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Study on Preparation and Mechanical Characterization of Blended Pineapple and Jute Fiber/Unsaturated Polyester Resin (UPR) Based Composite and Effect of Alkali on Composites

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Abstract In this study, blended pineapple and jute fiber reinforced unsaturated polyester resin (UPR) based composites were made by simple hand lay-up technique. The quantity of fibers were 50% by weight. The tensile strength (TS), tensile modulus (TM), elongation at break (Eb%), bending strength (BS) and bending modulus (BM) of the composites were found to be 48 MPa, 3096 MPa, 5.30%, 52 MPa and 1764 MPa respectively. Results revealed the increased percentage of TS, TM, BS and BM were 33%, 34%, 18% and 26% respectively. Reduced Eb% was noticed due to addition fo fibers. Water uptake test was executed by immersing the composites in deionized water and water uptake was higher. The composites were sunk in 3%, 5% and 7% solution of sodium for 1 hour to investigate the effect of alkali and reduced mechanical properties were evaluated. Soil degradation test was carried out on composites for 8 weeks and found that fiber/UPR composites retained about 48% of their original mechanical properties.

Keywords Natural fiber, Unsaturated polyester resin (UPR), Composite, Hand lay-up technique, Mechanical properties

1. Introduction

A composite material can be defined as a solid material which is fabricated by sandwiching a core layer by two or more other materials which are known as matrix material. The uses of natural fibers as a core layer for fabricating composites have been increasing day by day. Fiber reinforced composite materials are using in various fields such as aerospace, civil construction, medical sector, furniture and many more [1-9]. Nowadays, composites made from synthetic fibers are mostly used but they are expensive and not environmental friendly. For overcoming these problems, cellulose based natural fibers especially for high volume and cost effective applications are replacing them. Polarity and hydrophilicity properties are involved with natural fibers but non polar matrix material can be solved these problems. Besides, the natural fibers are available, cost effective and most importantly environmental friendly. [10–14].

Researchers have been giving their concentration for replacing synthetic fibers by natural fibers as a raw material that have similar physical and mechanical properties compared to synthetic fiber. There things need to be considered during the selection of raw materials are inexpensiveness, effect on environmental and human health, high flexibility, availability which are directly related with the suitability of natural fibers. Natural fibers are renewable source, besides they are durable, economical and hygienic [15].

Pineapple leaf fiber (PALF) is a natural fiber and considered as an agricultural wastage. It has chemical composition of 70–82% holocellulose, 5–12% lignin and 1.1% ash. For having higher percentage of hollocellulose in pineapple fiber, it shows excellent mechanical properties. For this reason it has been used for making of reinforced polymer composites. Jute is another important natural fiber. It is cultivated in Bangladesh, India, China, Uzbekistan, Bhutan, Vietnam and Thailand. Bangladesh and India produce 93% jute of the world. Clothes, ropes, gunny and shopping bags, floor coverings etc. are produced from jute fiber. Jute fibers can also be used with matrix material

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like low density polyethylene, unsaturated polyester resin, polypropylene, polyethylene etc. as filler or core layer of composites. It provides advantages such as low weight, density and elongation at break, high tensile modulus, availability and economic [16]. It has 82%-85% hollocellulose in which 58%-63% alpha-cellulose which make it more compatible for composite fabrication [17].

Matrix material is the most important part of composite material. Unsaturated polyester resin (UPR) has been widely used as a matrix material with natural fibers in composite preparation. UPR can also be used as sheet molding compounds. A good range of mechanical properties can be achieved by using UPR in composite fabrication. Besides, it has advantages such as low cost, good corrosion resistant and light weight [18].

In this study, the mechanical behaviour of fiber reinforced UPR based composites were reported. Water absorption profile and effect of alkali on mechanical properties of fiber/UPR composites were also investigated.

