

EFFECT OF CALCIUM CARBONATE FILLER AND ALKALI TREATMENT ON PHYSICAL AND ELASTIC PROPERTIES OF JUTE MAT REINFORCED POLYESTER RESIN COMPOSITES

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ABSTRACT

Polyester resin-jute mat reinforced composites with different wt% of calcium carbonate (CaCO₃) filler were fabricated using a simple cold press molding method. The effects of CaCO₃ filler and alkali (NaOH) treatment on various physical and elastic properties were evaluated. Water absorption (WA) increases with the increase of soaking time and load. The maximum WA was observed for 5 wt% addition of CaCO₃ and for more CaCO₃, WA decreases. The ultimate tensile strength (UTS) and flexural strength (FS) decreases with the addition of CaCO₃ for 0.5 wt% NaOH treated composites but for 5 wt% NaOH treated composites UTS and FS increases with the addition of CaCO₃ filler. The optimum filler addition is about 5 wt% CaCO₃. With the addition of CaCO₃, tangent modulus increases for 0.5 wt% NaOH treated composites and for 5 wt% NaOH treated composites it increases up to a maximum value and then decreases. The effect of load on tensile and flexural properties is also discussed.

Keywords: Calcium Carbonate, Jute Mat, Elastic Properties, Composite

1. INTRODUCTION

Nowadays, scientists and engineers working in the field of materials are very much concerned with sustainability issues and environmental protection. Therefore, environmental friendly, natural, biodegradable materials are attracting lot of interest among them. Because of environmental friendly, biodegradability and sustainability nature, natural fiber composites are preferred as compared to conventional synthetic fiber based composites [1]. Natural fiber from plants such as jute, bamboo, coir, sisal and pineapples are known to have very high strength and hence can be effectively utilized for many load-bearing applications. These fibers have special advantages over other synthetic fibers because they are abundantly biodegradable. At the same time they have low density, high toughness and acceptable specific strength properties. They also show reduced tool wear, reduced dermal and respiratory irritation and good thermal properties [2]. Among all the natural fiber reinforced materials jute appears to be a promising material, because it is relatively inexpensive and commercially available in many forms [3]. Bangladesh has a long history of jute fiber production and jute fiber is mainly used for producing gunny bags, carpet backing, ropes etc.

Jute fiber reinforced composites has lead to an increasing interest for high value added products, such as in household, packing, structural materials for housing, railways, automobiles products, piping etc. The idea of producing long lasting composite materials made of jute fibers has not been considered in the past because of its rotting, swelling and burning properties. It is now found that application of jute fibers for composites has many advantages. Jute fiber is versatile, non-abrasive, biodegradable and compatible [4-7]. Ray et al. [8] investigated on mechanical behavior of untreated and alkali treated jute fiber reinforced vinyl ester composites. They reported that longer alkali treatment removed the hemicelluloses and improved the crystallinity and gave better fiber dispersion. For 35 wt% jute/vinyl ester composites containing both untreated and alkali treated fibers, the flexural strength (FS) of the composite made from treated fiber was superior. Four hour alkali treated jute fibers gave the optimum combination of improved interfacial bonding and fiber strength properties. Islam et al. [9] studied on structural and mechanical behavior of PP-jute blends and showed that alkali treated jute reinforced have much better properties than the untreated properties one. SEM observations indicated good interfacial contact between the short fiber and PP matrix. TG/DTG revealed that the introduction of short jute fiber led to a slightly improved thermo oxidative stability of PP-jute composites. Ray et al. [10] reported the mechanical and thermal behavior of vinyl ester-resin-matrix composites reinforced with untreated and 5 wt% NaOH treated jute fibers. The glass transition temperature, T_g , of the unreinforced resin corresponding to the loss modulus peak was 101.2 °C whereas that of the composites increased by nearly 28 °C on account of the restricted mobility of the resin molecules in the presence of the fibers. In the case of treated composites, the T_g value showed a decreasing trend 128 °C to 125 °C unlike the plain resin a tiny hump was observed in the loss modulus E'' curves of all the composites around 166 °C, which became broader and more prominent with the increase in the jute fiber content. Manikandan et al. [11] studied the tensile properties of short fiber-reinforced polystyrene composites using untreated and benzoylated sisal fibers and investigated the influences of fiber length, fiber content, fiber orientation. Variation in fiber length produced no considerable change in the modulus of the composites but gave maximum TS (25 MPa) at a fiber length of about 10 mm.

