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Evaluation of Mechanical Properties of Bagasse-Glass Fiber Reinforced Composite

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Abstract

In the present work a bagasse-glass fiber reinforced composite material is developed with 15 wt%, 20 wt%, 25 wt% and 30 wt% of bagasse fiber with 5 wt% glass fiber mixed in resin. Scanning electron microscopy (SEM) shows that bagasse fibers 13.0 μm in diameter and 61.0 μm in length are well dispersed in the resin matrix. Addition of fiber increases the modulus of elasticity of the epoxy. Mixing of bagasse with glass fiber also improves the modulus of elasticity. Addition of bagasse fibers decreases the ultimate tensile strength. But addition of glass fiber further increases the ultimate tensile strength in comparison to commercially available bagasse based composite. Bagasse-glass reinforced fibers improve the impact strength of epoxy materials due to fiber has more elasticity in comparison to matrix material. Addition of fibers increases the capacity of water absorption. This test is necessary where composites are used in moisture affected areas. Addition of bagasse fiber reduces bending strength. But addition of glass fiber further increases the bending strength in comparison to commercially available bagasse based composite.

Keywords: Composite material, bagasse fiber, polymer, environment

1. Introduction

Composite is a material formed with two or more components, combined as a macroscopic structural unit with one component as continuous matrix, and other as fillers or reinforcements. Normally, the matrix is the material that holds the reinforcements together and has lower strength than the reinforcements. In the plastic based composites, the polymers, either thermoplastics, act as a matrix and flour of wood or other natural fiber are reinforcement. The reinforcing flour is the main load-carrying component in the composites. It provides high strength and stiffness as well as resistance to bending and breaking under the applied stress. Interface bonding between the fillers and the matrix is the key to transfer the stress from the matrix into the fillers across the interface. The interface adhesion between the polymer matrix and wood fillers can be improved using coupling agents. The coupling agents will form a bond between the wood flour (reinforcement) and the thermo-plastic (matrix) through the improved compatibility and developing a mechanical or chemical bonding.

With growing environmental awareness, ecological concerns and new legislations, bio fiber reinforced plastic composites have received increasing attention during the recent decades. The composites have many advantages over traditional glass fiber or inorganic mineral filled materials, including lower cost, lighter weight, environmental friendliness, and recyclability. Because wood and other bio-fibers easily undergo thermal degradation beyond 200°C, thermoplastic matrix used in the composites is mainly limited to low-melting-temperature commodity thermoplastic resins, like polyethylene (PE), and polypropylene (PP) [1]. However, the inherently unfavorable thermo mechanical and creep properties of the polyolefin matrix limit some structural applications of the materials.

Conventional fiber-reinforced composites are typically manufactured with carbon or glass fibers that are incorporated into unsaturated polyester or epoxy resin. These composites show high mechanical and thermal properties, so they are widely used in various applications from aerospace to sports. These advantages, on the other hand, can lead to environmental problems in disposal by incineration. Thus, in order to overcome these problems, there is keen interest in environmentally friendly composites that employ natural fibers as reinforcement [2].

The important aspect that has impacted favorably in the development of these composite materials is the possibility to incorporate waste agro fibers and recycled plastics with the advantage of a positive eco-environmental impact. One of the most important and abundant agro fiber resources is sugarcane with a worldwide annual production of 1170 million metric tons in 2005 [3]. Traditionally, bagasse has been used as a fuel in the sugar factories and, in smaller quantities, for cellulose and paper production. Small quantities are also employed by the particleboard industry in China and Pakistan [4]**.**

Sugarcane bagasse is a plentiful lignocellulosic waste typically found in tropical countries that process sugarcane, such as Brazil, India, Cuba, and China. It is called bagasse or cane-chuff, and it is obtained as a left-over matter after liquor extraction in a sugar factory. About 54 million tons of bagasse is produced annually throughout the world. In general, sugar factories generate approximately 270 kg of bagasse (50% moisture) per metric ton of sugarcane [5]. Bagasse fiber bundles are unusually coarse and stiff material. It is used either as a fuel for the boilers by the sugar factory or as a raw material for the manufacture of pulp and paper products, various types of building boards, and certain chemicals. It is suitable for making non-woven products. The chemical compositions of pure bagasse fiber bundles are cellulose (52.42%), lignin (21.69%), hemicelluloses (25.8%), ash (2.73%), and ethanol/dichloro methane extract (1.66%) [6].

Several studies have been carried out to understand the structure, mechanical properties, and the effect of chemical modification on bagasse fiber bundles. However, the traditional uses of bagasse husk consume only a small percentage of the potential total world production of bagasse husk. Hence, research and development efforts have been underway to find new applications for bagasse, including utilization of bagasse as reinforcement in polymer composites.

The mechanical properties of bagasse particle boards were compared to those of hardwood aspen fiber particle boards, delignified bagasse particle boards, as well as those of composites made from bagasse, polymers and coupling agents. Particle boards of bagasse comprising both thermoplastics and a coupling agent offer superior properties compared to those made of only thermoplastic or a coupling agent. The extent of improvement in the mechanical properties of particle boards depended on the concentration of polymers and the coupling agent; nature of the fiber, polymer and coupling agent; composition of PMPPIC and bagasse; as well as lignin content of the bagasse. Moreover, the mechanical properties and dimensional stability of coupling agent-treated particle boards are superior to non-treated ones [7].