2. Materials and Methods

Materials

Bleached PALF and jute fibers were purchased from two different places of Bangladesh. PLAF were bought from Modhupur, Tangail and jute fibers were from Bangladesh Jute Research Institute (BJRI), Dhaka, Bangladesh. Jute and pineapple fibers were opened mechanically in Bangladesh Jute Research Institute (BJRI), Dhaka, Bangladesh. The matrix polymer unsaturated polyester resin was supplied by Shakubal Kagaku Kogyo Company Limited, Chou-ku, Osaka, Japan and curing agent methyl ethyl ketone peroxide (MEKP) was brought from Tokuyama Corporation, Japan.

Making of Blended Pineapple and Jute Fiber/ Unsaturated Polyester Resin (UPR) Based Composite

Simple hand lay-up technique was used for fabricating composites. For easy removal of composites from the mylot paper, the mylot paper was treated with waxes and kept it on metal plate. At the beginning of the fabrication process, a solution containing 97% UPR and 3% MEKP as hardener was made at room temperature. After placing equal amount of fibers closely on mylot paper, the solution was laid down on the fibers. Then the fibers were covered with another mylot paper and rolled it by hand roller. Finally covered it with another metal plate and kept it for six hours under a weight of 15 kg. After six hours, the composites were uncovered and cut it into desired size. 25% pineapple and 25% jute fibers were in composites and the rest 50% was unsaturated polyester resin. The fabricated composites were then collected in polyethylene bags for further evaluation.

Mechanical Properties of Composites

The mechanical properties such as tensile and bending properties of the composites were assessed by using Hounsfield series S testing machine (UK) according to ASTM-D638-01. The initial separation of clamp was 20 mm and the loading force was 1 mm/sec. (60×10×3) mm was the dimension for mechanical tests of fiber/UPR composites. All the tests were carried out for five times and their average values were taken.

Water absorption Profile of the Composites

The investigation of water uptake percentage of fiber/UPR composites was performed to find out the water absorption profile. Three cut samples of different weight of fiber/UPR composites were used to determine the water uptake behaviour. The weights of the samples were measured initially. The samples were immersed in 500 ml deionized water at room temperature (25°C). After certain time interval they were brought out from the beaker, wiped by using tissue papers and again weighted. In this case, no considerable water uptake was noticed after 1 hour. That was the reason for conducting water uptake test for 1 hour. The percentage of water absorption was calculated by-

$$\text{Water absorption (\%)} = [(\text{Wet weight} - \text{Dry weight}) / \text{Dry weight}] \times 100 \qquad (1)$$

Effect of Alkali

The effect of alkali on fiber/UPR composites was investigated by alkali test. 3%, 5% and 7% aqueous solution of Sodium Hydroxide (NaOH) were used for treating the composites. The composite dimensions of (60×10×3) mm were immersed in the alkali solution for 24 hours. After taking out the samples from alkali solution, the samples were cleaned up by water for removing the remaining sodium hydroxide attached on the composites surface. Then the samples were dehydrated at 70°C for 1 hour and evaluated the tensile and bending properties.

Soil Degradation Test of the Composites

The aim of degradation test of composite is to explore the retained mechanical properties of composite when it comes to contact with soil or water during its uses. In this study the degradation test of fiber/UPR composites was carried out in soil medium up to 8 weeks. Cut composite samples were buried in 12 inch depth of the soil for different time periods. After certain time interval, the samples were withdrew from the soil carefully and washed by distilled water for removing dirt. After that the samples were dehydrated at 105°C for 6 hours and kept for 24 hours at room temperature. Finally the mechanical properties of fiber/UPR composites were measured for evaluation.