Considering practical and technological importance of composites, in this study we have focused on synthesizing polyester resin-jute mat reinforced composites using a simple cold press molding method in order to understand the influence of CaCO_3 filler and alkali treatment on their physical and elastic properties.

2. MATERIALS AND METHODS

2.1 Raw materials

The raw materials used for the samples are polyester resin, hardener, (methyl ethyl ketone peroxide 'MEKP'), jute mat, and fillers (calcium carbonate). Jute fabrics are obtained from a local market having 2.5 ft width and length. The chemical composition of jute fiber is presented in Table 1. Raw jute fabrics were treated with NaOH solution to extract impurities from jute fibers, such as hemi-cellulose, lignin, aromatic acids, esters, etc. which might weaken the adhesion between fibers and matrix. Jute fibers were immersed into 0.5 wt% and 5 wt% NaOH solution, for 24 hours at room temperature. Then, the fibers were washed with fresh water to neutralize the NaOH solution. These were dried at 100 °C for 24 hours.

2.2 Sample preparation

The Jute mat obtained was cut into 10" – 8" pieces. A paper was placed on dried SS sheets. A mixture of polyester resin, filler and hardener was spread evenly on SS sheets. Then jute mat was placed onto this resin. Again a mixture of resin was spread on the jute mat. The samples obtained from the above procedure were allowed to cure under a Weber press hydraulic machine. In compression molding, the polymeric materials and the fiber are subjected to heat and pressure in a single stroke, which was accomplished by using the hydraulic press with heated platens. Molding temperature and pressure was kept as high as 250 °C and 250 KN, respectively. The materials are placed into a die so as to fill the die. As the mold closes down under pressure, the material is squeezed or compressed between the two halves and compacted to the shape inside the die. The excess material flows out of the mold as a thin film. This film expelled out of the mold is known as the 'flash'. Under the influence of heat, the compacted mass get cured and hardened to shape. After completion of heating the mold is allowed to cool down and collected for characterization.

Table 1 Chemical Composition of jute fiber

Constituents	Amount (%)
Cellulose	59-65
Hemicellulose	22-25
Lignin	11-14
Pectine	0.3
Trains, protein, pigment, and inorganic materials	0.7
Wax and fatty mater	1.9-2.5
Moisture	10-11

2.3 Characterization

To evaluate the elastic properties of the prepared composites, tensile and flexural testing was performed by a universal testing machine [Hounsfield UTM 10KN; ASTM D-638–98] at a crosshead speed of 0.2 mm/min, keeping a gauge length of 0.05 m. Tensile specimen was prepared according to (ASTM D-638M-91) [12] at a crosshead speed of 1 mm/min. Flexural specimen was prepared according to (ASTM D790M) [13]. At last five samples of each composition were used in the mechanical testing.

3. RESULTS AND DISCUSSION

3.1 Physical properties

3.1.1 Water absorption

Fig.1 shows the effect of soaking time on water absorption (WA) of polyester-jute mat composite prepared by applying different loads. WA increases with soaking time and load except for composite of applied load 142 kN where the WA increases up to 120 hours and after that it starts to decrease. For composite with load 83 kN and 160 kN WA linearly increases with time (140 hours).

