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Study of Mechanical Properties of Bamboo fibers before and after Alkali Treatment

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Abstract

The objective of the present work is to study the physical, mechanical and water absorption behaviour of bamboo fiber reinforced epoxy composites filled with rice husk particulates. Bamboo fibers have been previously treated with various concentration of NaOH (1%, 2%, 3% and 4%) for 12 hours. The poor adhesion between fiber and matrix is commonly encountered problem in natural-fiber-reinforced composites. To overcome this problem, specific physical and chemical treatments were suggested for surface modification of fibers by investigators. Alkali treatment is one of the simple and effective surface modification technique which is widely used in natural fiber composites. The alkali treatment is found to be effective in improving the tensile and flexural properties while the impact strength decreases. Water absorption capacity also decreases after alkali treatment. However the variation of mechanical properties depends on the concentration of NaOH solution and immersion time of the fiber in NaOH solution.

Keywords: Bamboo fiber, Rice husk, Alkali treatment, Composites.

INTRODUCTION

Synthetic fibers are currently used for various type of applications. Synthetic fibers have comparatively higher tensile strength and flexural strength than that of natural fibers. They also have lower water retention capacity as compared to that of natural fibers. However synthetic fibers are more expensive and are also non bio-degradable. To address this challenge, scientists are focussing their attention on making bio-degradable composites with natural fibers as reinforcement [1]. Natural fibers have several other advantages such as high specific properties like high specific strength, light weight, less tool wear etc. In automobile industry, the natural fibers are extensively used in the interior of the automobiles like door panel, seal backs, engine and transmission covers. In spite of several advantages natural fibers have few drawbacks like high water retention capacity, low tensile strength and incompatibility with some polymeric matrices. In order to overcome such problems various physical and chemical treatments are done on the surface of natural fiber. Physical and chemical treatments are usually done to carry out surface modification of the natural fibers [2, 3]. Alkali treatment is the simplest chemical treatment method done to carry out surface modification of the natural fibers.

Natural fibers have hydroxyl group with them. NaOH reacts with the hydroxyl group of the natural fiber and is responsible for removing the hemicellulose, wax, lignin, oils and other impurities that surround the outer surface of the fiber leading to reduction in fiber diameter and increase in aspect ratio and surface roughness as shown in Equation (1) and fig. 1 [4, 5, 6]. Increase in surface roughness results in better bonding between matrix and the fiber [7, 8, 9].

$$\text{Fiber-OH} + \text{NaOH} \rightarrow \text{fiber-O-Na}^{+} + \text{H2 O} \quad (1)$$

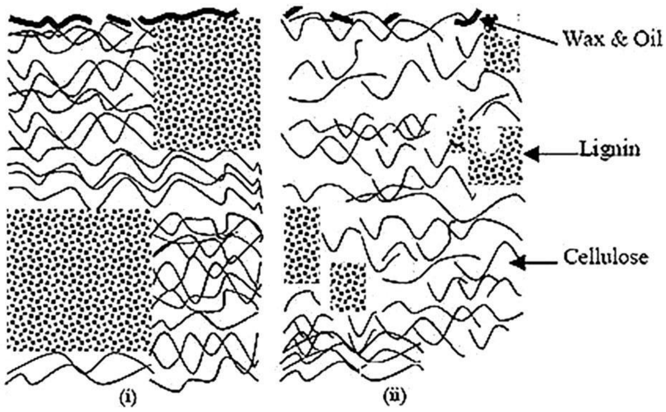


Figure 1. Typical structure of (i) untreated and (ii) NaOH treated natural fiber

The concentration of wax, oil, lignin and hemicellulose is found to be more in a typical untreated natural fiber, whereas the NaOH treated fiber is found to clean and rough due to removal of hemicellulose, lignin and oil. Crystalline properties of the fiber are also get affected by the NaOH treatment [10].

