STUDY OF PROPERTIES OF BANANA FIBER REINFORCED COMPOSITES

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Abstract

Natural fiber composites are nowadays being used in various engineering applications to increase the strength and to optimise the weight and the cost of the product. Various natural fibres such as coir, sisal, jute, coir and banana are used as reinforcement materials. In this paper both treated and untreated banana fiber are taken for the development of the hybrid composite material. The untreated banana fiber is treated by sodium hydroxide to increase the wettability. The untreated banana fiber and sodium hydroxide treated banana fiber are used as reinforcing material for both Epoxy resin matrix and Vinyl ester resin matrix. Coconut shell powder is used along with both untreated and treated banana fiber as a reinforcing material. In this process the banana fiber is treated with 5% of sodium hydroxide for one hour and the specimen is fabricated by hand moulding process. The mould used for fabricating the hybrid composite material is made up of aluminium with a debonding agent applied on the inner side. The banana fiber content is kept constant to 30% of weight fraction of entire composite material. The variation in mechanical properties are studied and analyzed. Here, the tensile strength has calculated by universal testing machine, impact strength has calculated by pendulum impact tester and flexural strength has calculated by universal testing machine with flexural test arrangement of the specimen. Then the treated and untreated specimens are analyzed and compared through Scanning Electron Microscope to study about its adhesion between fiber and resin matrix and surface morphology.

Keywords: *Natural Fiber Composites, Mechanical Properties, Surface morphology*

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1. INTRODUCTION

In today's modern world the need for more efficient material is very significant for the development of new products. For this composites play a major role as it has strong load carrying material embedded in weaker material. Reinforcement provides strength and rigidity to help and support the structural load. Polymer matrix composites are widely used but the mechanical properties of polymers are inadequate for many structural purposes [1]. In particular their strength and stiffness are low compared to ceramics and metals. These difficulties are overcome by reinforcing other materials with polymers. Applying natural fibers as reinforcing material in polymer composites is underway in various researches. In India, banana is abundantly cultivated. Banana fiber can be easily obtained from the pseudo stem after the fruits and leafs are utilized. Researchers [2-7] have been involved number of investigations on several types of natural fibers such as bamboo, kenaf, hemp, flax, and jute to study the effect of these fibers on the mechanical properties of composite materials. Venkateshwaran et al. [8-10] studied the mechanical properties of tensile, flexural, impact and water absorption tests were carried out using banana/epoxy composite material. Thiruchitrambalam et al. (2009) [5] studied the effect of alkali and SLS (Sodium Lauryl Sulphate) treatment on Banana/Kenaf Hybrid composites and woven hybrid composites. Thermosetting resins are costly and the thermosetting resins commonly used in engineering application are epoxy which has better mechanical properties. The thermoplastics offer recycling possibilities whereas the thermosets achieve improved mechanical properties. Polyester resins are low cost materials. Vinyl ester resins make a compromise between the above two limits. They have low properties comparing with epoxy, but are available at low cost.

In the present work, the fiber is treated with 5% of NaOH to increase the wettability. The Banana fibres are used as reinforcement in both epoxy and vinyl ester resin and coconut shell power is mixed with banana fiber to be used as reinforcement material to form hybrid composite

2. MATERIALS AND METHODS

2.1 Chemical Treatment

Banana fibers were purchased from Erode, Tamilnadu, India. The fibers were then treated with 5% of NaOH for one hour. The fibers are then washed thoroughly with distilled water. Fibers are then dried in oven for 2 hours at 100°C to remove the moisture present in it.

2.2 Matrix

Vinyl Ester and Epoxy Resin is obtained from Tamilnadu Chemicals pvt ltd, Salem under the trade mark of Lapox. The matrix is formed with six different combinations as untreated and treated fiber reinforcing Epoxy and Vinyl Ester Resin, untreated and treated fiber mixed with coconut shell powder to form a hybrid composite by reinforcing it with Epoxy and Vinyl Ester Resin to form a hybrid polymer composite.