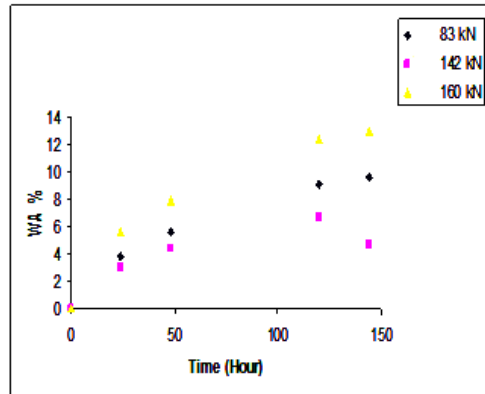


Fig. 1 Effect of soaking time on water absorption of polyester-jute mat composite for different loads.

The effect of soaking time on WA of polyester-jute mat composite for different concentration of CaCO_3 with 0.5 wt% and 5 wt% NaOH treated jute mat respectively are presented in Fig.2. For 0.5 wt% NaOH treated jute mat composites, WA linearly increases with soaking time. With the increase of CaCO_3 concentration, the WA increases. The maximum WA was observed for 5 wt% addition of CaCO_3 and after that, WA decreases. On the other hand for 5 wt% NaOH treated jute mat composites, WA increases linearly with time and decreases with the addition of CaCO_3 . The cellulosic effect, the lignin effect and also presence of void spaces in the composites might be responsible for the increase of WA with time. In jute fiber reinforced polyvinyl chloride (PVC) film composites [14], WA increases with increasing time.

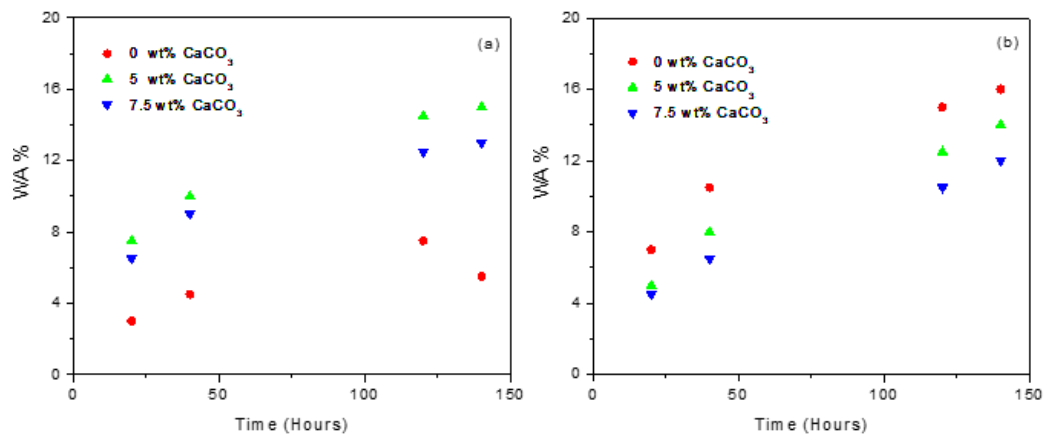


Fig. 2 Effect of soaking time on water absorption of (a) 0.5 wt% NaOH treated (b) 5 wt% NaOH treated polyester-jute mat composite for different concentration of CaCO_3 .

3.2 Elastic properties

3.2.1 Tensile properties

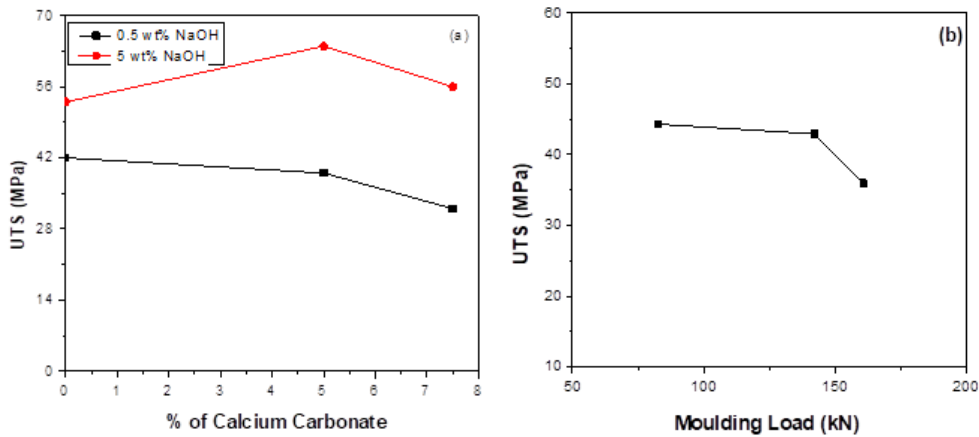


Fig. 3 Effect of (a) filler (CaCO_3) addition (b) moulding load on UTS of polyester resin-jute mat composites.

