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THE EFFECT OF SLS TREATMENT ON TENSILE PROPERTY OF COCONUT FIBER REINFORCED EPOXY COMPOSITES*

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Abstract– A study on the effect of fiber length and fiber surface modification on tensile property of alkaline treated coir fiber reinforced epoxy composites is presented in this paper. The fiber surface treatment was carried out using Sodium Lauryl Sulfate (SLS) solution at five different concentrations, 2%, 4%, 6%, 8% and 10% respectively. Each group of the coir fiber was treated for 10 days. For each group the coir fibers experiments were conducted for different fiber lengths namely 10, 20, and 30mm. The SLS treated coir fiber was used as a reinforcement and epoxy was used as a matrix to fabricate the composites. The tensile strength of different samples of composites was measured. Increased SLS concentration in fiber treatment was found to increase the tensile strength up to 4% and further increase in SLS concentration reduced the tensile strength, also, experimental results showed that an increase in fiber length increased tensile strength. The maximum tensile strength of the composite was found to be uniformly occurring for 4% SLS with 30mm fiber length composite samples. Based on the nonlinear regression analysis the tensile strength equation was proposed for coir fiber reinforced epoxy composites**.**

Keywords– Coir fiber, epoxy matrix, fiber length, sodium lauryl sulfate, regression analysis

1. INTRODUCTION

Nowadays, there is an increasing environmental consciousness and awareness of the need for sustainable development, which has raised interest in using natural fibers as reinforcements in polymer composites to replace synthetic fibers. The advantages of natural fibers includes low cost, low density, unlimited and sustainable availability, and low abrasive wear of processing machinery [1]. The performance of a polymer composite depends not only on the selection of their components, but also on the interface between them. In order to meet the specific needs, sometimes it is necessary to modify the matrix, and the reinforcement. Natural fibers play an important role in developing high performing fully biodegradable 'green' composites which will be a key material to solve the environmental problem. Natural fibers are largely divided into two categories depending on their origin: plant based and animal based. In general plant based fibers are lingo-cellulose in nature composed of cellulose, hemi cellulose and lignin, for example, jute, coir, sisal, cotton, etc. [2-6]. Whereas animal based fibers are composed of proteins, for example, silk and wool [7]. Natural fiber reinforced composites also have several drawbacks such as poor wettability, incompatibility with some polymeric matrices and high moisture absorption by the fibers. The main problem often encountered in its use is the fiber matrix adhesion problem due to the incompatibility between the hydrophilic natural fibers and the hydrophobic polymer matrix. This problem may be improved by chemical treating in the fiber surface. Alkali treatment is a common method to clean and

