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Effect of relative content on mechanical properties of coir and Napier grass fibers reinforced hybrid polyester composites

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ABSTRACT

Composite materials have been employed major part in current era for its light weight, good stiffness, high specific strength and flexible nature. In this research, The hybrid composites of unsaturated polyester based Coir/Napier grass hybrid fiber are prepared. The hybrid composites were prepared in the following proportion of Coir/Napier grass 100:0, 75:25, 50:50, 25:75 and 0:100 ratios whereas overall fibre weight ratios were maintained at $0.4W_f$. Coir/Napier grass fibers are united in the same matrix (unsaturated polyester) to prepare hybrid composites and the tensile, flexural and impact properties are studied experimentally. A significant improvement in tensile, flexural and impact properties of Coir/Napier grass fiber hybrid composites is found. The morphology of coir/Napier grass fiber hybrid composite was investigated using scanning electron microscope.
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1. Introduction

Much work has been done in the application of natural fibre as reinforcement in polymer composites. Napier grass is abundantly cultivated in India as cattle feed. So Napier grass fiber can be explored as a potential reinforcement in polymeric composites. It has been reported that Jute fiber composite have better strength than wood composites [1]. The tensile, impact, flexural properties and aging behavior of short banana fiber reinforced polyester composites with special reference to the effect of fiber length and fiber content has been studied [2]. Maximum tensile strength was perceived at 30 mm fiber length while impact strength gave the maximum value for 40 mm fiber length. Incorporation of 40% untreated fibers gave a 20% increase in the tensile strength and a 341% increase in impact strength.

The mechanical and thermal properties of composites prepared with locally produced hemp fibers, were compared with composites made with hemp fibers produced in France [3]. The curaua fibers has been considered as an alternative for glass fibers in the reinforcement of thermoplastics, especially in automotive devices, due to its excellent specific mechanical properties [4]. The fibre structure variation during the processing of a polypropylene matrix reinforced with cellulose flax pulp for different reinforcement concentrations were analyzed [5]. The structural characteristics and mechanical properties of coir fiber/ polyester composites were evaluated [6]. New natural fibers used as fillers in a polymeric matrix enabling production of economical and lightweight composites for load carrying structures was introduced [7]. The tensile and flexural strengths of coconut spathe-fiber reinforced epoxy composites has been studied and analyzed the possibility of using it as a new material in engineering applications [8]. Some researches were performed on Hybrid composites reinforced with natural fibers, very often combined with synthetic fibers such as glass fibers, demonstrated good mechanical performance [9–11]. The potentiality and feasibility of using bagasse fiber as geotextile products were investigated [12]. More recently the anatomical features, thermal, moisture absorption, and tensile strength properties of sugarcane rind flakes with wood flakes were compared [13]. The processing methods for extracting sisal fibres has been described [14,15].

a classical volumetric method has been devised using ethanol as a solvent for density determination of flax fiber [16]. Rice straw composites were formulated up to the volume fraction of 40% and found the mean tensile strength as 46 Mpa [17]. The tensile, flexural and impact properties of the non woven coir fiber

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reinforced composites with various fiber lengths and fiber contents were studied [18]. The sisal, jute and coir fiber reinforced composites with unsaturated polyester/epoxy resin were prepared and analyzed the various properties [19]. The strain-to-failure of sisal fibers was decreased from 5.2% to 2.6% when the gauge length was increased from 10 mm to 40 mm [20]. The mechanical behavior of short henequen fibers were analyzed [21]. Studies with the fiber Hildegardia populifolia were performed. The sugar cane leaf fibres reinforced polymer composites were prepared. The tensile and flexural properties of the laminated composited were studied and compared with other natural fibre reinforced composites [22]. The first natural-fibre-reinforced composites were developed with the thermoset matrices, such as unsaturated polyester or phenolic resins, together with sisal and jute [23,24]. Natural fibres are now considered as good alternative to synthetic fibres for use in various fields [25]. The natural fibers possesses the high specific strength properties, light weight, ease of separation, high toughness, low density, low cost, good thermal properties, than glass fibre, carbon fibre etc [6]. Many researchers in the past have developed composites using natural fibers such as coir [26,27]. The coir fibre and the reinforcement of polymer has been reported. Dynamic mechanical behavior of natural rubber and its composites reinforced with short coir fibres has been studied [28]. The chemical modification of jute fibre using fatty acid to confer hydrophobicity and resistance to biofibres were performed [29]. The mechanical properties of polymeric composites reinforced with short fibres depend on several factors which determine the surface area available for transmission of stresses from the matrix to the fibres [30].