The use of natural fibers as reinforcement for thermoplastics has generated much interest due to their low cost, possibility of environmental protection and use of locally available renewable resources. The mechanical and morphological properties of high density polyethylene/pre-treated and modified residues from sugarcane bagasse cellulose composites were analyzed. Composites were produced by a thermokinetic mixer. The microstructural analyses of fracture surface from composites can be easily evaluated by microscopic techniques. Results showed that the modification of sugarcane bagasse cellulose with zirconium oxychloride was successfully accomplished and that this reinforcement material with high density polyethylene showed tensile strength higher than non-modified sugarcane bagasse cellulose. Modification in the sugarcane bagasse cellulose influenced directly in mechanical properties of the composite material. This can be observed by the fracture surface, which showed that modified cellulose sugarcane bagasse improved interfacial adhesion between fiber and matrix [8].

In the present investigation, bagasse selected as the filler materials. This material is abundantly available and has very low cost. In all the cases discontinuous glass fibers are also incorporated in the material system. Glass fibers are the most widely used reinforcement material for commercial plastics. Glass fiber reinforced materials exhibit low specific gravity, high strength and stiffness, good dimensional stability and resistance against heat, cold, moisture and corrosion. They improve mechanical properties of denture base polymers, have easy manipulation, and they are esthetic. Reinforcement with fibers enhances the mechanical characteristics of denture bases, such as the transverse strength, ultimate tensile strength and impact strength.

A research was therefore initiated with the objective of studying the feasibility of manufacturing composite boards from a mix of fibrous bagasse particles with glass fiber by means of a flat press process and to show bagasse content, and pressure effect on selected board properties, i.e. bending strength, impact strength, modulus of elasticity, hardness etc.

2. Materials and methods

2.1 Matrix Material

2.1.1 Epoxy Resin CY230

Epoxy resin is widely used in industrial application because of their high strength and mechanical adhesiveness characteristic. It is also good solvent and have good chemical resistant over a wide range of temperature. Araldite CY 230 purchased from M/s Petro Araldite Pvt. Limited, Chennai, India is used in the present investigation.

2.1.2 Hardener HY951

Hardener HY951 purchased from M/s Petro Araldite Pvt. Limited, Chennai, India is used as curing agent. In the present investigation 8 wt% have been used in all material developed. The weight percentage of hardener used in the present investigation is as per recommendation of [9].

2.2 Reinforcing Element

Reinforcing agents are added to the resin to improve the mechanical strength and failure rates of the material.

2*.2.1 Bagasse Fiber (BG)*

The bagasse fiber used in the present investigation was arranged from nearby Kichha Sugar Mill. The collected sugarcane bagasse was dried in sun for a week and subsequently cut into small pieces. It was then ground in a ball mill to convert into small pieces of fibers. Then the material was washed in water to remove the pulps. It was again dried in sun for a week and then dried in oven at 100^0C to remove moisture content. Two Sieves of required (ASTM-30 & ASTM -60) size were used to get the final fiber size for casting.

2.2.2 Glass Fiber (GF)

Glass fiber of grade E-Class of Surfacing mats composed of continuous glass filaments in random pattern purchased from M/s Petro Araldite Pvt. Limited, Chennai, India is used as reinforcing agent. The glass fiber was extracted from the mat and was cut into the size of 2 to 3 mm. In the present investigation 5 wt% have been used in all material developed.

2.3 Method

Epoxy resin (CY230), hardener (HY951), bagasse fiber and glass fiber with different weight percentage were used. Different weight percentage (wt%) of bagasse fiber (15, 20, 25, 30 wt%), glass fiber (5 wt%) and epoxy resin were mixed by mechanical stirring at 3000 rpm. The curing curve of epoxy CY230 is shown in Fig. 1. Based on the curing curve, the solution obtained by mixing of bagasse fiber and glass fiber in resin is kept in the furnace at a temperature of 90 ± 10 °C for two hours [11]. At each interval of 30 minutes the solution is taken out from the electric furnace and remixed by mechanical stirrer at same speed. After two hours the whole solution is taken out and allowed to cool to a temperature of 45°C. When a temperature of 45°C has been attained the hardener HY951 (8 weight per cent) is mixed immediately [10]. Due to addition of hardener high viscous solution is obtained which is remixed mechanically at high speed by the mechanical stirrer. The viscous solution so obtained is poured into different moulds for sample preparation. Tensile and compression tests are conducted on 100 kN servo hydraulic universal testing machine (ADMET, USA) under displacement mode of control of 1 mm/min. The results are presented and discussed in subsequent sections.