3. PREPARATION OF THE COMPOSITE

The composite are fabricated by hand lay-up technique. The mould used for fabricating the composite is made up of aluminium with a debonding agent applied on the inner side. The inner cavity dimension of the mould is 150mm x 150mm x 10mm. The fiber is dipped in the resin and aligned in the mould where the resin is also poured. The fiber fraction is set as constant to 30%. The upper side is pressed using a roller under room temperature until the matrix is set properly. The setup is left to cure for 24 hours at room temperature. Now the prepared composite were cut for testing conform to the dimensions of the specimen as per ASTM standards.

3.1 Tensile Test

Fig. 1 shows the specimens prepared for tensile test. The testing is done using UTM to measure the force required to break a polymer composite specimen and the extent to which the specimen stretches or elongates to that breaking point. Here Fig. 2 indicates a broken piece during the tensile test.

Fig -1: Tensile test specimens

Fig -2: Tensile specimen in UTM

3.2 Flexural Test

Flexural strength is defined as a materials ability to resist deformation under load. It is a 3-point bend test, which generally promotes failure by inter-laminar shear. This test is conducted as per ASTM D790 standard using UTM. Flexural test arrangement is shown in the Fig. 3. Flexural MR is about 10 to 20 percent of compressive strength depending on the, size, volume and type of coarse aggregate used. Anyway the best correlation for specific materials is obtained by laboratory tests for given materials and mix design. The maximum fiber stress at failure on the tension side of a flexural specimen is considered the flexural strength of the material. Thus, using a homogeneous beam Equation (1), the flexural strength in a three-point flexural test is given by;

$$\sigma_f = (3P_{max}\, L)/2bh^2 \qquad (1)$$

where,
P_{max}= maximum load at failure
b = specimen width
h = specimen thickness
L = specimen length between the two support points

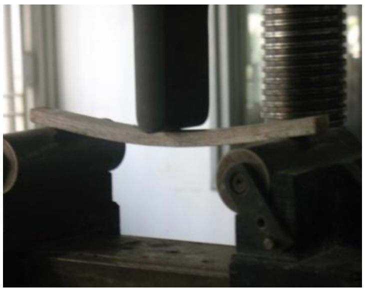

Fig -3: Flexural test arrangement

3.3 Impact Test

Impact is a single point test that measures a materials resistance to impact from a swinging pendulum. Impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken. The Fig.4 shows the impact testing observation during the experimental work.

Fig -4: Impact testing of the specimen

4. RESULTS AND DISCUSSIONS

This chapter presents the mechanical properties of the treated/un-treated banana fiber/epoxy, treated/un-treated banana fiber/vinyl-ester, treated banana fiber/epoxy, vinyl-ester and hybrid epoxy composites prepared for this present investigation. The Details of processing of these composites and the tests conducted on them have been described in the before chapter. The results of various characterization tests are reported here. These include evaluation of tensile strength, flexural strength, impact strength that has been studied and discussed.

4.1 Tensile Test

Tensile testing of specimen prepared according to ASTM D 3039 type IV sample was carried out, using electronic tensile testing machine with cross head speed of 2mm/min and a gauge length of 115 mm. Observations of tensile properties were presented in Table 1

