Effect of alkali treatment on mechanical properties of coir fibre and RHA reinforced polymer composites

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Abstract

In recent times, the development of eco friendly composites for various applications such as automotive, marine, chemical, Infrastructure, sporting goods etc. has been elicited by the growing environmental impact associated with the production, disposal and recycling of synthetic fibre based polymer composites. Among the various fibres available in nature like Coir, kenaf, jute, oil palm, cotton, flax, banana and hemp, sisal is gaining more importance as it is abundantly available, cheaper, eco-friendly and possess extraordinary and agreeable mechanical properties to hemp, banana and jute. Coir fibre and sisal fibre play a key role to fabricate a diverse range of structural and non-structural industrial products with different polymer matrix. This article deals with the mechanical properties of coir fibre and here the Rice Husk Ash (RHA) reinforced epoxy polymer hybrid composites are also being discussed with and without alkali treatment along with a comparative analysis.

Keywords: Coir fibres, Coir reinforced polymer composites, Mechanical properties, Chemical treatments.

1. INTRODUCTION

The most commonly used matrix materials are polymeric in Polymer Matrix Composites. There are two major reasons behind this. Firstly, in general the mechanical properties of polymers are inadequate for many structural purposes. In specific their strength and stiffness are low when compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly, the processing of polymer matrix composites need not involve high pressure and doesn't require high temperature. Also equipments required for manufacturing polymer matrix composites are simpler. This became the reason for the rapid development and popularity of polymer matrix composites for structural applications [1]. The overall properties of the composites are superior to those of the individual components and for this reason they have been used in abundance. An example for this is polymer/ceramic. Composites aren't as brittle as ceramics and have a greater modulus than the polymer component [2].

Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength, while matrix glues all the fibers together in shape and the stress is transferred between the reinforcing fibers. The fibers carry the loads along their longitudinal directions. Sometimes, filler might be added to smooth the manufacturing process, impact special properties to the composites, and / or reduce the production cost [3]. Both in terms of their industrial applications and fundamental research, the interest towards natural fiber-reinforced polymer composite materials is speedily growing. They are renewable, cheap, completely or partially recyclable, and biodegradable. As the reinforcement of composites plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lingo cellulosic fibers, are frequently applied. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber-containing composites are more eco-friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc [4].

Fibers are a class of hair-like material that are continuous filaments or are the ones in discrete elongated pieces, similar to pieces of thread. They can be spun into filaments, thread, or rope and can also be used as a component of composites materials. They can also be matted into sheets to make products such as paper or felt. There are two types of fibers: natural fiber and man-made or synthetic fiber [5].

Among natural fibres, coir fibres are generally used because of their inexpensive cost, durability and other advantages, which in turn has made them usable for producing floor furnishing materials, yarn, rope, etc. [6]. In tropical regions such as India, Bangladesh, Sri Lanka, Thailand etc., coir plays a significant role in their regional economy also. Owing to its qualities such as resilience, extensibility, fungi and rot resistance, moth-proof, excellent insulation against temperature and sound, Coir occupies a high up position, which has augmented its commercial and industrial application [7]. Coir is chiefly a multi-cellular fibre containing 30–300 or more cells in its cross section. Cells in coir are crystalline cellulose arranged helically in a matrix consisting of a non-crystalline cellulose-lignin complex [8]. Coir fibre has been reported to possess the highest elongation at break among typical natural fibres, which is also capable of taking a strain that is 4–6 times more than the other fibres [9].

Rice Hush Ash (RHA) is considered as one of the economic as well as promising reinforcement particle for Aluminium MMC. RHA is an agricultural waste which is available in surplus quantities across the globe. The constituents of a typical milled paddy are rice, bran and husk. Rice mills make use of this husk as fuel to produce steam for the parboiling process. The volatile matter in the husk evaporates during the process of burning and the residual husk is transformed into ash which is named as RHA. Silica is known for hardness. The percentage of ash in Rice Husk (RH) is about 10-25% higher than other biomass fuels and it also has 85-87% of silica content which shows the high level of porosity, less weight and high external surface area [10].