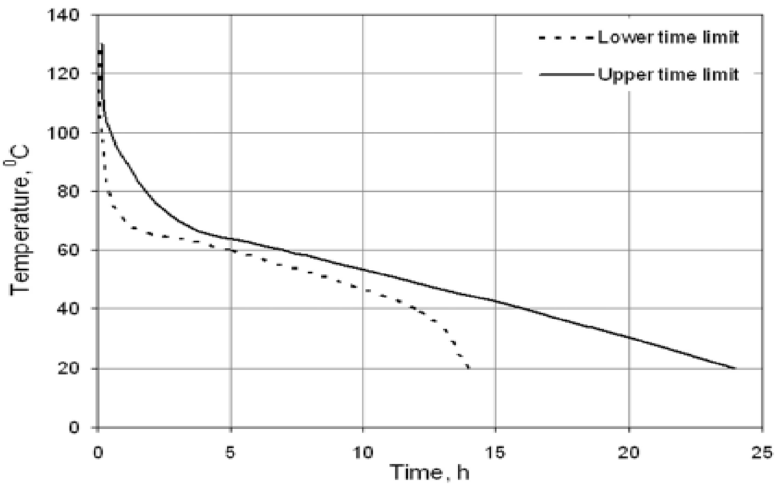

Fig. 1: Curing curve of CY 230 epoxy based composite [11]

3. Results and discussions

3.1 Density

Density is one of the most important mechanical properties of the material. The density of bagasse-glass fiber reinforced composite with different composition of composites are presented in Table 1.

Table 1 reveals that increase in wt% of reinforced particles, i.e. the bagasse-glass fiber in the resin solution decreases the density. The decrease in density can be related to the fact that the fibers are light in weight but occupy substantial amount of space. Hence there is decrease in the density of all the composite materials with regards to the epoxy resin.

In the present investigation density of bagasse-glass fiber filled composite is found be 1.04 gm/cm³ for 15wt% bagasse filled composites, 0.99 gm/cm³ for 20 wt% bagasse, 0.86 gm/cm³ for 25 wt% bagasse and 0.80 gm/cm³ for 30 wt% bagasse with 5 wt% glass fiber reinforced composite. These values are lower than the pure epoxy resin which is 1.176 gm/cm³. Hence, it can be concluded that proper combination of the bagasse and glass fiber hybrid composite material may have a varieties of industrial application when weight and strength would be the critical parameter in the design.

3.2 Water Absorption Capacity

Water absorption capacity is another crucial factor to be taken into account when considering the effect of water on the composite material developed. The results are presented in Table 2

Table 1: Density of epoxy resin and bagasse-glass fiber reinforced composite.

S.No	15 wt% BG 5 wt% GF (gm/cm^3)	20 wt% BG 5 wt% GF (gm/cm^3)	25 wt% BG 5 wt% GF (gm/cm^3)	30 wt% BG 5 wt% GF (gm/cm^3)	Epoxy (gm/cm^3)	10 wt% BG
1	1.02	1.00	0.82	0.80	1.159	1.11
2	1.03	0.97	0.90	0.79	1.184	1.10
3	1.06	0.99	0.86	0.82	1.186	1.08
Mean	1.04	0.99	0.86	0.80	1.176	1.097
S D	0.02	0.02	0.04	0.02	0.015	0.015

Table 2: Water Absorption capacity, (gm/cm^3)

S.No	15 wt% BG 5 wt% GF	20 wt% BG 5 wt% GF	25 wt% BG 5 wt% GF	30 wt% BG 5 wt% GF	Epoxy	10 wt% BG
1	2.69	2.80	2.91	2.98	0.633	2.63
2	2.72	2.83	2.87	2.97	0.699	3.08
3	2.70	2.79	2.89	3.01	0.609	2.66
Mean	2.70	2.81	2.89	2.99	0.647	2.79
S D	0.02	0.02	0.02	0.02	0.0466	0.252

The effect of water absorption is important in case the material that has been developed when used for applications comes in contact of water. The water absorption capacity was found to be maximum for 30 wt% bagasse-5 wt% glass fiber reinforced composite, where there was a percentage increase of 7.83% in the weight of the material. The increase in water absorption capacity due to increase bagasse wt% because of voids and water absorbing tendency of bagasse fiber present in the material.

3.3 Mechanical Properties

3.3.1 Tensile strength

The mechanical properties of the bagasse-glass fiber filled epoxy resin hybrid composite materials were determined by 100 kN ADMET make servo controlled universal testing machine at 1mm/min cross-head speed under displacement control mode.

3.3.2 Tensile stress-strain curve

Hybrid composite materials containing bagasse fiber (15, 20, 25, 30 wt%), glass fiber (5 wt%) reinforced composite is shown in figure 2. All tests are conducted as per ISO in 100 kN servo hydraulic Universal Testing.

Remarkable differences can be seen in the stress-strain behavior due to addition of different wt% of bagasse fibers with 5 wt% glass fiber in epoxy resin matrix.

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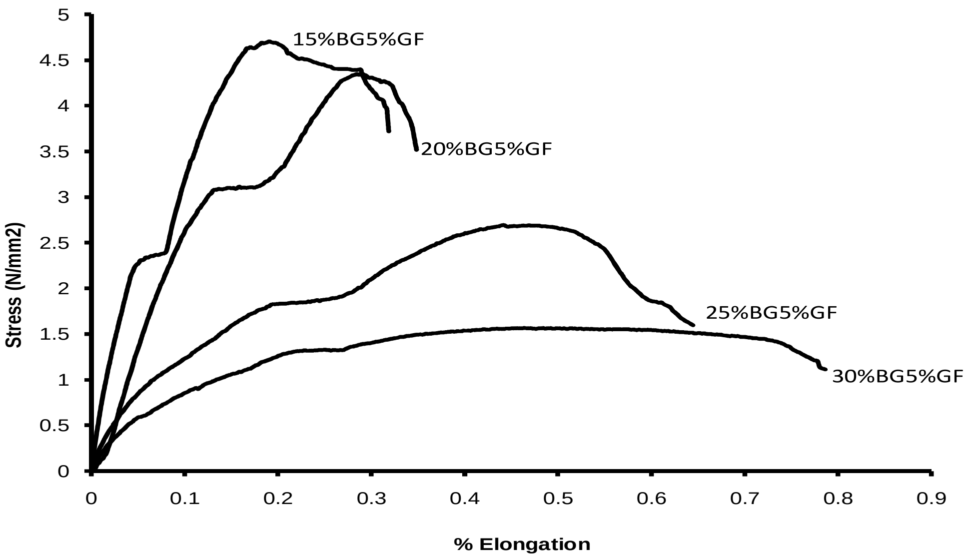

