EFFECT OF ALKALI TREATMENT, FIBER LOADING AND HYBRIDIZATION ON TENSILE PROPERTIES OF SISAL FIBER, BANANA EMPTY FRUIT BUNCH FIBER AND BAMBOO FIBER REINFORCED THERMOSET COMPOSITES

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Abstract

Nowadays natural fibers such as sisal, flax, hemp, jute, bamboo, banana, etc. are widely used for environmental concern on synthetic fibers (such as glass, carbon, ceramic fibers, etc.). In this research work, Sisal Fiber (SF), Banana Empty Fruit Bunch Fiber (BEFBF) and Bamboo Fibers (BF) reinforced with Epoxy matrix composites have been developed by manual hand layup technique with varying process parameters, such as fiber condition (untreated and alkali treated), fiber percentages (5%, 10%, 15%, 20%, 25% and 30% by weight) and various hybrid combinations (Sisal-Banana, Sisal-bamboo and Banana-Bamboo). The developed Sisal fiber, Banana empty fruit bunch fiber and Bamboo fiber reinforced composites were then characterized by tensile test and scanning electron microscopy. The results show that tensile strength increases with the fiber percentage; however, after a certain percentage of fiber reinforcement, the tensile strength decreases. Compared to untreated fiber a significant change in tensile strength has been observed for surface treated fiber composites. Also hybridization of the fibers shows an increase in the tensile strength as compared with pure Epoxy (matrix).

Index Terms**:** *Sisal fiber (SF), Banana Empty Fruit Bunch Fiber (BEFBF), Bamboo Fibers (BF), Epoxy, surface treatment, Hybrid composite, Tensile Strength.*

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1. INTRODUCTION

In recent times polymer matrix composites reinforced with fibers such as glass, carbon, aramid, etc. are getting in more uses because of their favorable mechanical properties. However, they are quite expensive materials. Composites made from glass fiber as reinforcement cause acute irritation of the skin, eyes, and upper respiratory tract. When released, glass fiber does not degrade and results in environmental pollutions and threatens animal life and nature. The new environmental regulations and uncertainty about petroleum and timber resources have triggered much interest in developing composite materials from natural fibers. This interest in the natural fibers has resulted in a large number of modifications to bring it at par and even superior to synthetic fibers. Because of such tremendous changes in the quality of natural fibers, they are fast emerging as a reinforcing material in composites. Considering the high performance standard of composite materials in terms of durability, maintenance and cost effectiveness, applications of natural fiber reinforced composites in industries holds the enormous potential and are critical for achieving sustainability. Natural fibers such as jute, flux, hemp, sisal, banana, bamboo, etc. can be alternately used to reduce the cost of the composites. The production of environmentally friendly materials is an important issue. The use of natural fibers, derived from annually renewable resources, as reinforcing fibers in both thermoplastic and thermoset matrix composites provide positive environmental benefits with respect to ultimate disposability and raw material utilization. Natural fiber composites have good mechanical properties with a low specific mass.

Yan Li., et al [1] reported the chemical composition, properties of sisal fibers and their composites by incorporating the fiber in different matrices before and after treatment by different methods; along with this they present a summary of recent developments of sisal fiber and its composites. The properties of sisal fiber interface between sisal fiber and matrix, properties of sisal fiber-reinforced composites and their hybrid composites. Natural fiber composites are likely to be environmentally superior to glass fiber composites in most cases for natural fiber production has lower environmental impacts compared to glass fiber production [2]. The physical properties of natural fibers are mainly determined by the chemical and physical composition such as the structure of fibers, cellulose content and angle of fibrils, cross section, and by the degree of polymerization as reported by Bledzki and Gassan [3]. The development, characterization and optimization of flax fiber composites were performed to establish that the fiber structure and adhesion between the fibers and resin are essential to get better composites [4]. The effects of chemical modification, loading and orientation of short coir fibers and natural rubber composites [5], the degree of fiber matrix adhesion and its effect on the mechanical reinforcement of short henequen fibers and polyethylene matrix [6] were analyzed to show that the alkali/silane treatment significantly increased the mechanical strength. Surface treated and untreated henequen fibers reinforced epoxy composites were made by compression moulding and their mechanical properties and failure modes were determined experimentally in tension, bending, and impact loading [7].