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modify the fiber surface to lower surface tension and enhance interfacial adhesion between a natural fiber and a polymeric matrix [8]. Lai et al. [9] have studied the mechanical and electrical properties of coconut coir fiber-reinforced polypropylene composites. Natural Fibers have an outstanding potential as reinforcement in thermoplastics. In this investigation the fibers were initially treated with various treatment agents namely alkali, stearic acid, acetone, and potassium permanganate in order to improve resin fiber interfacial bonding. The results revealed that composites that contain treated fiber have a higher tensile modulus and greater flexural modulus than do untreated fiber composites. Rout et al. [10] have studied the SEM observation of fractured surface of coir composites. Coir composites had been prepared using coir fiber as reinforcement with both thermosetting and thermoplastic as a matrix. The SEM image proved that the surface of composite showed varied extents of fiber pull out under both failure modes. Prasad et al. [11] have studied the alkali treatment of coir fiber for coir polyester composites. The experimental results proved that flexural strength, modulus and impact strength of treated fiber composites were 40% higher than those containing the same volume fraction of untreated fibers. Rout et al. [12] have studied the influence of fiber treatment on the performance of coir fiber polyester composites. The investigation proved that the 2% alkali treated coir fiber polyester composites showed better tensile strength (26.80Mpa) whereas 5% alkali treated composites showed better flexural (60.4Mpa) and impact strength (634.6 J/m). Huang et al. [13] have investigated the tensile behavior of coir fiber and related composites after NaOH treatment. The investigation proved that decreased trend of the fiber tensile strength increased NaOH density. The alkali treatment would improve the adhesion ability of the coir fiber with matrix resulting in a greater tensile strength. Sapuan et al. [14] have studied the tensile and flexural properties of composites made from coconut shell filler particles and epoxy resin. The tensile and flexural tests of composites were based on coconut shell filler particles at three different filler contents viz .5%, 10%, and 15% respectively. Experimental results revealed that tensile and flexural properties of the composites increased with the increase of the filler particle content. They investigated the relation between stress and percentage of filler for tensile and flexural tests, which were found to be linear with correlation factors of 0.9929 and 0.9973, respectively. Analytical correlation between maximum stress and filler contents is linear, whereas for modulus of elasticity and strain it is quadratic. Karthikeyan et al. [15] have studied the coconut fiber reinforced epoxy composite with alkali treatment. The results proved that treated fiber composites have better impact strength (27KJ/m2) and also impact strength was greatly influenced by the fiber lengths. The investigation also showed that the higher concentration of NaOH reduces the fiber strength. Thiruchitrambalam et al. [16] investigated the mechanical behavior of banana/kenaf polyester hybrid composite using sodium lauryl sulfate treatment. The results proved that the surface modification of SLS treatment has improved the tensile, flexural and impact properties compared with NaOH treatment. Karthikeyan et al. [17] have investigated the impact property of coconut Fiber Reinforced Epoxy Composites Using Sodium Lauryl Sulfate Treatment. The Impact strength of SLS treated fiber reinforced epoxy composite was measured with various fiber lengths and compared with NaOH treated fiber reinforced epoxy composites. The investigation proved that, the SLS treated fiber showed better impact property (28KJ/m2) with 30mm fiber length and also that the fiber length increases with increase in impact strength. Further, it was found that the NaOH treatment reduces the fiber strength drastically as compared to SLS. Although a great deal of work has been done on coir fiber reinforced polymer composites, very limited work has been done on the effect of fiber length with surface treatment through SLS treatment on the tensile behavior of coir fiber reinforced composites. Against this background, the present research work has been undertaken with the objective being to explore the potential use of coir fiber as a reinforcing material in polymer composites and to investigate its effect on the tensile strength of the resulting composites. In this investigation coir fibers were treated by SLS (sodium Lauryl Sulfate) with various concentrations. The coir fiber was used as a reinforcement and epoxy as the matrix to fabricate the composite by hand lay-up technique. The tensile strength of the produced specimens was measured, and SEM analysis was made.

2. MATERIALS

The coir fibers were removed from the shell & separated with a comb. After drying at room temperature, the coir fibers were combed in a carding frame to further separate the fibers into an individual state. The epoxy LY556 was used as a matrix with HY951as a hardener and this was purchased from Covai Seenu & Company, Coimbatore, Tamil Nadu, India. The SLS was purchased from Star Scientific, Erode, Tamil Nadu, India.

3. METHODS

a) Coir fiber treatment

The coir fibers were treated in SLS solution at room temperature (27° – 29° C) with various densities of 2%, 4%, 6%, 8% and 10%. Each group of the coir fiber was treated for 10 days. The treated fiber was washed with water to remove the excess SLS sticking to the fibers. Final washing was carried out with distilled water and the fibers were dried in hot air. Finally, the fibers were cut into 10, 20 and 30mm lengths of composite molding.

b) Preparation of coir fiber reinforced epoxy composite

The coir fiber reinforced epoxy composites were manufactured through a mold box of size 300 x 300 x 3mm. The fabrication of the composite material was carried out through the hand lay- up technique. The top and bottom surfaces of the mold and the walls were coated with remover and allowed to dry. The chopped fibers with epoxy resin were mixed manually. Epoxy resin properly mixed with coir fiber was transferred to the mold, the mold closed, and then pressed in the compression testing machine and left for 24hr for curing. After the curing process, the samples were cut into the required size prescribed in the ASTM standards. Figure 1 shows the appearance of the specimen of the coir fiber reinforced epoxy composites. The weight fraction of the coir fiber in the composite was 30%. Each piece of the fabricated board was cut into standard size.

