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Cover Page Footnote
The authors would like to thank all the staff members of the Department of Printing Technology, College of Engineering, Anna University, for the help rendered in the research activities.

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RESEARCH ARTICLE

Mechanical Characterization of Coir Fiber and Cotton Fiber reinforced Unsaturated Polyester Composites for Packaging Applications

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ABSTRACT

The aim of this work is to develop a natural fiber composites that can become a substitute for plywood and medium density fiber boards used in packaging application. In this work, the composite was fabricated with randomly oriented chopped coir and cotton fiber reinforced with unsaturated polyester resin. The different types of composite materials were prepared with different quantity of coir fiber and cotton fiber reinforced with unsaturated polyester by using hand lay-up technique. Mechanical properties such as tensile, flexural and impact strength are evaluated. Scanning Electron Microscope (SEM) was conducted on the fabricated composite to analysis the interfacial properties, internal cracks and internal structure of the fractured surfaces. Based on the results, cotton fiber reinforced with unsaturated polyester has better mechanical properties to be used for packaging applications compared with other combinations of coir/cotton fiber reinforced with unsaturated polyester.

KEY WORDS: *Composites, Unsaturated polyester, Cotton fiber, Coir fiber, Mechanical properties*

1.0 INTRODUCTION

A package has to protect a product during distribution, storage, sale and use. Packaging is a coordinated system of preparing goods for transport, warehousing, logistics, sale and end use. Hence, the materials employed to contain, handle, protect, and/or transport an article has to be given much of importance when designing a package. When products that are delicate are to be packed and moved, special precautions should be observed as they may break or crack when mishandled. Hence the case for packing should be specially engineered to handle in the safest and in the most practical way.

In most of the packaging applications, conventional materials such as metal or plastic are used as a package medium. These materials are mostly non-degrading generating environmental problems. In recent years researchers and academician are concentrating more on the utilization of natural fibers in polymer composites instead of conventional materials due to their ecofriendly nature and sustainability.

Natural fibers such as jute, coir, cotton, sisal, etc. are available in abundant which leads to the development of natural fiber composites. Natural fibers such as cotton and coir fiber have been used since past years in large variety of products ranging from clothes to household applications. These natural fibers can be recycled and hence it is environmentally friendly and has biodegradability. Composites prepared using natural fibers have many advantages like low density, low cost, high toughness, reasonable specific strength and biodegradability [1].

Coir fiber finds its application in producing novel composite due to its high strength and modulus properties [2]. The application of coir, a natural fiber used in composite for aerospace applications has been studied [3]. Cotton is the shortest commercial textile fiber and makes up just under half of all the fiber sold in the world. Cotton fiber is also used to produce composites by reinforcing them with resins. Unsaturated polyester, a popular thermoset polymer is used in preparing the composites. The polyester possess many advantages compared to other thermosetting resins including room temperature cure capability, good mechanical properties and transparency. Unsaturated polyester, a resin does not form any byproducts during the curing reaction; hence at low pressure and temperatures, resins can be molded, casted and laminated [4].

In previous studies, cotton fibers with polyester and coir fiber with polyester were investigated separately. In this study, combination of coir fiber and cotton fiber reinforced with unsaturated polyester resin is used to fabricate the composite, to enhance its mechanical properties suitable for packaging applications. A thorough study of the mechanical properties such as tensile, flexural and impact strength is carried out on the prepared composites and investigated. Results of Scanning Electron Microscope (SEM) are also examined in order to understand the interfacial properties, internal cracks and internal structure of the fractured surfaces of the composites. The fabricated Unsaturated Polyester/Natural Fiber Composites can be used for Packaging Applications.

2.0 MATERIALS PREPARATION

Coir fiber was collected from local coir processing unit (Nagercoil, Tamil Nadu, India). Cotton fiber was supplied by cotton processing industry (Coimbatore, Tamil Nadu, India). Unsaturated polyester resin and methyl- ethyl-ketone catalyst was purchased from Sakthi fibers (Chennai), sodium hydroxide in crystal form and suitable mould release agent was obtained from local supplier.

Chemical treatment was carried out by treating the coir fibers with 5% concentration of sodium hydroxide solution for 1hr at room temperature followed by washing it with distilled water. Washing the coir fibers was continued till the fibers were alkali free and later on the fibers was dried under natural sunlight with temperature 30ºC for 24 hrs [5,6]. The cotton fiber contains dirt and foreign materials and to clean the fiber, cotton is dried in room temperature. The treated coir and cotton fiber are shown in Figure 1

Figure 1: Treated coir (left) and cotton fiber (right)

The fabrication of the different types of composite materials is carried out through the hand lay-up technique [7]. The mould used for preparing composites is made from two rectangular glass

plates having dimensions of 300 x 300 mm. Four beadings were used to maintain a 3 mm thickness all around the mould plates. The functions of these plates are to cover, compress the fiber after the unsaturated polyester is applied and also to avoid the debris from entering into the composite parts during the curing time. [8, 9,10]

To fabricate a composite, unsaturated polyester resin (GP-7150) is mixed with methyl- ethyl-ketone, a catalyst [7]. The weight ratio of mixing unsaturated polyester and catalyst was 10:1 [11, 12] For fabrication, initially the coir/cotton fibers were weighed and laid uniformly over the mould and compressed for a few minutes. Then the compressed form of fibers is removed from the mould.

