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Study on Tensile, Bending and Water Uptake Properties of Sugarcane Bagasse Fiber Reinforced Polypropylene Based Composite

Mohammad Bellal Hoque[1, 3], Md. Sahadat Hossain[2], Ruhul A. Khan[3, *]

[1]Department of Textile Engineering, Fareast International University, Dhaka, Bangladesh

[2]Glass Research Division, Bangladesh Council of Scientific and Industrial Research, Dhaka, Bangladesh

[3]Institution of Radiation and Polymer Technology, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh

Email address:

hoque_bellal@yahoo.com (M. B. Hoque), saz8455@gmail.com (Md. S. Hossain), dr.ruhul_khan@yahoo.com (R. A. Khan)

[*]Corresponding author

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Abstract: In this study, sugarcane bagasse fiber reinforced polypropylene based composites were fabricated successfully and their tensile, bending and water uptake behavior were studied. The composites were prepared by compression molding process. The fiber composition in the composites was 30% by weight. Results revealed that due to reinforcement by fiber, composites achieved 51% increase in tensile strength, 151% in tensile modulus, 109% in bending strength and 68% in bending modulus over that of polypropylene. Elongation at break was reduced due to the lower elongation property of fiber. The composites were treated by alkali for checking out the effects of alkali on composites. The concentrations of alkali used for treating the composites were 3%, 5% and 7% solution of sodium hydroxide (NaOH) and it was found that 7% solution of sodium hydroxide demonstrated lowest tensile and bending properties. Sheared composite samples were immersed into deionized water and it was noticed that composite samples were absorbed 2.10% water within 40 minutes of water absorption test. Soil degradation test was carried out for 16 weeks and it was observed that, the tensile and bending properties of sugarcane bagasse fiber reinforced polypropylene based composites were degraded slowly. The composites lost 35% of their original mechanical properties and retained 54% of actual weight after 16 weeks of degradation in soil medium.

Keywords: Sugarcane Bagasse Fiber, Polypropylene, Composite, Tensile Properties, Bending Properties

1. Introduction

In recent years, research on natural fiber reinforced composite material has been increased in great extent because of its various favourable advantages including both environmental and cost effective aspects. Composites are the wonderful light weight stiff material. Besides, the ratio of strength to weight is very high. The implementation of composite materials in various fields such as: automotive sector, marine industries, furniture, civil construction, military applications, aerospace, medical applications and many more. Fiber reinforced composite materials can be made by using both cellulose based natural and man-made or synthetic fiber. But synthetic fiber reinforced polymer based composites have some inconveniences. The cost related to synthetic fiber reinforced polymer based composites is higher and they are not environmental friendly. That's why the interest of researcher on using natural fiber in composite fabrication has been increasing day by day. Natural fibers are biodegradable and also environment friendly. The researchers take various factors in their concern while selecting fibers as raw material for composite fabrication such as physical and mechanical properties, cost, environmental aspects, toxicity, health hazards, flexibility, plant's age, availability etc. The natural fibers are directly related with good mechanical and physical properties, effective cost, absence of health hazards, eco-friendly, non-toxicity, higher flexibility, availability, lower plant's age and ease of collection [1-17].

Natural fibers can be obtained from different sources such as bark, cotton, wood pulp, bagasse, bamboo, vegetables etc. Cellulose, Hemicellulos, lignin and pectin are the major composition of natural fiber. It has been noticed in recent years that the researchers are giving more emphasis on effective utilization of residual agro industrial products. Sugarcane bagasse is one of the residual agro products which is considered as wastage. It is generally known as "Bagasse" which is a natural fiber [18-19]. Sugarcane bagasse fiber consists of fibrous structure from which fibers can be obtained. It comprises of 50% cellulose, 25% polyoses and 25% lignin [20-21].