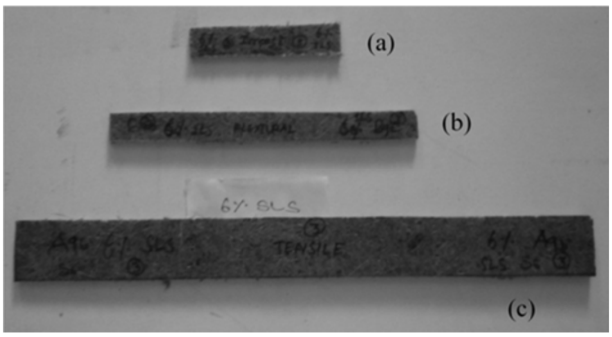

Fig. 1. (a) Specimen for impact test (6% SLS and 20 mm length), (b) Specimen for flexural test (6% SLS and 10 mm length), (c) Specimen for tensile test (6% SLS and 30 mm length)

c) Tensile test

The fiber tensile strength was carried out by using the model INSTRON 5500R, single fiber tensile strength tester (SITRA, Coimbatore, Tamil Nadu, India). Thirty samples were tested and the average value is reported. The distance between the two clamps before the test was set as 60mm and displacement rate was set as 10mm/min. as most of the researchers have used this strain rate. Images of the coir fiber before and after the alkali treatment were taken by using the scanning electron microscope (Model JEOL 6390, Karunya University, Coimbatore, Tamil Nadu, India.). The diameter of the coir fiber before and after the alkali treatment was measured using Image analyzer, taken from SITRA Coimbatore, Tamil Nadu, India. From the fabricated coir fiber reinforced epoxy composite test specimens were cut as per ASTM D3039 and tested for tensile strength using a computerized universal testing machine (INSTRON model 3369). The setup is illustrated in Fig. 2. The distance between the two clamps before the test was maintained at 150mm, the testing speed was 2mm/min, the normally used value. Five samples were tested and the average value was reported.

Fig. 2. Universal tensile tester model - instron 3369

4. RESULTS AND DISCUSSION

a) Image of the coir fiber

Figures 3, 4 and 5 represent the surface appearance of the coir fiber before and after the alkali treatment respectively. The fiber surface appearance of untreated and NaOH treated fibers is shown below for the comparison of SLS treated fiber. Figure 3 showed that the surface of the coir fiber is covered with a layer of substance, which may include pectin, lignin and other impurities. The surface is not smooth, spread with nodes and irregular strips. Figure 4 represents the surface of the coir fiber after NaOH treatment. It showed that most of the lignin, pectin are removed resulting in a rougher surface. Note that there are rows of pits on the surface. Figure 5 represents the surface of the coir fiber after SLS treatment. It also seems to like the surface of NaOH treatment. Further, rows of pits on the surface can be seen. This would increase the mechanical bonding between the coir fiber and matrix in the composite fabrication.

