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CHARACTERIZATION OF SINGLE COIR FIBER FOR PREPARING POLYMER MATRIX COMPOSITE

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ABSTRACT

In preparing polymer-matrix composites, natural fibers are widely used as “reinforcing agents” because of their biodegradable characteristic. Among various natural fibers, coir fibers (coconut fibers) are widely available and cheap in context to the economic condition of Bangladesh. The objectives of this current research are to characterize the single coir fiber by Fourier transform infrared (FTIR) spectroscopic analysis and scanning electron microscopy (SEM) and to study the mechanical properties of single coir fiber by conducting tensile tests. From FTIR analysis, characteristic peaks of the coir fibers, while quite compact and smooth surface of single fiber was found from SEM imaging. In mechanical characterization, tensile properties were measured by varying the span length (5, 10, 15, 25 and 35 mm) of fiber. It was found that, the Young’s modulus increased with increase in span length, whereas tensile strength and strain to failure decreased with increase in span length. This is due to the fact that, the longer the stressed distance of the natural fiber, the more inhomogenities will be in the stressed fiber segment, weakening the structure. The Young’s modulus values were found constant after correction using newly developed analytical equations.

Keywords: Natural Fiber (coir); Biodegradable; Tensile Properties.

1. INTRODUCTION

The term composite means “a substance, made up by mixing two or more distinct different substances”. In most cases mixing is done by physical process. In a few cases it is also done partly by chemical reaction. Composite materials (or composites for short) are engineered materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct on a macroscopic level within the finished structure. The fundamental goal in the production and application of composite materials is to achieve a performance that is not available from the separate constituents or from other materials. Polymer composites consist of one or more discontinuous phases embedded in a continuous-phase polymer matrix. The discontinuous phase, called reinforcements is usually harder and stronger than the continuous phase. The matrix can be classified as thermoplastic (capable of being separately hardened and softened by the decrease and increase of temperature respectively) or as thermoset (changing into a substantially infusible and insoluble material when cured by the application of heat or through chemical means).

Typical reinforcements for plastics are various synthetic fibers such as glass, graphite (carbon), boron, inorganic, metallic and ceramic materials. These materials are heavy, expensive and harmful to the environment. In preparing polymer-matrix composites, natural fibers are widely used as “reinforcing agents” because of their biodegradable characteristic.

Among various natural fibers, coir fibers are widely available and cheap in context to the economic condition of Bangladesh. Coir (From Tamil kayar, cord) is a coarse fiber extracted from the fibrous outer shell of a coconut. Coir is a lignocellulosic fiber obtained from the fibrous mesocarp of coconuts, the fruit of coconut trees (Cocos nucifera) cultivated extensively in tropical countries. It is used for making certain traditional products like furnishing materials, rope etc. which consume only a small percentage of the total coir production.

Natural fiber reinforced polymeric composites have recently attracted a considerable attention in the composite materials research community as well as in industry. This is due to a range of potential advantages of natural fibers (here, coir fibers), especially with regard to their environmental performance. Presence of large quantity of lignin (35-40%) makes these fibers rough and tough, brown and dark brown in colour. It possesses high weather resistance due to higher amount of lignin.The coir fiber is relatively water-proof and is one of the few natural fibers resistant to damage by salt water. They absorb water to a lesser extent compared to all the other natural fibers due to its less cellulose content. Also the fiber can be stretched beyond its elastic limit without rupture due to helical arrangement of micro-fibrils at 45^0. Coir fiber is biodegradable and recyclable, easily available and cheap, nonabrasive fiber and has no skin irritations. They are renewable resources and even when their composite waste is incinerated, they do not cause net emission of carbon dioxide to the environment (i.e. these materials are CO_2 neutral) [1]. Furthermore, these fibers are typically less abrasive than glass or carbon fibers. In recent years, wide range of research has been carried out on fiber reinforced polymer composites [2-10]. Natural fibers can not compete with the impressive properties of synthetic fibers such as carbon and glass fibers due to their low strength, but the use of natural fibers as reinforcement is increasingly replacing the conventional inorganic fibers in polymer matrix composites. The main objectives of the current work are to characterize coir fibers and determine their mechanical properties. The specific objective is to determine the actual Young's modulus and strain to failure from obtained experimental results.

2. EXPERIMENTAL PROCEDURE

2.1 Measurement of Fiber Diameter

The diameter of coir fiber was measured using a scanning electron microscope. The photographs are presented in the result and discussion section.

