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Assessment of Composites using Waste Sugarcane Bagasse Fibre and Wood Dust Powder

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Abstract: ***The present work aims to investigate relating to natural fibre-based epoxy composites. This study is dealt with the fabrication and chemical treatment evaluation of waste sugarcane bagasse fibre and wood dust powder composite. Sugarcane bagasse fibre and wood dust powder found to be good bonding owing to its properties like light-weight, high specific strength, bio-degradability and so on. The sugarcane shells are collected from local juice job and then it is chemically treated along with removal of sugar, and then dried in open atmosphere in the presence of sunlight. It is then pulverized to particle sizes of 1.0 mm, 1.5 mm, 2.0 mm and with a weight ratio of 75:25, the epoxy resins are mixed through which the fibres with 6 mm thick mould composites are made with different flat-shape. As per ASTM standards, specimens are made for conducting the experiments such as density determination, moisture absorption and mechanical tests. The sugarcane bagasse/epoxy composites (SB/EC) with wood dust powder were chemically treated with benzoic acid and sodium hydroxide for obtaining the mechanical properties. The results show that chemically treated composites have more flexural and tensile strength as compared with untreated sugar-free SB/EC. Alkali (NaoH) treatment obtains the highest flexural and tensile strength as compared with benzoic acid treatment. Both flexural and tensile strength of synthetically(chemical) treated composites, in any case, discovered lower than those of untreated sugarcane bagasse filled composite when unwashed sugarcane bagasse which contained sugar. Thus without additional chemical treatment, sugarcane bagasse perhaps used as a reinforcing agent since sugar contributes to the mechanical properties of the composites.***

Keywords: ***Chemical treatment, Epoxy matrix composites, Mechanical properties Sugarcane bagasse fibre, Wood dust powder.***

I. INTRODUCTION

In the world, after extracting the identified and required contents from a material, the rest of the materials are being wasted. Even that has a unique or similar property of the newly derived material until the proper application is found. Currently, the world focuses on eco-friendly material, especially the manufacturing industry emerging with natural resources [1]. Application wise people were showing interest in natural resource-based materials [2]. One such material is sugarcane bagasse. The sugarcane is being used for extracting sugarcane juice, from which various food and other products. are manufactured. After extracting sugarcane juice in a large factor, the bagasses are being utilized in thermal power plants for generating steam as co-generation. On the other hand, whenever sugarcane is crushed to extract juice in juice shops, the byproduct bagasse is not being utilized, which is fired at the open atmosphere mostly. This makes environmental pollution and also it leads to resources wastage. To avoid environmental pollution and wastage of the resources, crushed sugarcane bagasse is collected to make natural composite instead of synthetic fibers.

It is also noted that Graphene oxide and coir fiber with epoxy resin composite also improves the mechanical properties [3]. In this view, the work has already started with sugarcane bagasse, which is been used to manufacture reinforced polymer composites by using resin. A macro-level examination of the material has done by inspecting the mechanical properties and the result shows that the natural fiber sugarcane fiber can be the best alternative for synthetic fibers [4].

The sugarcane bagasse pretreatment plays an important role in material mechanical properties. The pretreatment using NaOH / anthraquinone (AQ) process of chemical pulping with 10 to 20 weight per cent fibers were considered for the experiment. The same fibers were introduced into the standard mechanical test and dynamic mechanical analysis tests. The results revealed that the pretreated fiber composite has improved mechanical properties [5]. At a micro level, the sugarcane fiber examined using scanning electron microscopy and Fourier transform infrared spectroscopy which revealed improved surfaces for better adhesion with matrix by performing chemical treatments like detergent washing, de-waxing, alkali, and acetic acid treatment [6].

Further, the sugarcane fibers are grinded in the range of 100 to 150 µm powders and blended with the PVC compounds then rolled in a hot rolling compression mould. The value-added product from the sugarcane microscopic characterization shows uniform distribution of the product has improved by 48%, 10% and 14% tensile modulus, thermal stability, and impact strength respectively [7]. Later, addition of one or more components and/or fibers in a composite material attracting much interest in the materials field of research.

