ASEAN J. Sci. Technol. Dev., **28(2)**: 115 – 121

Physical and Mechanical Properties of Jute Mat Reinforced Epoxy Composites

S. M. SADAF, M. SIDDIK, Q. AHSAN AND M. HASAN*

Department of Materials and Metallurgical Engineering,
Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

Cellulose jute fibre offers a number of benefits as reinforcement for synthetic polymers since it has a high specific strength and stiffness, low hardness, relatively low density and biodegradability. To reduce moisture uptake and hence to improve the mechanical properties of the composites, bleached jute mats were incorporated as reinforcing elements in the epoxy matrix. Composites at varying volume fractions and different orientations of jute mat were fabricated by hot compression machine under specific pressures and temperatures. Tensile, flexure, impact and water absorption tests of composites were conducted. Jute mat oriented at (0 ± 45–90)° composites showed reduced strength compared to (0–90)° fibre mat composites. Impact strength and water uptake of high volume fraction jute mat reinforced composites was higher compared to that of lower volume fraction composites. Fracture surfaces of jute mat composites were analyzed under SEM. Fracture surface of (0–90)° jute mat oriented composites showed twisted fibres, while (0 ± 45–90)° jute mat oriented composites had fibre pull-out without any twisting. Overall, composites containing 52% jute mat at orientations of (0–90)° showed better properties compared to other fabricated composites.

Key words: moisture reduction; SEM analysis; bleached jute mat; hot compression; pressure; temperature; tensile; flexure; water absorption; strength; fracture; fibre

Natural fibres exhibit many beneficial properties as reinforcements for composites. It is light in weight, cost effective and has high specific properties compared to synthetic fibres such as glass, carbon etc. Natural fibre reinforced composites are light in weight, possess better electrical resistance, good thermal and acoustic insulating properties and good resistance to fracture (Abu-Sharkh & Hamid 2004). Among all the natural fibre reinforcing materials, jute appears to be a promising material because it is relatively inexpensive and commercially available in the required form (Vilaseca *et al*. 2007; Planckett *et al*. 2003). It has higher strength and modulus compared to most of the plastics and is a good substitute for conventional fibres in many situations (Vilaseca *et al*. 2007; Planckett *et al*. 2003).

In this present work, jute fibre was used as the reinforcing material since it is produced in a large scale in the Indian sub-continent, especially in Bangladesh and has a minimal effect on the environment because of its biodegradable properties. Epoxy or polyepoxide, a thermosetting polymer formed from reaction of an epoxide ‘resin’ and with a suitable ‘hardener’ (hydrogen peroxide) was used as the matrix material. Thus, the aim of the study was to manufacture composites using raw bleached jute mat and epoxy, subsequently characterizing them using microstructural analysis and mechanical testing.

* Corresponding author (e-mail: mahbubmmebuet@gmail.com.)

EXPERIMENTAL PROCEDURE

Materials

The thermosetting co-polymer epoxy, used as matrix material, was supplied by the polyolefin Company Private Limited, Singapore. It had a specific gravity of 1.53. The jute, used as reinforcing fibre, was collected from Bangladesh Jute Research Institute (BJRI).

Fabrication of Composites and Preparation of Test Specimens

Four types of composites were manufactured by varying the number and orientation of jute mat ply. They were: (i) 4 ply in (0/90)° orientation; (ii) 4 ply in (0 ± 45–90)° orientation; (iii) 8 ply in 0/90° orientation and (iv) 8 ply in (0 ± 45–90)° orientation. The jute mat was first cut into 20 × 20 cm^2 sizes and dried in an oven at about 70°C. The required amount of resin and 0.1% hardener (H_2O_2) ware added and stirred properly. For the purpose of degassing the beaker, it was placed in desiccators which were connected to a vacuum pump. Degassing was carried out for 2 min – 3 min. The mould surface was cleaned very carefully and mould releasing agent (PVA, Wax) was sprayed thoroughly over the mould surface. Each ply was wet completely by the resin (epoxy). The ply was then passed through a roll mill for the removal of excess resin associated with the ply and to ensure it was rodden with resin. The ply was then placed in a female mould and then covered by a male mould. This arrangement was kept at 110°C temperature and 70 kN pressure under a hot pressure machine for about 1 h. The mould was then transferred to an oven and cured at 140°C–160°C for about 2 h and then cooled very slowly in the oven to complete curing. The mould specimen was carefully discharged from the mould.