2.2 FTIR Spectroscopy

The infrared spectra of coir fiber were recorded on a Nicolet 380 spectrophotometer with co-addition of 32 scans. The infrared spectra of raw fiber were measured by scratching a fiber with a knife and collecting some powdered sample. Then potassium bromide (KBr), which acts as a reagent, was mixed (at a ratio KBr: Sample = 100:1) with them in a mortar pestle. The mixture was then taken in a dice of specific dimensions. The pellet was formed by pressing with a hand press machine and was placed on the sample holder. The IR spectrum obtained in this study is presented in the result and discussion section.

2.3 Tensile Test of Fibers

Initially the fibers (randomly taken) were cut down to particular lengths (5, 15, 25, 35 mm). The fibers were glued in between two paper frame (figure 1) to conform a good gripping and straight direction to the test clamps. This paper frame was clamped in the machine at top to bottom and cut the paper frame carefully (figure 2) before testing.

Tensile Testing was done using a Instron machine. The cross-head speed used for coir fibers was 4 mm/min with 50KN load cells. Tensile strength was calculated by using Eq. (1)

$$\sigma = \frac{F_{\max}}{A} \qquad (1)$$

Fig 1. Specimens for tensile test

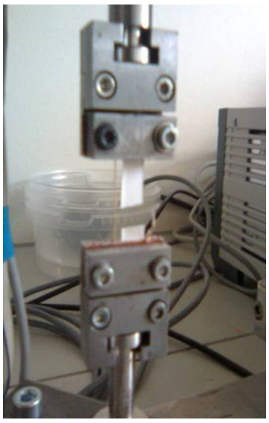

Fig 2. Specimen clamping system

Cross-sectional area was measured by using Eq. (2)

$$A = \frac{\pi}{4} d2 \qquad (2)$$

The Young's modulus was measured from the linear portion of the stress/strain curve. The Young's modulus was later corrected by using analytical equations.

Correction of tensile properties

$$L_{total} = \Delta L_{fiber} + \Delta L_{grip} \qquad (3)$$

$$\alpha_i = \frac{\Delta L_{\text{total}}}{F} - \frac{L_0}{E_0 \times A_i} \qquad (4)$$

$$\Delta L_{total} / F = \frac{e^* \times L_o}{\sigma^*_{\max} \times A_i} = \frac{1}{E_i} \times \frac{L_0}{A_i} \qquad (5)$$

$$E_i = \frac{\sigma^*_{\max} \times i}{e^*} \qquad (6)$$

$$\frac{\Delta L_{grip}}{L_0} = \frac{\alpha_i \times A_i \times \sigma^*_{\max}}{L_0} \qquad (7)$$

The corrected Young's modulus values are shown in the result and discussion section.

3. RESULTS AND DISCUSSION

3.1 FTIR Spectroscopic Analysis of Coir Fiber

The FTIR spectrum of raw coir fiber is shown in figure 3. The peak assignments of the absorption bands corresponding to various groups are summarized in Table 1, which are quite similar to the literature value [11-14].

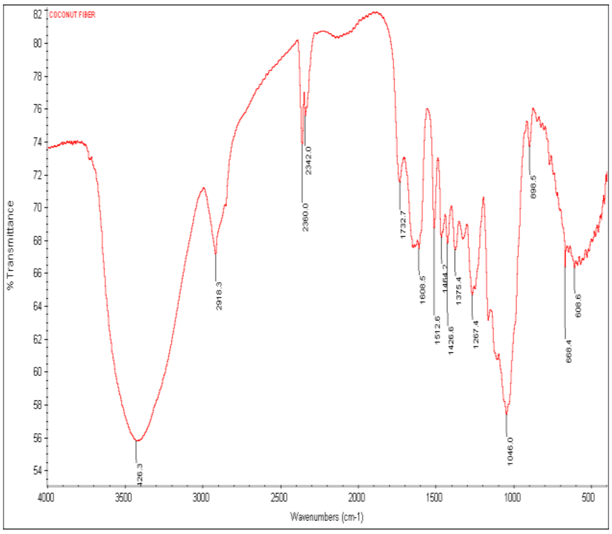

Fig 3. FTIR spectrum of coir fiber

Table 1: FTIR spectral data of raw coir fiber [11]