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Like sugarcane bagasse with curaua acidolysis lignins improves the weight gain of 14% which reduces the methoxy and aromatic components in macromolecules, due to which the structure of the material has improved [8].

Palm wood flour with glass fiber reinforcements also increases the mechanical properties and it has good adhesion [9]. Wheat straw, sugarcane bagasse, and teak sawdust power blend applied to a mesh with a 50:50 (w/w) ratio. The treated composite increases the hardness 2-3 times more than the untreated also it reduces the swelling, water, and steam absorption [10]. The commonly harvesting crops around the world are sugarcane and paddy. In addition to the sugarcane and paddy rice husk and sawdust, composite has fabricated with 40% weight with epoxy resign. The tensile strength increases with a decrease in fiber weight percentage and compressive strength increase up to a certain weight ratio then decreases [11]. Some other research performed on the fruit waste, after extracting juice from the fruits in a juice shop. The byproducts are considered are sugarcane, apple, and orange. These fruit waste composite mechanical properties such as elongation at break, tensile strength, Young modulus are dependent on nature, filler material, and environmental conditions [12].

In addition to the mechanical properties, the thermal properties of the composite materials were also evaluated using dynamic analysis. In a natural fiber composite, there were few additional components like kenaf fiber, rice hulls, wood flour and newsprint fibers added at 25% and 50% weight ratio. The molded test specimen was tested with the temperature range of -60°C to +120°C and the frequency of the oscillator was fixed as 1 Hz with 0.1% strain amplitude and 2°C/min. The results indicated that a slight shift in composite was observed [13].

In the present study dealt with the fabrication and chemical treatments (includes sodium hydroxide and benzoic acid) evaluation of waste sugarcane bagasse fibre and wood dust powder composite. As per ASTM standards, specimens are made for conducting the experiments such as density determination, moisture absorption and mechanical tests.

II. EXPERIMENTAL PROCEDURE

A. Mould Preparation

The base mold has designed with mild steel material of dimensions 340 x 340 x 6 mm. Due to its easy availability, fair hardness and shock absorption capability the base mould has planned to make with mild steel. For enclosure of the mould material, four supporting bars are made with mild steel of dimensions 165×6×6 mm. Bolt and nuts are used as a fastener for obtaining easy removal of the composite from the mould box. The preparation of the fibres plays a vital role in the strengthening of the composites. The sugarcane bagasse fibre is collected from a local juice job. The wood waste powder is collected from sawmills.

B. Sugar Removal

At first, sugarcane shell fibre was cleaned with water to evacuate sugar and different substances on the interface before the concoction medications. The way toward washing is basic to ease direct contact among fibre and the synthetic substances to accomplish the compound responses. The sieved sugarcane bagasse was washed a considerable amount of times into water to expel the overabundance sugar. The sugar present in sugarcane bagasse was broken up in water and changes the water shading. A similar system was rehashed until the water shading shows up as crisp water shading, and it was an indication of low substance of sugar remaining on the outside of sugarcane bagasse. Both sugar-free (washed) and unwashed sugarcane bagasse were used and compared to study the mechanical properties of SB/EC.

C. Alkali (Sodium Hydroxide) Treatment

Contaminations present in sugarcane bagasse and wood dust particles is seen and artificially treated with 10% NaOH solution for evacuate polluting influences for 30 min at room temperature and afterward the filaments were washed with water and cleaned fiber was then dried for 24 hours utilizing the air flowing boiler at 80°C as reported by Saini et al [14].

D. Benzoic Acid Treatment

The washed sugarcane bagasse was treated with hydrogen peroxide (H_2O_2) solution for 1 hour and afterward blended in with a benzoic corrosive arrangement (C_6H_5COOH) in a modest quantity of ethanol. The measure of benzoic corrosive is considered for 5% of the heaviness of sugarcane bagasse. At that point the strands were kept in the open air for a minute to let the dissolvable get vanished. After vanishing, it was dried in an air coursing boiler at a temperature of 120°C for 24 hours as reported by Zheng et al [15].