In the present study, both untreated and alkali treated bamboo fibers were used as reinforcement in epoxy resin composites and rice husk was used as a filler material. Tensile and flexural properties were determined at different concentration of NaOH (1%, 2%, 3%, and 4%). The immersion time of the fiber was taken as 12 hour for all the five different concentration of NaOH solution. The alkali treatment was found to be effective in improving the tensile and flexural properties of Bamboo fiber reinforced epoxy resin composites.

THE EXPERIMENTAL WORK DETAILS

Fibers and Resins

Bamboo fibers were used as reinforcement. The bamboo fibers were made from the starchy pulp of bamboo plants. In order to remove the dirt and other contaminants, these fibres were washed by water. Subsequently, fibres were cut into small length (18 to 20 cm). Cellulose, hemicellulose, lignin and wax are the major constituents of bamboo fibres. The average diameter of the bamboo fibre used was in the range of 100-550 µm. In this experiment, epoxy was used as a resin. Rice husk particulates were used as filler material. The particle size of rice husk fibre used were from 60-100 µm. The rice husk fibre was oven dried at 70 ^{o}C for 25 hours to adjust its moisture content and then the filler material was used without any subsequent treatment.

Alkali Treatment

Bamboo fibers were immersed in 0.5, 1, 2, 3 and 4 (wt) % of NaOH solutions at 24°C for 12 h, maintaining a liquor ratio of 15:1. After the alkali treatment, the fibres were washed for several times with water to remove any alkali solution sticking on their surface. After washing the fibres with water, the fibres were washed for about 15 minutes with acetone to remove the NaOH solution on the fibre surface. After the cleaning process was completed, the fibres were d ried und er the su n fo r 2 4 ho urs .

Composite Fabrication

The mould box was made with the dimension of 232 mm (Length) ×170 mm (Width) ×3.0 mm (Thickness).The hardener was mixed with epoxy to prepare the matrix. The hardener and the epoxy ratio was maintained at 1:10. The epoxy and the hardener must be mixed gently and slowly to get a well cured and better quality specimen. The fibers were arranged unidirectionally inside the mould, proper care and precautions were taken to get uniform distribution. Before the fibers were placed inside the mould, the mould was filled with epoxy resin mixture and then the fibers were arranged such that the epoxy completely spread over the fibers. After that the rice husk filler material were spread over the fibers. The filler material was fixed at 10wt (%) for all the composite materials.

Before the application of compression pressure, proper efforts were made to remove all the bubbles with help of a roller. After that the compression load was applied uniformly on the mould to achieve a uniform thickness of 3 mm and then it was cured for 30 hours at room temperature. The obtained composite specimen was of the size 232 × 170 × 3.0 mm^3.

Tensile Strength Testing

The Tensile test was conducted at a temperature of about 24 ^{o}C by using an INSTRON-3369 model Universal Testing Machine based on ASTM D 3039-76. The specimen dimensions were 174 × 17 × 3 mm^3. The test was carried out at a constant crosshead speed of 10 mm/min. The variation of tensile strength and tensile modulus of different composite specimens at different concentration of NaOH is represented in figure 2 and figure 3.

Flexural Strength Testing

The Flexural test was performed using an INSTRON-3369 model Universal Testing Machine as per ASTM D 5943-96 standards using three point bending method at a constant crosshead speed of 5 mm/min. The specimen dimensions were 117 × 17 × 3 mm^3. The variation of flexural strength and flexural modulus of different composite specimens at different concentration of NaOH is represented in figure 4 and figure 5.

Impact Strength Testing

The impact strength measurement was done according to ASTM D 256-88 with help of an Izod impact tester with unnotched specimen. The specimen dimensions were 142 × 15 × 3 mm^3. Impact strength was measured by dividing energy (Joule) with the thickness (m) of the composite specimen. The variation of impact strength before and after the alkali treatment is represented in the figure 6.

