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MECHANICAL BEHAVIOUR DETERMINATION OF SUGARCANE BAGASSE FIBER REINFORCED COMPOSITE

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Abstract — The recent interest in composite materials reinforced with natural fibers has considerably increased, due to the new environmental legislation as well as consumer pressure that forced manufacturing industries to search substitutes for the conventional materials. The natural, bio-degradable features and chemical constituents of the sugarcane bagasse (SCB) have attracted the attention of current industries as a highly versatile and potential ingredient in composite materials. The present work intent to investigate the mechanical properties of sugarcane bagasse fiber reinforced composite with araldite matrix. The Major role of the composite is reducing the weight of component to increase the strength of the material (Weight-off ratio). Bagasse fiber was powdered with various fiber volume fractions. For the first case, bagasse fiber of 60% volume is mixed with 40% resin and in the second case 40% of fiber with 60 % resin. SCB fiber is mixed with araldite resin and the composite plate was manufactured by hand lay-up method. After curing, the testing specimen was cut out from the composite plate as per ASTM Dimensions. The specimens are tested to evaluate the mechanical properties with tensile test, impact test, flexural test

and moisture test. The properties of various testing results are compared and the best volume fraction is concluded from both the cases.

Keywords— Araldite resin, ASTM, Bagasse, Mechanical test, Moisture test.

I. Introduction

Composites are the combination of two or more materials, in which one of the constituents is called the reinforcing phase, which is in the form of fibers, sheets, flakes or particles and is embedded in the other, known as matrix phase. The matrix phase materials are generally continuous [1]. The fibers are usually of high strength and modulus which serve as the principal load-carrying members. The matrix keeps the fibers in desired orientations, separating them from each other to protect the fibers from abrasion and provides a means of disturbing the load and transmitting the load in between the fibers without fracturing itself [2-5]. A composite material is therefore, a collegial combination of two or more micro-constituents that differ in chemical composition and physical form, which are insoluble in each other [4-12]. The natural fibers are mainly made of cellulose, hemicelluloses, lignin and pectin's, with a small quantity of extractives [13-14]. The bleaching of cellulose fibers from sugarcane bagasse provided by Mulinari et al. [15] evidenced an improved interfacial of the fibers and matrix. The objective of current work is to take advantage of the superior properties of both materials (SCB and araldite) without compromising on the weakness of either for application in structural components. This objective led to analyze the mechanical properties of bagasse composite as in structural areas, mechanical strength i.e. Tensile, Impact and flexural strength are greatly required.

Material Selection

The materials selected for this project are sugarcane bagasse (SCB) fiber and araldite matrix.

A. SCB Fiber:

The sugar cane bagasse is a residue of agro-industry, widely generated in high proportions. It is a fibrous residue left over after the extraction of juice from the sugarcane. Bagasse is generally grey-yellow to pale green as shown in Fig.1. In particle size, it is very bulky and quite non-uniform. The sugarcane-based bagasse fiber is a renewable agricultural material that has two distinct cellular constituents. The first one is a thick-walled, and relatively long fibrous fraction which is derived from the fibro-vascular bundles and rind, dispersed throughout the interior and the other is a pith fraction derived from the ground tissue's thin-walled cells. The main chemical constituents of SCB are cellulose, hemicelluloses and lignin. Cellulose and hemicellulose are present in the form of hollow cellulose which contributes about 70 % of the total chemical constituents present in SCB. Another important chemical constituent present in it is lignin. Lignin acts as a binder for the cellulose and hemicellulose fibers, also behaves as an energy storage system. The complete composition is shown in Fig. 2 as provided by Y.R. Loha et al. [16].