The present study aims to develop natural fiber composites from the most widely available Sisal fiber, Banana empty fruit bunch fiber and Bamboo fibers, which are normally used in yarns, ropes, twines, carpets, mats and handicrafts. This paper describes an investigation of the mechanical properties of *Sisal fiber; Banana empty fruit bunch fiber and Bamboo fibers* reinforced epoxy composites and also the effect of fiber loading (fiber percentage), fiber treatment (Alkali) and hybridization on the properties of composites. The goal of this work is to understand the changes of tensile strength under various process parameters considered. Fracture surfaces of tensile test specimens were examined under scanning electron microscope to analyze the fracture behavior.

2. MATERIALS AND METHODS

2.1 Matrix preparation

Epoxy is a thermosetting polymer that cures (polymerizes and cross links) when mixed with a hardener. Epoxy resin of the grade LM-556 with a density of 1.1–1.5 g/cm3 was prepared with a mixture of epoxy and hardener (HY-951) at a ratio of 10:1.

2.2 Fiber preparation

The natural fibers such as Sisal, banana empty fruit bunch fibers and bamboo were extracted by the process of retting and decorticating. The cured fibers were then thoroughly washed and combed to free the flesh thoroughly and dried. The dried fibers were thinned by ramming to remove the unwanted short and broken fibers.

2.3 Surface treatment

As the natural fibers bear hydroxyl groups from cellulose and lignin, therefore, they are amenable to modification. The hydroxyl groups may be involved in the hydrogen bonding within the cellulose molecules thereby reducing the activity towards the matrix. Chemical modifications may activate these groups or can introduce new moieties that can effectively interlock with the matrix. Pretreatments of the fiber can clean the fiber surface, chemically modify the surface, stop the moisture absorption process and increase the surface roughness.

Initially, all the fibers were washed with water for five times, dried at room temperature for 48 hours, then, were immersed in 10% sodium hydroxide (NaOH) solution for 24 hours and finally washed with very dilute hydrochloric acid (HCl) to remove the residual alkali. Then, the fibers were rinsed with distilled water twice or thrice. The rinsed fibers were dried at room temperature for 2–3 days.

2.4 Preparation of the Mould

A mould made up of GI (gauge 25) sheet of dimension 170X15X3 mm is prepared. Casting of the composite materials is done in this mould by hand lay up process. Later specimens are cut from the prepared casting according to the ASTM (D 638 M) Standard.

2.5 Weight fraction of the fiber

The weight of the matrix was calculated by multiplying density of the matrix and the volume (volume in the mould). Corresponding to the weight of the matrix the specified weight percentage of fibers is taken. For hybrid combination the corresponding weight of fiber obtained is shared by two fibers.

2.6 Preparation of the Specimen

Mixing the Epoxy resin LM-556 and the hardener HY-951 with a ratio of 10:1. This solution is used as Matrix and the different types of natural fibers are used as reinforcements; the types of composites manufactured are Sisal, Banana Empty fruit bunch fiber and bamboo fibers. Various hybrid combinations of natural fibers such as Sisal- Banana Empty fruit bunch fiber, Sisal –Bamboo fiber and Banana Empty fruit bunch fiber-Bamboo fiber. The natural fibers are used in different weight percentages of 5%, 10%, 15%, 20%, 25% and 30%.

3. TESTING OF COMPOSITE MATERIAL

Tensile test specimens were made according to the ASTM (D 638 M) to measure the tensile properties. The samples were 160 mm long, 12.5mm wide and 3mm thick. Eight identical specimens were tested for each composition and average tensile strength has been taken. GI sheet tabs were glued to the ends of the specimen with epoxy resin so as to prevent the compression of the sample at the grip. The samples were tested at a cross speed of 2 mm/min and the corresponding strain occurred was measured using an extensometer.