Micro-hardness Testing

Micro-hardness testing is a technique used to determine material's hardness or resistance to penetration when test samples are very small or thin, or when small regions in a composite sample or plating are to be measured. The Vickers hardness test was used in this experiment to determine the micro-hardness of the composite specimens. The Vickers hardness test can be performed on both the micro and macro scales with a maximum test load of up to 50 kilograms. Like Knoop micro-hardness testing, these tests are also performed by applying controlled pressure for a standard length of time, but with a square-based diamond pyramid indenter. The diagonal of the resulting indention is measured under a microscope. The variation of Vickers hardness number of different composite specimens at different concentration of NaOH is represented in the figure 7.

Water Absorption Testing

The water absorption tests of Bamboo fiber reinforced epoxy composites were performed as per ASTM D570. For the water absorption test, the specimens are dried in an oven for a specified time and temperature and then placed in a desiccator to cool. Immediately upon cooling the specimens are weighed. The material is then emerged in water at agreed upon conditions, often 24°C for 25 hours. Specimens are removed, patted dry with a lint free cloth, and weighed. The specimens were weighed regularly at 25, 50, 75, 100, 125, 150, 175, 200, 225 and 250 hours. Water absorption is expressed as increase in weight percent.

Percent Water Absorption = [(Wet weight - Dry weight)/ Dry weight] x 100.

Scanning Electron Microscopy

The SEM analysis of untreated and alkali treated Bamboo fibers were done with the help of a JEOL Scanning Electron Microscope (JSM6400, JEOL Ltd., Tokyo, Japan) with an acceleration voltage of 20 kV. The SEM analysis was performed to study the surface morphology of alkali treated and untreated fibers.

RESULTS AND DISCUSSION

Tensile Test and Flexural Test Results

Tensile strength, Tensile modulus, Flexural strength and Flexural modulus of untreated and alkali treated fiber reinforced composites are represented in figure 2, 3, 4 and 5.

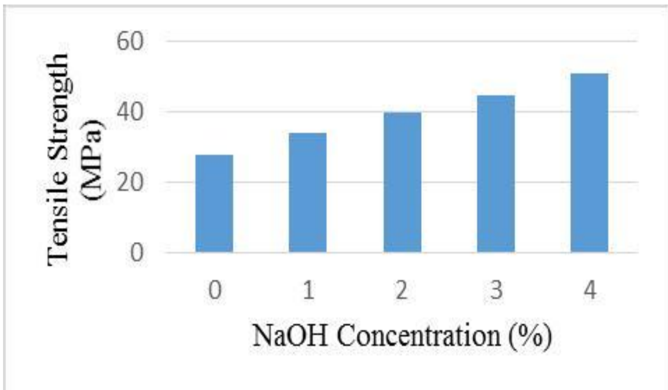


Figure 2. Tensile strength of untreated and alkali treated Bamboo fiber reinforced epoxy composites.

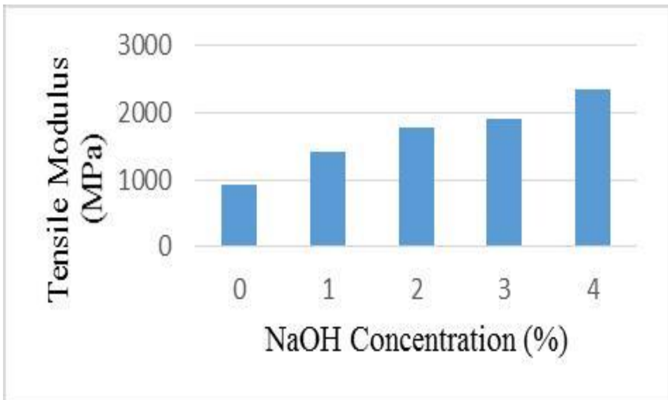


Figure 3. Tensile modulus of untreated and alkali treated Bamboo fiber reinforced epoxy composites.