The present paper predicts the mechanical properties such as tensile, flexural and impact properties of Coir/Napier grass hybrid composite. The composition of the Coir/Napier grass was varied keeping the total fiber weight fraction as constant. This study provides value addition to the agriculture waste such Napier grass and coconut coir.

2. Materials and methods

2.1. Matrix

Unsaturated polyester is a thermosetting polymer that cures when mixed with hardener. Polyester resin of the grade was used as matrix. The properties of polyester resin is shown in Table 1.

2.2. Coir and Napier grass fiber

Coconut coir is a lingo-cellulosic natural fiber. Coir fibers comprise more lignin and less cellulose than other fibers such as flax and cotton. The coir fibers are extracted manually from the coconut after soaking the husk in water. The Napier grass fibers used in this study were obtained from a farm located in the city of Erode in the southeast state of Tamil nadu, India. The Napier grass fibers were extracted from grass inner nodes manually and by water retting process. They were hammered by a mallet and was rinsed in water thoroughly. Fig. 1 shows the extracted napier grass and coir. The extracted fiber was dried in sunlight for 48 h to remove the moisture content. The properties of coir and napier grass fibers are given in Table 2.

2.3. Preparation of composites

A steel mould having dimension 300x300x3 mm was used to prepare the composite plate with thickness of 3 mm. The untreated Napier grass fibers were cut for the dimensions of 100 mm length. The total fiber content was maintained as 40% in weight percentage in hybrid composite. The ratio of coir and Napier grass fiber was varied as 100:0, 75:25, 50:50, 25:75 and 0:100 ratios in each

Fig. 2. Tensile test specimen.

Table 1
Polyester resin properties.

Properties	Specific Gravity	Density	Tensile strength	Tensile modulus	Compressive strength	Flexural strength	Flexural modulus	Shrinkage
Values	1.1–1.46	1125 kg/m^3	18 MPa	0.8–1.1 GPa	90–250 MPa	1.2–1.5 MPa	1.2–1.5 GPa	0.004–0.008%

Fig. 1. Napier grass and coir fiber.

Table 2
Napier grass and coir properties.

Properties	Density	Diameter	Mean tensile strain	Average tensile modulus	Tensile strength	Cellulose
Napier grass	817.53 kg/m^3	70–400 μm	2.50%	7.40 Gpa	185 MPa	
coir	1150 kg/m^3	100–460 μm			131–175 MPa	36–43 (wt %)

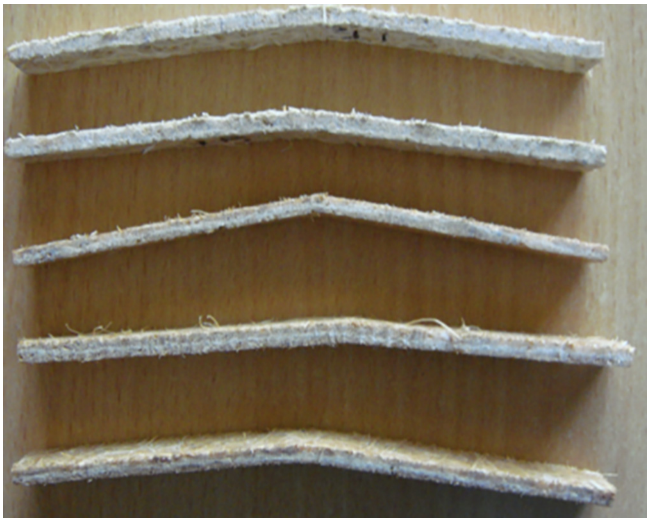

Fig. 3. Flexural test specimen.