Position / cm	Possible Assignment
~3600-3200	ν (OH) broad, strong band from the cellulose, hemicellulose and lignin of coir
~3000-2900	ν (C-H) in aromatic rings and alkanes
~1732.7	ν (C=O) most probably from the lignin and hemicelluloses
~1608.5	ν (C=C) aromatic in-plane
~1512.6	ν (C=C) aromatic skeletal ring vibration due to lignin
~1464.2	δ (C-H); δ (C-OH) 1^0 & 2^0 alcohol
~1426.6	δ (C-H)
~1375.4	δ (C-H)
~1267.4	δ (C-OH) out-of-plane
~1046.0	ν (C-OH) 2^0 alcohol
~898.5	ν (C-O-C) in plane symmetric

3.2 Tensile Properties of Coir Fiber

Coir fiber has been characterized by evaluating the effect of variation of span length on tensile properties. The Young's modulus, strain to failure and tensile strength were measured for fifteen samples for each span length (5, 15, 25, 35 mm) with the help of stress/ strain curves. Stress/strain curves of coir fiber (5mm span) are shown in figure 4, while uncorrected extrapolated curves (1/span vs. the Young's modulus, strain to failure and tensile strength) for the span length of 5 mm, 15 mm, 25 mm and 35 mm of coir fibers are shown in figures 5 to 7 respectively. It seems that with an increase in span length, the Young's modulus increased. On the other hand, the tensile strength and strain to failure decreased with an increase in span length.

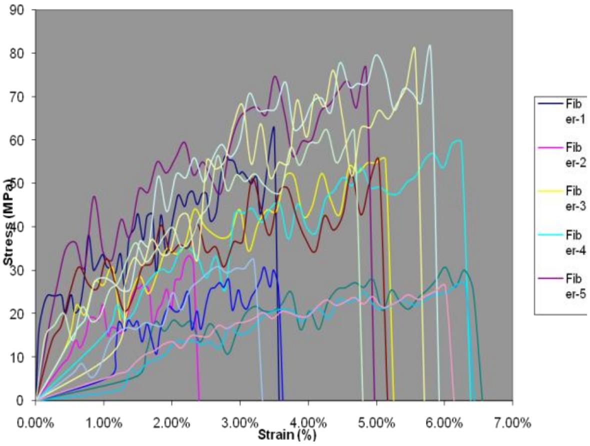

Fig 4. Stress vs. strain curves for fibers of 5 mm span length

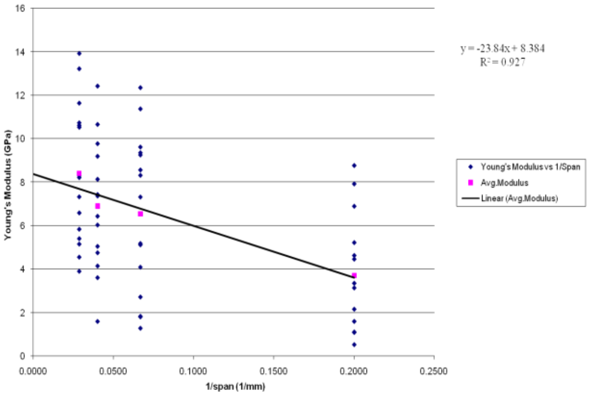

Fig 5. Young's modulus vs. 1/span length (Uncorrected)

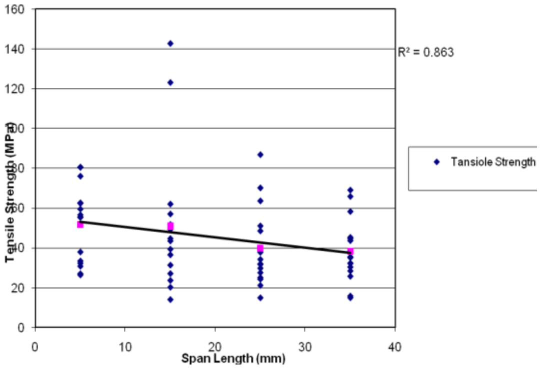

Fig 6. Tensile strength vs. span length (Uncorrected)

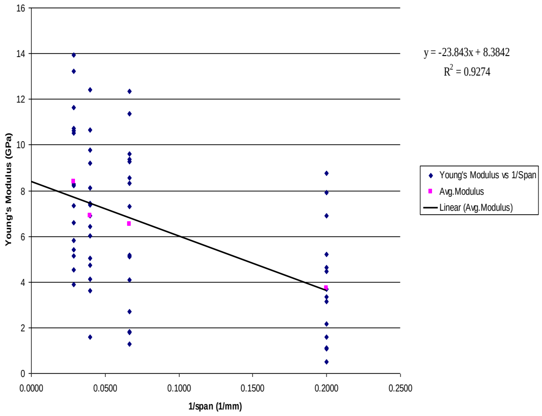

Fig 7. Strain to failure vs. span length (Uncorrected)

The Young’s modulus was corrected by using newly developed analytical equations (equations 3 to 7). The corrected Young’s modulus is plotted against span length as shown in figure 8. The corrected Young’s module values were almost constant with variation of span length.