Similar to other natural fibres, coir fibres also possess some negative characteristics: they are hydrophilic; their mechanical and physical properties are strongly reliant on the climate, location and weather, and thereby it is difficult to predict their respective composite properties [11]. Because of the presence of pendant hydroxyl and polar groups in various constituents of fibres, moisture absorption of fibres is very high and leads to poor interfacial bonding with the hydrophobic matrix polymers [12]. Thus, it is necessary to decrease the moisture absorption and hydrophilic character of fibres by suitable surface chemical modification [13]. To date, only few work has been conducted on treatment of coir fibre to improve the mechanical properties of coir fibre reinforced polymer composites [14]. Therefore, in current study, coir fibres were chemically treated with 5 wt. % NaOH solution (20 ˚C) for 30 min to increase the compatibility of coir fibre with epoxy matrices. The review of microstructures and mechanical properties of untreated and alkali-treated coir fibres, coir fibre and the effect of addition of Rice Husk Ash (RHA) reinforced epoxy composites were investigated.

2. MATERIALS AND METHOD

2.1 Materials

The coir has been collected from the local sources of kanyakumari District, Tamilnadu, India. Normally coir fiber is extracted from coconut. The coir thus obtained was alkali treated in 10% NaOH solution for removal of waxes. The NaOH treated coir was then washed with water. In order to remove the moisture contents the washed coir is then subjected to heating at 60^0C for 10 hours. This treatment was done to change the nature of the coir from hydrophobic to hydrophilic. This treatment increases the wettability of fibre in the epoxy matrix and enhances the surface roughness, so that there is a strong interfacial bonding formed between coir and epoxy. The treated fibre is then chopped and the same treatments as explained in [11] are done to it. Fig.2 shows the images of the coir treatment.

The RHA can be used as reinforcement material by obtaining Silica from rice husk. The rice husk was collected from agricultural waste sources of Tamilnadu, India.

Fig. 2 Treatment of coir fibre (a) untreated (b) NaOH treated (c) treated in hot over dryer and chopped

Table 1 Chemical composition of coir fibres [16].

Natural fibres	Cellulose (%)	Hemi-cellulose (%)	Pectin (%)	Lignin (%)	Wax (%)	Moisture content (wt.%)
Coir	36 – 43	0.2	1.8	41 – 45	-	10.0

Table 2 Physical and tensile properties of coir fibre [16]

Natural fibres	Diameter (lm)	Relative density (g/cm3)	Tensile strength (MPa)	Elastic modulus (GPa)	Specific modulus (GPa cm3 /g)	Elongation at failure (%)
Coir	10 – 460	1.15 – 1.46	95 – 230	2.2 – 6	4	15 – 51.4

The mixing is done in mixing containers with mixing stick and it also does not entrain any excess air bubbles in the resin. Sample fabrication using coir fiber particle and RHA particle reinforced with epoxy resin was carried out in a square mould of volume 300 × 300 × 3mm^3. Initially, the mould was polished and then the mould releasing agent (Polish wax) was applied on its surface. The polyester resin was prepared in the appropriate proportion. Cobalt naphthenate is used as the accelerator and it is added with the epoxy resin with the ratio of 100:1 (100 ml resin × 1 ml accelerator). The appropriate proportion of coir was placed in the mould and RHA were added with epoxy resin and stirred properly. Finally, a sample preparation with methyl ethyl ketone peroxide used as a catalyst along with a quantity of 1% of the weight of epoxy resin was made. The resin mixture was then poured into the mould box. It was closed, pressed and cured at room temperature. A hand press was used to compress the mould at room temperature for 24 Hrs. The pressure was maintained at 10 kg/cm^2. The required composite was obtained after curing for 24 Hrs.

2.2 Damping Ratio

Three specimens with a size of 250 × 25 × 5mm^3 (length × wide × thickness) for each composite was clamped in the form of cantilever beams with 225 mm effective length span; the accelerometer was attached on the free end side of each cantilever laminate, and then stimulated for free vibration. The histories of vibration acceleration time were recorded by the data acquisition software with a computer. The logarithmic decrement was used for calculating the damping ratio of cantilever laminates from the recorded acceleration time histories.

