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STUDY ON SYNTHESIS AND MECHANICAL CHARACTERISATION OF BAGASSE REINFORCED POLYMER COMPOSITES

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ABSTRACT

Natural fibre composites are expected to be in high demand in the coming years due to increased consumer awareness to reduce waste and to make environment friendly composites. Recently, there has been rapid growth in research and innovation in the natural fibre composite area. The greatest advantage of these materials compared to synthetic fibre composites is that these are environment friendly. This paper provides an insight on current trends in development and characterization of bagasse based composites. Numerous chemical treatment methods and processing techniques used to improve the thermal, ageing, mechanical and acoustic properties of sugarcane bagasse reinforced composites are summarized in this paper. This research aims at development of polymer matrix composites using sugarcane bagasse fibres and to study its mechanical behaviour under external loads. The test specimens are prepared according to the ASTM standards. Testing of Mechanical properties such as impact energy, tensile strength and flexural strength is undertaken and the results are presented.

KEYWORDS: *Natural Fibre, Environment, Sugarcane Bagasse, Composite, Mechanical Property*

Article History

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INTRODUCTION

India is an agrarian nation. Agricultural crop residues are abundantly available in India, material development and fabrication of these residues offers numerous advantages such as easy and safe disposal at the end of service life, lightweight alternative materials with optimal acoustic properties, creation of attractive environment and considerable value addition to the agricultural organic products. The rapid advancements in the field of composites materials and its applications is vast in the current scenario because of its excellent properties blended for numerous applications. Composites have proven to possess less weight, high strength to weight ratio and excellent stiffness properties. By the virtue of these properties, composites can easily replace the traditional materials such as wood, metals etc. Fundamentally, composites are prepared by combining two or more materials which gives the special combination of properties. One phase is known as reinforcement and other as a matrix which holds fibres in place. The combination of two or more materials results in better properties than the individual components [1].In contrast, in the metallic alloys each materials holds its unique physical, chemical and mechanical properties. In composites the reinforcing phase enhances the strength and stiffness to the fibres [2].Sugarcane is cultivated extensively in India, Brazil, Pakistan, Mexico, Columbia, Thailand, Philippines and Indonesia. Bagasse is the dry fibrous by-product extracted from crushed sugarcane. Currently bagasse is used as biofuel in a cogeneration plant to generate power for industrial purposes. The bagasse consists of 45-55 % of cellulose, 20-25 % hemicellulose, 18-24 % of lignin, 1-4 % of ash and remaining wax. Currently, 85 % of bagasse is used in industries for generating power and 9 % for the production of ethanol, alcohol based products and remaining is not utilised productively [3].The wastage can be reduced by manufacturing fibre based composites for various applications. The present work is focused on development of polymer matrix composites using sugarcane bagasse fibres and studies the mechanical behaviour of composites under external loading conditions.

NATURAL FIBRE AS A REINFORCEMENT

In tropical and subtropical regions, natural fibres such as sisal, bamboo, coconut shell, bagasse (bagasse), oil palm, and pineapple leaves are abundantly available and inexpensive. Fibre from agricultural wastes, such as the abundant coconut husks, oil palm fruits, and bagasse was used in this study. The properties of these fibres were studied, with the objective of using them as reinforcing materials in soil blocks to produce environmental friendly and low-cost bricks.

Coconut Fibre

Coconut fibre, also known as coconut husk fibre, is extracted from the outer shell of the coconut fruit. Coconut plants mainly grow in tropical and subtropical regions. In India, the annual output of coconuts is about 305,000 tons[4], which generates a lot of waste in the country. Coconut fibre is usually used in three main forms, [5]bristles (long fibre), mattress (short fibre) and peeling (mixed fibre length).The application of coconut fibre in engineering is not widely known, but it has good properties for engineering purposes. The size of the coconut husk varies, depends on the type, location of the plant and maturity of the coconut plant. The flexibility and fracture of the fibre are affected by the length and diameter (aspect ratio) of the fibre, which largely determines its use [6].Coconut fibre is mainly composed of cellulose, hemicellulose and lignin, which affect the physical and mechanical properties of the fibre.