Fig. 2: Stress-elongation(%) diagram for different composite materials at 1 mm/min cross head speed

Table 3: Tensile properties of the composite materials and epoxy resin.

Property	15 wt% BG 5 wt% GF	20 wt% BG 5 wt% GF	25 wt% BG 5 wt% GF	30 wt% BG 5 wt% GF	Epoxy	10 wt% BG
E, (MPa)	10.20	08.00	05.20	04.00	01.40	1.64
Ultimate stress, (MPa)	4.69	4.33	2.87	1.56	35.79	22.26
Percentage elongation	20.50	26.40	46.60	56.70	14.10	18.67

3.3.3 Tensile Properties

The properties of different percentage of bagasse fiber reinforced composite along with that of epoxy resin are presented in Table 3.

The results of modulus of elasticity, the ultimate tensile strength and percentage elongation are shown in the table 3 for strain rate of 1 mm/min. Remarkable differences can be seen on the ultimate tensile strength of the hybrid composite material having different wt% reinforcing materials. It can be noticed that for all tested material, the ultimate tensile strength is lowest for the 30 wt% bagasse-5 wt% glass fiber filled composite and is 1.56 MPa. When bagasse fiber is decreased to 10 wt%, the value of the ultimate strength is about 22.26 MPa. All these strength are less than pure epoxy and is only about 5% to 62% of pure epoxy. The decrease of ultimate strength due to increase in bagasse fiber content is because of pure binding with the epoxy and voids present in the material. However, significant increase in modulus of elasticity is seen due to increase in bagasse content in the material. Without glass fiber the increase in modulus of elasticity is less, but only 5 wt% of glass fiber improves to about 10 times of the pure epoxy. The percentage elongation of material also increases with increasing the fiber percentage.

From the figure 3 it can be concluded that modulus of elasticity and ultimate strength decreases with higher percentage of bagasse content whereas percentage elongation increases with increasing percentage of bagasse fiber.

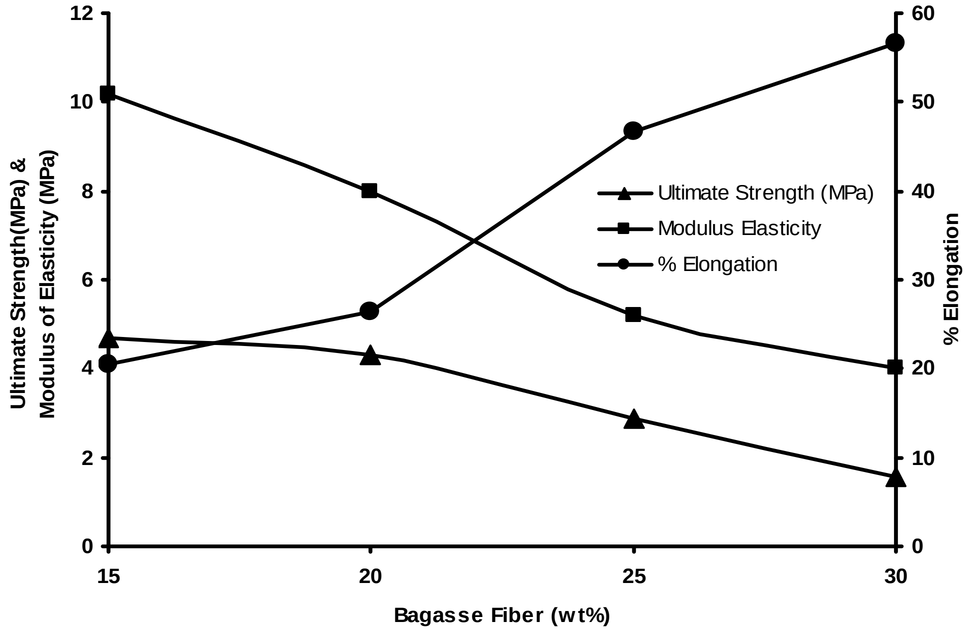

Fig. 3: Effect of bagasse fiber on mechanical properties.

3.3.4 Compressive Strength

The compressive strength of the bagasse-glass fiber filled epoxy resin hybrid composite materials were determined by 100 kN ADMET make servo controlled universal testing machine at 1 mm/min cross head speed under displacement control mode. The results are presented in figure 4-5 and table 4.