2.3 Tensile test

Tensile test of CFRE, a flat coupon tensile test was conducted on the Instron 5567 machine according to ASTM D3039 [39] on plates with size of 250 mm × 25 mm × 5 mm for each composite. The crosshead speed was 2 mm/min. To register the elongation during the test, an extensometer with a gauge was placed on each specimen. For each composite, five specimens were tested at room temperature and the average tensile strength and modulus were obtained directly from the machine.

2.4 Flexural test

Flexural test of hybrid composite was carried out on the Instron 1185 machine according to ASTM D790 on plates with size of 100 mm × 20 mm × 5 mm for each composite. The crosshead speed was 2.2 mm/min for each test. The length of the support span was 80 mm and the overhang length on both sides was 10 mm. The average flexural strength and modulus were obtained directly from the machine.

3. RESULTS AND DISCUSSIONS

3.1 Effect of damping ratio

Damping defines the energy dissipation capability of a material. Fig. 2 gives the average damping ratio of the untreated and alkali-treated hybrid composites. The alkali treatment reduces the damping ratio. It is believed that the damping of coir/epoxy composites is attributed to the presence of air voids, viscoelastic properties of polymer matrix and interphase (the region adjacent to fibre surface all along the fibre length) between coir fibres and the polymer matrices. The reduction in damping by alkali treatment could be interpreted by the treatment effect at the fibre/matrix interfaces. For coir/epoxy composites without treatment, more voids and gaps existed at their interfaces. For the composites with fibre treatment, the interfacial bond was found to be better between the coir fibres.

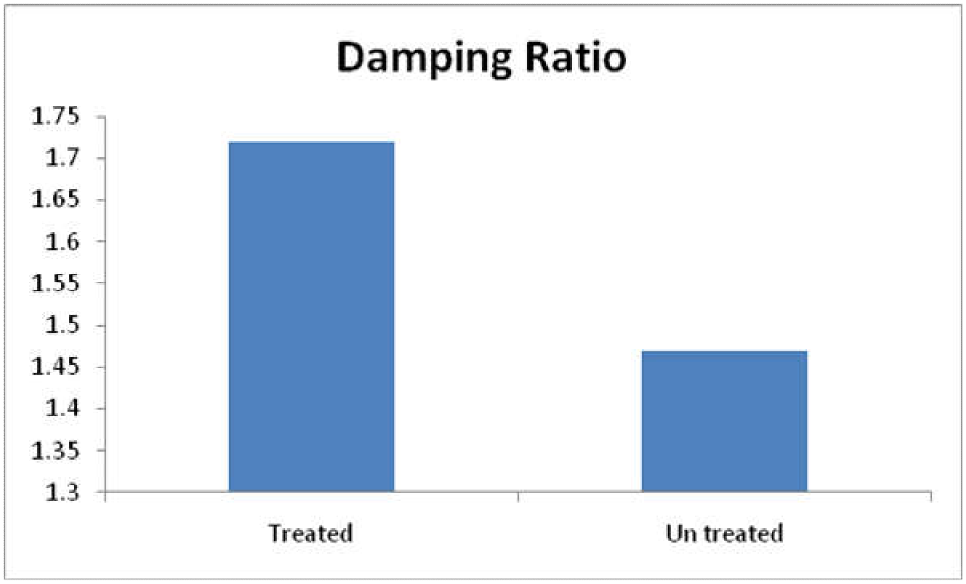

Fig. 2 Effect of damping ratio

3.2 Effect of tensile strength

Fig. 4 gives the tensile properties of untreated and alkali treated hybrid composites. The tensile strength and the modulus of untreated sample is 22.2 MPa. The tensile strength and modulus of the treated sample is 25.5 MPa. The treatment leads to the enhancement in the stress.