Matrix material is a very essential part of composite. The use of polypropylene (pp) as a matrix material in composite fabrication with natural fibers has been noticed in different research papers. [1-3, 5-14]. Polypropylene is possessed with various striking properties such as good mechanical and bending properties, transparency, dimensional stability, flame resistance, high heat distortion temperature and high impact strength. Polypropylene is familiar as an amorphous thermoplastic polymer and extensively used as an engineering thermoplastic material because of its unique properties. Polypropylene is also very compatible for filling, reinforcing and blending purpose. Using polypropylene for fabricating natural fiber synthetic polymer composites is one of the most promising routes in present era [22-28].

In this present study, the tensile and bending properties of sugarcane bagasse fiber reinforced PP based composites were evaluated. Also the water uptake behaviour of prepared composites was measured. And finally, the effects of alkali and soil on sugarcane bagasse fiber reinforced PP based composites were investigated.

2. Materials and Methods

2.1. Materials

The polypropylene granules were bought from Polyolefin Company Limited, Singapore. (C3H6) n is the symbolic expression of polypropylene. Sodium Hydroxide was purchased from the local market of Dhaka, Bangladesh. For this study, fresh bagasse fibers which were crushed for extracting juice by hand crushing machine were collected from the local market.

2.2. Process of Fiber Extraction

Collected fresh bagasse fibers were spread on a water proof sheet for two weeks under sunlight for reducing moisture present in the fiber. After two weeks, the fibers were teased by hand comb for removing attached loose particles from the fibers. Finally the long bagasse fibers were cut manually by using scissor for shortening. These short fibers were used for composite fabrication.

2.3. Fabrication of Composites

The polypropylene granules were placed in between two metal plates of heat press machine (Carver, INC, USA Model 3856) for preparing polypropylene sheets. The temperature of heart press machine was 360°F, time range 5 min and a load of 2 tons. The sheets were then cooled inside the cold press machine. For fabricating composites, the polypropylene sheets were cut into desired size and the sugarcane bagasse fibers were sandwiched between them. Finally the composites were made by the same method used for making polypropylene sheets. The calculated fiber percentage of composites was 30% by weight. The fabricated composites was then stored in polyethylene bag.

2.4. Mechanical Properties of Composites

The mechanical properties such as tensile and bending properties of sugarcane bagasse fiber reinforced polypropylene based composites were measured by using a universal testing machine (H50 KS-0404) according to the European standard (ISO/ DIS 527-1: 2010). The initial distance between the clamp and the cross head speed of the clamp were 20 mm and 10 mm/min respectively. The dimensions of the composite samples were (60×10×1.70) mm^3. The test samples were conditioned at 25°C and 50% relative humidity for three days before testing. All the tests were performed under same experimental condition. In this study, all the test values of mechanical properties were the average of five samples.

2.5. Water Uptake Behavior

Composite samples were sunk into a beaker containing 100 ml distilled water for 1 hour at room temperature. The weight of the sample was measured initially. After certain interval of time, the samples were picked out from the water, wiped by using tissue paper and reweighted. No considerable water uptake was noticed after 40 minutes in this study. The water uptake percentage of sugarcane bagasse fiber reinforced polypropylene based composites was determined by following formula.

$$\text{Water uptake (\%)} = \frac{\text{Wet wet} - \text{Dry wet}}{\text{Dry wet}} \times 100 \qquad (1)$$

2.6. Effect of Alkali

Alkali test was performed to check out the effect of alkali on sugarcane fiber bagasse reinforced polypropylene based composites. The test was carried out by using aqueous solution of 3%, 5% and 7% Sodium Hydroxide (NaOH). The composite samples were immersed into the mentioned amount of solution for 24 hours. After 24 hours, the samples were taken out from the solution and washed with distilled water for removing the remaining NaOH. Then dried the samples at 70°C for 1 hour and measured their mechanical properties.

2.7. Soil Degradation Test

Degradation test of the composites expresses the retained mechanical properties of the composites after staying in the soil or water medium for a certain time period. The degradation test of the sugarcane bagasse fiber reinforced polypropylene based composites was carried out up to 16 weeks in soil medium. The samples were placed 6 inches below the crust. After 2 weeks of time interval, the samples were taken out from the soil very carefully and washed by water for removing attached soil particles. Then dried them at 105°C for 6 hours and mechanical properties were evaluated.