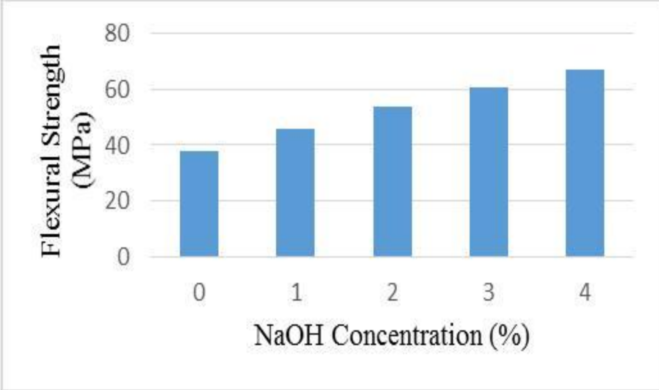


Figure 4. Flexural strength of untreated and alkali treated Bamboo fiber reinforced epoxy composites.

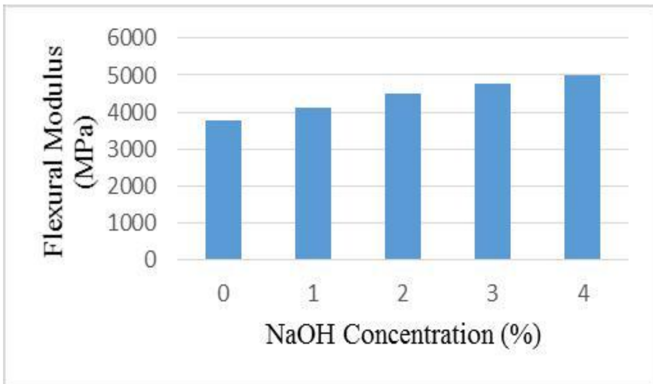


Figure 5. Flexural modulus of untreated and alkali treated Bamboo fiber reinforced epoxy composites.

From the figure 2, 3, 4 and 5, it is clear that the alkali treated fiber reinforced composites have superior tensile and flexural properties when compared to untreated fiber reinforced composites. These properties further improves with increase in concentration of Sodium Hydroxide.

Impact strength and Micro-hardness of untreated and alkali treated fiber reinforced composites are shown in figure 6 and 7.

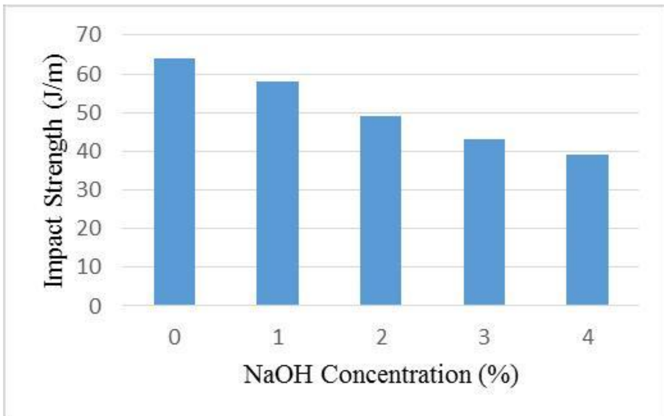


Figure 6. Impact strength of untreated and alkali treated Bamboo fiber reinforced epoxy composites.

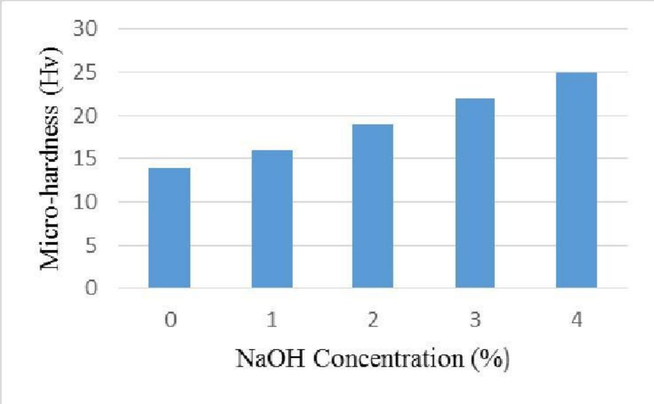
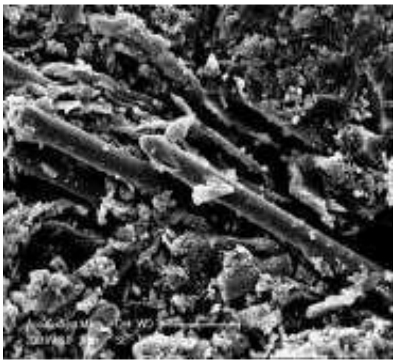


Figure 7. Micro-hardness of untreated and alkali treated Bamboo fiber reinforced epoxy composites.