Test specimens were fabricated individually to eliminate void conditions and to minimize edge and cutting effects during machining. Specimens were prepared to required dimensions according to ASTM standards [ASTM Standard D 638-01 (2002); ASTM Standard D 790-00 (2002); ASTM Standard D 6110-97 (2002); ASTM Standard D 570-99 (2002)].

Mechanical Testing

Tensile, flexure, impact and water absorption tests were subsequently conducted. Ten specimens of the type of composite were analysed for each test and the average values were recorded. Tensile tests were conducted according to ASTM-D 638-01 (2002) using a universal testing machine at a cross-head speed of 3 mm/min. The dimensions of the specimen were 120 mm × 10 mm × 4 mm. Three point static flexural tests were carried out according to ASTM D 790-00 (2002) using the same testing machine mentioned above. Dynamic Charpy impact tests were conducted using a universal impact testing machine following ASTM D 6110-97 (2002). Water absorption characteristics of the manufactured composites were measured according to ASTM D 570-99 (2002) using 2 h immersion.

Microstructural Analysis

Fractured surfaces of the tensile tested specimens were examined by using a scanning electron microscope (SEM) at a magnification of 200.

RESULTS AND DISCUSSION

Tensile Properties

Variation of tensile strength at different orientations and volume fractions (%) of jute mat are shown in Figure 1. Tensile strength of the composite was influenced by the tensile strength and modulus of the fibre. It was found that there was an increase in tensile strength with the incorporation of higher volume jute mat into epoxy matrix. The tensile properties were affected by the layering sequences. Tensile strength was higher for (0–90)° orientation of jute mat compared to (0 ± 45–90)° orientation. This was because the

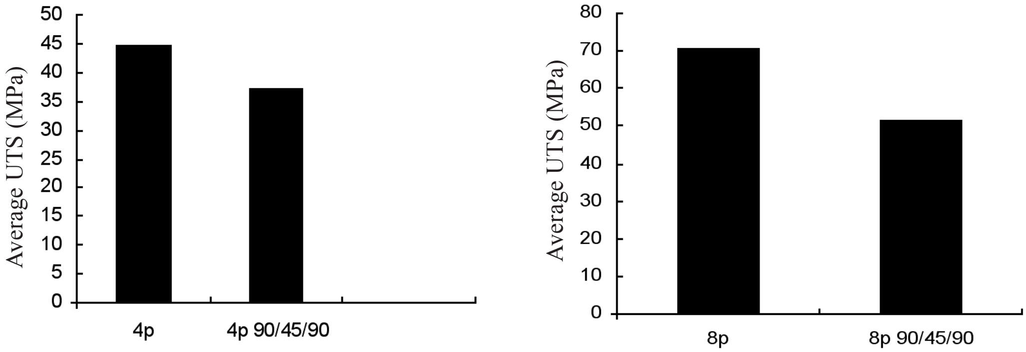

Figure 1. Variation of tensile strength at different orientation and volume fraction (%) of jute mat.

load applied was transferred through the fibre at 45° to the loading axis. Shearing action was predominant and hence the strength became somewhat lower.

Flexural Properties

Variation of flexural strength against fibre volume fraction (%) is shown in Figure 2. According to Figure 2, flexural strength initially decreased, then increased with increase in jute mat volume fraction (%).

Impact Strength Results

Figure 3 shows variation of Charpy impact strength against fibre volume fraction (%). The impact strength increased with fibre volume fraction (Lin *et al*. 2006; Joseph 2002; Jayaraman *et al*. 2003; Islam *et al*. 2009). The increase in impact strength of composites was due to the fact that the fibre was capable of absorbing energy because of the strong interfacial bonding between the fibre and the matrix. Another factor for the impact failure of the composite was fibre pull out. With increase in fibre volume fraction, bigger force was required to pull-out the fibres. This consequently increased the impact strength.

Water Absorption Characteristics

The water absorption characteristics of the manufactured composites against time at

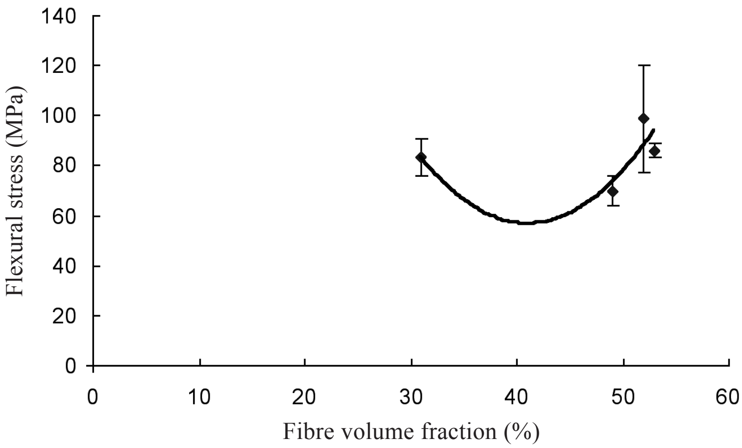

Figure 2. Variation of flexural strength against jute mat volume fraction (%).