E. Preparation of Composites and Samples

Table. 1 Types of sugarcane fibre reinforced composites

Type	Combinations	Cases	Particle size (mm)
1	Untreated sugarcane fibre	Unwashed	1.0
2	Untreated sugarcane fibre	Unwashed	1.5
3	Untreated sugarcane fibre	Unwashed	2.0
4	Untreated sugarcane fibre	Sugar-free	1.0
5	Untreated sugarcane fibre	Sugar-free	1.5
6	Untreated sugarcane fibre	Sugar-free	2.0
7	Alkali (NaoH) treated sugarcane fibre	Sugar-free	1.0
8	Alkali (NaoH) treated sugarcane fibre	Sugar-free	1.5
9	Alkali (NaoH) treated sugarcane fibre	Sugar-free	2.0
10	Benzoic acid treated sugarcane fibre	Sugar-free	1.0
11	Benzoic acid treated sugarcane fibre	Sugar-free	1.5
12	Benzoic acid treated sugarcane fibre	Sugar-free	2.0
13	Untreated sugarcane fibre + wood dust powder	Unwashed	1.0
14	Untreated sugarcane fibre + wood dust powder	Unwashed	1.5
15	Untreated sugarcane fibre + wood dust powder	Unwashed	2.0
16	Untreated sugarcane fibre + wood dust powder	Sugar-free	1.0
17	Untreated sugarcane fibre + wood dust powder	Sugar-free	1.5
18	Untreated sugarcane fibre + wood dust powder	Sugar-free	2.0
19	Alkali (NaoH) treated sugarcane fibre + wood dust powder	Sugar-free	1.0
20	Alkali (NaoH) treated sugarcane fibre + wood dust powder	Sugar-free	1.5

21	Alkali (NaoH) treated sugarcane fibre + wood dust powder	Sugar-free	2.0
22	Benzoic acid treated sugarcane fibre + wood dust powder	Sugar-free	1.0
23	Benzoic acid treated sugarcane fibre + wood dust powder	Sugar-free	1.5
24	Benzoic acid treated sugarcane fibre + wood dust powder	Sugar-free	2.0

Types of Sugarcane fibre reinforced composites are shown in Table 1.Thus the sugarcane bagasse and wood dust powder fibres were prepared for reinforcement in the composites, which were then pulverized by sieved meshes of 1.0 mm, 1.5mm and 2.0 mm with epoxy polymer matrix. By means of suitable release agent and matrix material, the specimens were prepared using hand lay-up technique. Matrix material such as Hardener HY-951 and Araldite LY-556 were used.

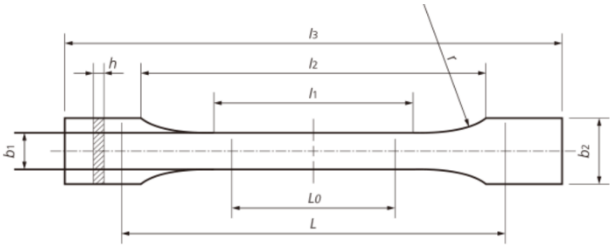

Fig. 1. Standard ASTM D638 specimens

As per ASTM D638 testing standard (see Fig.1 and Table 2) specimens of size 165×19×6 mm, are made ready for testing mechanical properties. Visual inspection has made to ensure the quality of the composite moulded. For flexural (bending) testing of specimens, three-point bending test were used.

Table. 2 ASTM D638 Specimen Dimensions

S.No	Particulars	Dimensions(mm)
1	Size	Type I
2	Full length, l_3	165
3	Parallel length l_2	57
4	Gauge length l_1	50
5	Parallel section width, strong b_1	13
6	Thickness, h	6
7	Grip section width, strong b_2	19
8	Distance between grips, l	115

F. Mechanical Testing

The tensile test was performed utilizing a general testing machine according to the standard methods with determined work examples as referenced previously. The tractable samples were set up as per the ASTM D 638. The flexural test was performed utilizing a computerized universal testing machine according to ASTM D 790 on a three-point twist configuration and the flexural test tests were arranged likewise. The heap was applied at the focal point of the samples in the flexural test. Both tensile and flexural testing was performed at a crosshead speed of 2 mm/min. A similar technique was followed with fresh three examples and the readings were noted.