Fig. 4. Impact test specimen.

fiber loading arrangement. Simple hand layup method was followed to prepare the specimen for experimental testing. The balance of the mixture was made up of the unsaturated polyester resin, always to give a total weight batch size of 100%. First Poly vinyl acetate release agent was applied to the surfaces mold. The unaligned coir and Napier grass fibers were pre-impregnated with the matrix material consisting of unsaturated polyester resin, cobalt octoate accelerator, and MEKP catalyst in the ratios required. After four hour, the composite laminates were removed from the mold and cured at room temperature.

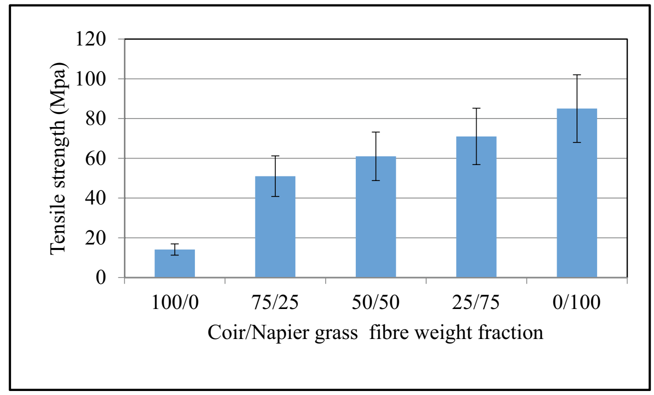

Fig. 5. Tensile strength of composite specimen.

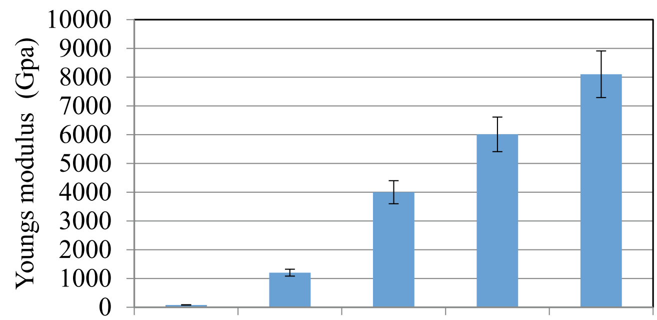

Fig. 6. Tensile modulus of composite specimen.

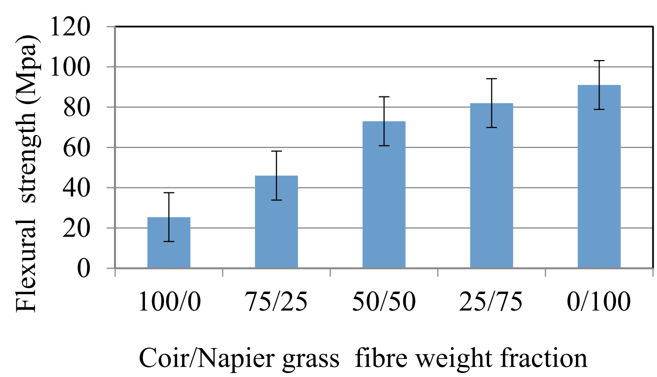

Fig. 7. Flexural strength of composite specimen.

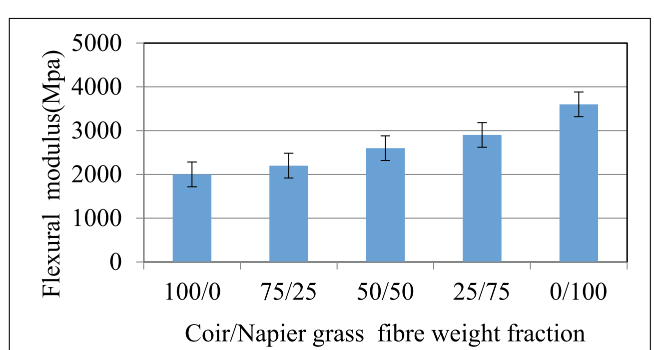

Fig. 8. Flexural modulus of composite specimen.