A remarkable difference can be noticed in the value of the compressive strength with different wt% bagasse-glass fibers. It can be noticed that addition of bagasse fiber decreases the ultimate compressive strength of the hybrid composite materials. It is found that ultimate compressive strength of 30 wt% of bagasse fiber with 5 wt% of glass fiber is about 1.83 MPa. It is seen that addition of fibers significantly affects the compressive modulus of elasticity. About 10% increase in modulus of elasticity has been seen due to addition of 30 wt% bagasse-5 wt% glass fibers. The ultimate compressive strength is compared with tensile ultimate strength in Table 5.

Table 4: Compressive properties of the composite materials and epoxy resin

Property	15 wt% BG 5 wt% GF	20 wt% BG 5 wt% GF	25 wt% BG 5 wt% GF	30 wt% BG 5 wt% GF	Epoxy	10 wt% BG
E,(MPa)	46.00	21.25	13.50	7.00	0.74	0.51
Ultimate stress, (MPa)	9.60	5.92	4.57	1.83	65.28	49.85
Percentage elongation	35.50	40.10	45.00	53.10	22.00	27.40

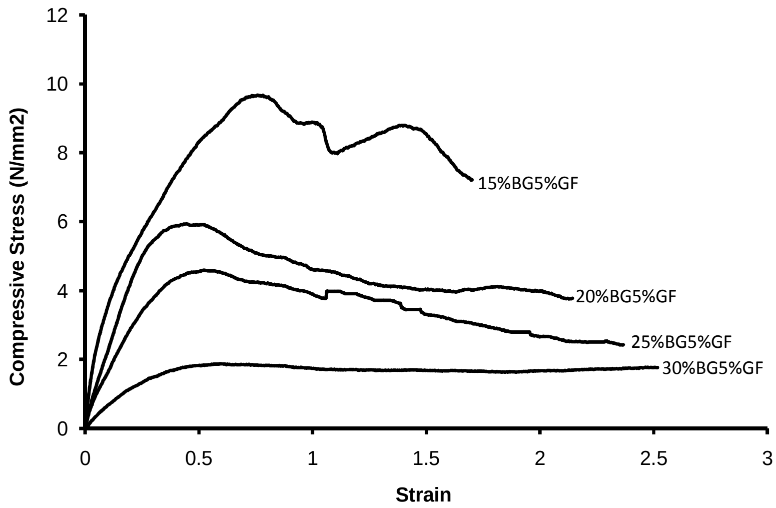

Fig. 4: Stress-strain diagram for different composite materials

Fig. 5: Variation of compression strength with wt% of bagasse fibers

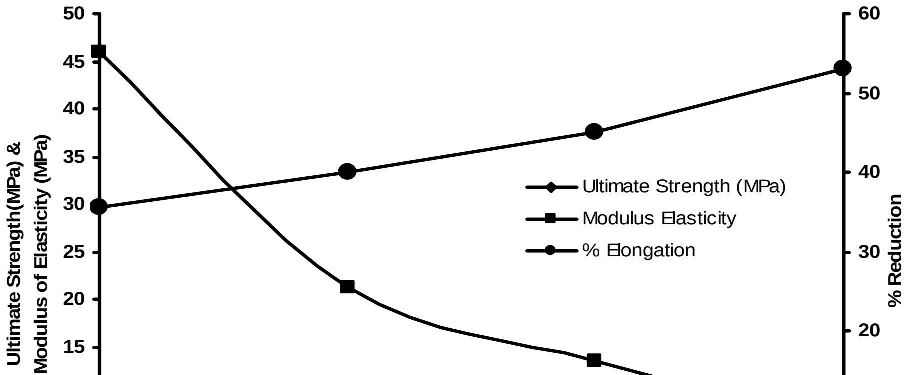

Table 5: Comparison between compressive and tensile strength

Ultimate stress	15 wt% BG 5 wt% GF	20 wt% BG 5 wt% GF	25 wt% BG 5 wt% GF	30 wt% BG 5 wt% GF	Epoxy
Tensile (MPa)	4.69	4.33	2.87	1.56	35.79
Compressive, (MPa)	9.60	5.92	4.57	1.83	65.28
Ratio of Compressive strength/ Tensile strength	2.05	1.37	1.59	1.17	1.82

It is seen that the ratio of ultimate compressive strength to ultimate tensile strength varies from 1.17 to 2.05. The reason for decreases of ultimate compressive strength due to addition of bagasse fiber may be as explained as follows. The rigidity and compressive strength of bagasse fiber are much lower compared to that of epoxy. So that low compressive strength is expected due to addition of bagasse fiber into epoxy. In the present investigated material such trend has been observed.

The bagasse fiber increases the modulus of elasticity strength because bagasse fibers are less stiff than resin. Due to addition of bagasse fiber substantially elastic deformation taken place in the matrix and the developed material is able to resist more load.

3.3.5 Impact Strength

The results obtained from Charpy test are presented in table 6. The effects of bagasse fibers on the impact strength are studied and discussed in this section.

