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Mechanical Properties of Coir Rope-Glass Fibers Reinforced Polymer Hybrid Composites

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***Abstract*—Natural fiber composites have been developed and taken more attention in the last decades. Coir fiber is the natural fiber which has been used as reinforcement of composites. This fiber is hybridized with glass fiber for reinforcement composite. In this paper, coir rope and glass fibers were combined as reinforcement into hybrid composites with unsaturated polyester resin as matrix. The composition of fibers and matrix into hybrid composites are used 30:70 (volume fraction) with unsaturated polyester. Volume fractions of coir rope mat and glass fiber mat in hybrid composites are 10:20, 15:15 and 20:10 respectively. The mechanical properties of the coir rope-glass fiber composite hybrid were described in this paper. Their properties include tensile strength, tensile modulus, flexural strength, flexural modulus, impact energy and impact strength. Fractography of tensile composite hybrid is also analyzed using Scanning Electron Microscope.**

***Index Terms*—coir rope, glass fiber, hybrid composite, volume fraction.**

I. INTRODUCTION

Synthetic fibers have been used as reinforcement composite because of their excellent mechanical properties compared to natural fibers. But, they have limitation of use due to their high production cost and environmental effect. Natural fibers have been developed as an alternative to change or combine synthetic fibers for reinforcing composite. The advantages of natural fiber are high specific strength and modulus, lightweight, low cost and easily available in many countries [1, 2,3]. One of natural fiber has been developed for reinforcing composite i.e. coir fiber. Coir fiber was evaluated its mechanical properties by Kulkarni et al. [4], Bakri and Eichhorn [5]. Its fiber has been used for reinforcing thermoset or thermoplastic in composite. Coir fiber was used as reinforcement in polyester composite by Prasad et al. [6]. They found increasing mechanical properties of composite due to alkali treatment. Monteiro et al. [7] studied randomly orientation of coir fiber as reinforcement polyester composite and found coir fiber/polyester composite are low flexural strength and modulus but it has potential for non-structural application. For variation of fiber content in composite, Jayabal and Natarajan [8] stated that mechanical properties non woven coir fiber composite are influenced by fiber content. Wambua et al. [9] found that coir fiber/polypropylene composite has lower mechanical properties than sisal, kenaf hemp and jute fiber composites, with the exception of the impact strength is higher than jute and kenaf composite. Coir reinforced epoxy composite was investigated by Harish et al. [10]. Their results show that all strength values (tensile, flexural and impact strengths) of coir/epoxy composite are lower than glass/epoxy composite laminate. From these, mechanical properties of coir composite are inferior to glass fiber composites. To solve this problem, hybridization of natural fiber and glass fiber as reinforcing composite has been done.

The study of hybrid composite has been investigated by researchers. Rout et al. [11] hybridized glass fiber mat and coir fiber mat for reinforcing polyester composite. They found that surface modified coir fiber using glass fiber improved flexural strength. Kumar et al. [12] studied mechanical properties of phenolic resin hybrid composite with coir/glass fiber as reinforcement related to fiber content and fiber volume fraction. They assessed the mechanical properties hybrid composite increased with increasing of glass fiber content. Then, woven coir/glass fiber reinforced polyester composite was carried out by Jayabal et al. [13]. They stated that incorporation of woven coir and glass fiber increased performance of composite than coir fiber as reinforcement of composite. Tensile strength of coir/glass fiber sandwich structure reinforced polyester composite is higher than coir/polyester composite. This is also similar for flexural strength increases when glass fiber woven as skin to coir/polyester composite [14].

This paper presents the mechanical properties of hybrid composite with coir rope and glass fiber mat as reinforcement. Coir rope as reinforcement composite has been performed by Yao et al. [15] which can improve tensile strength of composite. Tensile, flexural and impact tests were carried out to evaluate the mechanical behavior of coir rope-glass fiber mat reinforced unsaturated polyester hybrid composite. The tensile fracture was analyzed with scanning electron microscope.