3. Result and Discussion

Mechanical Properties of Composites

The effects of pineapple and jute fiber on tensile and bending properties of the composites are shown in table 1 and 2. From the table it is seen that the mechanical properties such as the tensile strength (TS), tensile modulus (TM), elongation at break (Eb%), bending strength (BS) and bending modulus (BM) of the UPR were found to be 36 MPa, 2310 MPa, 6.95%, 44 MPa and 1400 MPa respectively. And the TS, TM, Eb%, BS and BM of fiber/UPR composites were 48 MPa, 3096 MPa, 5.30%, 52 MPa and 1764 MPa respectively. By analyzing the values of the table, it is seen that fiber/UPR composites gained increased mechanical properties. Due to addition of pineapple and jute fibers with the UPR, 33% increased in TS, 34% in TM, 18% in BS and 26% in BM were observed. In this study, reduced Eb% was observed though the other mechanical properties were improved. Incorporation of pineapple and jute fibers into composites was the main reason of resucing Eb%.

Table 1. Tensile properties of UPR and fiber/UPR composites

Materials	Tensile Properties		
	Tensile Strength (MPa)	**Tensile Modulus (MPa)**	**Elongation at Break (%)**
UPR	36±2	2310±250	6.95±0.5
Fiber/UPR	48±2	3096±210	5.30±0.4

Table 2. Bending properties of UPR and fiber/UPR composites

Materials	Bending Properties	
	Bending Strength (MPa)	**Bending Modulus (MPa)**
UPR	44±3	1400±120
Fiber/UPR	52±3	1764±120

The reason behind the improved mechanical properties was the unifrm distribution of stress. Adequate amount of load was tranferred from fiber to fiber due to applied force results in uniform stress distribution. Besides, the cellulosic structure of pineapple and jute fibres contributed a lot for this augmentation of mechanical properties. This proved a better interfacial interaction between the fibers and matrix UPR.

Water absorption Profile of the Composites

Water absorption profile exhibits the water uptake behavior of the composite. The average value of water uptake percentage of three samples of different weight of same composite (50 wt% fiber content) is depicted in Figure 1 against the time of water absorption at room temperature. From the figure, the water uptake percentage increases with the increase of soaking time. This augmentation was occurred up to 60 minutes. After 60 minutes the samples were absorbed no considerable water. 14.4% water was absorbed by fiber/UPR composites after the mentioned time period. Ismail et al. stated in their study that jute/UPR composite absorbed 13% water after 65 minutes and after that water absorption rate became constant [19]. So, a little variation was observed for fiber/UPR composite due to addition of pineapple fiber in the composites.

The water absorption of the composites can be described on the basis of hydroxyl (–OH) groups. The hydroxyl (–OH) groups are existed in the cellulose of pineapple and jute fiber. Pineapple and jute fiber are composed of 70%-82% and 82%-85% cellulose respectively. These higher contents of cellulose was responsible for hydrophilic nature of composites [20]. Besides, the water was penetrated into composite through the cutting edge of composites.

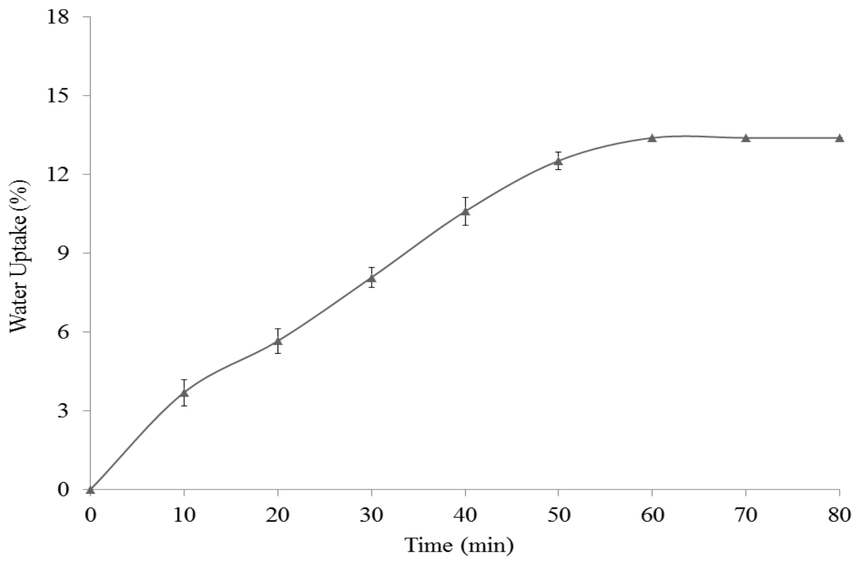

Figure 1. Water uptake % of Blended Pineapple and Jute Fiber/Unsaturated Polyester Resin (UPR) Based Composite

