RESEARCH ARTICLE OPEN ACCESS

# Mechanical and Chemical Properties of Bamboo/Glass Fibers Reinforced Polyester Composites

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**Abstract**
The chemical resistance of Bamboo/Glass reinforced Polyester hybrid composites to acetic acid, Nitric acid, Hydrochloric acid, Sodium hydroxide, Sodium carbonate, Benzene, Toluene, Carbon tetrachloride and Water was studied. The tensile and impact properties of these composites were also studied. The effect of alkali treatment of bamboo fibers on these properties was studied. It was observed that the tensile and impact properties of the hybrid composites increase with glass fiber content. The author investigated the interfacial bonding between Glsss/Bamboo fiber composites by SEM. These properties found to be higher when alkali treated bamboo fibers were used in hybrid composites. The hybrid fiber composites showed better resistance to the chemicals mentioned above. The elimination of amorphous hemi-cellulose with alkali treatment leading to higher crystallinity of the bamboo fibers with alkali treatment may be responsible for these observations.
***Keywords***- Bamboo Fiber, Composites, Chemical Resistance, Tensile Strength, Polyester, Impact Strength, Glass Fiber.

## I. INTRODUCTION

Several studies on the composites made from Polyester matrix and natural fibers like Jute, Wood, Banana, Sisal, Cotton, Coir and Wheat Straw were reported in the literature. Jindal, (1986) reported the development of bamboo fiber reinforced plastic composites using Polyester resin as matrix. Though bamboo is extensively used as a valuable material from times immemorial (because of its high strength and low weight) the studies on this fiber reinforced plastics are meager. In the present work, the bamboo/glass fiber reinforced high performance Polyester hybrid composites were developed and their tensile and impact properties with fiber content (with varying ratio of glass/bamboo fibers) were studied. The effect of alkali treatment of the bamboo fibers on these properties was also studied. The chemical resistance properties with varying fiber percentage were also studied.

### *A. Materials*

High performance Unsaturated Polyester resin and the curing agent hardener HY 951 system were used as the matrix. Bamboo fibers (*Dendrocalamus Strictus*) were procured from Tripura State of India in the dried form. Some of these fibers were soaked in 1% of NaOH solution for 30 minutes to remove any greasy material and hemi cellulose. Washed thoroughly in distilled water and dried under the sun for one week. The fibers with a thickness of 0.3 mm were selected in the mat form. The Glass fibers (chopped form) have been procured from company (Owens Corning Fiber Glass Mat, Bombay) is used in making the hybrid composite percentage.

### *B. Preparation of mould*

For making the composites, a moulding box was prepared with glass with 200mm×200mm×3mm mould (length × width × thickness).

## II. PREPARATION OF THE COMPOSITES AND TEST SPECIMENS

The mould cavity was coated with a thin layer of aqueous solution of *Poly Vinyl Alcohol* (PVA) which acts as a good releasing agent. Further a thin coating of hard wax laid over it and finally another thin layer of PVA was coated. Each coat was allowed to dry for 20 minutes at room temperature. A 3mm thick plate was made from the Polyester and hardener taken in the ratio of 100 and 10 parts by weight respectively. Then the moulding box was loaded with the matrix mixture, bamboo and glass fiber in random orientation (with varying percentage) and was placed in vacuum oven which was maintained at $100^{o}$c for 3 hours to complete the curing. After curing, the plate was removed from the moulding box with simple tapering and it was cut into samples for tensile test 150mm x 15mm x 3mm, Impact test 120mm × 13mm × 3mm and for chemical test with dimensions of 10mm × 5mm × 5mm. For comparison sake the specimen for matrix were also prepared in similar lines.

### *A. Tensile load measurement*

The Tensile stress and tensile moduli were determined using Instron 3369 model UTM. The cross head speed for tensile test was maintained at 10 mm per minute. In each case 5 samples were tested and average values are reported. The test specimens with dimensions 15mm × 10mm × 3 mm are cut as per ASTM D 3410-695 specifications. In each case five specimens are tested and average value is recorded.

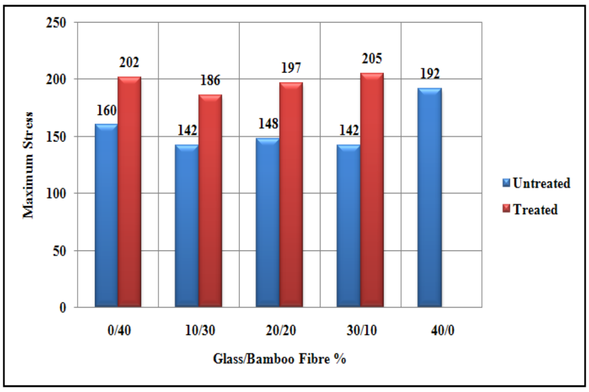


Fig.1. Variation of tensile stress at yield with ratio of % Glass/Bamboo fibers reinforced Polyester composites.