Oil Palm Fibre

Oil palm fibre is extracted from three parts of the oil palm plant, namely [5]empty fruit clusters, [6]stems/stems, andnuts. Oil palm originally came from the tropical rain forests of western Africa, where its fruit was processed for food and cooking oil, medicine, wine, handicrafts and industrial purposes. Oil palm fibre is porous, short in length and variable in diameter, which affects mechanical properties. Compared with coconut and bagasse fibres oil palm fibre has a lower cellulose content, so it is easy to extract.

Sugarcane Bagasse Fibre

Bagasse is the residue of sugar or wine after the sugarcane juice is extracted. During processing, the cane stalks are crushed to extract sucrose, which produces a large amount (32 %) of bagasse [5].The fibre is then extracted from the bagasse; therefore, bagasse fibre is easily obtained as a waste product, The stem of a sugarcane plant consists of an outer skin and an inner pith. The outer skin is made of tough fibrous material and surrounds the central core of the medulla. Due to its spongy structural components, it is softer[7].The use of sugarcane fibre is due to its characteristics as a natural filling reinforcing agent, which plays an important role in improving the performance of composite materials[8].In the last decade, significant efforts have been directed towards the use of a variety of natural fibres, available in abundance in tropical and subtropical countries, as reinforcement in composites to produce cost effective building materials for sustainable development purposes, natural fibres commonly used in textile, bag packing ropes have potential for use as reinforcement in composite materials such as soil blocks [9].These materials have excellent physical and mechanical properties, providing the advantages of excellent environmental benefits and low cost for use as building materials [10].It is also used as natural fibre composite to reduce the weight and increase its strength, making it very safe for handling, processing and use with the requirements of economical and environmentally friendly materials, there is a growing interest in natural fibres [11-15].The use of natural fibres in composites, but also solves the problem of sustainability [12].In addition, these materials do not pollute the environment, utilize local technology and are inexpensive.

Sugarcane Bagasse as Reinforcement

It is estimated that more than 200 million tonnes of bagasse are obtained each year in India alone [6].Sugarcane is a renewable natural agricultural resource. Bagasse is made up of approximately 50 % cellulose, 25 % hemicellulose and 25 % lignin [7].The ideal behaviour of bagasse as a composite reinforcing material is due to the presence of a large amount of cellulose and the crystalline structure of these celluloses [8].From a chemical point of view, bagasse contains approximately 50 % alpha cellulose, 30 % pentane and 2 % ash. Fibre composition depends on age, fibre source, soil conditions, and subsequent extraction method.

Applications of Bagasse Fibre Composites

Due to low density, reasonable mechanical, sound and heat insulation properties, these fibres are adapting to various applications in daily life. Cement composite materials, particleboard, suspended ceilings, and lightweight structures are some of the applications where bagasse is used as one of the reinforcement materials [16]. In the preparation of the insulation board, a mixed compound of bagasse, oil palm empty clusters (25 % by weight) and phenol formaldehyde (50 % by weight) was used. A rotary mixer was used to mix cement boards made with tertiary carbon nanotubes (CNT) (0.5, 1, and 1.5 % by weight) with 10 % 1.45 mm long bagasse fibres. It is found that the board thus prepared has better bending properties than pure cement board. The composite board containing 10 gauze has higher impact resistance than the cement board embedded with 20 gas fibre and clean cement samples. It is worth noting that the bagasse fibre composite material can be applied to lightweight structures or products with moderate to good performance, where the ability to withstand cost and engineering performance requirements is moderate [17].

RAW MATERIALS

The Raw Materials that are Utilized in this Work are

- Sugarcane bagasse fibre
- Epoxy resin
- Hardener

Sugarcane Bagasse Fibre

The sugarcane bagasse is a by-product obtained in huge quantity in the sugarcane mills. After extracting the juice from sugarcane whatever the fibrous residue left that is called sugarcane bagasse (natural fibre). The sugarcane bagasse fibres of volume certain volume fraction (0 %, 2.5 %, 5 % and 7.5 % by weight) is taken as reinforcement in the present work. The morphology of sugarcane bagasse fibre is shown in Figure 1.