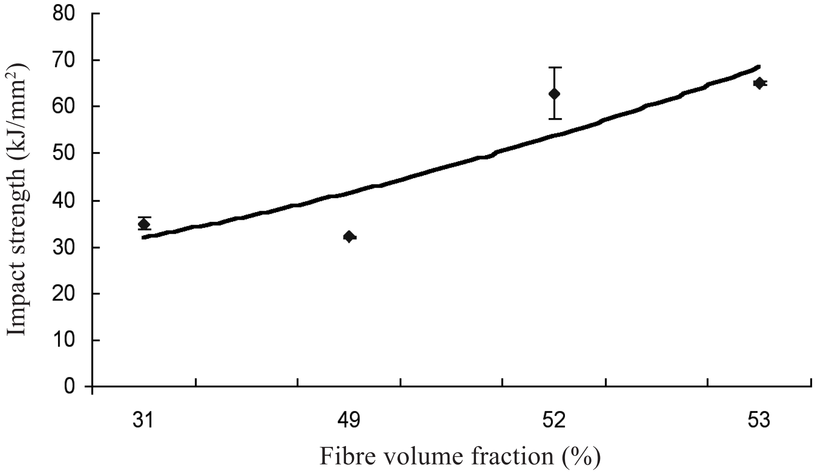

Figure 3. Variation of impact strength against jute mat volume fraction (%).

2 types of jute mat ply and orientation, that is for 4 ply in (0 ± 45–90)° and 8 ply in (0 ± 45–90)° orientation are shown in Figures 4 and 5 respectively. The water absorption (%) increased with the increase in fibre loading (Yang *et al*. 2006; Matuana *et al*. 2001). The hydroxyl group in jute mat is mainly responsible for water absorption. With increase in jute fibre volume fraction, the number of hydroxyl groups in the composite increased, which subsequently increased water absorption. Figures 4 and 5 also show that with an increase in time, water absorption increased.

SEM Morphology

Figure 6 shows the SEM fracture surface of 4 ply jute mat composite in (0–90)° fibre orientation, while *Figure 7* shows the SEM fracture surface of 4 ply jute mat composite in (0 ± 45–90)° fibre orientation. The fracture surface of (0–90)° jute mat oriented composites showed twisted fibre (*Figure 6*), which meant the fibres were twisted during the tensile test. On the other hand, (0 ± 45–90)° jute mat oriented composites had fibres pulled out without any twisting (*Figure 7*) that meant that the fibres were pulled out from the composites during tensile loading.

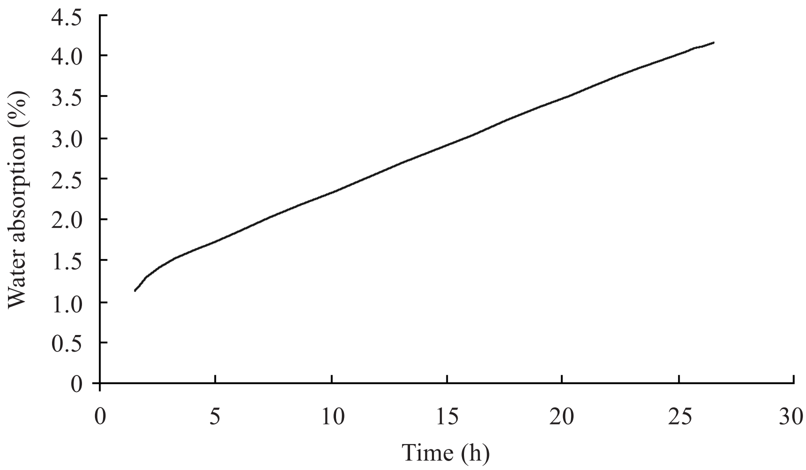

Figure 4. Variation of water absorption (%) against time for 4 ply in (0 ± 45–90)° orientation.