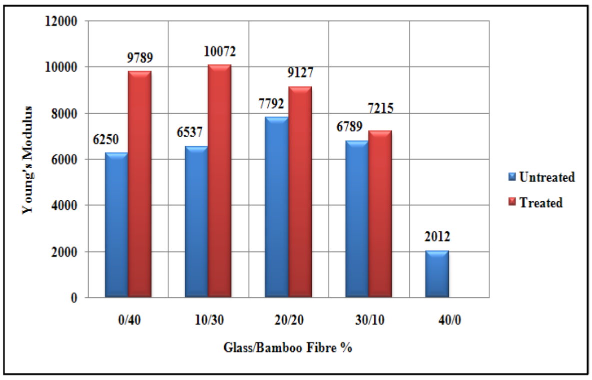


Fig. 2. Variation of tensile modulus with ratio of % Glass/Bamboo fibers Reinforced Polyester composites

## III. IMPACT LOAD MEASUREMENT

The impact strength is determined using IZOD impact tester. The test specimens with dimensions 120mm × 13mm × 3 mm are cut as per ASTM D 256-88 specifications. In each case five specimens are tested and average value is recorded.

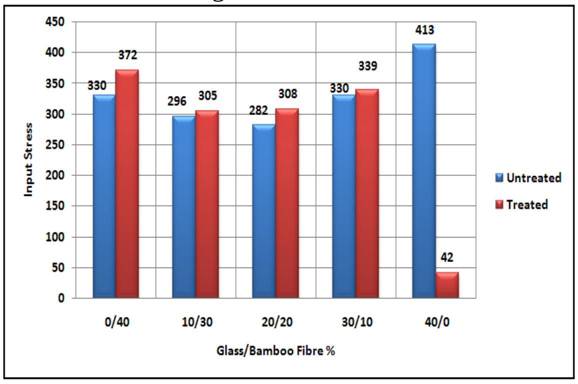


Fig.3. Variation of impact strength with the ratio of % Glass/Bamboo fibers reinforced Polyester composites

### A. *Chemical resistance of composites*

The chemical resistance of the composites was studied as per ASTM D 543-87 method. For chemical resistance test, the acids namely concentrated hydrochloric acid (10%), concentrated nitric acid (40%) and glacial acetic acid (8%), the alkalis namely aqueous solutions of sodium hydroxide (10%), ammonium hydroxide (10%) and sodium carbonate (20%) and the solvents- Benzene, Carbon tetra chloride, Toluene and Water were selected. In each case, ten pre-weighted samples were dipped in the respective chemicals under study for 24 hours, removed and immediately washed thoroughly with distilled water and dried by pressing them on both sides by filter papers. The final weight of the samples and % weight loss/gain was determined. The resistance test was repeated for ten samples in each case and the average values are reported as shown in Table 1.

TABLE 1
RESISTANCE OF HYBRID (GLASS/BAMBOO) COMPOSITE REINFORCED POLYESTER TO CHEMICAL REGENT'S % OF CHANGE IN WEIGHT AFTER IMMERSION FOR 24 HOURS

| Chemicals | Matrix | Composite |
|---|---|---|
| 40% nitric acid | +0.2169 | +0.25490 |
| 10% Hydrochloric acid | +0.9405 | +0.22491 |
| 8% Acetic acid | +0.3065 | +2.4239 |
| 10% sodium hydroxide | -0.3361 | -2.2191 |
| 20% sodium carbonate | +0.726 | -3.9726 |
| 10% Ammonium Hydroxide | -0.3273 | -2.9135 |
| Benzene | -1.271 | -1.326 |
| Toluene | -0.671 | -2.350 |
| Carbon tetrachloride | -1.114 | +4.3858 |
| Water | -1.1212 | -1.6326 |

## IV. SEM ANALYSIS

The performance of a composite depends mainly on the selection of the components and effective stress transfer from the matrix to the reinforcement. In order to achieve this, the interface between the matrix and the reinforcement should be as narrow as possible. This can be achieved only when the matrix and the reinforcement are closer to each other.