Effect of Alkali

The mechanical property of the composites can be improved with alkali by treating natural cellulosic and crystal structure fibers which act as the filler of the composite. But when the fabricated composites material treats with alkali, its mechanical properties would be reduced [1]. The alkali treatment on the composite was carried out in room temperature for 24 hours. The used concentrations were 3%, 5% and 7% NaOH. The tensile and bending properties are shown in figure 2 and 3 against the concentration of alkali solution. Decreased tensile and bending properties were investigated for all condition of alkali treatment under this study. Maximum amount of diminished mechanical properties were observed after treating with 7% NaOH solution as shown in figures. In this study, the amount of reduced mechanical properties after 24 hours of 7% NaOH treatment were 33% TS, 35% TM, 41% Eb%, 32% BS and 38% BM.

The reason of reducing mechanical properties can be explained by mercerization process. The composites lost its strength by decay of composites upon time and the decay particles were accumulated under the solution during the process of alkali treatment. So, due to alkali treatment fiber/UPR composites lost its tensile and bending properties because of increasing breaking tendency of the composites [1].

Soil Degradation Test of the Composites

Treated composite with soil medium was lengthened up to 8 weeks to determine the degradation test of fiber/UPR composites. The values of tensile strength (TS), tensile modulus (TM) and elongation at break (Eb%) are depicted in figure 4. It is clear from the figure that the tensile properties such as TS, TM and Eb% of the composites were decreased slowly with time. After 8 weeks, results revealed that the degradation occurred 52% in TS, 61% in TM and 19% in Eb% by soil. On the other hand, decreased bending properties (bending strength and bending modulus) of fiber/UPR composites were also observed due to soil degradation. The values of bending properties are shown in figure 5. It was found that fiber/UPR composites degraded 42% and 64% of BS and BM respectively after 8 weeks of soil degradation. The composites were retained about 48% of their original mechanical properties after the stated time period. It was also evaluated from the figure 6 that, 31.50% mass of the composites was lost due to the effect of soil on composites after the mentioned time period. One of the studies showed that the TS, TM, Eb%, BS and BM of natural fiber (15% pineapple, 7.5% jute and 7.5% cotton fiber) reinforced polypropylene based composites were reduced 50%, 48%, 49%, 45% and 47% respectively because of soil degradation [23]. In this study, the variations of soil degraded mechanical properties were noticed clearly due to the different fiber composition (25% pineapple and 25% jute) and different matrix material.

Pineapple and jute fibers have higher content of cellulose which make them biodegradable natural fiber. So they are strongly hydrophilic in nature. Cellulose has a great tendency to degrade when buried in soil medium. For being hydrophilic and biodegradable natural fiber, pineapple and jute fibers absorbed water very easily from the soil [20]. That’s why significant reduced of mechanical properties were observed in this study.