3. Result and Discussions

3.1. Mechanical Properties of Composite

The tensile and bending properties of polypropylene matrix and sugarcane bagasse fiber reinforced polypropylene based composites are presented in table 1 and 2. It was noticed that, the tensile properties such as tensile strength, tensile modulus and elongation at break of polypropylene sheet were 25 MPa, 396 MPa and 76% respectively. Comparing these values with the sugarcane bagasse fiber reinforced polypropylene based composites, the composites achieved an improvement of 54% in tensile strength and 151% in tensile modulus. The elongation at break of the composites was reduced significantly due to addition of sugarcane bagasse fiber with polypropylene. On the other hand, the bending strength and bending modulus of composites were found to be 46 MPa and 537 MPa respectively. Improved bending properties were investigated in this study over that of polypropylene matrix. Due to reinforcement by fiber, 109% increase of bending strength and 68% of bending modulus were observed.

By analyzing the above it can be said that, improved mechanical properties were observed in this study due to excellent fiber matrix interaction where core layer sugarcane bagasse fiber played an important role.

Table 1. *Tensile properties of polypropylene and composites.*

Materials	Tensile Properties		
	Tensile Strength (MPa)	Tensile Modulus (MPa)	Elongation at Break (%)
Polypropylene	25±1.8	396±22	76±3.90
Composites	38.5±2.15	997±60	9.25±0.50

Table 2. *Bending properties of polypropylene and composites.*

Materials	Bending Properties	
	Bending Strength (MPa)	Bending Modulus (MPa)
Polypropylene	22±2.10	320±18.10
Composites	46±2.60	537±23.95

3.2. Water Uptake Behavior of Composites

Water up take test divulged the water swelling properties of composites. Three samples of different weight of 30 wt% sugarcane bagasse fiber reinforced polypropylene based composites were taken for the test and their average values were considered. Figure 1 shows the water uptake up take percentage of composites against the time of soaking. Figure reveals that, initially the composites are absorbing higher amount of water till first 10 minutes. After 10 minutes water absorption rate was gradually decreased. The values of water absorption became static at 40 minutes. The composite samples were absorbed 2.10% water within the mentioned time period. After that, no considerable water absorption was noticed in this research work.

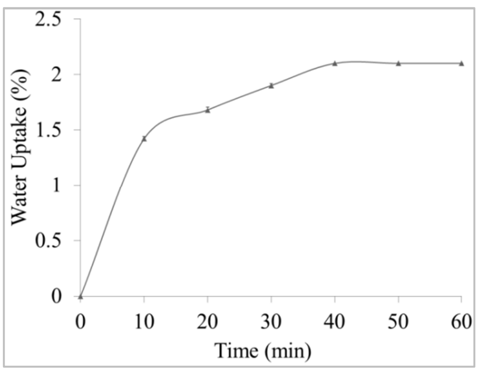

Figure 1. *Water up take percentages of composite.*

Generally polypropylene does not absorb water i.e. hydrophilic in nature. But sugarcane bagasse fiber absorbs water very easily due to the presence of hydroxide group in their fiber cellulose. Polypropylene acts as a resistant of water absorption when it is added with the sugarcane bagasse fiber for composite fabrication. In fact, the composites absorbed water through the cutting edge of the samples.

3.3. Effect of Alkali

The effects of alkali on mechanical properties of the composites were investigated in 3%, 5% and 7% solution of NaOH. The results are depicted in figure 2 and 3. It was found that, the mechanical properties were decreased with the increased of alkali solution. The composites lost 9% tensile strength, 10% tensile modulus, 3% elongation at break, 6% bending strength and 10% bending modulus after treating with 3% solution of NaOH. But highest amount of tensile and bending properties were reduced when the samples were treated by 7% alkali solution. It was observed that, sugarcane fiber reinforced polypropylene based composites degraded 22% tensile strength, 24% tensile modulus, 26% elongation ate break, 17% bending strength and 25% bending modulus in 7% alkali medium.