To probe the bonding between the reinforcement and matrix, the scanning electron micrograms of fractured surfaces of glass/bamboo reinforced Polyester hybrid composites were recorded. These micrograms were recorded at different magnifications and regions. The analysis of the micrograms of the composites prepared under different conditions is presented in the following paragraphs.

### A. *Untreated bamboo fiber*

The micrograms of fractured surfaces of untreated bamboo fiber are presented in figure 4 (a), (b), (c) and (d). Figures 4 (a) and (b) represents the fractograms at two regions with a magnification of 100X. Figure 4 (c) and (d) are the fractograms at these regions at magnification of 200X. From all these micrograms, it is evident that fiber pullout is observed, indicating a poor bonding between the fibers. When the interfacial bonding is poor, the mechanical properties of the composites will be inferior. All the mechanical properties of the glass/bamboo fiber composites studied (Chapter 4 to 8) indicate that these properties are the least for these composites with untreated bamboo fibers. The poor adhesion is indicated in Fig 4 supports this observation.

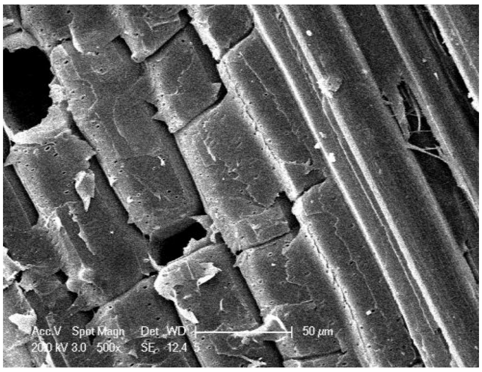


Figure 4(a)

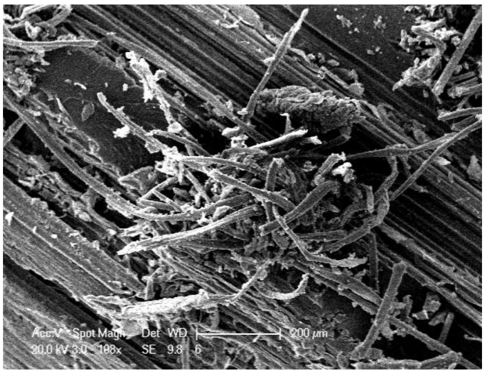


Figure 4(b)

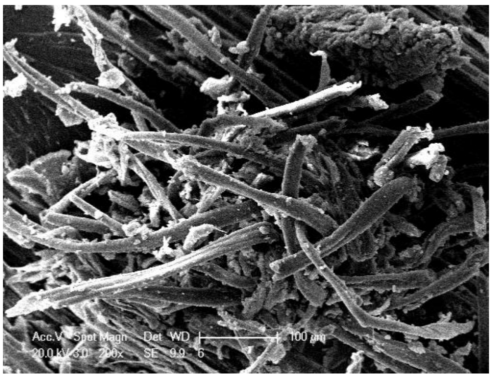


Figure 4(c)

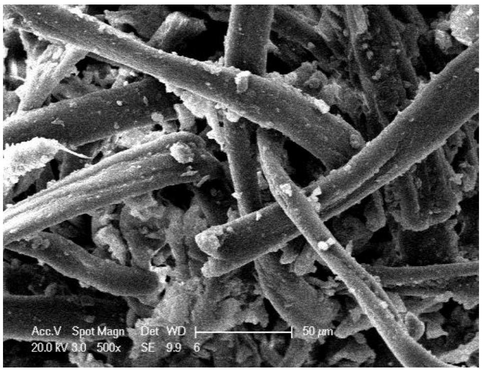


Figure 4(d)

### B. *Treated bamboo fiber*

The fractograms of alkali treated bamboo fiber composites are presented in figures 5 (a), (b), (c) and (d). These fractograms were recorded at two different regions and 100X and 500 X magnifications. From these micrograms it is clearly evident that the surface of the fibers becomes rough on alkali treatment. The elimination of hemi-cellulose from the surface of the bamboo fiber may be responsible for the roughening of the surface. Here, though the bonding is improved, fiber pullout is reduced. Thus the alkali treatment improved the bonding. This is in accordance with the mechanical properties of these composites.