Table -1: Observations of tensile property

SPECIMEN	Engg. Stress (N / Sq mm)	Strain	Max Load (N)	Disp. In mm(at Max Load)	Min Load In (N)	Disp. In mm(at Min Load)
UNTREATED BANANA FIBER – EPOXY COMPOSITE						
A1	6.54	0.0139	254.98	0.6961	19.61	0.7301
A2	6.54	0.0139	254.98	0.6961	19.61	0.7385
A3	5.53	0.0163	215.75	0.8149	49.04	0.0594
A4	5.53	0.0163	215.75	0.8149	49.04	0.0594
A5	6.79	0.019	264.79	0.9508	49.04	0.034
UNTREATED BANANA FIBER –VINYLESTER COMPOSITE						
B1	11.82	0.0618	460.93	3.09	49.04	0.034
B2	11.06	0.0503	431.51	2.5127	49.04	0.0509
B3	12.82	0.046	500.16	2.3005	9.81	2.3684
B4	10.06	0.0428	392.28	2.1392	49.04	0.0424
B5	11.32	0.0447	441.32	2.2326	49.04	0.0509
TREATED BANANA FIBER – EPOXY COMPOSITE						
C1	20.37	0.0584	794.37	2.9202	9.81	2.9542
C2	24.39	0.073	951.28	3.6503	49.04	0.034
C3	23.89	0.0708	931.67	3.5399	58.84	0.0594
C4	22.38	0.0699	872.82	3.4975	58.84	0.0679
C5	22.13	0.0489	863.02	2.4448	19.61	2.5127
TREATED BANANA FIBER –VINYLESTER COMPOSITE						
D1	20.62	0.0733	804.17	3.6672	49.04	0.0509
D2	19.11	0.0654	745.33	3.2683	49.04	0.0509
D3	14.58	0.1014	568.81	5.0679	29.42	0.4669
D4	18.11	0.0739	706.1	3.6927	49.04	0.0594
D5	15.84	0.0594	617.84	2.9712	49.04	0.0764
HYBRID FIBER –EPOXY COMPOSITE						
E1	22.88	0.0608	892.44	3.0391	49.04	0.0509
E2	21.63	0.0706	843.4	3.5314	49.04	0.0509
E3	18.36	0.0664	715.91	3.3192	49.04	0.0509
E4	17.35	0.0589	676.68	2.9457	9.81	2.9627
E5	18.61	0.0452	725.72	2.2581	49.04	0.0934
HYBRID FIBER –VINYLESTER COMPOSITE						
F1	17.35	0.0569	676.68	2.8438	49.04	2.8693
F2	22.38	0.0852	872.82	4.2615	49.04	0.0509
F3	19.87	0.0772	774.75	3.8625	58.84	0.0594
F4	19.36	0.0657	755.14	3.2852	49.04	0.034
F5	19.11	0.0569	745.33	2.8438	19.61	2.8608

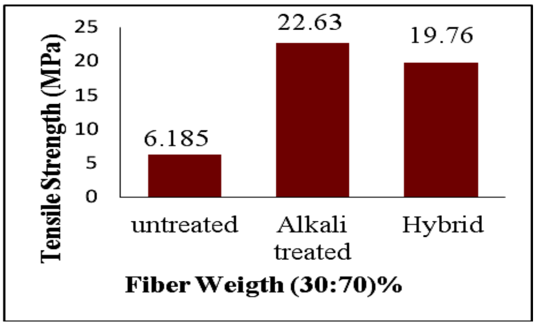

Chart -1: Variation of tensile strength banana fiber epoxy composite

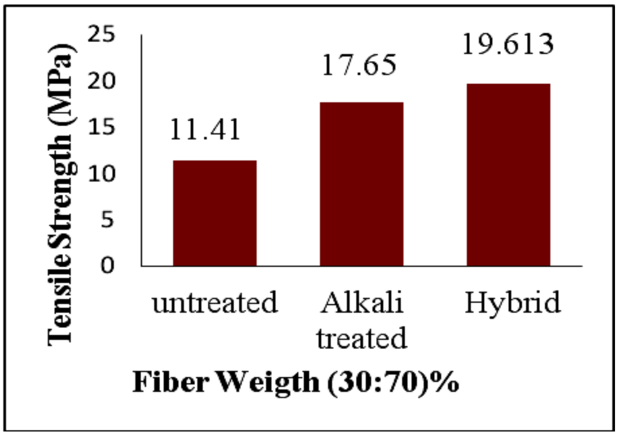

Chart -2: Variation of tensile strength of banana fiber vinyl ester composite

The tensile modulus and elongation at break of the composites were calculated from the stress strain curve. Five specimens were tested for each set of samples and mean values were reported.

As expected, from Chart 1 and Chart 2 the surface modification by chemical treatment of fibers resulted in a significant increase in tensile strength. From the table it can be easily found that the alkali treatment provides better improvement in the tensile strength. The range of the tensile strength was between 6.18-22.63MPa for 30 wt% fiber loading. The maximum tensile stress value of the alkali treated composites was 22.63MPa for 30 wt % fiber loading. When fiber reinforced composites are subjected to load, the fibers act as carrier of load and stress is transferred from the matrix along the fibers leading to effective and uniform stress distribution, which results in a hybrid composite having good mechanical properties. Untreated fibers causing the bond between matrix and fiber is poor to break, leaving the matrix diluted by non-reinforcing deboned fiber. In the case of hybrid banana/coconut shell powder/epoxy composite compare to banana/epoxy composite have high tensile strength.