Figure 1: Sugarcane Bagasse Fibre.

Epoxy Resin (Lapox L-12):

The matrix material employed in this work is Lapox L-12 which is manufactured by Atul Industries Limited (Mumbai, India). Lapox resin has distinctive features like great adherence to different substances, excellent dimensional firmness, excellent resistance to ambience and artificial strike, minor shrinkage, this resin is nontoxic and it has no odour and taste and it has outstanding electrical and mechanical features. Epoxy resins are low molecular weight pre-polymers or high molecular weight polymers, usually containing glycidyl or ethylene oxide groups. The epoxy number or equivalent is used to calculate the amount of co-reactant (hardener) that will be used when curing the epoxy resin. Epoxy resins are generally cured with stoichiometric or near stoichiometric curing agents to obtain maximum physical properties.

Hardener

Hardener K6 is used in this present work. It has a viscosity in the range of 10 to 20 MPA at 25°C.The curing agent is of medium viscosity, used to cure Araldite's low molecular weight solid epoxy resin, and can provide excellent flexibility, toughness and good comprehensive performance for certain coating systems

FABRICATION

Bagasse Fibre Preparation

The bagasse fibres are extracted from the sugar factory, first the unwanted fibres that are not properly shredded in the machine are vacuumed, the bagasse fibres are washed in water to remove the dust and dust form from the fibres, then dried for 6 hours under the natural sunshine, the peel fibres are extracted from the outer skin of the crushed sugarcane. After extraction, the outer skin fibres are dried in the sun for two full days, then the fibres are cleaned by removing excess marrow on the fibres of the cortex. The pith fibres are obtained from crushed sugarcane, simple fibres are removed from the string by hand and then immersed in the saline solution for 3 to 4 hours. The fibres are allowed to dry completely at normal room temperature.

Figure 2: Sugarcane Bagasse

Alkaline Treatment

The Important change brought about by the alkali treatment is the breaking of hydrogen bonds in the lattice structure, thus increasing the surface roughness. This treatment removes some amount of lignin, waxes and oils coating the outer surface of fibrous cell walls, de-cellulose and exposing crystals of short length.

Acetylation Treatment

In this treatment, the bagasse fibre is immersed in 1 MOL citric acid solution at temperature, and the fibre is immersed in the acetyl solution for 1 hour, then rinsed with clean water several times to get rid of the acetyl radical attached to the surface of the fibre. Neutralized with dilute acetic acid, and at last washed with water, the ultimate pH value is maintained at 7; thereafter the fibre is dried in the sun for twenty-four hours.$C_6H_8O_7$ reacts with the hydroxyl groups of hemicellulose (a coalescing material), destroying the cell structure and separating the fibres into strands. The untreated fibres were squeezed together, but separation was observed after the acetylation treatment, which degraded the untreated fibres. Because of the dissolution of hemicellulose, the fibre bundles become smaller. Fibrillation increases the effective surface area available for substrate contact, improves interfacial adhesion, and improves interfacial adhesion.

Preparation of Composite

The sugarcane bagasse was pulverized with a mill, the first sample group was produced with a fibre weight fraction of 0, 2, 4, 8 % (10:1 by weight) was mixed thoroughly with gentle stirring to minimize air entrapment. Next, pressure was applied from above and the mould was allowed to cure for 48 hours at room temperature. Samples were removed from the mould, cut into various sizes according to ASTM standards for further experimentation.

Figure 3: Setting of Mixture in the Mould

EXPERIMENTAL PROCEDURES

Determination of Tensile and Flexural Strength

The tensile and flexural strength tests of the sugarcane fibre composite were performed on ASTM D638 and ASTM D790 using a UTM (INSTRON 3382). The specimen was tested with a load cell 100KN with a gauge length of 80 mm, crosshead velocities 5mm/min and 1.32mm/min. The test was carried out the National Institute of engineering laboratory's CMR lab.