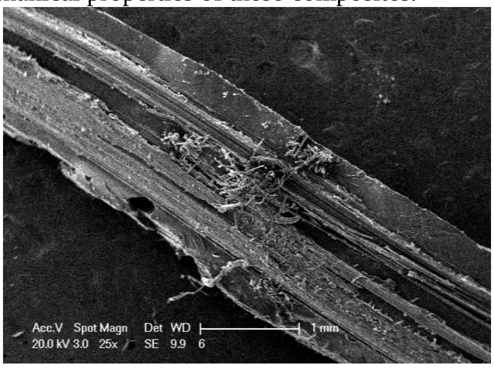


Figure 5(a)

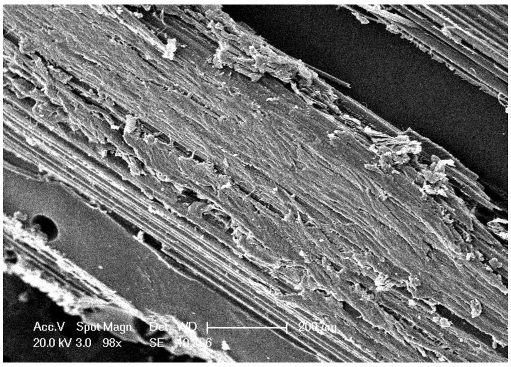


Figure 5(b)

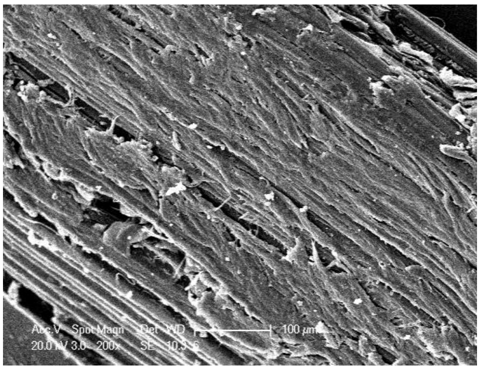


Figure 5(c)

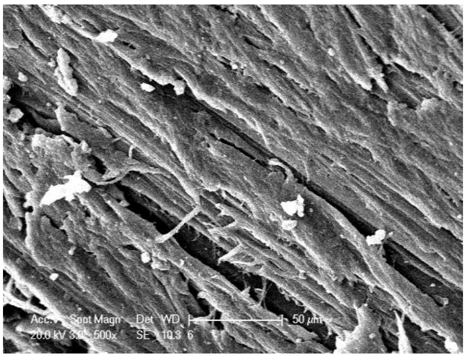


Figure 5(d)

## V. RESULTS AND DISCUSSION

The variation of tensile stress, tensile modulus and impact stress with percentage glass/bamboo fiber ratio is presented in Fig. 1, Fig. 2 and Fig. 3 respectively.

For comparison, these values for the matrix are also presented in the same figures. From these figures it is evident that the tensile and impact properties are enhanced when the alkali treated bamboo fibers were used in the hybrid composites. This is understandable as the hemi cellulose and the lignin contents decrease leading to higher percentage of crystalline α-cellulose in bamboo fibers on alkali treatment. The minimum and maximum values of tensile modulus for these composites are found to be 2012 and 10072 MPa respectively. Similarly the tensile stress values vary in the range of 142 to 205 MPa. The minimum and maximum values of impact strength for these composites are found to be 282 and 413 MPa respectively. Similar observation was made by Varadarajulu *et al.* (1998 – 2004) and Srinivasulu *et al.* (2006) in the case of some fiber composites and polymer coated bamboo fibers. The effect of some acids, alkalis and solvents on the matrix and composite under study is presented in Table 1. From this table it is clearly evident that for matrix and composite, the weight gained is observed after immersion. This is understandable as the matrix is cross linked and as a result formation of gel takes place instead of dissolution. Similar observation was made by Varadarajulu *et al.* (1998 – 2004) in the case of short bamboo fiber reinforced high performance epoxy composites. It is also observed that the effect of sodium carbonate, benzene, toluene and carbon tetra chloride is negligible on both the matrix and composites. The chemical resistance of the hybrid composites with treated bamboo fibers is found to be better for the chemicals mentioned.

## VI. CONCLUSIONS

The hybrid composites of bamboo/glass fiber reinforced polyester were made and their tensile, impact and chemical resistance properties were studied. The effect of alkali treatment of the bamboo fibers on these properties was studied. These hybrid composites were found to exhibit good impact and chemical resistance properties. The hybrid composites with alkali treated bamboo fibers were found to possess higher tensile and impact properties. The composites were found to be resistant to some acids, alkalis and solvents. The elimination of amorphous weak hemi cellulose components from the bamboo fibers on alkali treatment may be responsible for this behaviour.

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