II. METHODOLOGY

The following materials are used for hybrid composite including coir fiber, glass fiber and unsaturated polyester. Coir fibers were extracted from the husk of coconut shell. Prior to form coir rope fiber, fiber was soaked in 5% dilute solution of NaOH for 24 hours. Fibers was rinsed and followed by drying at room temperature during 2 days and oven drying for 2 hours at 100°C. The coir rope was made by hand and formed coir

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rope mat as shown in Fig. 1. Glass fiber mat (Fig. 2) and unsaturated polyester were purchased from local supplier.

Fig.1 Photograph of coir rope fiber mat

Fig. 2 Glass fiber mat

Hybrid composite was fabricated with 30% volume fraction of fiber and 70% volume fraction of matrix. Compositions of volume fraction of coir rope mat (C) and glass fiber mat (G) are 10:20, 15:15, and 20:10 (Table 1).

TABLE 1. COMPOSITION AND CODE OF HYBRID COMPOSITE

Sample Code	Coir rope volume fraction (%)	Glass fiber volume fraction (%)	Matrix volume fraction (%)
10C20G	10	20	70
15C15G	15	15	70
20C10G	20	10	70

Coir rope mat was placed as a core and glass fiber mat as a skin. Composite is molded by hand layup method followed by compression molding process using matrix of unsaturated polyester. Mechanical properties of hybrid composites were examined including tensile strength, flexural strength and impact strength. Tensile test was carried out using Universal Testing Machine with the ASTM 638-02 standard. The flexural test (three- point bend) was carried out according to ASTM D 790-02 standard and impact test with Charpy method used ASTM D 5942-96 standard. The fracture of tensile testing was observed using Scanning Electron Microscope (SEM).

III. RESULTS AND DISCUSSIONS

The tested mechanical properties of coir rope–glass fiber hybrid composite are shown in Table 2.

TABLE 2. MECHANICAL PROPERTIES OF COIR ROPE/GLASS FIBER HYBRID COMPOSITE

Sample Code	Tensile Strength (MPa)	Tensile Modulus (MPa)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Impact Energy (J)	Impact Strength (kJ/m²)
10C20G	110.4	895.3	287.4	8.8	10.0	165.5
15C15G	79.4	636.0	206.7	7.8	12.8	177.1
20C10G	51.7	501.6	223.9	8.1	8.9	116.5

The results of tensile strength and tensile modulus are plotted in Fig. 3 and Fig. 4 as a function of volume fraction of fibers (coir rope and glass fiber). The tensile strength reaches a maximum value of 110.4 MPa for 10C20G sample followed by 79.4 MPa for 15C15G sample and 51.7 MPa for 20C10G sample. The highest tensile strength of 10C20G sample is because of the higher content of glass fiber in hybrid composite than other samples. This is attributed to high strength of glass fiber than coir fiber.