The variation of tensile strength of banana fiber /coconut shell powder/ vinyl ester composite has better tensile strength. The maximum tensile stress value of the composites was 19.61 MPa. In a hybrid composite, the occurrence of a hybrid effect (negative or positive) of the composite are mainly dependent on the strength and elongation at break of the individual reinforcing fibers and relative weight fraction of the fiber. As can be seen from fig 6 the weight fraction of banana/vinyl ester fiber resulted in negative effect on tensile properties.

4.2 Flexural Test

The flexural test was performed by the three point bending method according to ASTM D 790, and cross head speed of 1 mm/min. The flexural properties were presented below in Table.2

Table -2: Composite materials flexural property

SPECIMEN	Ult/Break Load (kN)	Disp. At FMAX (mm)	Max.Disp (mm)	Area (mm^2)	Ult. Stress (kN/mm^2)
UNTREATED BANANA FIBER –EPOXY COMPOSITE					
A1	0.025	1.100	6.400	39	0.001
A2	0.025	0.900	3.400	39	0.001
A3	0.025	0.800	1.500	39	0.001
A4	0.015	0.900	4.400	39	0.000
A5	0.030	1.300	2.500	39	0.001
UNTREATED BANANA FIBER–VINYLESTER COMPOSITE					
B1	0.035	1.900	4.700	39	0.001
B2	0.055	2.800	3.300	39	0.001
B3	0.025	2.100	3.000	39	0.001
B4	0.025	1.700	3.900	39	0.001
B5	0.025	2.100	3.100	39	0.001
TREATED BANANA FIBER –EPOXY COMPOSITE					
C1	0.050	1.800	2.500	39	0.001
C2	0.035	0.900	2.000	39	0.001
C3	0.045	1.200	1.500	39	0.001
C4	0.040	1.200	1.700	39	0.001
C5	0.040	1.300	1.800	39	0.001
TREATED BANANA FIBER –VINYLESTER COMPOSITE					
D1	0.045	2.000	4.900	39	0.001
D2	0.035	1.900	2.700	39	0.001
D3	0.045	2.400	3.300	39	0.001
D4	0.045	2.200	3.400	39	0.001
D5	0.050	2.300	3.600	39	0.001
HYBRID FIBER –EPOXY COMPOSITE					
E1	0.050	1.300	1.600	39	0.001
E2	0.050	1.600	1.900	39	0.001
E3	0.035	0.900	3.000	39	0.001
E4	0.055	1.000	1.500	39	0.001
E5	0.060	0.900	1.300	39	0.001
HYBRID FIBER –VINYLESTER COMPOSITE					
F1	0.050	1.900	2.400	39	0.001
F2	0.050	1.700	2.400	39	0.001
F3	0.045	1.700	2.300	39	0.001
F4	0.045	1.600	1.900	39	0.001
F5	0.045	2.100	2.700	39	0.001

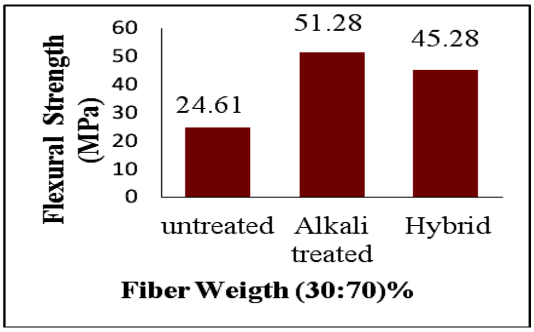

Chart -3: Variation of flexural strength of banana fiber epoxy composite

Five specimens were tested, and the average was calculated. The flexural properties of untreated/alkali treated banana fiber/epoxy composites at 30% fiber loadings are shown in Chart 3. Flexural strength is a combination of the tensile and compressive strength and varies with the interfacial shear strength between the fiber and matrix. In order to achieve effective fiber reinforcement, interfacial strength between the fiber and matrix is the most essential factor. It was observed from Chart 3 that the flexural strength and modulus of alkali treated banana fiber /epoxy composite has high flexural strength. The maximum flexural stress of the composite was 51.28 MPa.