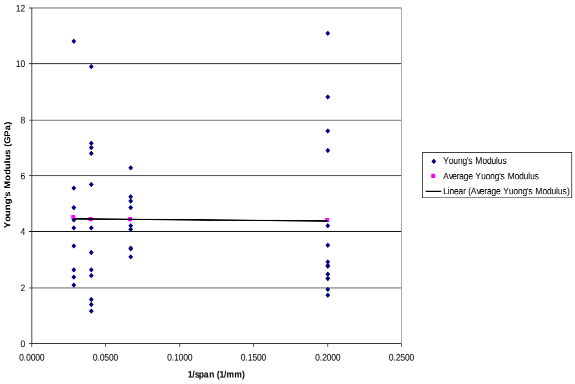

Fig 8. Young’s modulus vs. 1/span length (Corrected)

The Young’s modulus (uncorrected and corrected) values for various span lengths (5, 15, 25 and 35 mm) are shown in table 2.

Table 2: Comparison between corrected and uncorrected Young’s modulus and strain to failure

Span Length (mm)	**Tensile Strength** (MPa)	**Strain to Failure** (%)	**Young’s Modulus** (GPa)	**Corrected Young’s Modulus** (GPa)
5	51.456	5.01	3.707	4.386
15	50.689	2.23	6.543	4.412
25	39.960	2.20	6.897	4.433
35	34.178	2.05	8.395	4.490

As mentioned by Bledski and Gassan, the longer the stressed distance of the natural fiber, the more inhomogenities will be in the stressed fiber segment, weakening the structure [15]. Thus the strength decreased with clamping length. For the fiber modulus, however, the situation is reverse. As no extensometer can be used in current set-up and machine displacement is used for the modulus determination, at longer gauge lengths, the relative effect of slippage in the clamps will be smaller.

Netravali found the modulus for coir fibers to be 4-6 GPa [16]. Thus the experimental values found in current research are quite close to those found before.

3.3 SEM Morphology of Coir Fiber

To study the surface morphology of the coir fiber, scanning electron micrograph was taken. Figure 9 shows the structure of coir fibers respectively. It is observed that coir fiber had smooth and compact structure.

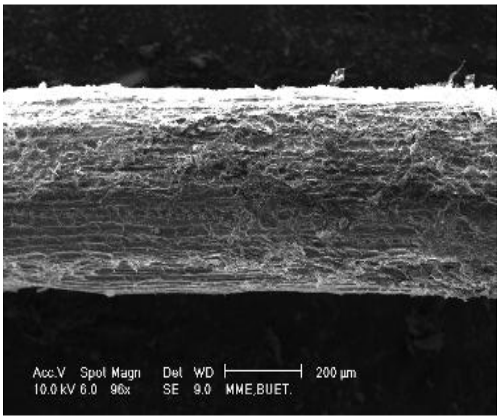

Fig 9. SEM image of coir fiber at Magnification 96×

4. CONCLUSION

In this present work, coir fibers were collected from local market and characterized using the microstructural analysis (Fourier transform infrared spectroscopy and scanning electron microscopy) and mechanical testing (Tensile testing). While performing the tensile tests, span length of the fibers was varied to achieve the effect of span length on the tensile properties of coir fibers.

From the experimental results of this study, the following conclusions have been drawn:

1. Young’s modulus remained constant with increase in span length of single coir fiber.
2. Tensile strength and strain to failure decreased with increase in span length of single coir fiber.
3. The surface of coir fiber was quite smooth.

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6. NOMENCLATURE

Symbol	Meaning	Unit
σ	Tensile strength	(MPa)
F_{max}	Maximum force	(N)
A	Cross-sectional area	(mm^2)
d	Diameter	(mm^2)
ΔL_{total}	Total displacement	(mm)
ΔL_{fiber}	Displacement due to fiber	(mm)
ΔL_{grip}	Displacement due to grip	(mm)
α_i	Machine displacement	
L_0	Original length of fiber	(mm)
A_i	cross-sectional area of each fiber	(mm^2)
i	1, 2, 3,………,n	
E_0	Extrapolated modulus	MPa
$\sigma_{max}{}^*{}_i$	Maximum stress for each fiber	MPa
e_i	Corresponding strain	

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