container. The samples for tensile test, flexural test and hardness test are prepared in the following volume fractions.

Table-2: Volume fractions of different samples

S. No.	Composites	Composition
1	EBSF-1	Epoxy + sugarcane bagasse fiber (0% Volume Fraction)
2	EBSF-2	Epoxy + sugarcane bagasse fiber (5% Volume Fraction)
3	EBSF-3	Epoxy + sugarcane bagasse fiber (10% Volume Fraction)
4	EBSF-4	Epoxy + sugarcane bagasse fiber (20% Volume Fraction)
5	EBSF-5	Epoxy + sugarcane bagasse fiber (25% Volume Fraction)
6	EBSF-6	Epoxy + sugarcane bagasse fiber (30% Volume Fraction)

Fig.4 : Mold Preparation for preparing the samples

Fig.5(a) Tensile Test Specimen

Fig.5(b) Flexural Test Specimen

Fig.5: Samples prepared for tensile test and flexural testing

8. CHARACTERIZATION OF MECHANICAL PROPERTIES

Tensile and flexural tests were carried out on INSTRON 3382,100 KN Universal Testing Machine at a temperature of 23±2ÚC, and with relative humidity of 50±5%. Testing procedures were carried out in ASTM D638 for tensile tests and ASTM D790 for flexural tests. Summary of the entire test performed are shown in the Table 3.

Table-3: Summary of Tests

Testing	Machine Used	Working Variables	No of Specimen	Standard Used
Tensile	INSTRON 3382 UTM	Load cell : 100 KN Rate : 5 mm/min	6 x 5 = 30	ASTM D638
Flexural	INSTRON 3382 UTM	Load cell : 100 KN Rate : 1.32 mm/min	6 x 5 = 30	ASTM D790

8.1 Tensile Testing

Tensile test is a measurement of the ability of a material to withstand forces that tend to pull it apart and to what extent the material stretches before fracture. For tensile testing the specimens were cut as per the dimensions, detailed dimensions for this are shown in figure 6 and Table 4. The testing were done in standard laboratory atmosphere of 23°C ± 2°C and 50 ± 5 percent relative humidity. Universal Testing Machine UTM, INSTRON 3382 was used at cross-head speed of 5 mm/minute. Universal Testing Machine (UTM, INSTRON 3382) used for tensile testing. The specimens were positioned vertically in the grips of the testing machine. The grips were then tightened evenly and firmly to prevent any slippage with gauge length kept at 50mm. The average of five test result was chosen for each fiber composition of sugarcane bagasse fiber based composites.

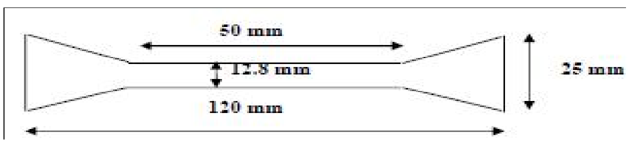

Fig.6: Dimensions of Tensile Test Specimen

Table-4: Dimensions of Tensile Test Specimen

Dimension	Value, mm
Thickness, T	3.5
Width W	25
Length, L	120
Gauge length, G	50

As the tensile test starts, the specimen elongates; the resistance of the specimen increases and is detected by a load cell. This load value (F) is recorded until a rupture of the specimen occurred. Instrument software provided along with the equipment will calculate the tensile properties for yield strength and elongation at break. Below are the basic relationships to determine these properties: Tensile strength at yield= Maximum load recorded/Cross section area.

8.2 Flexural Testing

Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. Sometime it is referred as cross-breaking strength where maximum stress developed when a bar-shaped test piece, acting as a simple beam, is subjected to a bending force perpendicular to the bar. This stress decreased due to the flexural load is a combination of compressive and tensile stresses. There are two methods that cover the determination of flexural properties of material: three-point loading system and four point loading system. As described in ASTM D790, three-point loading system applied on a supported beam was utilized. Flexural test 43 is important for designer as well as manufacturer in the form of a beam. If the service failure is significant in bending, flexural test is more relevant for design and specification purpose than tensile test. According to ASTM D790, specimens of test pieces were prepared with dimension of 126 mm × 12.57 mm × 3mm. The test pieces were tested flat wise on a support span resulting span-to-depth ratio of 16. This means the span is 16 times greater the thickness of specimen. As per ASTM D790, width and depth of the specimen were measured to the nearest 0.03mm at the center of the support span. The test pieces were then placed on two supports and load will be applied. The distance of two supports span (L) was fixed at 49.6 mm. Figure 7 shows the arrangement of loading nose and support attachment.

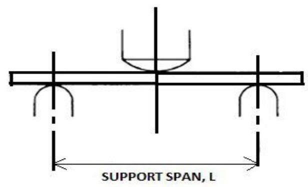

Fig.7 : Loading Nose and Support arrangement

Flexural tests were done on Universal Testing Machine (UTM, INSTRON 3382) at standard laboratory atmosphere of 23°C ± 2°C and 50 ± 5 percent relative humidity. The load was applied at specified cross-head rate of 1.32 mm / minute. The constant load was then applied on test piece and deflection is recorded. The testing will be terminated when the maximum strain in the outer surface of the specimen has reached the maximum strain of 5 % or rupture occurs. Three consistent test pieces results were chosen for each fiber loading composition. When the homogeneous elastic material is tested with three-point system, the maximum stress occurs at the midpoint. The maximum stress is related to the load and sample dimensions and is calculated using equation of = 3PL/2bd2 — where off = maximum stress, MPa P = load applied, N L = support span, mm b = width of specimen tested, mm d = depth of specimen tested, mm.