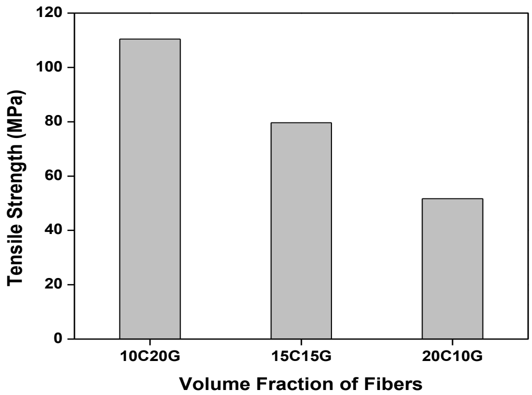

Fig. 3 Tensile strength of coir rope-glass fiber hybrid composite

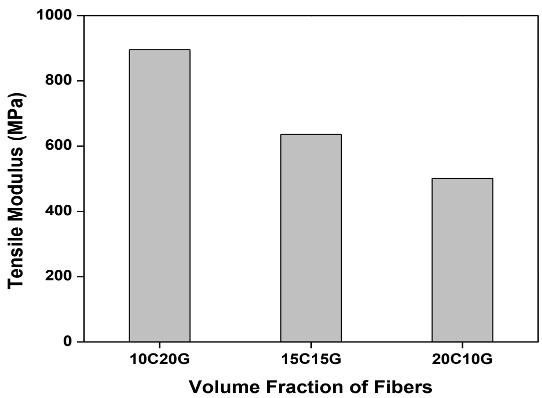

Fig. 4 Tensile modulus of coir rope-glass fiber hybrid composite

For tensile modulus, 10C20G sample showed higher value of modulus than other samples as shown in Fig. 4. This condition is similar investigation found by Kumar et al. [12] that tensile strength and modulus of coir/glass fiber hybrid composite increased with increasing of fiber glass content.

Fig. 5 shows the flexural strength of coir/glass hybrid composite as a function of volume fraction of fiber. It shows that flexural strength increases with increasing volume fraction of glass fiber in hybrid composite. The maximum flexural strength is 287.4 MPa for 10C20G sample (Table 2). This is because the high glass fiber as skin in hybrid composite and coir rope mat as core. Meanwhile, flexural modulus in Fig. 6 shows that sample of 10C20G is also the highest value compared to other samples. This value is 8.8 GPa (Table 2). The condition of flexural modulus is similar case in the flexural strength of hybrid composite.

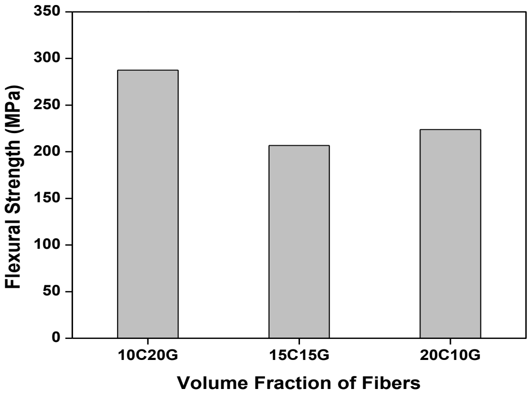

Fig. 5 Flexural strength of coir rope-glass fiber hybrid composite

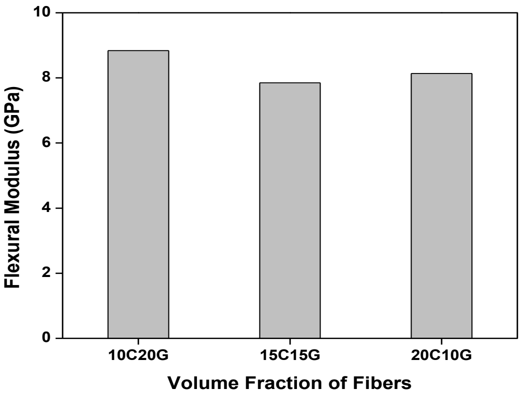

Fig. 6 Flexural modulus of coir rope-glass fiber hybrid composite

For Charpy's impact test, impact energy and impact strength were evaluated as shown in Fig. 7 and Fig. 8. The highest impact energy and impact strength are 12.8 J and 177.1 kJ/m² respectively for 15C15G sample (Table 2). Meanwhile, 20C10G sample is the lowest both impact energy and impact strength, that is 8.9 J and 116.5 kJ/m². This may be caused by poor interface bonding [13] and delamination in coir rope and glass fiber mat or between coir rope and glass fiber mat layer.