4. RESULTS AND DISCUSSION

The primary role of a composite material in a product is to support the applied mechanical forces. A composite achieves this by load transfer between the matrix and the fibers induced by the shear deformation of the matrix around the fibers. This shear deformation is produced because of the high Young's modulus of the fiber and the large difference between the mechanical properties of the composite's constituents. In the present study, the behavior of composites containing 5, 10, 15, 20, 25 and 30% of the natural fibers were analyzed. The fibers were subjected to water treatment and Alkali treatment.

4.1 Analysis of Tensile Strength:

4.1.1 Effect of fiber loading and Hybridization.

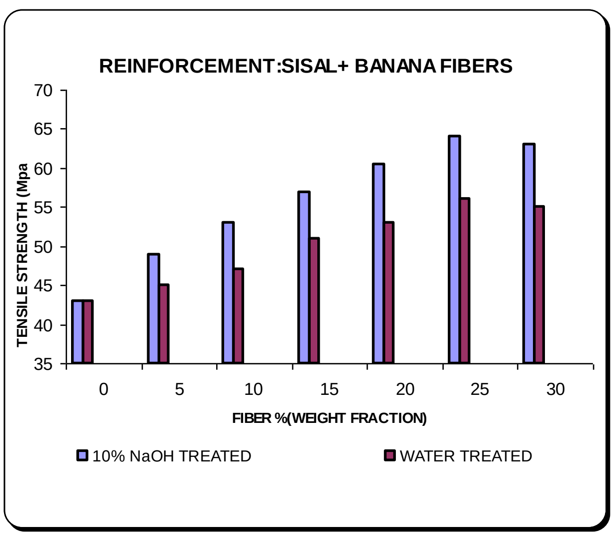

Fig-1: Tensile strength of SF+BEFBF, at different fiber loading and surface treated with water and 10% NaOH.

The tensile test results of Hybrid composite with the fiber combination Sisal fiber and Banana empty fruit bunch fiber has been plotted in Fig-1 as a function of fiber loading(Weight fraction) and also the condition of the fiber i,e treated with water and treated with 10% NaOH for 24 hours. From the graph, it is clear that as the fiber loading increases, the value of tensile strength increases and then decreases. This observation is true for others cases also.

From Figure-1 it can be seen that the tensile strength increases sharply with increase in fiber loading up to 25 % and then shows a slight decrease for composites containing 30% fiber loading. When the amount of fibers is not enough to restrain the matrix, large stresses will be developed at low strains and the distribution of these stresses will not be uniform. But after 25% fiber loading the fibers is sufficient to restrain the matrix, the stress distribution will be uniform and therefore the fibers start reinforcing the matrix. A maximum tensile strength of 63 MPa was found for the fiber loading (weight fraction) of 25% for the Sisal fiber and Banana empty fruit bunch fiber hybrid composite. The maximum Tensile strength of 55 MPa was obtained for untreated fiber reinforced hybrid composite.

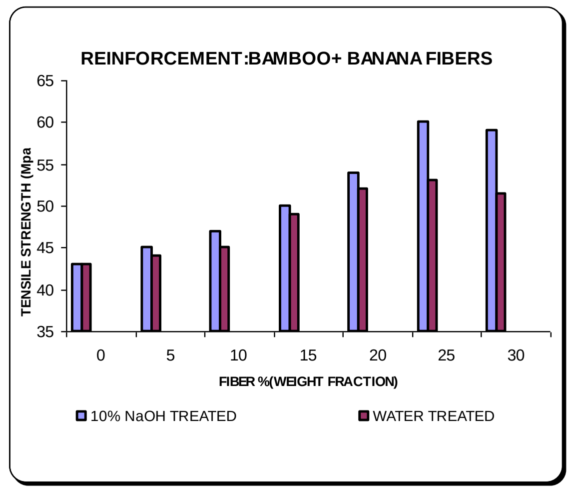

Fig-2: Tensile strength of BF+BEFBF, at different fiber loading and surface treated with water and 10% NaOH.