Fig. 1 Chopped Sugercane Bagasse fiber

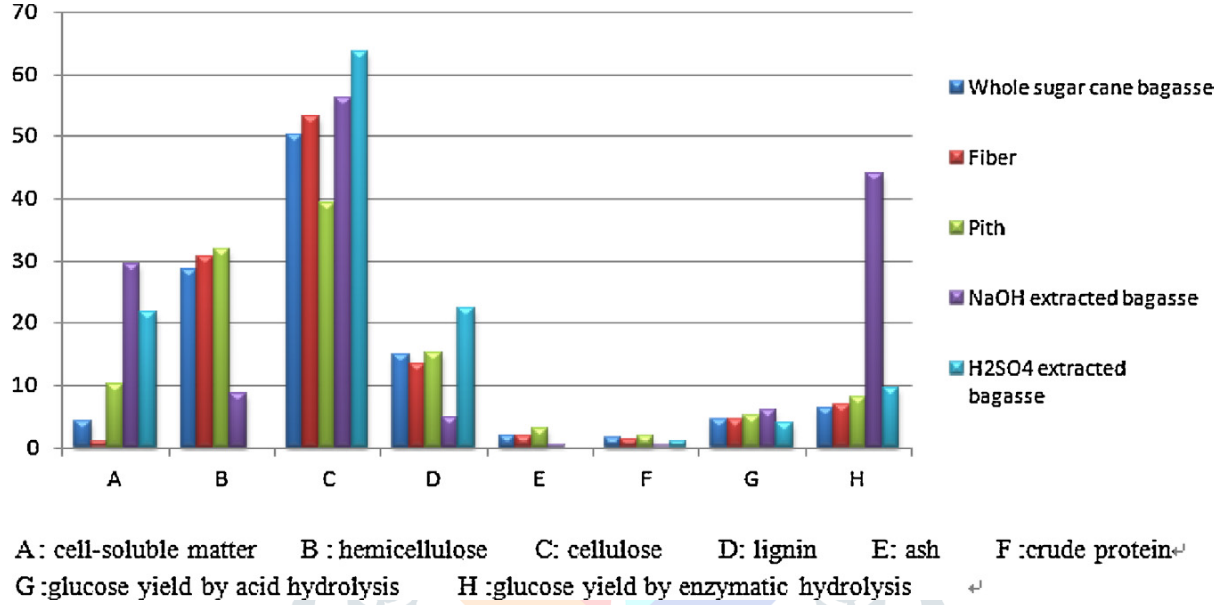

Fig. 2 Standard chemical composition of sugercane bagasse fiber [16]

B. Araldite Resin:

Araldite resin is a new synthetic resin adhesive for bonding materials. It is used to make strong bonds between two materials. The resin and hardener mixed together before using for making a strong bond. Heat is not required for curing purpose and improves the strength of the bond. Bonding also depends upon the volume fraction in which the hardener and resin are mixed. This is most commonly used to join two sections together.

C. Composition Selection:

The total weight of a composite material plays a major role in their application which is dependent on the correct composition of fiber and resin. This imparts the necessity of composition selection. The composition of this bagasse fiber composite has been selected after analyzing weight based on the different volume fraction of fiber and resin. The density of bagasse fiber and araldite matrix utilized in this paper was 0.45 g/cm^3 and 1.2 g/cm^3. Based on the volume fraction, the weight of final composite can be found out as provided in Table 1.

Sl.No	**Volume Fraction %**		**Total volume of composite plate (25×19×0.5cm^3)**	**Mass of matix/fiber (g)**		**Total mass (g)**
	Fiber	***Resin***		***Fiber***	***Resin***	
1	20	80	273.5	24.61	262.56	287.17
2	30	70	273.5	36.92	229.74	266.66

3	40	60	273.5	49.23	196.92	246.15
4	50	50	273.5	61.53	164.1	225.64
5	60	40	273.5	73.84	131.28	205.13
6	70	30	273.5	86.15	98.46	184.61

TABLE. 1: WEIGHT CALCULATION OF DIFFERENT VOLUME FRACTION

The provided calculation states that if the least amount of resin (say 30%) is added up with more amount of fiber (say 70%) then the total mass of composite plate was found to be minimum (181.61 g) while inverse causes more weight. But if the volume of resin is lower then, inefficient bonding will happen and more volume of resin causes very rich mixture and the penalty of weight will be caused with an increase in strength. Hence, for optimum results, there must be a balance between the compositions. 50-50% will be efficient but is widely in use. Therefore, this paper intents to understand the mechanical behavior of these composites at 60% and 40% resin.

EXPERIMENTAL PREPARATION

The experimental setup and model preparation was carried out at a standard level and are described sequentially. The specimen preparation was carried out by preparing a die of specified dimensions, preparation of hardener and finally manufacturing of composite plate.

A. Die Preparation

The mould for manufacturing composite was initially prepared. The mould of dimension 250×190×30mm as shown in Fig. 3 was prepared using a metal rod of square cross-sectional area. A clean smooth-surfaced mild steel plate is taken and washed thoroughly. The steel plate was used to give a cover to the mould with the addition of a non-reactive thin plastic sheet. Also, the steel plate was covered with a mould release sheet.