Table 1: Fibers and Resin Percentage

Sample No.	Resin Content (%)	Fiber Content (%)	
	Polyester	Coir	Cotton
1	80	20	0
2	80	16	4
3	80	12	8
4	80	8	12
5	80	4	16
6	80	0	20

The moulds are cleaned and dried for the removal of foreign particles followed by the application of releasing agent (PVOH). To prepare the composite, the mould was coated with unsaturated polyester over which the compressed fiber was laid, ensuring uniform distribution of fibers. The unsaturated polyester mixture is then poured into the fibers uniformly and kept under compression for a curing time of 24hr. After the curing process, test sample was cut to the required size prescribed in the ASTM Standards [11,13]. By following the same procedure, the different types of composite materials was made with different quantity of coir and cotton fiber reinforced with unsaturated polyester as shown in Table 1. The composite samples with different combinations of coir, cotton and unsaturated polyester resins are shown in figure 2.

(a)

Figure 2a: Coir-Unsaturated Polyester Composite

(b)

Figure 2b: Cotton-Unsaturated Polyester Composite

(c)

Figure 2c: Coir-Cotton-Unsaturated Polyester Composite

2.1 Test Methods

Prepared natural fiber with unsaturated polyester composite materials were analyzed to different mechanical tests as per ASTM Standard methods. The standards followed were ASTM D 3039/ D3039M, ASTM D790-03, ASTM D25605 and ASTM D785-08 for tensile, flexural, impact and hardness tests respectively.

3.0 RESULTS AND DISCUSSION

In the present work natural fibers such as coir and cotton fiber reinforced with unsaturated polyester resin is used to prepare composite materials and their effect on mechanical properties is evaluated and their properties are compared. The test results of tensile, flexural and impact strength for composite samples are presented in Table 2.

Table 2: Mechanical Properties of different composite samples

Sample No.	Tensile strength in MPa	Flexural strength in MPa	Impact strength in Joules
1	17.92	9.78	2
2	20.13	10.51	2
3	21.81	10.94	2
4	22.61	14.66	4
5	26.97	14.70	4
6	30.97	15.90	4

3.1 Tensile test result

Six different types of composite samples are tested in Tinius Olsen universal testing machine. Samples are left to break till the ultimate strength occurs. The figure 3 shows the variations in tensile strength of different samples. From the chart it was found that cotton-unsaturated polyester composite sample gives better tensile strength of 30.97 MPa compared with other combinations of cotton-coir-unsaturated polyester composites. Tensile strength of the fabricated composite material increases linearly with addition of cotton fiber.

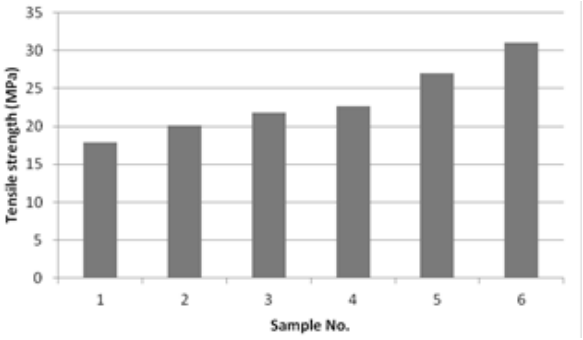


Figure 3: Tensile strength comparison of different composite materials

3.2 Flexural test result

Universal testing machine (Tinius Olsen) model is used to test the flexural strength of the composites. Six different composite samples are tested and the graphs generated for flexural strength is shown in figure 4.

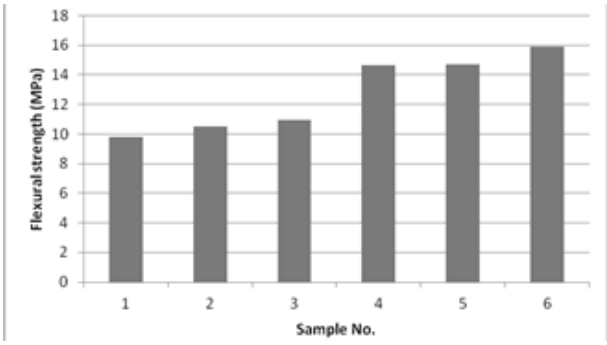


Figure 4: Flexural strength comparison of different composite material

Cotton-unsaturated polyester composite sample gives better flexural strength of 15.90 MPa compared with other different combinations of cotton-coir-unsaturated polyester composites as shown in the graph. Higher flexural strength is found in composite material with high amount of cotton and low amount of coir fiber.