Table 6: Impact strength of the composite materials and epoxy resin

S.No	15 wt% BG 5 wt% GF	20 wt% BG 5 wt% GF	25 wt% BG 5 wt% GF	30 wt% BG 5 wt% GF	Epoxy	10 wt% BG
1	24.32	25.81	26.65	27.01	22.52	22.05
2	23.92	25.48	25.93	26.90	22.07	22.05
3	23.78	25.38	26.05	27.12	21.62	17.15
Mean	24.01	25.56	26.21	27.01	22.07	20.42
S D	0.28	0.23	0.39	0.11	0.45	2.83

In the present investigation, an improvement in the impact strength has been observed due to addition of bagasse fibers. An increase of impact strength from 22.07 Nm to 27.01 Nm has been noticed due to addition of 30 wt% bagasse to the epoxy composite. From the present observations it can be concluded that bagasse fiber improve the impact strength when added as filler material. Hence, keeping view of this mechanical property presence of bagasse fibers is beneficial.

3.3.6 Hardness Test

As known, hardness implies a resistance to indentation, permanent or plastic deformation of material. In a hybrid composite material, filler weight fraction significantly affects the hardness value of the hybrid composite material. Hardness values measured on the Rockwell M-Scale showing the effect of weight percentage of bagasse fibers on the hardness values of hybrid composite are presented in Table 7.

It is found that hardness of neat epoxy resin (CY-230+ 8 wt% of HY-951) is 57.8. The hardness of the fabricated composite made of 30 wt% bagasse wt% is 39.80. The hardness decreases with high wt% of bagasse reinforcement in the hybrid composite.

Table 7: Rockwell Hardness values on M-Scale for various filled hybrid composite

S.No	15 wt% BG 5 wt% GF	20 wt% BG 5 wt% GF	25 wt% BG 5 wt% GF	30 wt% BG 5 wt% GF	Epoxy	10 wt% BG
1	53	48	43	40	60	53
2	58	51	44	41	55	48
3	49	46	49	42	58	54
4	54	49	42	37	61	65
5	51	44	47	39	55	57
Mean	53.00	47.60	45.00	39.80	57.8	55.4
S D	3.39	2.70	2.92	1.92	2.775	6.269

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3.3.7 Bending Test

The Bending strength properties of bagasse-glass filled epoxy resin hybrid composite materials were determined by 100 kN ADMET make servo controlled universal testing machine at 1mm/min strain rate under displacement control mode. The results are presented in Table 8.

Table 8: Flexure strength properties of composite materials

S.No	15 wt% BG 5 wt% GF	20 wt% BG 5 wt% GF	25 wt% BG 5 wt% GF	30 wt% BG 5 wt% GF	Epoxy	10 wt% BG
1	4.13	3.54	1.38	0.81	5.10	3.26
2	3.82	3.54	1.39	0.87	5.00	3.26
3	3.92	3.50	1.44	0.78	5.18	3.26
Mean	3.96	3.53	1.41	0.82	5.09	3.26
S D	0.16	0.02	0.03	0.05	0.09	0.00

I
t is found that flexure strength of neat epoxy resin (CY-230+ 8 wt% of HY-951) is 5.09. The flexure strength of the fabricated composite made of 30 wt% bagasse wt% is 0.82.

3.4 Scanning Electron Microscopy (SEM)

The state of dispersion of bagasse fiber into the resin matrix plays a role on the mechanical properties of the composite. Various methods such as SEM, TEM can be used to evaluate the fiber dispersion in the composite. In the present investigation SEM was carried out for hybrid composite containing different weight percentage of Bagasse fiber and glass fiber in the epoxy resin matrix.

Figure 6(a) to 6(h) shows the SEM micrographs of different hybrid composite material investigated in the present work. In all the cases, good dispersion of bagasse-glass fiber in the resin matrix has been observed. Hence, from the above micrographs it is can be said that due to uniform dispersion of bagasse-glass fiber in the epoxy resin, a remarkably effect on the mechanical properties are obtained.

Figure 6(a) shows the vertical cut section of SEM micrographs of 20 wt% bagasse and 5 wt% glass fiber composite material. In this case, good dispersion of bagasse fiber and glass fiber in the resin matrix has been observed. The absence of any voids around the fibers indicates a good adhesion between fibers and epoxy matrix. From the Figure 6(b) it can be concluded that the vertical fracture section of SEM micrographs of 20 wt% bagasse and 5 wt% glass fiber composite material is well bonded and there is no stretching of fibers, rather fibers are broken uniformly. Similar observations are seen for 30 wt% bagasse and 5 wt% glass fiber mixed epoxy resin in figure 6(e-h). From the above figures it is also evident that there is no chemical reaction between fibers and epoxy resin. It is estimated that average size of the bagasse fiber are 13.0 μm in diameter and 61.0 μm in length.

The commercially available bagasse boards were purchased from the M/S Adlakhha Glass Stores, Rudrapur, INDIA having approximately same density in comparison to 25 wt% bagasse- 5 wt% glass fiber mixed composite to compare the mechanical properties. The test results are presented in the table 9-10.