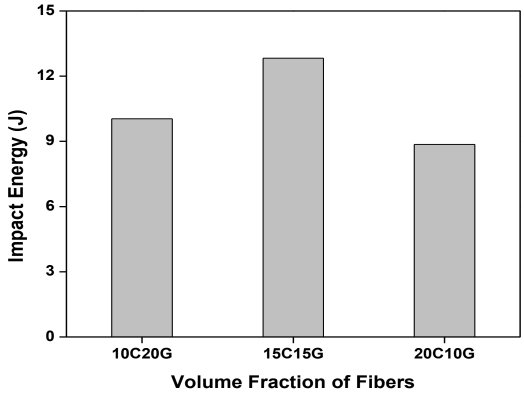

Fig. 7 Impact energy of coir rope-glass fiber hybrid composite

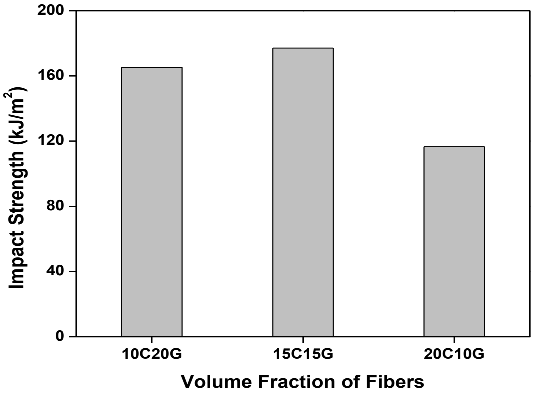

Fig. 8 Impact strength of coir rope-glass fiber hybrid composite

Scanning electron microscopy images of coir rope-glass fiber hybrid composite are shown in Fig. 9 and Fig. 10 for evaluating tensile fracture after tensile test. In Fig. 9, SEM image of 10C20G sample shows some voids on matrix surface, fiber pull-out and breakage of matrix. Harish et al. [10] state that some voids on matrix surface are caused by fiber pull-out. which indicates a low interfacial bonding between fiber and matrix. These influenced the tensile strength and modulus of the coir rope-glass fiber hybrid composite. These also occur in sample of 20C10G in Fig. 10.

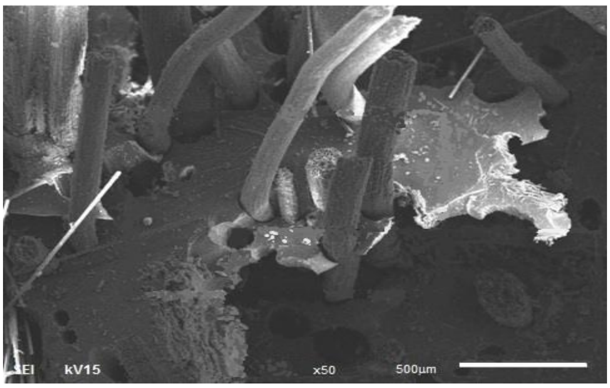

Fig. 9 SEM image of 10C20G sample of hybrid composite after tensile test

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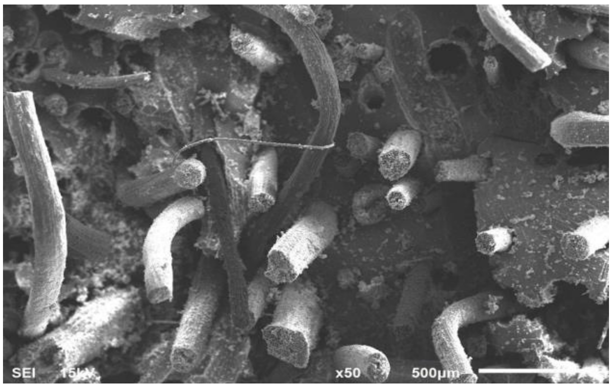

Fig. 10 SEM image of 20C10G sample of hybrid composite after tensile test

IV. SUMMARY

The mechanical properties of coir rope and glass fiber as reinforcement in polymer hybrid composite can be summarized as follow:

(1). Tensile strength and tensile modulus increased with increasing volume fraction of glass fiber in hybrid composite. The highest strength and modulus are 110.4 MPa and 895.3 MPa for coir /glass fiber at 10:20 volume fraction.

(2). The maximum flexural strength and modulus strength of hybrid composite are 287.4 MPa and 8.8 GPa respectively for volume fraction of fiber coir (10%) and glass fiber (20%).

(3). For impact energi and impact strength, 15C15G is higher than 10C20G and 20C10G that is 12.8 J and 177.1 kJ/m² respectively.

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