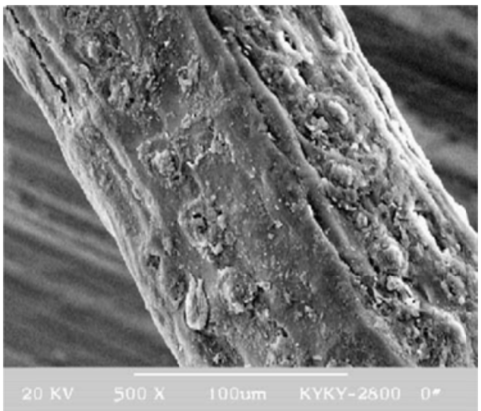

Fig. 3. Surface appearance of the coir fiber before alkali treatment

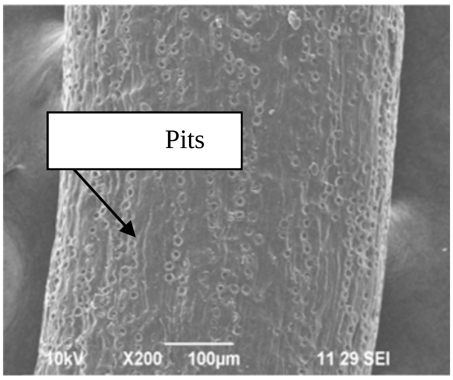

Fig. 4. Surface appearance of the coir fiber after 4% of NaOH treatment

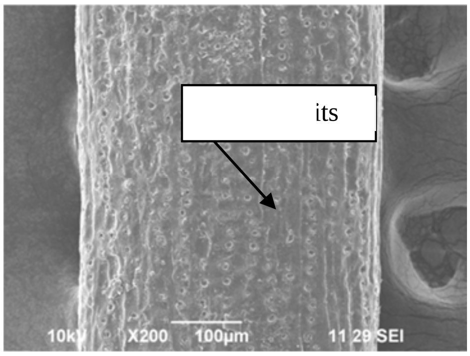

Fig. 5. Surface appearance of the coir fiber after 4% of SLS treatment

b) Tensile strength of coir fiber

Tensile strength of NaOH and SLS treated fibers is listed in the table below for the comparison. The tensile strength of the untreated fiber is also included in the same table because the considerable variation of the fiber fitness causes tensile strength of the fiber to vary greatly. To observe the influence of the coir fiber variation, 30 samples were adopted for each group.

Figure 6 represents the tensile strength of the coir fiber before and after the alkali treatment. The results revealed that a decreased trend is seen in the fiber tensile strength with increased alkali density. The difference of the tensile strength among each group proved to be significant. An increase in alkali density causes greater amounts of lignin, pectin to leach out, which would be detrimental to fiber strength.

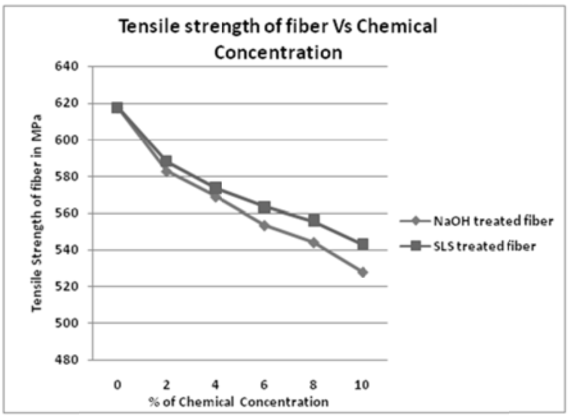

Fig. 6. Tensile strength of fiber Vs chemical concentration

Figure 7 represents a comparison of the coir fiber diameter before and after the alkali treatment. Note that a decreased trend is seen in the fiber diameter with an increase in alkali densities. Figure 7 proves that the NaOH treatment reduced the fiber strength drastically as compared to the SLS treatment because the pH value of NaOH is high, whereas the pH value of SLS is less compared to NaOH. These results revealed that the SLS treatment retains the fiber strength as compared to the NaOH treatment. After both alkali treatments, a rough fiber surface was resulted, which might improve the bonding ability of the fiber with matrix.