G. Density Determination

A&D GR-200 analytical balance with density measurement kit is used for determining the density which was performed by Archimedes' principle (buoyancy method). It was determined using the below equation;

$$\rho = \frac{W_a}{W_a - W_b}(0.997)$$

where,Wa - weight of displaced fluid; Wb - weight of immersed fluid; ρ- density of displaced fluid.

H. Moisture Absorption Determination

Water absorption was determined using the below equation;

$$W_g = \left(\frac{W_t - W_0}{W_0}\right) \times 100\ \%$$

where, W_g - weight increase because of water retention; W_0 - weight of dried specimens; W_t - weight of the samples after a specific time of inundation

III. RESULTS AND DISCUSSION

Fig. 2 shows the impact of different treatments on the tensile strength of SB/EC as for the molecule size. From the outline, it is seen that synthetically treated composites acquire increasingly tensile strength when contrasted with untreated without sugar SB/EC. Be that as it may, the tensile strengths of the synthetically treated composite are not exactly those of untreated sugarcane bagasse filled composite which contained sugar at unwashed condition. In this way sugar assumes an essential job in the mechanical properties of SB/EC when contrasted with the chemical treatments. The maximum tensile strength of untreated and unwashed is 47 MPa for the particle size of 1.0 mm.

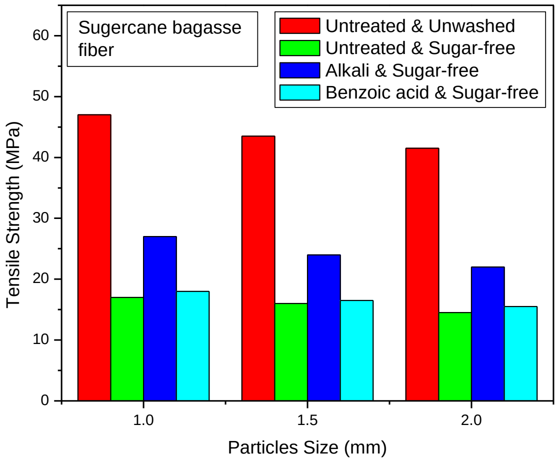

Fig. 2. Impact of different treatments on the tensile strength of SB/EC

Alkali chemically treated sugar-free SB/EC was more than that of untreated washed SB/EC and benzoic acid-sugar free composite. Moreover the tensile strength of untreated sugar-free SB/EC and benzoic acid-sugar free are utmost same with respect to the size of the particle. However, irrespective of chemical treatments condition the tensile strength is found to be maximum for the particle size of 1.0 mm.

The maximum tensile strength of alkali treatment is 26 MPa for the particle size of 1.0 mm. Alkali treatment was seen as the appropriate treatment to build up the mechanical properties of washed SB/EC Fig. 3. shows the impact of different treatments on the tensile strength of sugarcane bagasse fiber with wood dust/epoxy composites.

The impact of different treatment to the elasticity of sugarcane bagasse fiber with wood dust/epoxy composites is moderately equivalent to that of SB/EC with further increment in tensile strength at all conditions. Thus the addition of wood improves the interfacial bonding with sugar-free SB/EC tends to increase the tensile strength further.

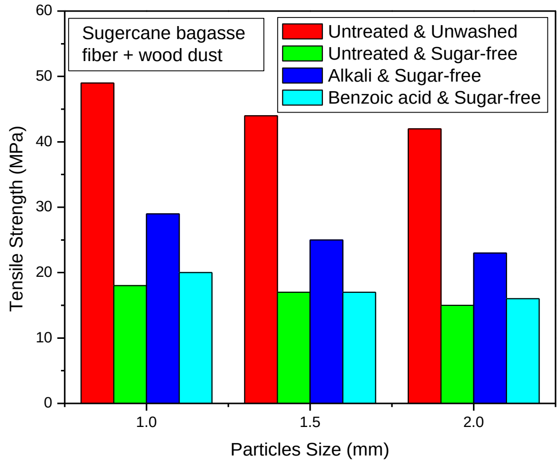

Fig. 3. Impact of different treatments on the tensile strength of sugarcane bagasse fibre with wood dust /epoxy composites

Fig. 4 shows the impact of different treatments on the flexural strength of SB/EC. From the chart, it is noticed that chemical treatment results in a reduction of the flexural strength at the unwashed condition of sugar [16]. The maximum flexural strength of untreated and unwashed is 58 MPa for all the particle size.

