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Technical Report

Development of coir pith/nylon fabric/epoxy hybrid composites: Mechanical and ageing studies

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ABSTRACT

The coir pith epoxy composites were hybridized with nylon fabric/epoxy resin by hand lay up technique followed by compression moulding. A set of composites of same composition having chemically treated coir pith was also prepared. Mechanical properties of composites such as tensile strength, flexural strength, impact strength and hardness were evaluated. Though coir pith acts as a good reinforcement in epoxy resin, the incorporation of nylon fabric and the chemical treatment of coir pith were found to enhance the properties of the composites further. Chemical resistance and flame resistance of composite systems were also found to be improved with hybrid composites. Since water uptake and retentions property of coir pith is a major drawback when it comes to its application in composites, the ageing of composite panels in moist environment was investigated. The results suggested that the presence of nylon fabric and chemically treated pith can contribute to longer durability of the panels in moist conditions.

1. Introduction

The use of lignocellulosic materials as reinforcing fillers in polymeric products has increased recently. These natural fillers are eco-friendly, have low density, low-cost, non-abrasive in nature and are biodegradable. Sisal [1], banana fiber [2], cotton [3], flax [4], hemp [5], jute [6] and ramie [7] have been well recognized as reinforcements for natural filler composites. Most of these fillers are categorized under agro wastes and their disposal is a huge responsibility for the government. They pose severe environmental pollution problems and occupy fertile useful land. Therefore developing engineering end use such as building materials and structural parts out of these materials has become a requirement. Application of agro-wastes as particle boards, thermal insulators, building material composites/bricks, cementitious/binder and aggregates [8–12] have been well studied.

Coir pith is one of the major agro wastes found in the southern coastal regions of India. Coir pith is generated in the separation process of the fiber from the coconut husk and is generally dumped as an agro waste. Because of its low degradation in the environment, the hillocks of coir pith collected or dumped pause serious health hazards and loss of fertile lands. Because of the high lignin content left it takes decades to decompose; it only begins to break down when it is 10 years old. The tannins and phenols from coir pith leach out into the soil and water bodies causing pollution. It is estimated that at present there is an accumulated stock of 10×10^6 metric tons of coir pith in the southern states of India and about 7.5×10^5 tons of coir pith is produced annually in India [13]. Developing alternate ways to dispose of coir pith is of critical importance. Cost effective technologies that address the development of value added products from coir pith therefore become relevant for countries producing coir pith. The application of coir pith as reinforcement in polymer has not been reported so far.

One factor that has prevented a more extended utilization of the agro-wastes in composite industry is the lack of compatibility of these fillers in most polymeric matrices. The hydrophilic nature of natural fillers adversely affects adhesion to hydrophobic matrix and as a result, causes poor mechanical properties. One of the most commonly adopted methods to overcome this issue is the chemical treatment of natural fillers. The effect of chemical treatments on the mechanical and other properties of composites are well documented. Gassan and Bledzki [14] studied the mechanical properties of jute/epoxy composites. Composite strength and stiffness increased as a consequence of the improved mechanical properties of the fibers by alkali treatment. Kenaf/epoxy composites were prepared after subjecting the fiber to mercerization. The failure mechanism and damage features of the materials revealed that reinforcement of epoxy with treated kenaf fibers increased the flexural strength of the composite compare to untreated fibers Yousif et al. [15]. Bachtiar et al. [16] reported the mechanical properties of sugar palm fiber treated with sodium hydroxide. Tensile modulus of composites was much higher than untreated fiber composite specimens, which proved the effectiveness of the

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treatment. Min Zhi Rong et al. [17] studied the sisal fiber reinforced epoxy composites. Results showed that alkali treatment removed cementing materials which were partially replaced by epoxy resin. This greatly improved fiber bundle/matrix bonding and also enhanced mechanical strength of composite.

Hybrid composites are made by the incorporation of several different types of reinforcements into a single matrix. They imply a step beyond in the search for novel materials with improved mechanical properties and/or reduced cost. Hybrid polymer composites have been studied many researchers in the past [18–22]. The use of synthetic reinforcements in combination with natural fillers has been shown to exhibit excellent performance and at the same time reduce the environmental impact. The hybrid effect of glass fiber and oil palm empty fruit bunch (OPEFB) fiber on the mechanical properties of phenol–formaldehyde composites was studied by Sreekala et al. [23]. The introduction of small amount of glass fiber improved the impact strength of the composites. Meanwhile density of the hybrid composite decreased as the volume fraction of the OPEFB fiber increased. Mechanical properties of jute/glass fiber reinforced epoxy composites were studied by Koradiya et al. [24]. Experimental results showed that hybrid composites have good mechanical properties than those of jute and glass composites. Jarukumjorn and Suppakarn [25] investigated the effect of glass fiber hybridization on the physico-mechanical properties of sisal–polypropylene composites. Incorporation of glass fiber into sisal/polypropylene composites enhanced tensile, flexural and impact strength.