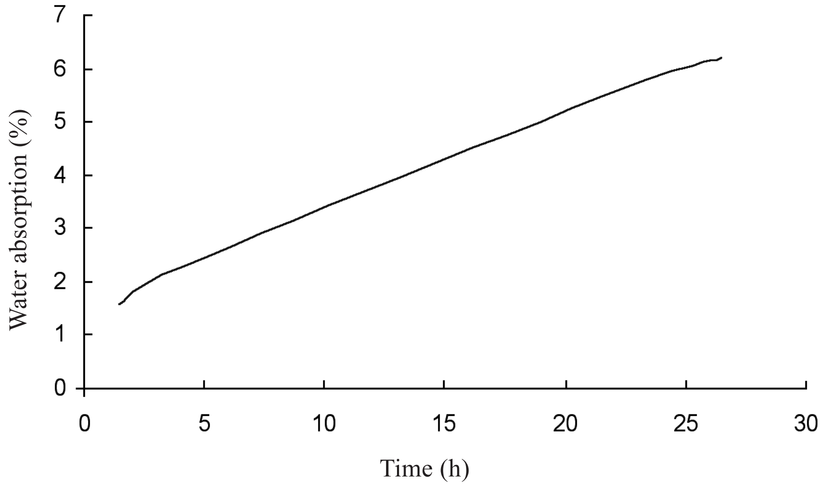

Figure 5. Variation of water absorption (%) against time for 8 ply in (0 ± 45–90)° orientation.

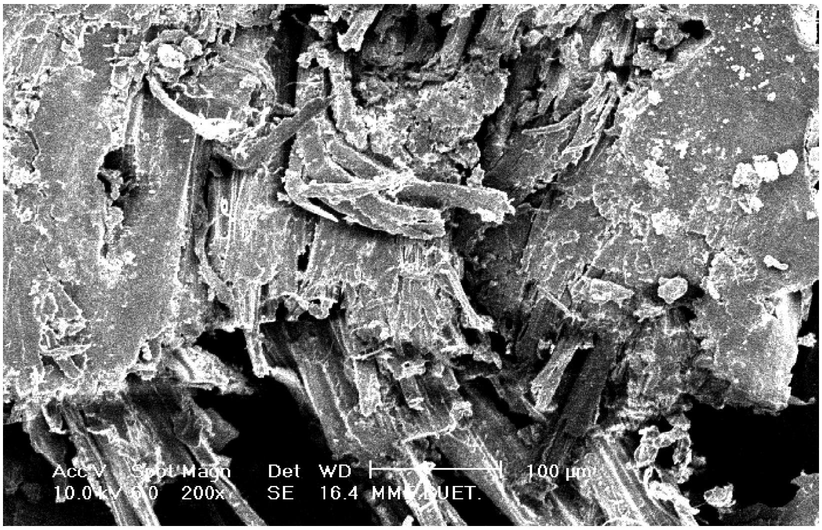

Figure 6. Fractured surface of 4 ply composite in (0–90)° fibre orientation.

CONCLUSION

Bleached jute mat reinforced-epoxy composites of varying volume fractions (%) and at different orientations of jute mat were fabricated using the hot compression machine under specific pressure and temperature. Tensile, flexure, impact, water absorption of composites and scanning electron micrography of fracture surface of composites were conducted. Jute mat oriented at (0–90)° composites had a higher tensile strength compared to (0 ± 45–90)° fibre mat composites. Impact strength and water uptake increased with increase in jute mat fraction. Fracture surfaces of jute mat composites were analyzed under SEM. Fracture surface of (0–90)° jute mat oriented composites had twisted fibres, while (0 ± 45–90)° jute mat oriented composites had fibre pull-out without any twisting. Considering the experimental results, composites containing 52% jute mat at orientations of (0–90)° had better properties compared to other fabricated composites. Thus