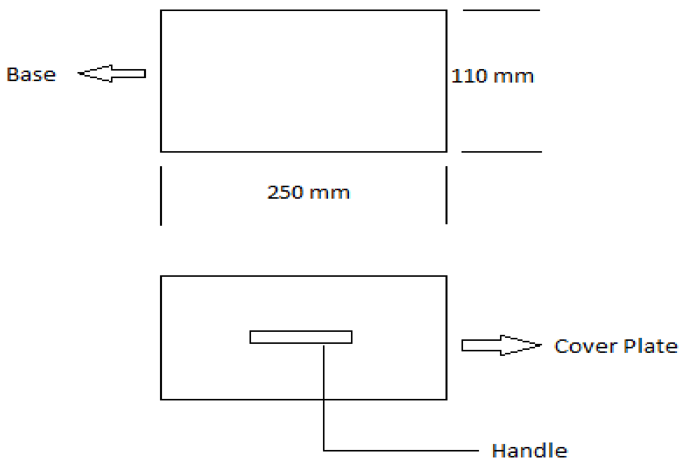

Fig. 3 Mould dimension of base and cover plate

B. Preparation of Resin and Hardener

For making good composite material with the best mechanical properties, the measurement of the samples should be accurate and very uniform. The accurate amount of araldite resin and hardener are taken using a weighing machine as per the calculated values. Both the resin and hardener are weighed in the glass beaker shown in Fig. 4. The mixture was then stirred thoroughly until it became a bit deep in colour. A little extra amount of hardener is taken by considering the material wastage in the process. Hardener composition must be done very carefully because a small amount of access hardener can spoil the composite.

Fig. 4 Araldite matrix & hardner after weighing

C. Manufacturing of Composite Plate

The composite plate was manufactured using hand layup process. In the beginning, sugar cane fibers were powdered to a uniform size. Then the fibers were weighed based on volume fraction calculation and resin's weight was also calculated using predefined formulas. The hardener and resin were measured separately as discussed in section (IIIB). They were mixed in a bowl with a ratio of 1:1. Mixing and stirring were done until it became like a white cream. Then the calculated fiber is added to the bowl and mixed up by hands, using safety gloves. They are mixed till a warm heat is felt in hands. Then the mixture of fiber and resin is placed inside the mould for getting the desired shape. Ramming was done on the top to make a good surface finish without ups and downs then it was covered using the prepared metal plate shown in Fig. 5.

A heavy weight was placed at the top of the arrangements to get it fixed. After one and half days the plate was ready, it was removed from the mould and grinded on the sides for good edge finish Fig. 6. The manufactured plate was then marked with dimensions by using the ASTM standard shown in Fig. 7 to cut-out the specimen. Five different specimens as marked are separated for the testing and comparing the results. Fig. 8 shows the specimens for further experimental testing.

Fig. 5 Hand moulded and covered composite before curing

Fig. 6 Final edge grinded composite plate after curing

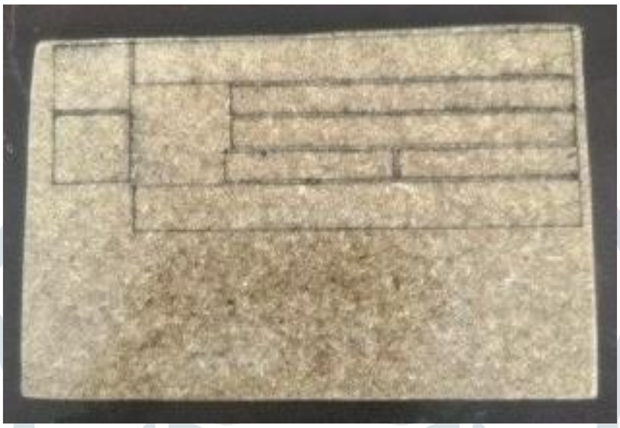

Fig. 7 Final composite plate after marking ASTM dimensions forcutting out sample specimen

Fig. 8 Test specimen as per mentioned ASTM dimensions

RESULT AND VALIDATION

The specimen materials manufactured using the said cases; case 1 (60% fiber and 40% resin) and case 2 (40% fiber and 60% resin) were tested for five different samples for the sake of accuracy. All the mechanical property tests i.e. impact test, flexural test, tensile test and moisture tests are carried out and the obtained values are tabulated and provided in figures.The results were validated using analytical and statistical method.