Generally alkali treatment is carried out on fibers for removing the fiber lignin and thus increases the mechanical properties [1]. But when the fiber is covered with polypropylene for composite fabrication, polypropylene prohibits the penetration of alkali solution into the fiber. The reduced mechanical properties of sugarcane fiber reinforced polypropylene based composites due to alkali treatment can be well explained by the mercerization process. During the experiment it was seen that, the composite samples were degraded in small particles and accumulated as precipitation into the alkali solution resulting in decreased tensile and bending properties.

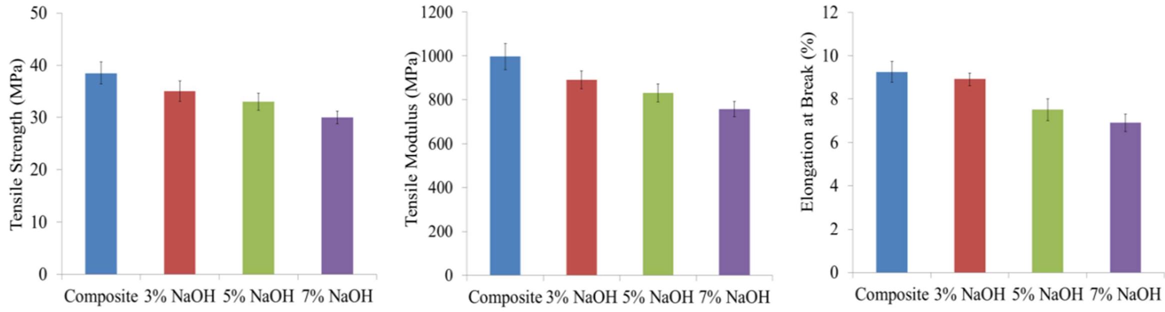

Figure 2. *Effect of alkali on tensile properties of composites.*

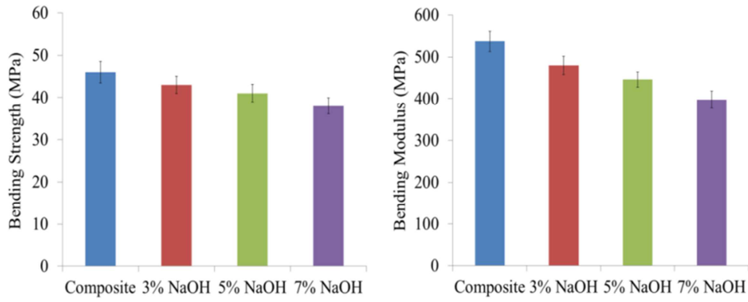

Figure 3. *Effect of alkali on bending properties of composites.*

3.4. Soil Degradation Test

The effects of soil on tensile and bending properties of sugarcane bagasse fiber reinforced polypropylene based composites were investigated for 16 weeks and their results are shown in figure 4 and 5. Reduced mechanical properties were observed due to the effect of soil on composites. It was noticed that, the composites degraded their tensile and bending properties with the time. Results revealed that, the composites lost 31% tensile strength, 42% tensile modulus, 23% elongation at break, 37% bending strength, 44% bending modulus after 16 weeks of degradation in soil medium. The composites were retained 65% of their mechanical properties within the stated period of time. With the degradation of mechanical properties, the weight of composites was also reduced. Figure 6 represented the percentage reduction of weight of composites with the time. Sugarcane fiber reinforced polypropylene based composites lost 46% weights after 16 weeks of soil degradation.