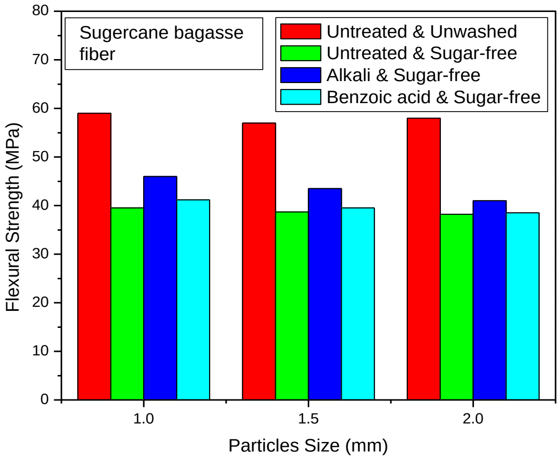

Fig. 4. Impact of different treatments on the flexural strength of SB/EC

Alkali chemically treated sugar-free SB/EC was more than that of untreated washed SB/EC and benzoic acid-sugar free composite. Moreover the flexural strength of untreated sugar-free SB/EC and benzoic acid-sugar free are utmost same with respect to the size of the particle. However, the flexural strength of alkali treatment is more than 1-5 MPa that of untreated sugar-free SB/EC and benzoic acid-sugar free composite at all size of particles. The maximum flexural strength of alkali treatment is 46 MPa for the particle size of 1.0 mm.

Fig. 5 shows the impact of different treatments on the flexural strength of sugarcane bagasse fibre with wood dust /epoxy composites. The impact of various treatments to the flexural strength of sugarcane bagasse fibre with wood dust /epoxy composites is relatively the same as that of SB/EC with further increase in flexural strength at all conditions. Thus the addition of wood improves the interfacial bonding with sugar-free SB/EC tends to increase the flexural strength further.

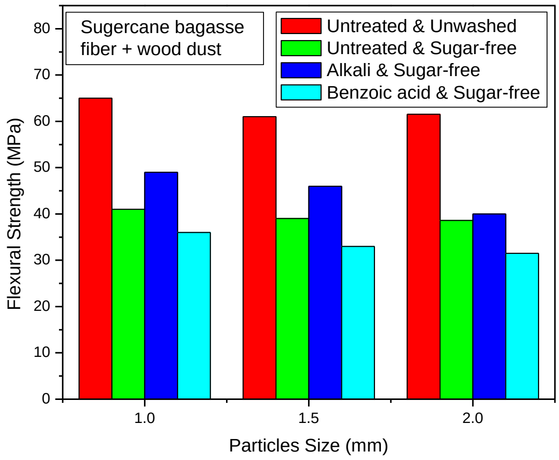

Fig. 5. Impact of different treatments on the flexural strength of sugarcane bagasse fibre with wood dust /epoxy composites

Generally, theoretical determination of density of same materials irrespective of particle size will not differ. But, there may be slight changes occurs while it is chemically treated. Table. 3 shows the abbreviations of different treatments.

Table. 3 Abbreviations of different treatments

S.No	Abbreviations	
1	UW-UT-SCF	Unwashed - Untreated sugarcane fibre
2	SF-UT-SCF	sugar-free - Untreated sugarcane fibre
3	SF-AT-SCF	sugar-free - Alkali (NaoH) treated sugarcane fibre
4	SF-BT-SCF	sugar-free - Benzoic acid treated sugarcane fibre
5	UW-UT-SCFW	Unwashed - Untreated sugarcane fibre + wood dust powder
6	SF-UT-SCFW	sugar-free - Untreated sugarcane fibre + wood dust powder
7	SF-AT-SCFW	sugar-free - Alkali (NaoH) treated sugarcane fibre + wood dust powder
8	SF-BT-SCFW	sugar-free - Benzoic acid treated sugarcane fibre + wood dust powder

Table. 4 shows the density of SB/EC at different conditions. The most extreme density is seen at unwashed conditions because of the presence of sugar inside the lumen of sugarcane stuff and in the middle of sugarcane baggage and surfaces of epoxy.