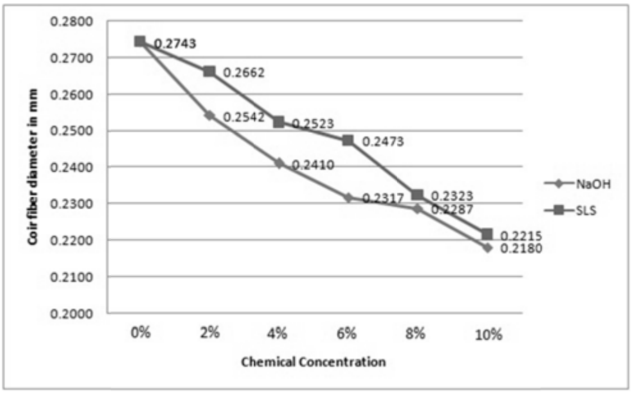

Fig. 7. Diameter of the coir fiber before and after the alkali treatment

c) Tensile strength of the coir fiber reinforced epoxy composites

Figure 8 showed the appearance of the specimen of the coir fiber reinforced epoxy composites after tensile strength. The tensile strength of coir fiber reinforced epoxy composites with and without alkali treatment testing results were summarized in Tables 1, 2 & 3

Fig. 8. (a) Specimen for tensile test (4% SLS and 10 mm length), (b) Specimen for tensile test (4% SLS and 20 mm length)

Table 1. Effect of fiber length on the tensile property of untreated coir fiber reinforced epoxy composite

Fiber length in mm	Tensile strength (MPa)
10	6.208
20	9.155
30	13.05

Table 2. Effect of fiber length on tensile strength of NaOH treated coir fiber reinforced epoxy composites

Fiber length in mm	NaOH concentration in %					
	2%	4%	6%	8%	10%	Tensile strength in MPa
10	8.567	12.845	12.807	9.908	8.455	
20	9.242	13.380	13.327	10.098	8.659	
30	13.171	13.782	13.702	10.498	8.941	

Table 3. Effect of fiber length on tensile strength of SLS treated composites

Fiber length in mm	SLS concentration in %					
	2%	4%	6%	8%	10%	
10	10.885	16.942	16.797	12.861	10.245	Tensile Strength in MPa
20	11.107	17.648	17.497	13.259	10.455	
30	14.329	18.178	17.847	13.524	10.663	

d) Effect of fiber length on tensile property of coir fiber reinforced epoxy composites

Zuraida et al. [18] investigated the effect of fiber length on mechanical properties of coir fiber reinforced cement-album composites. The experiment revealed that increasing the length of fiber increases the flexural strength. But the incorporation of long fiber in the cement paste reduced the workability and thus introduced voids, resulting in lower density; in fact, water absorption and water content also increased. Pongsathorn et al. [19] investigated the tensile properties of bamboo fiber reinforced epoxy composite. From this investigation it was found that the tensile strength showed an increasing trend as the fiber length was increased but the elongation at break of the composite was not affected significantly by the fiber length. The optimum of fiber length in epoxy resin to obtain the highest tensile strength was found at 10 mm. It was also found that the void, fiber length and interfacial adhesion between fiber-matrix can affect the mechanical properties of the composite. Joseph et al. [20] studied the tensile properties of short sisal fiber/polyethylene composites in relation to processing methods and the effects of fiber content, length and orientation. In this experiment, it is shown that the chopped fiber distribution in epoxy is random, so the fiber could not hold the load when the matrix was transferred. Dona et al. [21] stated that fiber length plays an important role in the mechanical performance of fiber reinforced composites. Arib et al. [22] compared the experimental and theoretical tensile strength for pineapple leaf fiber reinforced polypropylene composites and found that the equation for the rule of mixture fails to provide a good fit, and the discrepancy increases with the increase in the fiber volume fraction. The fiber is not perfectly aligned and the presence of voids in the composites may also be the factor contributing to the lower experimental values. According to Baiardo et al. [23] the mechanical properties of short fiber reinforced composites are expected to depend on (i) the intrinsic properties of matrix and fibers, (ii) aspect ratio, content length distribution and orientation of the fibers in the composites and (iii) fiber – matrix adhesion that is responsible for the efficiency of load transfer in the composites. In Tables 1, 2 & 3 as expected, the tensile strength showed gradual increases with increase in fiber length reaching a maximum at about 30mm (18.178Mpa). The reason for this increase in the strength properties of these composites is that the chemical bonding between the fiber and matrix may be too strong to transfer the tensile.