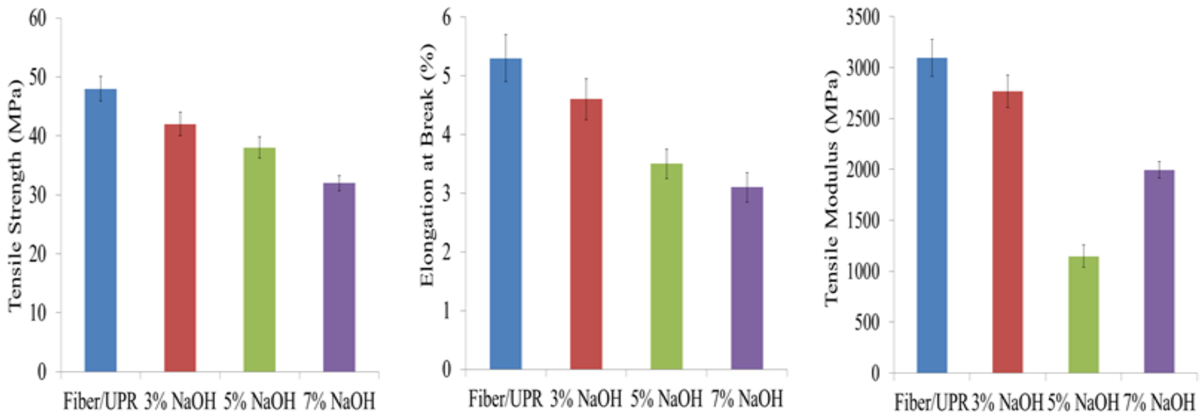

Figure 2. Effect of alkali on tensile properties of the composites

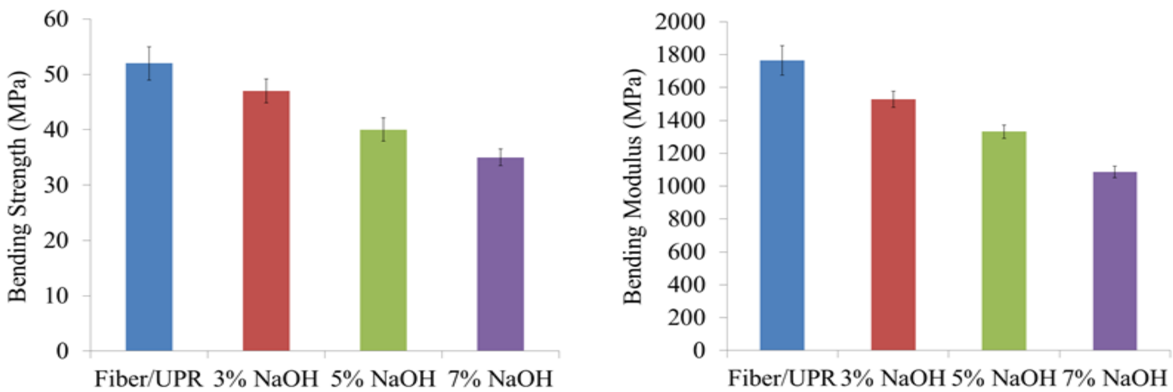

Figure 3. Effect of alkali on bending properties of the composites

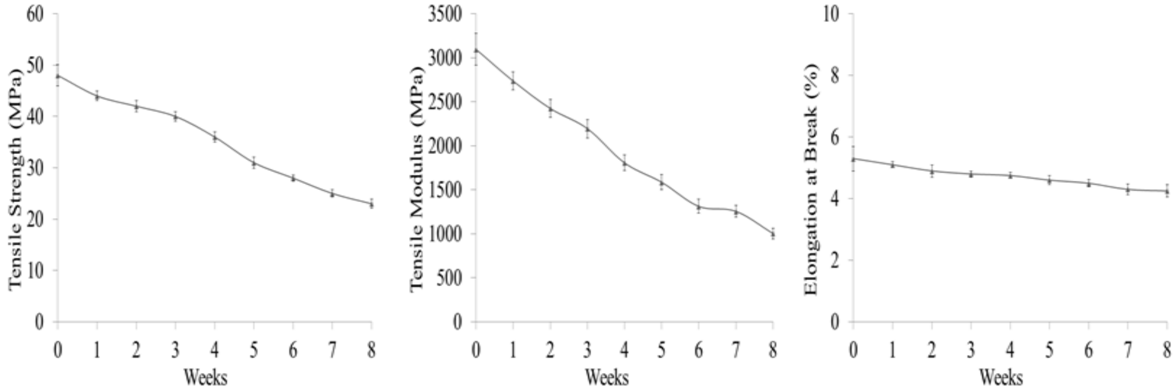

Figure 4. Effect of soil degradation on tensile properties of fiber/UPR composites