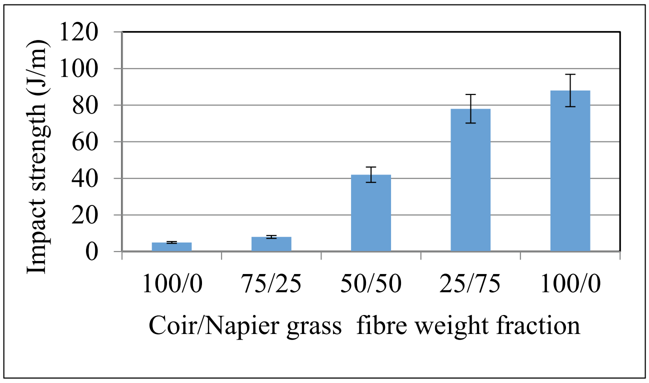

Fig. 9. Impact strength of composite specimen.

2.4. Tensile, flexural and impact testing

The tensile properties of coir/Napier grass fiber composites were determined by INSTRAN 5500 R-60211 machine at 40 ± 2% RH and 20 ± 1 °C temperature with cross head speed of 5 mm/min as per ASTM D638-08. The dimensions of the sample were 165x25x3 mm. five identical specimens were used for testing and average result was derived. The photograph of tested specimens after tensile fracture is shown in Fig. 2. Flexural properties of the composite specimens were measured at 23 °C according to the ASTM D790 at a speed of 1.4 mm/min. Five identical specimens were used for testing, and average result was calculated. Fig. 3 shows the flexural test specimen after testing. The impact test was carried out according to ASTM D256 standard. The impact tested specimens are depicted in Fig. 4.

3. Results and discussion

3.1. Tensile properties

Fig. 5 depicts the tensile strength of the hybrid composites. By testing the samples, it was found that for 100/0, 75/25, 50/50, 25/75 and 0/100 of hybrid composites the tensile strength were 14.1 MPa, 51 MPa, 61Mpa, 71Mpa and 85 MPa respectively. From the Fig. 5, it is clear that the tensile strength of the coir was enhanced nearly 4 times due to the addition of higher strength fiber Napier grass.

The Young's modulus values of coir/Npier fiber reinforced polyester composites for different fiber loading are shown in "Fig. 6". From the Fig. 6 is observed that the young's modulus was increased from 78 Mpa to 4000 Mpa when hybridization of coir was done with the napier grass fiber.

3.2. Flexural properties

The Flexural strength of hybrid composite is shown in Fig. 7. Here also the coir fiber composite flexural strength was increased from 25.4 Mpa to 73Mpa.

The Flexural modulus of hybrid composite is shown in Fig. 8. Here also the coir fiber composite flexural modulus was increased from 2001 Mpa to 2600Mpa.

3.3. Impact properties

The Impact strength of hybrid composite is shown in Fig. 9. Here also the coir fiber composite impact strength was increased from 5 J/m to 42 J/m.

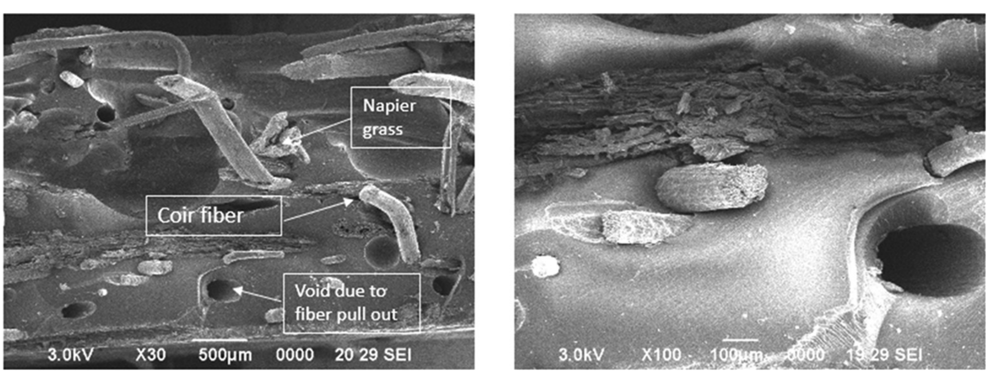

Fig. 10. SEM image of tensile specimen.