A. Impact Test

The impact test is a single point test in which the material's resistance to impact is measured using a swinging pendulum. The impact test deals with the minimum kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken. This test can be used as a quick and easy quality check to determine if the provided material meets specific impact properties or not to compare materials for general toughness. The standard specimen dimensions from ASTM is 64 ×

12.7 × 5mm. Totally 10 specimens were tested for impact 5-5 for each case. The data of impact values graph is plotted, The values obtained from the experiment were further validated using analytical calculation as provided.

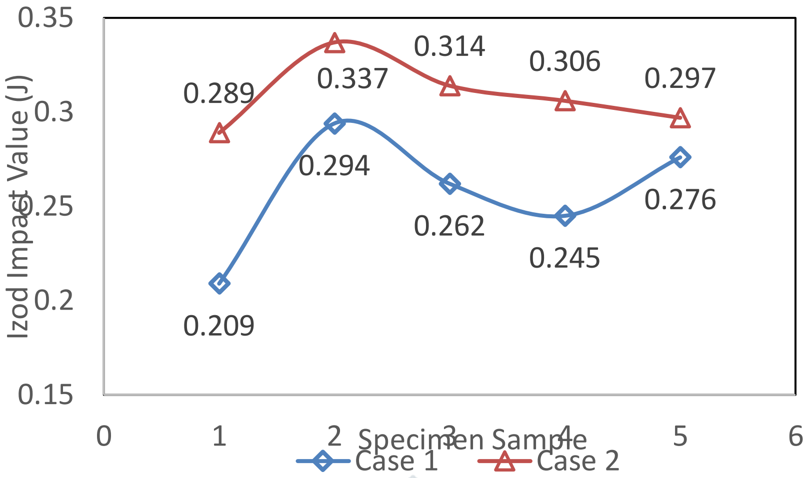

Fig. 9 Izod impact test value for various specimen in cases 1 and case 2 composite

From this Izod impact test, it was seen that all the five specimens of each case are having almost similar fluctuation in test values from the experiment. The analytical calculation also supports the obtained experimental values. The specimens of case 2 (40% fiber and 60% resin) was found out to be having high impact resistance than that of case 1. The maximum value of impact resistance was found to be 0.337 J for specimen 2 of case 2 composition. The values are utilized to estimate a nominal average value which is 0.2572 J/cm2 and 0.3086J/cm2 for case 1 and case 2 respectively.

B. Flexural Test

The flexural test uses the 3-point bending method according to ASTM D7264. The standard specimen dimensions from ASTM is 142 × 20 × 5mm. The flexural test was conducted to study the behavior and ability of the material to the bending load acted upon it. The loads were applied to the specimen until it gets broken. The flexural was conducted for different samples and results are noted in Table. 4, also a graph plotted with the value of flexural strength for each specimen in both cases provided in Fig. 10. These test results can be used for understanding the material's strength to resist bending load, which can also provide details of the maximum permissible load on the specimen of the provided dimensions. These results of the flexural test are validated using analytical calculation provided in.

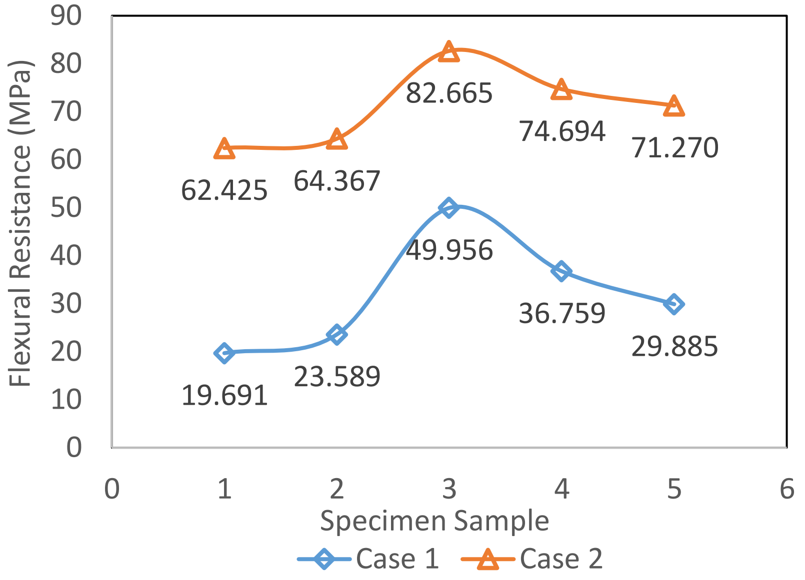

Fig. 10 Flexural test values for various specimen in both cases of composite

From the values plotted in Fig. 10 a similar fluctuation of flexural resistance is seen in the specimen of both the cases. Specimen of case 2 has provided better results than that of case 1. The maximum flexural resistance is found out to be 82.665 MPa and a minimum of 62.42 MPa. This proves that a composition of 40% fiber and 60% resin is better suitable for components used to sustain bending loads. However, the average value of all the samples needs to be considered for optimizing flexural strength. The maximum load attained by all the samples while testing was used to calculate the flexural strength analytically. The calculated values are quite the same as what obtained in experimental data.