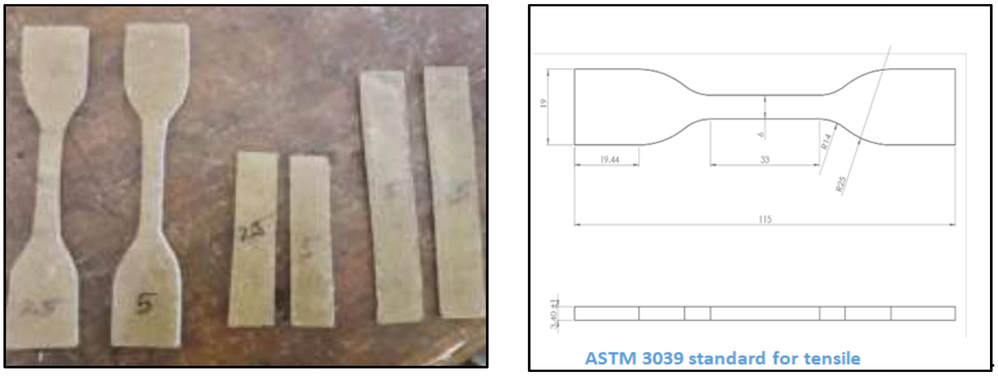

Figure 4: Testing Specimens

Tensile Test Procedure

The specimens generally used for tensile tests are the types depicted in Figure 4. During tests, uniaxial loads are applied through both ends of the test part. The dimensions of the specimen are (150 × 19 × 3) mm. A typical point of typical interest when test materials include: Final tensile strength (UTS) representing points that represent the start of permanent deformation. The test is carried out by means of the Universal Testing Machine (UTM) KIC21000C.

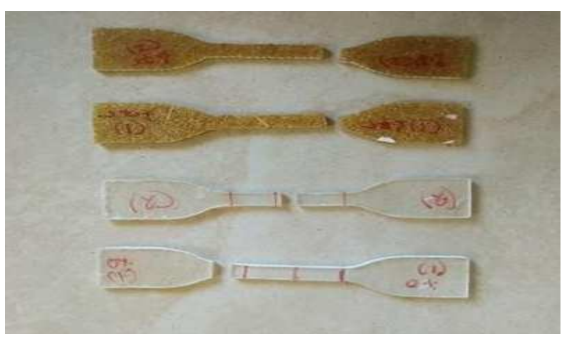

Figure 5: Tested Specimens

Flexural Test Procedure

The flexural test method measures the behaviour of a material under a simple beam load. For some materials, it is also called a beam test. Most commonly, the specimen is located in the support span and the load is applied to the canter through the load tip to produce a three-point flex at a specified rate. The parameters of this test are the support span, the load speed and the maximum deflection of the test. These parameters are based on the thickness of the sample and are defined differently by ASTM and ISO standards. Test was carried out according to the procedure of ASTM D785. The bending test was also performed on the KIC21000C universal testing machine (UTM).

Figure 6: Tested Specimens of Flexural Test

Impact Test Procedure

Impact testing is a method of evaluating the toughness and notch sensitivity of engineering materials. It is typically used to test the toughness of metals, but similar tests are also used for polymers, ceramics, and composites. The cantilever beam impact test specimen is processed into a square or circular cross section with one, two, or three notches. The sample is held vertically on the anvil with the notch facing the hammer. Figure 7 shows the impact test sample.

Figure 7: Tested Specimens after Impact Test.

RESULTS

Tensile Test Results

The tensile test is performed on the UTM machine in accordance with ASTM D638 Type IV. Specimens have dimensions of (115 × 19 ×3) mm.

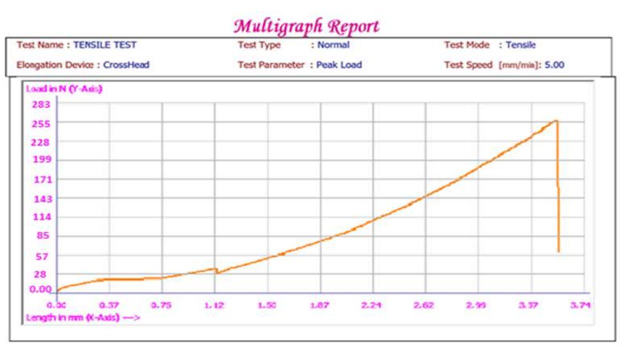

Figure 7:Multi-Graph Report of Tensile Test 5 % Weight Fraction.