The tensile test results of Hybrid composite with the fiber combination Bamboo fiber and Banana empty fruit bunch fiber has been plotted in Fig-2 as a function of fiber loading(Weight fraction) and also the condition of the fiber i,e treated with water and treated with 10% NaOH for 24 hours. Considering the effect of fiber loading on tensile strength of hybrid composites, generally the tensile strength initially increases up to a certain amount of fiber and then decreases. For the hybrid composites the fiber amount (Weight fraction) ranged from 25% to 30% and also this weight fraction of the fiber varies with the nature of the fiber and the matrix, fiber aspect ratio and fiber/ matrix interfacial adhesion. A maximum tensile strength of 59 MPa was found for the fiber loading (weight fraction) of 25% for the Bamboo fiber and Banana empty fruit bunch fiber hybrid composite. This hybrid combination gave least tensile strength among the tested hybrid composite.

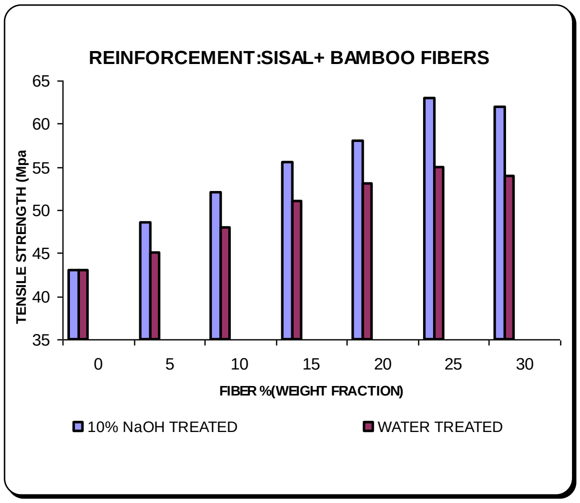

Fig-3: Tensile strength of SF+BF, at different fiber loading and surface treated with water and 10% NaOH.

The tensile test results of Hybrid composite with the fiber combination Sisal Fiber and Bamboo fiber has been plotted in Fig-3 as a function of fiber loading(Weight fraction) and also the condition of the fiber i,e treated with water and treated with 10% NaOH for 24 hours. A maximum tensile strength of 61.5 MPa was found for the fiber loading (weight fraction) of 25% for the Sisal fiber and Bamboo fiber hybrid composite.

As fiber percentage increases, gathering of fibers takes place instead of dispersion of the fibers in the epoxy matrix, thus not wetting the adjacent fibers properly .Since no adhesion is present between the fibers and fibers are also not bonded with matrix, failure occurs before attaining the theoretical strength of composite. As the percentage of fiber increases the fibers may be folded and there may be no bonding between the folded and unfolded portion of fiber which resulted in a lower strength. Fiber entanglement may also contribute to reduce the strength. Thus high fiber content was limited by the incompatibility issue and the maximum fiber loading (weight fraction) was restricted to 30%.

4.1.2 Effect of chemical treatment on interfacial adhesion

Alkali treatment of cellulosic fibers, also called mercerization, is the usual method to produce high quality fibers. Alkali treatment improves the fiber-matrix adhesion due to the removal of natural and artificial impurities. Moreover, alkali treatment leads to fibrillation which causes the breaking down of the composite fiber bundle into smaller fibers. In other words, alkali treatment reduces fiber diameter and thereby increases the aspect ratio. Therefore, the development of a rough surface topography and enhancement in aspect ratio offer better fiber-matrix interface adhesion and an increase in mechanical properties [9]. Alkali treatment increases surface roughness resulting in better mechanical interlocking and the amount of cellulose exposed on the fiber surface. This increases the number of possible reaction sites and allows better fiber wetting. The possible reaction of the fiber and NaOH is as below.