C. Tensile Test

The tensile test specimen was prepared according to ASTM D638 the most common specimen for ASTM D638 has a constant rectangular cross-section, 20 mm wide and 165 mm long. The specimen was mounted in the grips of the universal tester with 10 mm gauge length. The stress-strain curve was plotted during the test for the determination of ultimate tensile strength and elastic modulus. All the test results were taken from the five test specimens of both compositions. Graph is plotted as shown in Fig. 11. The values obtained from the experiment were further validated using analytical calculation as provided .

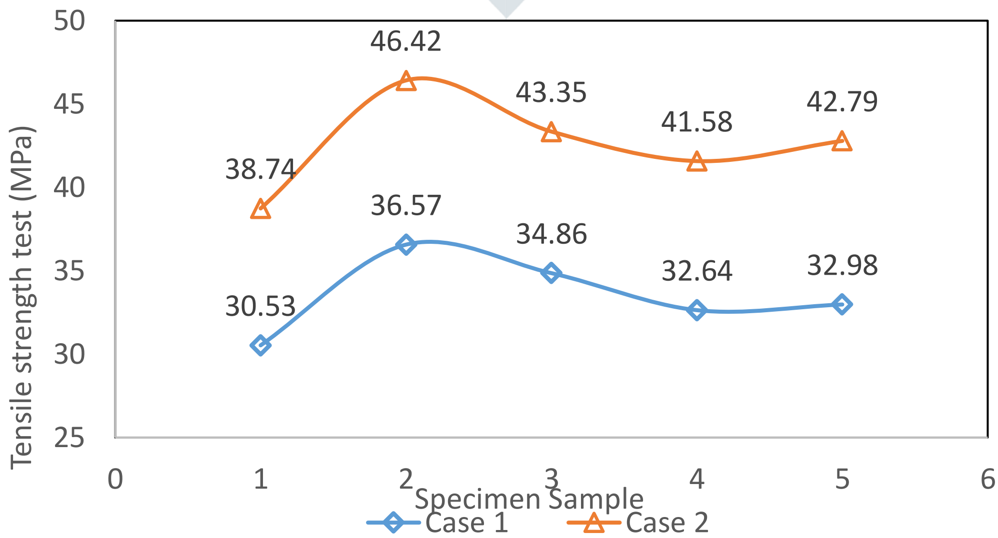

Fig. 11 Tensile strength values for all specimen

The graph of Fig. 11 also shows a similar fluctuation in tensile strength readings and the case 2 specimensare found to be the best among both cases. The analytical calculations of Table 7 show a little deviation in tensile strength while comparing with the average value in the experimental data. This accounts for validating the experimental data in a more précised way.

Conclusion

The mechanical properties of sugar cane fiber were evaluated with different volume fractions, 60% SCB fiber with 40% resin in case 1 and 40% SCB fiber with 60% resin in case 2. The experimental test results of the provided volume fraction of sugarcane fiber with araldite resin specimen were validated using an analytical calculation. Based on their properties; impact, tensile, flexural and moisture test values are determined and tabulated. The following conclusions are made from the results and discussion.

- Impact test and flexural test of both composite compositions have provided that, the case 2 specimen is having a high value of impact, as well as flexural resistance and, will have a delay in breakage as compared to case 1 specimen.
- The average value of impact resistance of all sample specimens of case 1 is 0.2572 J while that of case 2 is 0.3086 J. Therefore, composite with composition as case 2 is more preferred to be used in components undergoing impact loads.
- The average value of flexural resistance of all sample specimens of case 1 is 31.97 MPa while that of case 2 is 71.08 MPa. Therefore, composite with composition as case 2 is more preferred to use in components undergoing bending loads.
- Tensile test over both types of compositions had shown that case 1 material is having 33.51MPatensile strength and case 2 material having 42.576 MPa tensile strength.
- The moisture test also provides that the case 2 material is having high workability as it is having less moisture content than case 1.

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