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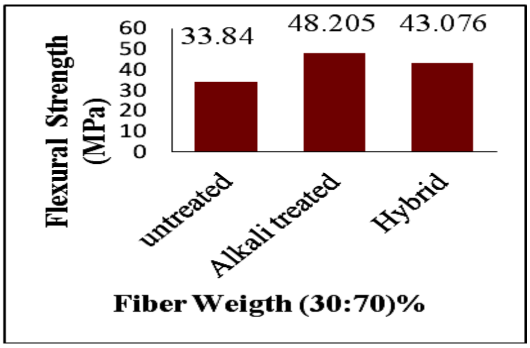

Chart– 4: Variation of flexural strength of banana fiber vinyl ester composite

The flexural properties of untreated/alkali treated banana fiber/vinyl ester composite is shown in Chart 4. Flexural test in various mechanisms such as tensile, compressive, shearing etc. will take place simultaneously. In order to achieve effective fiber reinforcement, interfacial strength between the fiber and matrix is the most essential factor. The maximum tensile stress value of the composites was 48.205 MPa.

4.3 Impact Test

Table-3 Composite materials Impact property

SPECIMEN	A(J)	B(J)	C(J)	D(J)	E(J)	F(J)
I	0.1	0.15	0.2	0.25	0.2	0.1
II	0.1	0.20	0.15	0.1	0.2	0.15
III	0.1	0.15	0.15	0.15	0.15	0.15
IV	0.1	0.20	0.1	0.1	0.15	0.15
V	0.1	0.15	0.1	0.2	0.15	0.15
VI	0.1	0.30	0.1	0.15	0.15	0.15

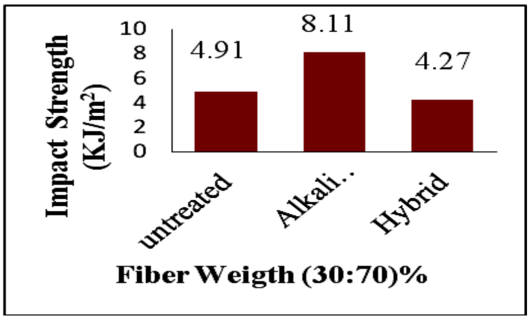

Chart -5: Variation of impact strength of banana fiber epoxy composite

The relationship between fiber weight and impact strength is shown in Chart -5. The impact property of a material shows its capacity to absorb and dissipate energies under impact or shock loading. The impact energy level of the composites depends upon several factors such as the nature of the constituents, construction and geometry of the composites, fiber arrangement, fiber/matrix adhesion, and test conditions. The matrix fracture, fiber matrix de-bonding, fiber breakage and fiber pull out are important modes of failure in the fiber composites due to impact loading. The applied load, transferred by shear to the fibers, may exceed the fiber/matrix interfacial bond, and deboning may occur. The frictional force along the interface may transfer the stress to the deboned fiber. If the fiber stress level exceeds the fiber strength, fibers may breakage. The breakage fibers may be pulled out of the matrix, and this involves energy dissipation. The impact strength of alkali treated banana fiber /epoxy composite has higher strength. However untreated/hybrid loading above this value caused a moderate decrease in impact strength.

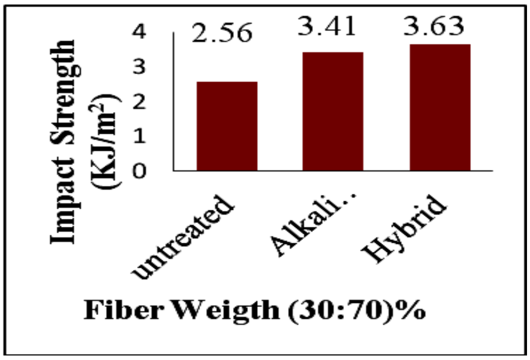

Chart -6: Variation of impact strength of banana fiber vinyl ester composite

These results suggest that the fiber is capable of absorbing energy because of strong interfacial bonding between the fiber and matrix up to 30 wt. % fiber loading. But at higher loadings the inter fiber interaction decreases the effective stress transfer between the fiber and matrix. This contributes to a decrease in impact properties at higher fiber loadings. The impact strength of alkali treated banana/epoxy composite has maximum strength 8.11 kJ/m^2. Chart 6 illustrates the impact strength of banana fiber/coconut shell powder hybrid vinyl ester composite. The impact strength of hybrid composite was found to be 3.63 kJ/m^2.