Table 1: Result for Tensile Strength

Weight Fraction (%)	CS Area (mm²)	Peak Load (N)	%Elongation	Stress(N/mm²)	Strain	UTS (N/mm²)	Theoretical Young's Modulus(Mpa)	Experimental Young's Modulus(Mpa)
2.5	22.39	255.62	8.054	6.779	0.056	11.301	188.02	121.05
5	22.14	228.78	7.992	6.232	0.053	9.416	151.04	89.56
7.5	21.78	205.45	7.981	5.891	0.054	8.521	126.98	73.45
10	22.17	152.80	6.672	4.962	0.049	5.144	96.53	51.26

Flexural Test Results

The flex test is also performed on the UTM machine in accordance with ASTM D638 Type IV. All samples are rectangular with a size of (90 * 12.5 * 3) mm. The resulting multi graph report for Flexural Test 5 % Weight Fraction is depicted in Figure 8 and details of Flexural Strength 2.5 % weight Fraction Values are depicted in Table 2.

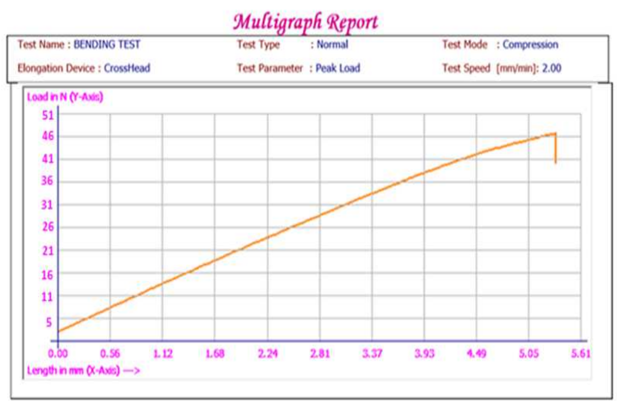

Figure 8: Multi Graph Report for Flexural Test 5 % Weight Fraction.

Table 2: Tabulation for Flexural Strength 2.5 % Weight Fraction Values

Weight Fraction (%)	CS Area (mm²)	Peak Load (N)	%Elongation	Theoretical Flexural Strength (MPa)	Experimental Flexural Strength (Mpa)
2.5	44.77	41.849	6.218	50.22	41.256
5	43.56	38.756	6.005	44.93	36.623
7.5	42.64	31.687	5.462	37.41	31.466
10	44.59	21.462	4.096	26.56	25.228

Impact Test Results

The Impact test is a method to evaluate the toughness and notch sensitivity of engineering materials. It is usually used to test the toughness of metals. All samples are rectangular in size (60*12*3) mm. The results of impact test are tabulated in Table 3.

Table 3: Result Tabulation of Impact Test

Weight Ratio (%)	Width (mm)	Thickness (mm)	Energy (J)	Angle (Degree)	Energyper meter(J/m)
2.5	12.47	3.28	0.13	141	41.28
5	12.21	3.24	0.13	142	41.16
7.5	11.94	4.0	0.12	141	37.52
10	12.56	3.2	0.8	139	29.19

CONCLUSIONS

The current focus of the work is to develop bagasse fibre for the manufacture of composite materials and to strive to use the advantages that renewable resources offer to develop bio-composite materials. The current focus of the work is to improve the performance of bagasse fibre as a composite material. Creating better materials to improve the quality of structural composites with better mechanical properties is a challenge. This work provides a comparative study of manufacturing methods and an evaluation of the mechanical and physical properties of bagasse as a reinforcing fibre in an epoxy resin matrix. The composite material produced from bagasse fibre has good strength properties and can be further improved by modifying or mixing the material. The test results of bagasse flake compound show that the performance of the compound produced is very poor, and the strength performance is very low. Therefore, it is not recommended to add bagasse flakes in the manufacture of composite materials.

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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