8.3 Macro-Hardness

Macro-hardness measurement is done using a Rockwell Hardness tester .A diamond indenter, of size ¼ inches, is forced into the material under a load F. The working range of hardness machine is 150 kg. Accuracy of machine is 0.1 gm. of in the present study, the load considered F = 60 Kg and Rockwell hardness is calculated by taking the reading on red dial.

9. RESULTS

9.1 Mechanical Characteristics of Composites

The experimental results of composite testing by varying fiber content are presented in Table 5.

Table-5: Mechanical properties with varying %

S. No .	Fiber Content (%)	Orientation (deg)	Tensile Strength (MPa)	Flexural Strength (MPa)	Hardness (HRL)
1	-	Random	18.61	19.03	46
2	5	Random	27.03	24.20	58
3	10	Random	46.87	32.97	72
4	20	Random	58.36	59.60	93
5	25	Random	52.68	53.36	97
6	30	Random	46.07	51.42	98

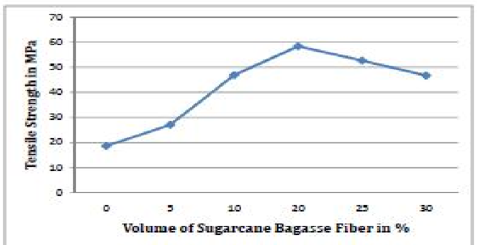

Fig.8: Variation of tensile strength with different of sugarcane bagasse fiber

9.2 Effect of fiber content on tensile properties

From the above figure it is very evident that tensile strength increases with increasing volume fraction of sugarcane bagasse fiber. It is maximum when volume fraction is 20% and decreases with further increase in volume fraction.1

9.3 Flexural Strength

Figure 3.2 shows the variation in flexural strength with varying volume fraction of sugarcane bagasse fiber.

9.4 Effect of fiber content on flexural strength

From the above figure it is very evident that flexural strength increases with increasing volume fraction of sugarcane bagasse fiber. It is maximum when volume fraction is 20% and decreases with further increase in volume fraction.

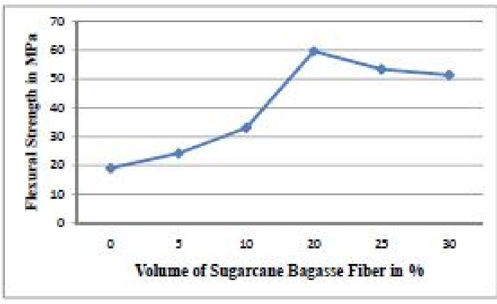

Fig.9: Variation of flexural strength with different fiber loading conditions

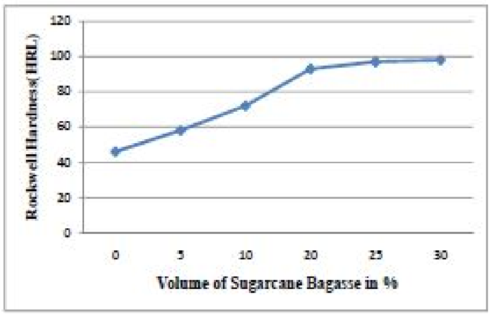

Fig.10: Variation of Rockwell macro hardness with values different volume fraction of fiber composites

9.5 Effect of Fiber Loading on Macro Hardness

From the above figure it is very evident that hardness increases with increasing volume fraction of sugarcane bagasse fiber. It is maximum when volume fraction is 20% and then remains almost constant.

10. CONCLUSIONS AND FUTURE WORK

The results of the work shows that a useful composite with good properties could be successfully development using sugarcane bagasse fiber as reinforcing agent for the polymers matrix. From this, several conclusions can be drawn regarding to mechanical properties of composite tensile strength, flexural and macro hardness to the effect of content of the fiber. As the fiber content in unsaturated polymer increased in term of volume percentage, the Tensile strength increased slowly till 20 percentages. It is found that the tensile strength declined as the fiber concentration in composite increased. The increase of fiber-to-fiber interaction and dispersion problem in matrix has contributed to this phenomenon Flexural strength and hardness also increases up to 20% and then starts decreasing. Finally to summarize everything, sugarcane bagasse fiber has enhanced tensile properties, flexural as well as impact properties of the unsaturated polymers. The study has demonstrated the optimum for select performance for tensile, flexural and macro hardness testing at 20% of fiber content.

11. FUTURE WORKS

The results of this study suggested a number of new avenues for research in future. They are:

1. Determination of the chemical constituents inside the local abundant sugarcane bagasse fiber to the extent of chemical content and its effects to certain properties.
2. The work extended to study other properties such as creep, fatigue, compressive, shear strength, chemical resistance and electrical properties.
3. The use of different types of chemical promoters and coupling agents can be studied.
4. The other epoxy-hardener polymeric matrix system can be studied.
5. The Hybrid composite comprising other fiber such as glass fiber with sugarcane bagasse fiber can be studied as this will definitely yield better performance of composite system.
6. The above results can be more precise by optimizing the above data.
7. Chemical treatment of fibers can be done. It can improve the mechanical properties of the composite.
8. Different composites can be prepared with different length of fibers. Length can be factor in improving the mechanical properties of the composites.
9. Different composites can be prepared by placing the fibers at different angles. This can affect the mechanical properties of the composites.

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