Effect of CaCO_3 filler on ultimate tensile strength (UTS) of polyester resin jute mat with 0.5 % and 5 % NaOH treated composite is shown in the Fig. 3(a). It reveals that for 0.5 wt% NaOH treated composites the UTS decreases with the addition of CaCO_3 . For 5 wt% NaOH treated composites UTS increases with addition of CaCO_3 up to certain percentage of filler and after that it decreases. The optimum filler addition is about 5 wt% for CaCO_3 . The 5 wt% NaOH treated composites showed better TS than the 0.5 % NaOH treated composites. Alkali treatment generally increases the strength of natural fiber composites [15, 16, and 17]. A strong NaOH treatment may remove lignin, hemicellulose and other alkali soluble compounds from the surface of the composites to increase the numbers of reactive hydroxyl groups on the composites surface available for chemical bonding. So, TS of 5 wt% NaOH treated composites is higher than 0.5 wt% NaOH treated composites. In jute fiber reinforced composites with polyester [18], higher TS was found for 5 wt% NaOH treated composites than the 10% NaOH treated composites. Effect of load on UTS of 0.5 wt% treated polyester jute mat composites is shown in Fig. 3(b). It displays that UTS decreases with increasing moulding load.

3.2.2 Flexural properties

Fig. 4(a) shows the effect of CaCO_3 addition as a filler and NaOH treatment on flexural strength (FS) of the polyester jute mat composite. It is demonstrated that, the trends of the flexural properties are similar with the trends of TS. FS decreases with the addition of CaCO_3 for 0.5 wt% NaOH treated composites but for 5 wt% NaOH treated composites it increases up to certain percentage of filler addition and after that it decreases. The optimum filler addition is about 5 wt% for CaCO_3 . Reason of increasing FS, may be due to the fiber and matrix are well distributed up to 5 wt% filler addition. The FS of the composites with 0.5 wt% NaOH treated composites decreases with increasing load as represented in Fig. 4(b).

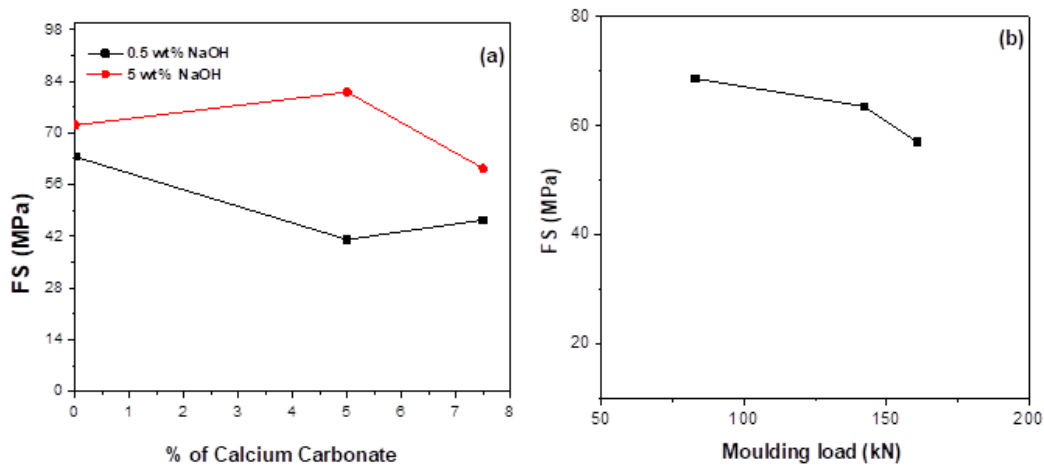


Fig.4 Effect of (a) CaCO₃ filler (b) moulding load on flexural strength of polyester resin jute mat composites