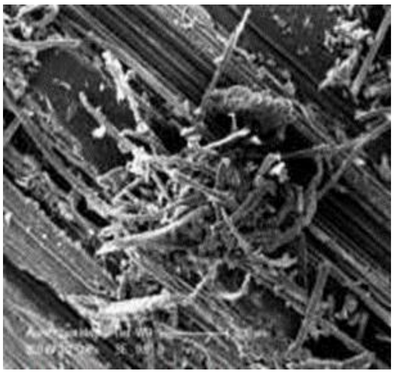
From the figure 6, it can be concluded that unlike other mechanical properties, untreated fiber reinforced composites have better Impact strength as compared to alkali treated fiber reinforced composites.

However, alkali treated fiber reinforced composites have better micro-hardness and it further improves with increase in NaOH concentration.

Scanning Electron Micrographs of untreated and alkali treated fibers are shown in figure 8 and 9.

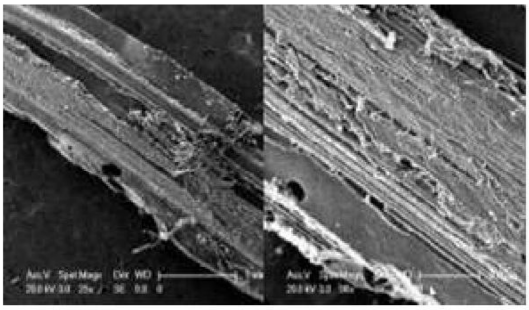


(a)



(b)

Figure 8. SEM micrographs of untreated Bamboo fiber (a) and (b) at two regions recorded at 100x magnification.



(a) (b)

Figure 9. SEM micrographs of 1% NaOH treated Bamboo fiber (a) and (b) at two regions recorded at 100x magnification.

The SEM analysis of untreated Bamboo fiber in fig. 8 showed that the fiber surface was smooth. After the alkali treatment of the fiber, the SEM analysis was again performed. After the alkali treatment, it was observed that the treatment has removed most of the hemicellulose, lignin and oil from the fiber surface resulting in a rougher surface as shown in fig. 9. As a consequence of this, better bonding between the fiber and the matrix was possible. This results in improved mechanical properties of composites reinforced with alkali treated Bamboo fibers

Water Absorption test of both untreated and alkali treated Bamboo fibers were performed according to ASTM D570. The specimens were weighed regularly 25, 50, 75, 100, 125, 150, 175, 200, 225 and 250 hours. From the Water Absorption test it was found that the water absorption capacity of the alkali treated composites have been reduced.

CONCLUSIONS

The following salient conclusions have been drawn from the present study:-

(1) As compared to composites reinforced with untreated fibers, alkali treated Bamboo fiber reinforced epoxy composites showed improved mechanical properties.

(2) Tensile strength and tensile modulus of untreated and alkali treated Bamboo fiber reinforced composites were increased with increase in alkali concentration. The improvement was maximum for the composite prepared with 4% NaOH.

(3) The Composites prepared with alkali treated fibers have shown superior Flexural properties as compared to composites reinforced with untreated fibers.

(4) The Impact strength of alkali treated Bamboo fiber reinforced epoxy composite was less as compared to composites reinforced with untreated fibers. The Impact strength further deteriorates with increase in concentration of NaOH.

(5) As the concentration of NaOH increases, the hardness of the composites also increases. The improvement was maximum for the composite prepared with 4% NaOH.

(6) Water retention capacity of composites reinforced with alkali treated fibers were less as compared to that of composites reinforced with untreated Bamboo fibers.

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