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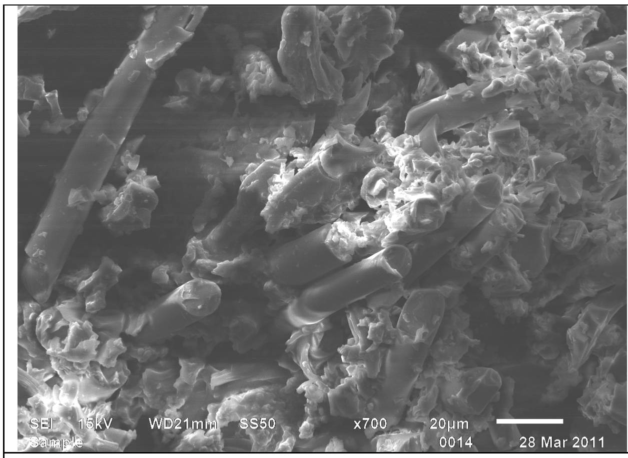

Fig. 6(a): Scanning electron micrograph for (20 wt%BG & 5 wt%GF) of vertical cut section

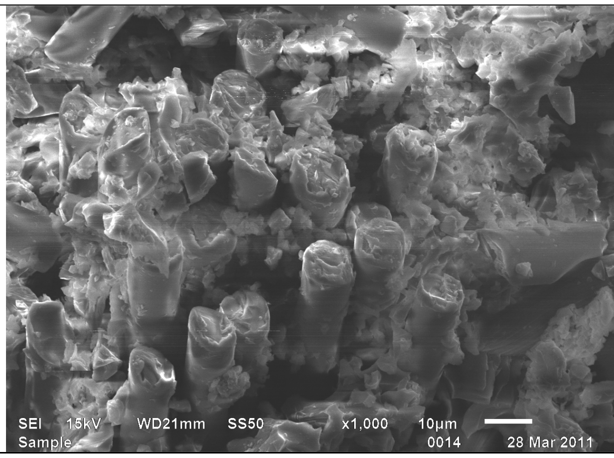

Fig. 6(b): Scanning electron micrograph for (20 wt%BG & 5 wt%GF) of vertical fracture section

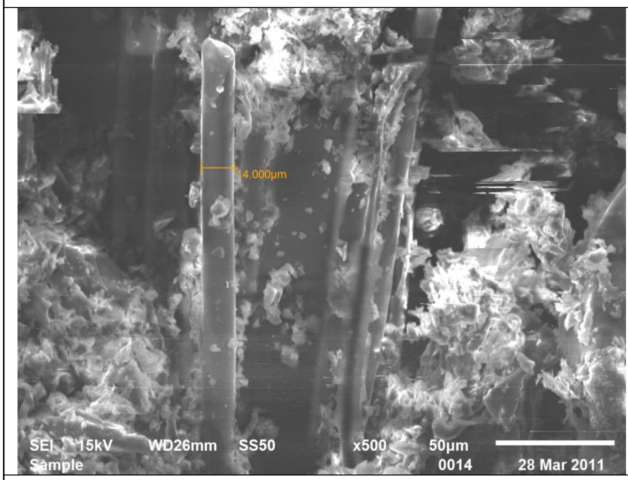

Fig. 6(c): Scanning electron micrograph for (20 wt%BG & 5 wt%GF) of Horizontal right side section

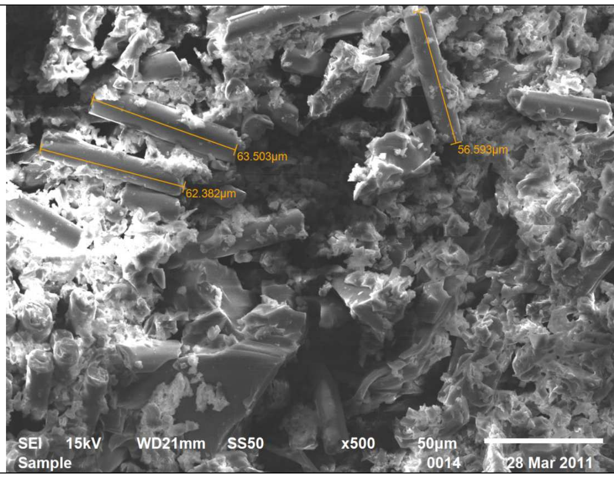

Fig. 6(d): Scanning electron micrograph for (20 wt%BG & 5 wt%GF) of Horizontal left side section

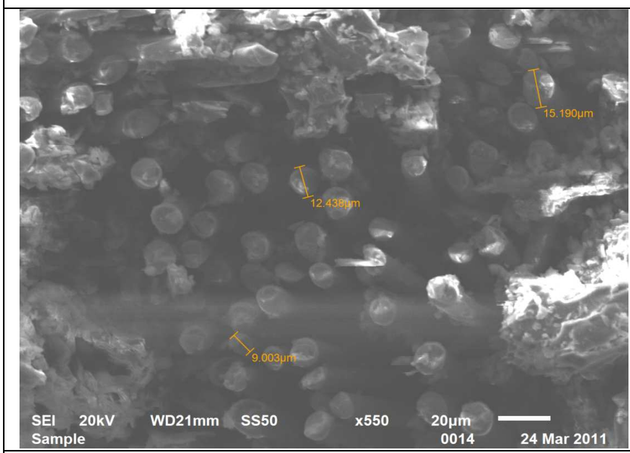

Fig. 6(e): Scanning electron micrograph for (30 wt%BG & 5 wt%GF) of vertical cut section