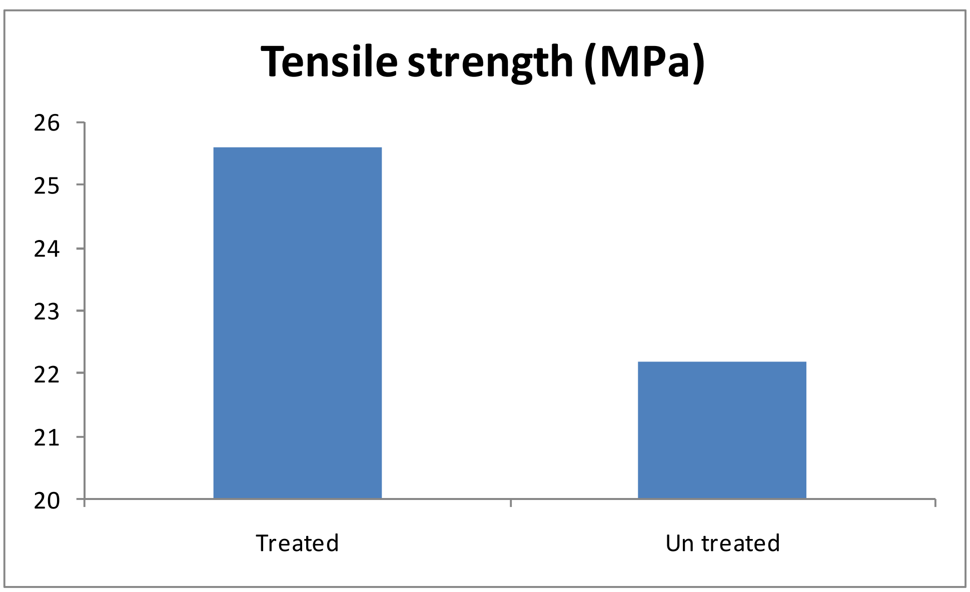

Fig. 3 Effect of tensile strength

3.3 Effect of flexural strength

The flexural property of untreated and alkali-treated hybrid composites is shown in Fig. 4. Similar to the tensile properties, the alkali treatment increases the increase in flexural strength.

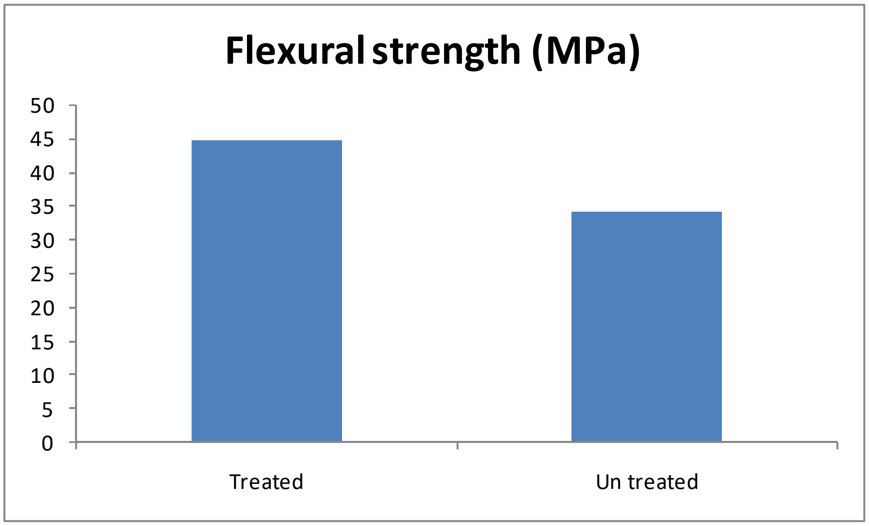

Fig. 4 Effect of flexural strength

4. CONCLUSION

In this study, untreated and alkali-treated (10% NaOH solution, 60 °C for 10 hours in order to remove the moisture contents) coir fibres and RHA were used as reinforcement. Mechanical properties of hybrid composite were determined by vibration, tensile and flexure tests. Alkali treatment solution causes a clearer and rougher surface of the coir fibre, compared with the untreated fibre surface. Compared with the untreated hybrid composite, the alkali treatment increases the damping ratio, tensile strength and the flexural strength.

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