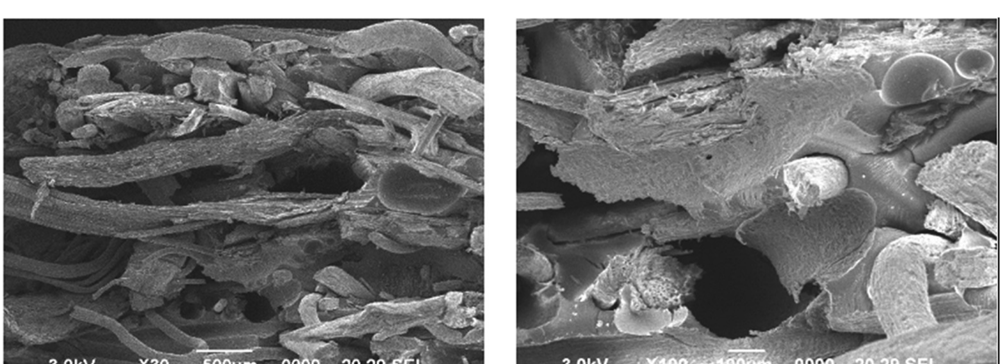

Fig. 11. SEM image of flexural specimen.

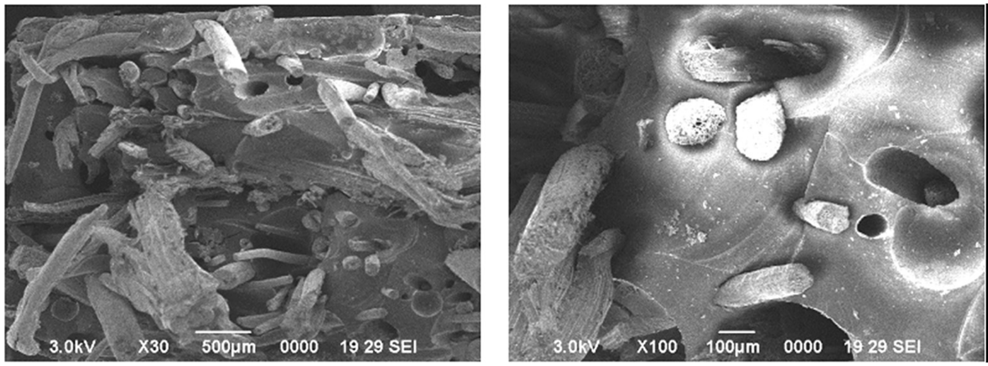

Fig. 12. SEM image of impact specimen.

4. Fractography

The surface morphology of the Coir/Napier grass fiber composite was studied by scanning electron microscopy (SEM). Fig. 10 shows the fractured surface of the hybrid composites from tensile tested specimen. From all these pictures, it is evident that fiber pullout can be observed, resulting in a poor bonding between the fiber and matrix. When the interfacial bonding is poor, the mechanical properties of the composites will be lesser. It can also be witnessed from the Fig. 10 that, no matrix followed to the surface of pulled out fiber, representing the incompatibility between matrix and fiber.

Fig. 11 shows the fractured surface of the hybrid composites from flexural tested specimen. Fig. 12 shows the fractured surface of the hybrid composites from impact tested specimen.

5. Conclusion

This study has proved that the mechanical properties of coir fiber reinforced composites can be effectively enhanced by hybridizing it with Napier grass fiber. In the present work, coir and Napier grass hybrid fiber reinforced polyester composites were fabricated. The level of fiber loading was maintained at 30 wt% with coir/Napier ratio varied as 100/0, 75/25, 50/50, 25/75 and 0/100. The tensile strength of the composites increased with an increase in Napier grass fiber loading. The Young's modulus also increased with Napier grass fiber loading. Flexural strength, flexural modulus, impact strength values increased with an increase in Napier grass fiber loading. Scanning electron microscopic analysis revealed strongest adhesion between the fiber and matrix. Basically these composite can be further altered by treatment of the fiber.

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