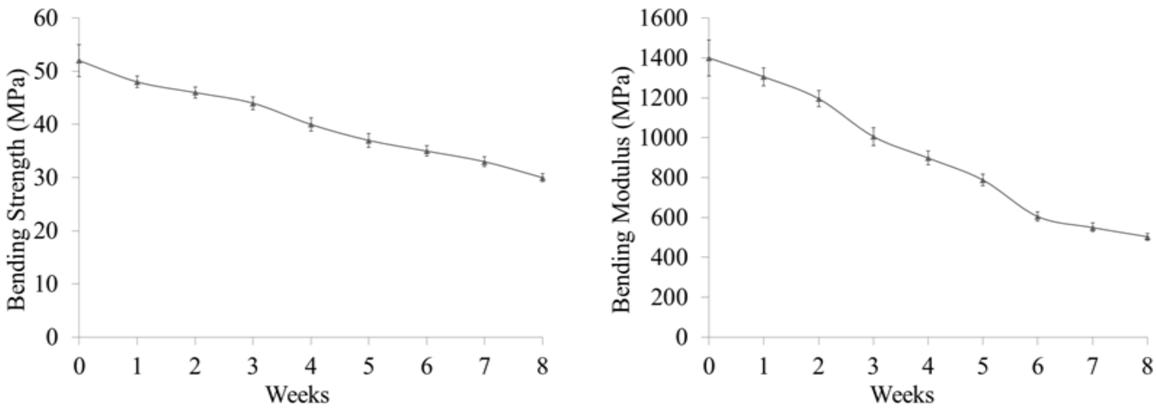

Figure 5. Effect of soil degradation on bending properties of fiber/UPR composites

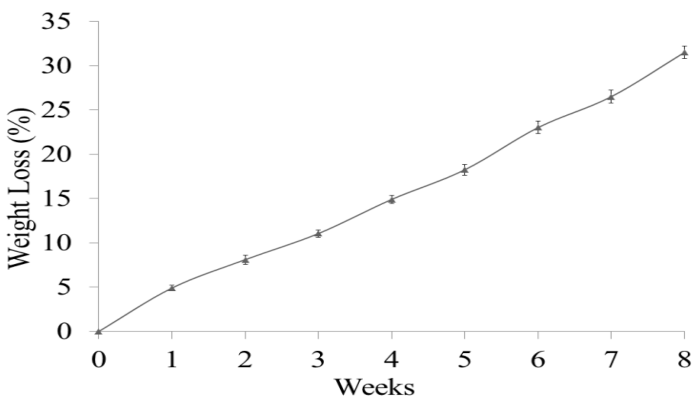

Figure 6. Effect of soil degradation on weight of fiber/UPR composites

4. Conclusions

Pineapple and jute fibers/UPR composites were successfully fabricated by simple hand lay-up technique and characterized in this study. Use of blended pineapple and jute fiber can be a new source of composite material in sense of environmental issue. Under this study, 50 wt% PALF and Jute fiber/UPR composites were studied throughout. Acceptable values of mechanical properties were achieved at this composition. The tensile and bending properties of the composites were increased significantly in this study. Diminished tensile and bending properties were also investigated by alkali treated PALF and Jute fiber/UPR composites. The soil degradation test was conducted for a time period of 8 weeks and after 8 weeks the composites lost about 52% of their original mechanical properties which indicated the biodegradability of PALF and jute fiber/UPR composites. PALF and jute fiber are water susceptible natural fiber. Initially, the rate of water absorption of fiber/UPR composites was higher but after 60 minute the composites were absorbed no water. Further research on PALF and jute fiber reinforced unsaturated polyester resin based composites is needed to achieve improve knowledge about the topic.

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