Fig. 5 represents the effect CaCO₃ filler on tangent modulus (TM) of 0.5 wt% and 5 wt% NaOH treated polyester resin-jute mat composites, respectively. It shows that with the addition of CaCO₃, TM increases for 0.5 wt% NaOH treated composites and for 5 wt% NaOH treated composites it increases up to a maximum value and then decreases. The maximum TM was observed for 5 wt% addition of CaCO₃ filler. 10 wt% NaOH concentration is reported as the ideal condition for maximum FS in sisal fiber reinforced polyester composites [19]. Therefore, the surface treatment of the fiber composites is considered significantly increases the adhesion characteristics and thereby improving mechanical properties. Similar improvements in the flexural properties of alkali treated natural fiber reinforced composites were reported previously [19, 20].

Fig.5b shows the effect of moulding load on tangent modulus of 5 wt% NaOH treated jute composites. It reveals that TM decreases up to load 142 kN and after that it increases.

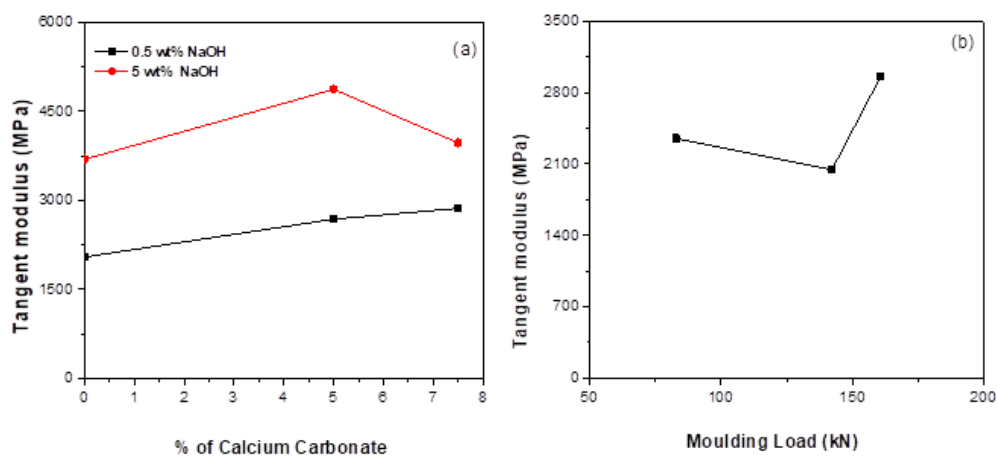


Fig.5 Effect of (a) CaCO₃ filler (b) moulding load on tangent modulus of polyester resin jute mat composites

4. CONCLUSIONS

WA increases with increasing load except for composite of applied load 142 kN. For 0.5 wt% NaOH treated jute mat composites WA linearly increases with the increase of soaking time and with of addition of CaCO₃. The maximum WA was observed for 5 wt% addition of CaCO₃. For the sample with filler addition more than that, WA decreases. On the other hand for 5 wt% NaOH treated jute mat composites, WA increases linearly with time and decreases with the addition of CaCO₃. The UTS and FS decreases with the addition of CaCO₃ for 0.5 wt% NaOH treated composites but for 5 wt% NaOH treated composites UTS and FS increases with the addition of CaCO₃ up to certain percentage of filler and after that it decreases. The optimum filler addition is about 5 wt% CaCO₃. With the addition of CaCO₃ TM increases for 0.5 wt% NaOH treated composites and for 5 wt% NaOH treated composites it increases up to a maximum value and then decreases. With increasing load UTS and FS decreases. From all of these results it can be concluded that increment of load and CaCO₃ filler significantly affected different properties of the polyester-jute mat composites and 5 wt% NaOH treated polyester-jute mat composites shows improved elastic properties in comparison to 0.5 wt% NaOH treated composites.

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