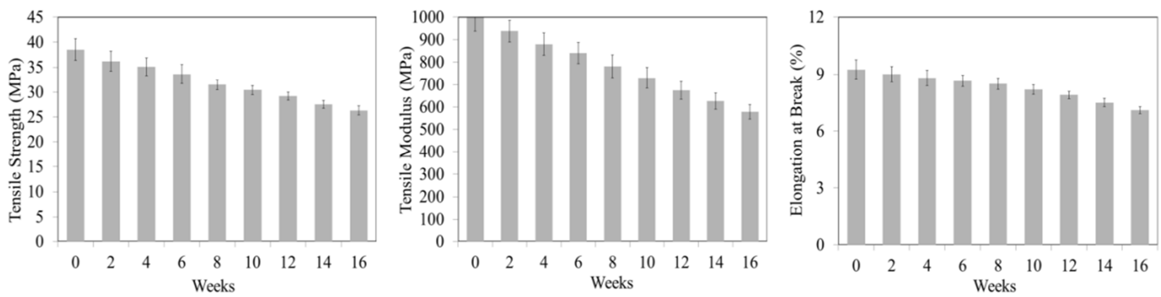

Figure 4. *Effect of soil on mechanical properties of composites.*

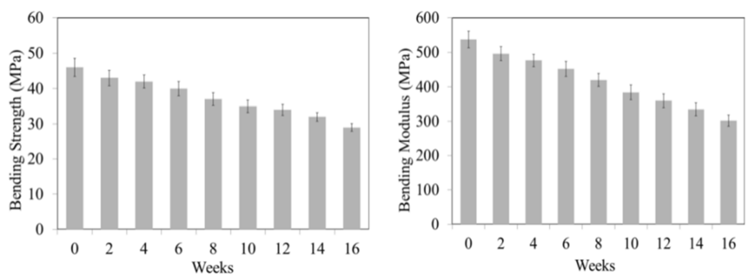

Figure 5. *Effect of soil on bending properties of composites.*

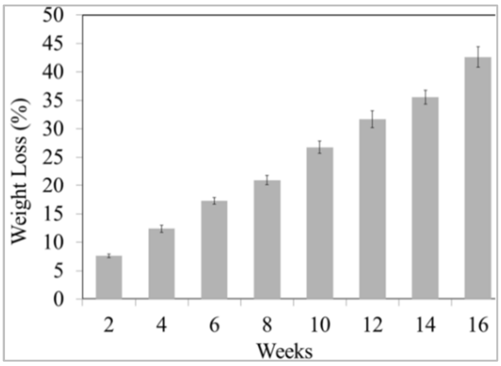

Figure 6. *Effect of soil on weight of composites.*

The degradations of tensile and bending properties were happened due the water absorption by the fibers. Cellulosic fibers have the strong tendency to absorb water very easily. That's why after placing the composite samples in the soil medium, they up took water within few minutes resulting in reduced tensile and bending properties were observed in this study. Water was absorbed through the cutting edge of the composite samples [1].

4. Conclusion

Sugarcane bagasse is very available in the world and easy to extract fiber from bagasse. Moreover for being natural, sugarcane bagasse fiber is environment friendly. So, fabricating composites by using sugarcane bagasse fiber can be a new source of materials. In this study, the mechanical properties such as tensile and bending properties, effect of alkali and soil on mechanical properties and water uptake behavior of sugarcane bagasse fiber reinforced polypropylene based composites were analyzed throughout. Comparatively the tensile and bending properties of composites were increased over that of the matrix material polypropylene. But the exception was happened for elongation at break (%) of the composites. On the other hand, in case of alkali treatment the tensile and bending properties of the composites were decreased compared with the mechanical properties of the composites. Higher reduction of mechanical properties was found when treating the composites at 7% solution of sodium hydroxide. The tensile and bending properties of composites were also reduced in soil medium. Sugarcane bagasse fiber reinforced polypropylene based composites were degraded 35% of their mechanical properties by soil. For being cellulosic structure of fiber, the composite samples were absorbed water very easily through the cutting edge. But the amount of water absorbed by the composites was very low. The hydrophilic nature of the fibers can be removed greatly by fabricating composite. So sugarcane bagasse fiber reinforced polypropylene based composites can be used as hydrophobic composite materials. Further research is required to improve the knowledge on sugarcane bagasse fiber reinforced polypropylene based composites.

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