3.3 Impact test result

In order to find the impact capability of samples, impact test is carried out using charpy impact machine. Absorbed energy obtained for six different composite samples from the charpy impact test is show in figure 5.

From the result it is found that maximum impact strength of 4 joules is obtained for cotton-unsaturated polyester composites compared with other coir-cotton unsaturated polyester composites. The more the percentage of cotton fiber with coir fiber and unsaturated polyester, better the impact strength.

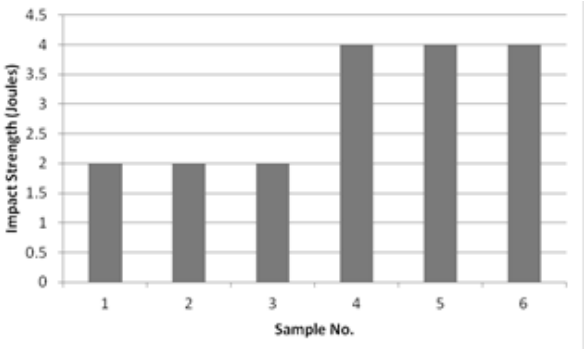
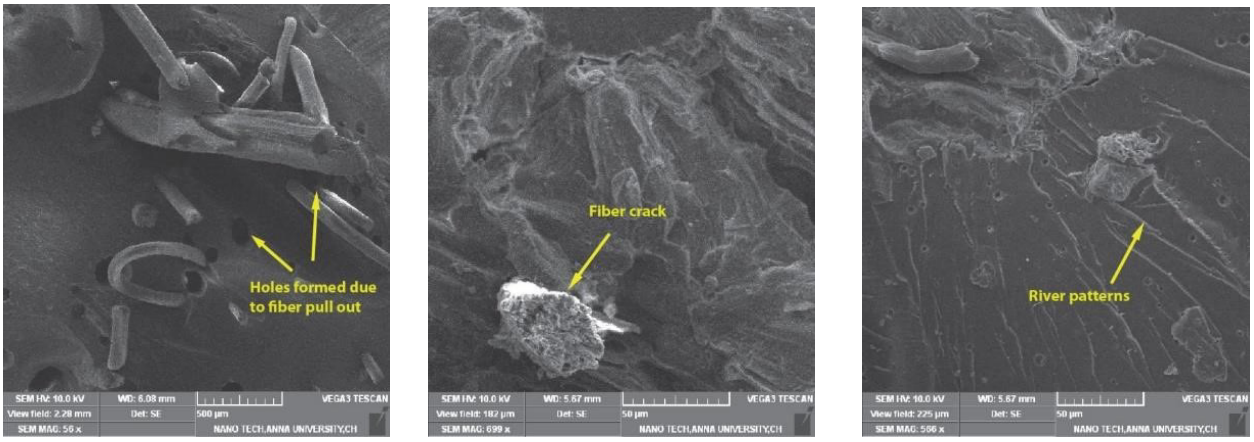
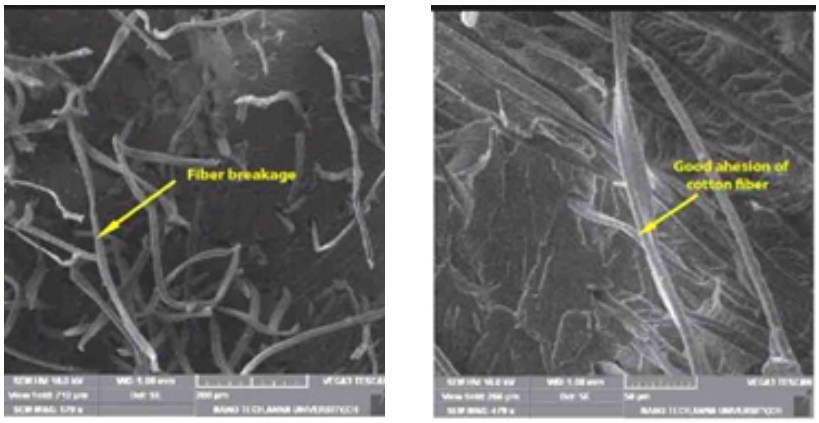


Figure 5: Impact strength comparison of different composite materials



(a) *(b)* *(c)*

Figure 6 (a) (b) (c): SEM images of coir-unsaturated polyester composite sample after tensil fracture



(a) *(b)*

Figure 7 (a) and (b): SEM images of cotton-unsaturated polyester composite sample after tensile fracture

3.4 Scanning Electron Microscopy (SEM) analysis

Scanning electron microscopy analysis was conducted to investigate the interfacial properties, internal cracks and internal structure of the fractured surfaces on the fabricated composite samples. All the composite materials which are subjected to tensile load are taken for the SEM analysis. The samples are coated with conducting material before the SEM analysis. The SEM images of the composite materials are shown in Figure 6, Figure 7 and Figure 8.