Table. 4 Density of SB/EC

Pre-treatment	Density (g/cm^3) for Particle size (mm)			Standard Deviation for Particle size (mm)		
	1.0	*1.5*	*2.0*	*1.0*	*1.5*	*2.0*
UW-UT-SCF	1.443	1.442	1.442	0.011	0.012	0.011
SF-UT-SCF	1.384	1.383	1.383	0.002	0.002	0.003
SF-AT-SCF	1.420	1.419	1.418	0.009	0.009	0.008
SF-BT-SCF	1.413	1.413	1.412	0.002	0.003	0.003
UW-UT-SCFW	1.443	1.442	1.442	0.010	0.010	0.011
SF-UT-SCFW	1.384	1.383	1.383	0.003	0.002	0.003
SF-AT-SCFW	1.420	1.419	1.418	0.009	0.008	0.008
SF-BT-SCFW	1.413	1.413	1.412	0.003	0.002	0.003

However, the theoretical value of density was seen as higher than the determined density, which represents space inside the composite. Table. 5 shows the moisture absorption of SB/EC.

Table. 5 Moisture absorption of SB/EC

Pre-treatment	Initial rate of absorption, k (% $h^{-1/2}$) for particle size (mm)			Maximum weight gain, W_m (%)for particle size (mm)		
	1.0	*1.5*	*2.0*	*1.0*	*1.5*	*2.0*
UW-UT-SCF	0.85	0.86	0.88	9.72	12.78	15.68
SF-UT-SCF	0.95	0.94	0.96	12.46	16.72	18.66
SF-AT-SCF	1.38	1.36	1.37	13.84	18.08	20.68
SF-BT-SCF	1.00	0.99	0.99	11.93	14.68	17.56
UW-UT-SCFW	0.88	0.89	0.91	9.82	12.86	15.74
SF-UT-SCFW	0.98	0.97	0.98	12.54	16.78	18.72
SF-AT-SCFW	1.42	1.38	1.39	13.88	18.16	20.76
SF-BT-SCFW	1.02	0.100	0.99	11.99	14.86	17.96

Fig. 6, 7 and 8. show the moisture absorption of the composites Vs √time for molecule size 1.0 mm, 1.5 mm and 2.0 mm separately. Fig. 6,7 and 8 shows that the percent of weight increase because of retention of water directly increments about with the √time and after that saw as steady at extended time. Linear regression is assists with finding the underlying pace of assimilation by deciding the underlying plot incline.

Table. 6 Level of Moisture absorption rate according to the conditions

S.No	Level of Moisture Absorption Rate (From High to low)
1	SF-AT-SCFW
2	SF-AT-SCF
3	SF-UT-SCFW
4	SF-UT-SCF
5	SF-BT-SCFW
6	SF-BT-SCF
7	UW-UT-SCFW
8	UW-UT-SCF