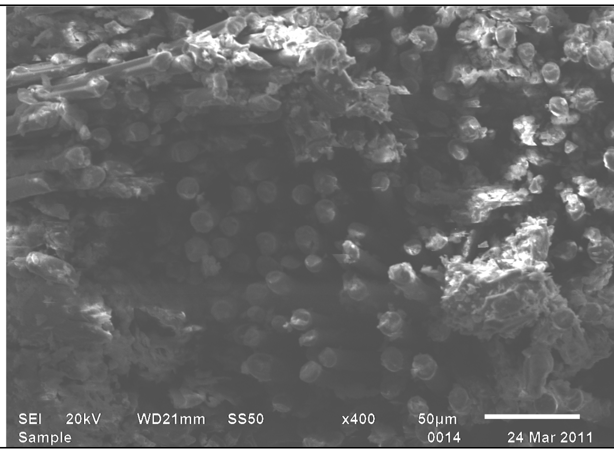

Fig. 6(f): Scanning electron micrograph for (30 wt%BG & 5 wt%GF) of vertical fracture section

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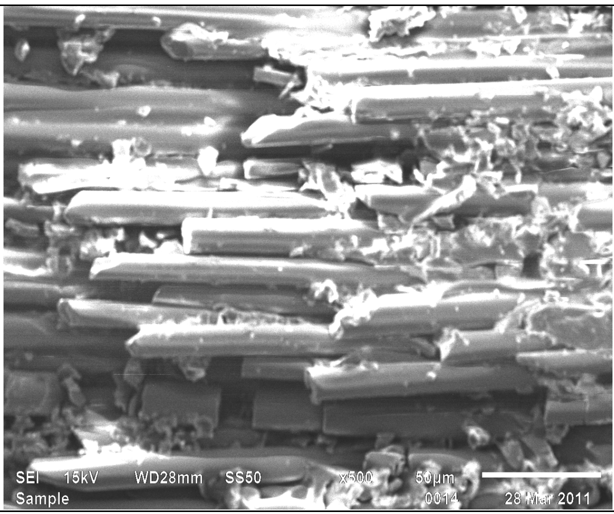

Fig. 6(h): Scanning electron micrograph for (30 wt%BG & 5 wt%GF) of Horizontal left side section.

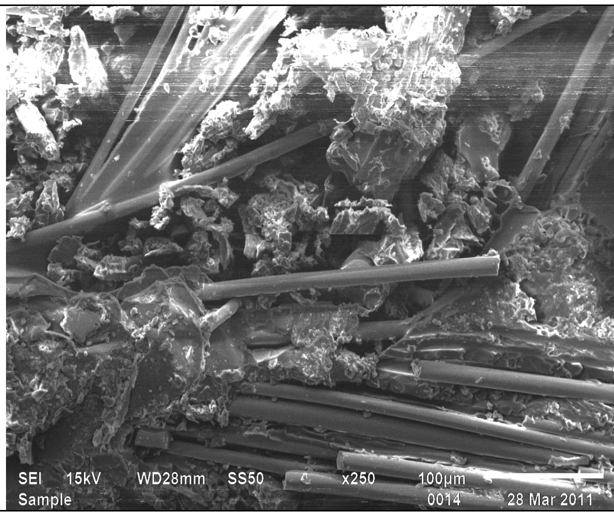

Fig. 6(g): Scanning electron micrograph for (30 wt%BG & 5 wt%GF) of Horizontal right side section

Table 9: Tensile properties of the composite materials and epoxy resin.

Property	15 wt% BG 5 wt% GF	20 wt% BG 5 wt% GF	25 wt% BG 5 wt% GF	30 wt% BG 5 wt% GF	Commercially available bagasse board
E,(MPa)	10.20	08.00	05.20	04.00	3.23
Ultimate stress, (MPa)	4.69	4.33	2.87	1.56	2.50
Percentage elongation	20.50	26.40	46.60	56.70	48.00

Table 10: Flexure strength, compressive strength, hardness and density of composite materials

Properties	15 wt% BG 5 wt% GF	20 wt% BG 5 wt% GF	25 wt% BG 5 wt% GF	30 wt% BG 5 wt% GF	Commercially available bagasse board
Flexure strength	3.96	3.53	1.41	0.82	0.75
Compressive strength	9.60	5.92	4.57	1.83	2.30
Hardness (M-scale)	53.00	47.60	45.00	39.80	32.00
Density, (g/mm^2)	1.04	0.99	0.86	0.80	0.87

The results show that the commercially available bagasse fiber boards have less tensile strength as compared to the bagasse board obtained in the present study due to presence of glass fibers. Similar effect is also seen in case of compressive and bending strength as mentioned in table 10. It is also found that hardness and density of commercially available bagasse fiber boards and bagasse board obtained in the present study are approximately same due to lesser amount of glass fiber mixed.

Conclusions

Addition of fiber increases the modulus of elasticity of the epoxy. Mixing of bagasse with glass fiber also improves the modulus of elasticity. Addition of bagasse fibers decreases the ultimate tensile strength. But addition of glass fiber further increases the ultimate tensile strength in comparison to commercially available bagasse based composite. Bagasse and bagasse-glass fibers improve the impact strength of epoxy materials due to high elasticity properties of fiber as compared to pure resin. Addition of fibers increases the water absorption capacity. This test is necessary where composites are used in moisture affected areas. Addition of bagasse fiber reduces bending strength. But addition of glass fiber further increases the bending strength in comparison to commercially available bagasse based composite. It is found that 30 wt% bagasse and 5 wt% glass fiber-mixed composite have approximately same hardness as seen in commercially available bagasse board.

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