e) Effect of alkali treatment on tensile property of coir fiber reinforced epoxy composites

Note the significant difference in the tensile strength between the alkali treated coir fiber reinforced epoxy composites and untreated coir fiber reinforced epoxy composites. The tensile strength of the composites when using the alkali treated coir fibers is usually greater. This implies that after alkali treatment, most of the impurities like lignin, pectin that covered the fiber surface were removed, which improved the fiber adhesive character in combination with the matrix. Especially in Tables 2 & 3 the important difference in the tensile strength is clearly shown and it is also found that the SLS treated coir fiber reinforced epoxy composites showed better tensile strength compared to the NaOH treated coir fiber reinforced epoxy composites. These results revealed that the SLS treatment does not reduce the fiber strength as compared to the NaOH treatment. To achieve a composite with better strength, SLS concentration with 4% may be recommended for economical consideration. The significant difference is noticed for the elongation at break values between the composites made by using the alkali treated and untreated coir fiber. The higher elongation at break for the alkali treated coir fiber composites indicates that the removal of the lignin and pectin improved the elasticity of the coir fiber.

5. REGRESSION ANALYSIS

It was observed that the relationship between fiber lengths (L), chemical concentrations (C) on the tensile strength (TS) of coir fiber reinforced epoxy composite varies non-linearly. From the parametric study, interaction between the parameters like coir fiber lengths (L), sodium hydroxide concentration (C), and influence of the tensile strength (TS) of the coir fiber reinforced epoxy composite are ascertained. The non-linear regression analysis is carried out using statistical analysis software SPSS to estimate the arbitrary relationship between the dependent variable (TS) and a set of independent variables (L and C). The following design equation was developed using nonlinear regression analysis,

$$TS = (17.711) - \left(\frac{112.345}{L}\right) + \left(\frac{689.340}{L^2}\right) - \left(\frac{282.237}{C}\right) + \left(\frac{3703.584}{C^2}\right) - \left(\frac{13841.125}{C^3}\right) + \left(\frac{15095.946}{C^4}\right) \quad (1)$$

It is found that for the above mentioned proposed design, Eq. (1) R squared value (1 - (Residuals sum of squares / Corrected sum of squares)) is found to be 0.97 which is more than 0.95. Hence it best fits the data obtained using nonlinear analysis. The experimental investigation has been extended for 25mm fiber length with 2% of SLS concentration. The proposed equation was validated with the help of the extended experimental study. The validation is shown in Table 4 below.

Table 4. Validation of design equation

Fiber length in mm	SLS Concentration in %	Experimental TS in Mpa	Predicted TS in Mpa
25	2	13.68	12.45

6. CONCLUSION

In this investigation, the effect of fiber length and SLS treatment of coir fiber on the tensile strength was studied. Conclusions from this study are as follows

- The SLS treatment of the coir fiber would remove the impurities like pectin, lignin in the fiber. On the other hand, a rougher fiber surface may result after the treatment. This would increase the adhesive ability of the coir fiber with the matrix in the fabricated composites, resulting in a greater tensile strength of the material.
- This study has confirmed that the length of the fiber increases with increase in tensile strength.
- The investigation showed that the higher concentration would deteriorate the fiber strength, the higher the concentration, the greater the damage to the fiber.
- When the alkali concentration was 10%, the decrease of the fiber strength may have played a major role as far as the composite tensile strength was concerned.
- The NaOH treatment reduces the fiber strength drastically as compared to the SLS treatment.
- After alkali treatment, the elongation at break of the composites increased. This result revealed that the ductility of the surface modified coir fiber had been improved.

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