Fiber-OH + NaOH ------- Fiber-$O^{-}Na^{+}$ + H_2O

Alkali treated natural fibers favored the reinforcement in the epoxy matrix in the composite showing perfect chemical bond and better interface adhesion and thus increased the tensile strength of Hybrid composite samples. The failure of Natural fiber–epoxy Hybrid samples, characterized by brittle failure, showed long tails after the predominant damage. It is thus estimated that an interfacial interaction in the present composite would result in a higher elongation to break due to alkali treatment. In figure-4, we can clearly absorb the fiber wetting of the treated fiber and also good fiber matrix interaction.

It is also absorbed that the waxy layer and impurities are completely removed from the fiber surface. The treated surface of fiber becomes smoother as compared to that of untreated fiber and also the alkaline treatment used on the natural fibers produce fibrillation and collapse of the cellular structure due to the removal of the cementing material, which leads to a better packing of cellulose chains. A part from this alkali treatment also leads to fiber bundle fibrillation that is, breakdown of the composite fiber bundle into smaller fibers, which increases the effective surface area available for contact with the wet matrix [8].

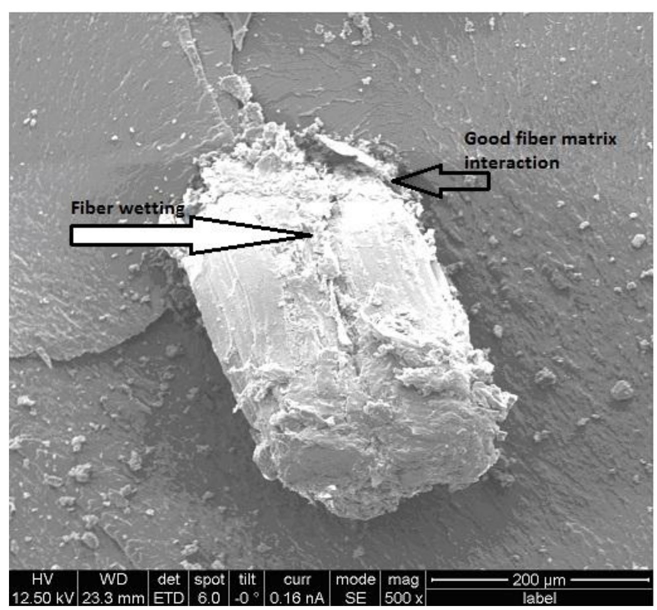

Figure-4: SEM image of the composite showing good fiber matrix interaction and fiber wetting.(10% NaoH treated)

5. CONCLUSIONS

- The effect of various parameters like alkali treatment, fiber loading and hybridization of Natural fiber reinforced Epoxy composites have been studied.
- The natural fibers used such as Sisal Fiber (SF), Banana Empty Fruit Bunch Fiber (BEFBF) and Bamboo Fibers (BF) have shown good compatibility with the matrix.
- The mechanical behavior of Natural fibers reinforced epoxy composites showed improved results when compared with pure epoxy. In addition, the composite with alkali treated fibers exhibited a slightly higher tensile strength than the one with untreated fibers.
- The alkali treatment of natural fibers improved the quality of the fiber/matrix interface.
- Tensile test results showed that both NaOH treatment used and Hybridization have a significant effect on the mechanical properties of Natural fiber reinforced composites.
- A maximum Tensile strength of 63 MPa was found for the hybrid combination of Sisal Fiber and Banana Empty Fruit Bunch Fiber.
- Out of the composites tested maximum tensile strength was obtained for the fiber loading (weight fraction) of 25-30%. This can be considered as the optimum fiber loading.
- It can be concluded that alkali treatment of the natural fibers is necessary to get composites with moderate mechanical properties as well as better adhesion between fibers and matrix.

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