In the present work coir pith/epoxy composites were hybridized with nylon fabric impregnated with epoxy resin. The composites were prepared by hand lay up technique and than compression moulded. A set of composites with same composition having chemically treated coir pith was also fabricated. Mechanical properties, chemical resistance and flame resistance of composites were investigated in detail. Research investigations showed that the exposure of natural filler composites in a wet environment leads to a decrease of the mechanical properties when water spreads in the material [26–30]. Since coir pith has a higher tendency to absorb and retain water, it becomes essential to know how the composites made of coir pith behave in a wet environment. Hence the composite panels were subjected to wet environment and their mechanical properties were evaluated.

2. Materials and methods

2.1. Materials

Coir pith was collected from a local coir processing unit (Gudiyathum, Tamilnadu, India). Sodium hydroxide was purchased from Sigma–Aldrich, epoxy resin (LY556) and hardener (HY951) were purchased from Huntsman. Maaxil 402 mould release spray was purchased from Maax lubrication.

2.2. Methods

2.2.1. Chemical treatment

Coir pith was soaked in 5% concentration of NaOH solution for 1 h at room temperature followed by washing with distilled water. Afterwards, the samples were oven dried at 70 °C for 2 h.

2.2.2. Composites preparation

A square steel plate mould with dimension of 450 × 450 mm assembled with top plate and base plate was used for the fabrication of composites. To help the complete removal of composites from the mould and to avoid sticking, a polyethylene sheets sprayed with mould release agent is layered on the top and base plate. Nylon fabric with a uniform coating of epoxy and hardener was spread on the polyethylene sheet. The pith/resin mixture (mixed in an internal mixer) is spread on this followed by another layer of resin coated nylon fabric. The samples were compression molded and cured over-night as shown (Fig. 1a and b). The resin hardener ratio is maintained at 10:1 in all formulations. The composites thus fabricated are denoted as given in Table 1.

3. Characterization

3.1. Fourier transform infrared (FTIR) spectroscopy

FT-IR spectroscopy was used to investigate the surface modification in treated and untreated coir pith. FT-IR analysis was carried out in the range of 4000–400 cm^{-1} with a resolution of 2 cm^{-1} using a JASCO 400 Infrared spectrometer.

3.2. Morphology analysis

Scanning electron microscope (SEM) of Carl Ziess, EVO make was used to analyze the morphology of coir pith and impact failure surface of epoxy composites. Optical microscopic image of treated and untreated coir pith were obtained using Brucker Carl Zeiss optical microscopy.

3.3. Mechanical properties

Tensile test was carried out according to ASTM: D 638-10 using a universal testing machine of AG-IS Shimadzu, TMI make. Flexural tests were performed according to ASTM: D 790-10 using Instron UTM, USA. Impact Izod test was done according to ASTM: D 256-10 using Tinius Olsen Model impact analyzer. Hardness was measured by using Shore A hardness tester (Durometer-Mitutoyo Shore A meter).

3.4. Chemical resistance test

The chemical resistance properties of the epoxy resin/coir pith/nylon composites in CCl_4, water, NaOH and HNO_3 were studied according to ASTM: D543-06. In each case, five pre-weighed samples were dipped in the respective chemical reagents for 24 h. They were then removed and immediately washed in distilled water and dried by pressing them on both sides with a tissue paper at room temperature. The samples were then weighed and the percentage weight loss/gain was determined using the following equation.

$$\text{Weight loss/gain}(\%) = \frac{\text{Final weight} - \text{Original weight}}{\text{Orginal weight}} \quad (1)$$

3.5. Ageing studies

The ageing of composites on exposure to water was evaluated by keeping the samples immersed in water. Five specimens of each sample were kept immersed in distilled water at 30 °C for 31 days. The samples were taken out, dried at room temperature and the impact strength was measured as mentioned above.

3.6. Flammability test

Flammability of polymer composites were evaluated as mentioned in a previous report [31]. The tests closely simulate the Federal Aviation Regulation, FAR 25.853 60 s vertical burn test specification [46]. 290 mm × 70 mm sized samples were suspended vertically using a clamp on a lab stand. An LPG Bunsen flame was applied to the leading edge of the bottom surface of