5. SURFACE MORPHOLOGY

SEM images of untreated, alkali treated, and hybrid fiber composite specimens are shown in fig 5 to fig 7. Fig 5 shows the SEM of untreated composite after tensile test and it reveal that the arrangements of fiber is not dense and voids are present in it, so mechanical properties yield poor in this category.

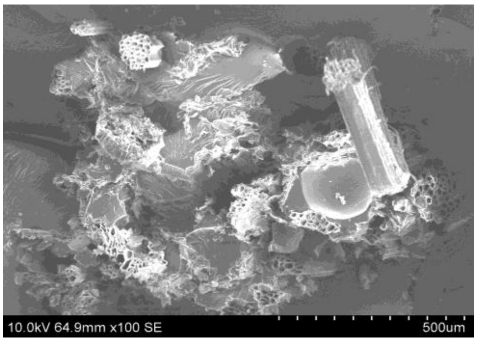

Fig -5: Untreated SEM image (x500) of banana fiber epoxy composite

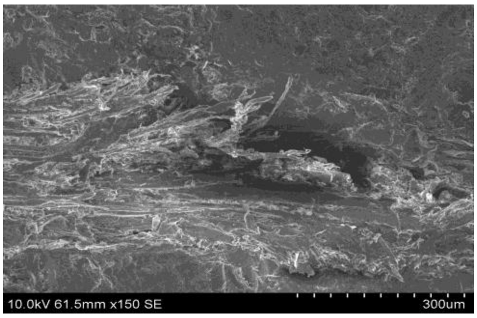

Fig -6: Alkali treated SEM image (x300) of banana fiber epoxy composite

Fig. 6 is the SEM view of alkali treated banana fiber composite sample after the tensile investigations. This image reveals that treatment has improved the property by adhesion between fiber and matrix which turn improved the mechanical strength. Fig 7 presents the SEM details of banana Hybrid fiber epoxy composite. From the image we can say that the distribution of hybrid resin is dominated the fiber effect. So the results compare to the treated fiber shows better result in this investigations.

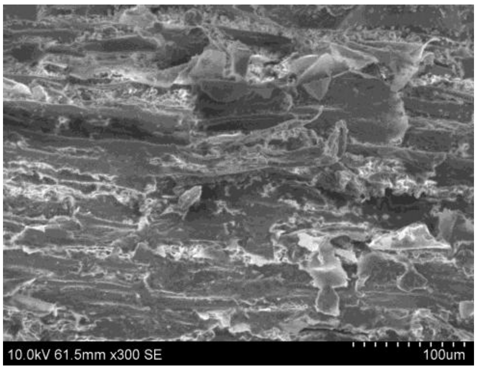

Fig -7: SEM image (x100) of banana Hybrid fiber epoxy composite

6. CONCLUSION

In this work, Mechanical properties of untreated/alkali treated banana fiber/epoxy, untreated/alkali treated banana fiber/vinyl ester and treated banana/coconut shell powder/epoxy, treated banana/coconut shell powder/vinyl ester hybrid composites were investigated. It has been observed from the literatures [2 -4, 6-11] were compared the resulting mechanical properties. The tensile, flexural and impact properties of the composites as a function of fiber content were analyzed.

The surface modification by alkali treatment has improved the Mechanical properties than untreated fiber composites. The alkali treatment of banana fiber has improved the mechanical properties like tensile, flexural and impact strength of both the epoxy/vinyl ester and hybrid composite. Therefore it is conclusive from the above result that the alkali treatment has provided better mechanical properties. In future various other natural reinforcing material could be used to mix with banana fiber to form a better hybrid composite which has a better mechanical properties and as well as cost effective.

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