From the figure 6 (a-c), it is seen that, the coir fibers are detached from the unsaturated polyester resin surface, the fibers are also pulled out, many holes are seen from fractured surface and cracks have been propagated through the resin matrix and presence of river patterns near the fiber surface. The SEM results indicate the poor interfacial bonding of the coir fibers with the resin.

Cotton fibers have a good adhesion with the resin and it is observed from the SEM analysis shown in figure 7 (a-b). Cracks developed in the matrix are due to stronger interaction of fiber with the resin. The mechanical behaviors of cotton/unsaturated polyester composite sample are superior compared to other combinations of coir/cotton/unsaturated polyester because of their good interfacial bonding.

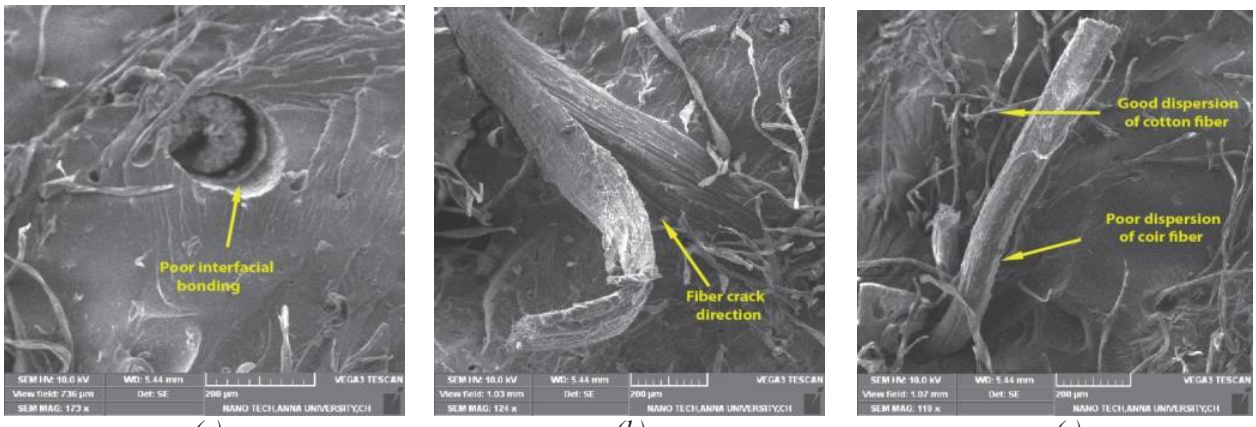
The SEM image of the cotton-coir- unsaturated polyester composites material which subjected to tensile load is presented in figure 8 (a-c). It was observed that, there was poor dispersion of coir fiber and good dispersion of cotton fiber in the matrix. It is also seen that the fibers are fractured and pulled out from the matrix. It has better mechanical strength compared to coir/unsaturated polyester and inferior to cotton/unsaturated polyester.

In case of coir fiber composite, fiber pull out is evident from SEM image. The adhesion between cotton-polyester is better than coir-polyester composite. Hence, it resulted in improved tensile, flexural and impact strength.

4. CONCLUSION

Coir-Cotton-Unsaturated Polyester composite materials are fabricated and the samples are subjected to mechanical testing such as tensile, flexural, impact and hardness strength. Based on the test results, the following conclusions are obtained.

- The cotton-unsaturated polyester composite material show the maximum tensile strength of 30.97 MPa when compared with the other combinations of coir-cotton-unsaturated polyester. Tensile strength of the fabricated composite material increases linearly with addition of cotton fiber.



(a) *(b)* *(c)*

Figure 8 (a) (b) (c): SEM images of coir-cotton - unsaturated polyester composite sample after tensile fracture

- The cotton-unsaturated polyester composites sample are capable of having maximum flexural strength of 15.90 MPa with a displacement of 1.50 mm and Force 124 N. Higher flexural strength is found in composite materials with high amount of cotton and low amount of coir fiber.

- The maximum impact strength of 4 joules is obtained for cotton-unsaturated polyester composite material. The more percentage of cotton fiber with coir fiber and unsaturated polyester, increases the impact strength.

- The interfacial properties, internal cracks and internal structure of the fractured surfaces of the tested composite samples are observed using Scanning Electron Microscope.

- It is concluded that composite material fabricated with cotton fiber and unsaturated polyester has better mechanical strength compared with other combinations of coir-cotton fiber reinforced with unsaturated polyester and can be used in packaging applications.

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