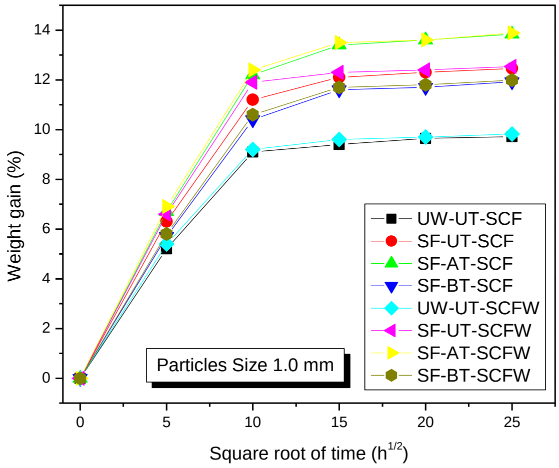

Fig. 6 Moisture absorption of the composites Vs √time for particle size 1.0 mm

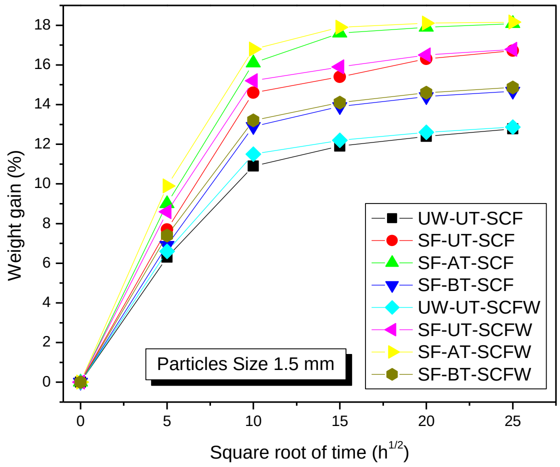

Fig. 7 Moisture absorption of the composites Vs √time for particle size 1.5 mm

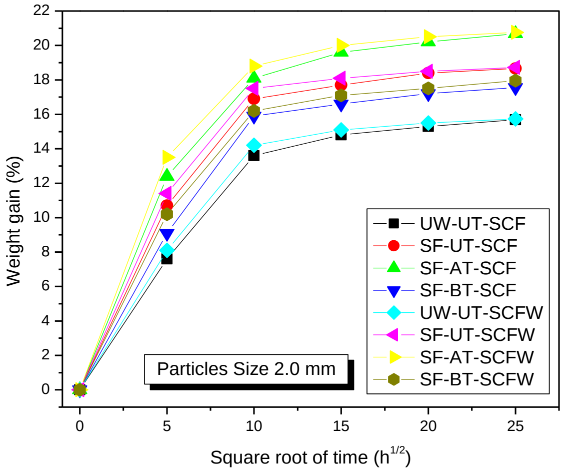

Fig. 8 Moisture absorption of the composites Vs √time for particle size 2.0 mm

Table. 6 shows the level of moisture absorption rate (From High to low). The maximum moisture absorption rate was found to be sugar-free - Alkali (NaoH) treated sugarcane bagasse fibre with wood dust powder composites and the minimum moisture absorption rate was found to be unwashed untreated sugarcane bagasse fibre composites.

From this, clearly the cell walls are secured by sugar of sugarcane bagasse, henceforth hindered the water retention process by holding up the entrance of water into the cell walls. Moisture absorption increases with respect to an increase in particle size. The void spaces volume assumes an essential job in the water absorption rate. Progressively void spaces volume brings about a more water absorption rate. As talked about over, the sugar nearness may limit the void space volume in unwashed bagasse. Henceforth, water absorption is less at unwashed SB/EC.

IV. CONCLUSIONS

With or without consideration of chemical treatments condition the tensile strength and flexural strength are found to be maximum for the particle size of 1.0 mm, thus the grain size significantly influence the mechanical properties of concerned composites.

Unwashed sugarcane bagasse fibre with wood dust /epoxy composites results in higher tensile strength and flexural strength. Subsequently sugar assumes a crucial job in the mechanical properties of SB/EC when contrasted with the chemical treatments. Thus without additional chemical treatment, sugarcane bagasse perhaps used as a reinforcing agent since sugar contributes to the mechanical properties of the composites.

Alkali (NaOH) treatment gives better results on mechanical properties compared to benzoic acid treatment. The effect of wood dust powder along with sugarcane bagasse fibre composites improves the mechanical properties with the Alkali (NaOH) treatment.

The maximum density is seen at unwashed conditions because of the presence of sugar inside the lumen of sugarcane baggage and in the middle of sugarcane baggage and surfaces of epoxy.

The maximum moisture absorption rate was found to be sugar-free - Alkali (NaoH) treated sugarcane bagasse fibre with wood dust powder composites and the minimum moisture absorption rate was found to be unwashed untreated sugarcane bagasse fibre composites. Moisture absorption rate increases with respect to an increase in particle size.

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