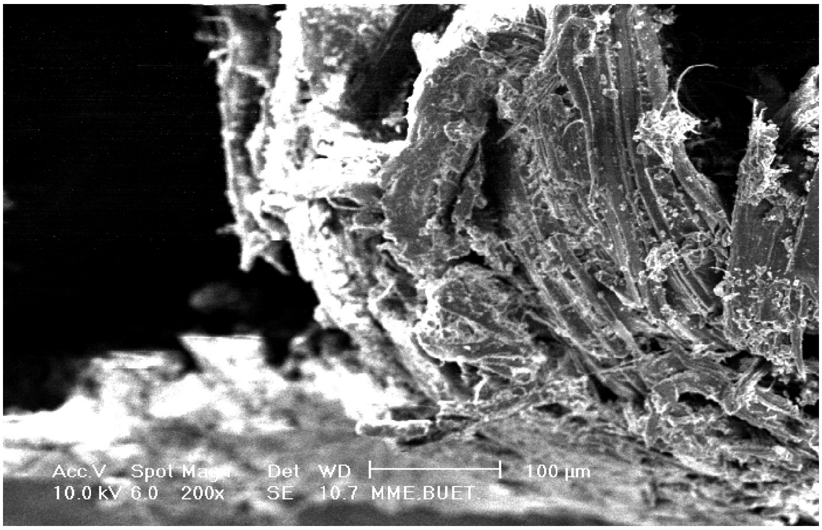

Figure 7. Fractured surface of 4 ply composite in (0 ± 45–90)° fibre orientation.

it would be better to manufacture composites with 52 volume fraction (%) jute mat at (0–90)° orientations to obtain optimum utilization during service.

Date of submission: June 2011
Date of acceptance: September 2011

REFERENCES

Abu-Sharkh, BF & Hamid, H 2004, 'Degradation study of date palm fibre/polypropylene composites in natural and artificial weathering: mechanical and thermal analysis', *Poly. Deg. Stab.,* vol. 85, no. 3, pp. 967–973.

ASTM Standard D 638-01 2002, *Standard Test Methods for Tensile Properties of Plastices,* vol. 8, Annual Book of ASTM Standard, USA.

ASTM Standard D 790-00 2002, *Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastices and Electrical Insulating Materials,* vol. 8, Annual Book of ASTM Standard, USA.

ASTM Standard D 6110-97 2002, *Standard Test Methods for Determining the Charpy Impact Resistance of Notched Specimens of Plastics,* vol. 8, Annual Book of ASTM Standard, USA.

ASTM Standard D 570-99 2002, *Standard Test Methods for Water Absorption of Plastices,* vol. 8, Annual Book of ASTM Standard, USA.

Haque, MM, Hasan, M, Islam, MS & Ali, ME 2009, 'Physico-mechanical properties of chemically treated palm and coir fiber reinforced polypropylene composites', *Bio. Tech.,* vol. 100, 4903–4906.

Haque, MM, Islam, MN, Hasan, M, Islam, MS, Islam, MS & Huque, MM 2010, 'Coir fiber reinforced polypropylene composites: physical and mechanical properties', *Adv. Comp. Mat.,* vol. 19, pp. 91–106.

Islam, MN, Haque, MM & Huque, MM 2009, 'Mechanical and morphological properties of chemically treated coir filler PP composites', *Ind. Eng. Chem. Res,* vol. 48, pp. 10491–10497.

Islam, MN, Rahman, MR, Haque, MM & Huque, MM 2010, 'Physico-mechanical properties of chemically treated coir reinforced polypropylene composites', *Comp. A,* vol. 41, pp. 192–198.

Jayaraman, K 2003, 'Manufacturing sisal-polypropylene composites with minimum fiber degradation', *Comp. Sci. Tech.,* vol. 63, pp. 367–374.

Joseph, S, Sreekala, MS, Oommen, Z, Koshy P & Thomas, S 2002, 'A comparison of mechanical properties of phenol formaldehyde composites reinforced with bana fibers and glass fibers', *Comp. Sci. Tech.,*vol. 62, pp. 1857–1868.

Lin, JC, Chang, LC, Nien, MN & Ho, HL 2006, 'Mechanical behaviour of various nanoparticle filled composites at low-velocity impact', *Comp. Stru.,* vol. 27, pp. 30–36.

Matuana, LM, Balatinez, JJ, Sodhi, RNS & Park, CB 2001, 'Surface characterization of esterified cellulosic fibers by XPS and FTIR spectroscopy', *W. Sci. Tech.,* vol. 35, pp. 191–201.

Planckett, D, Andersen, TL, Pedersen, WB & Nielsen, L 2003, 'Biodegradable composites based on l-polylactide and jute fibers', *Comp. Sci. Tech.,* vol. 63, pp. 1287–1296.

Vilaseca, F, Mendez, JA, Pelach, A, Llop, M, Canigueral, N, Girones, J, Turon, X & Mutje, P 2007, 'Composite materials derived from biodegradable starch polymer and jute strands', *Process Biochemistry*, vol. 42, pp. 329–334.

Yang, HS, Kim, HJ, Park, HJ, Lee, BJ & Hwang, TS 2006, 'Water absorption behaviour and mechanical properties of lignocellulosic filler-polyolefin bio-composites', *Comp. Stru.,* vol. 72, pp. 429–437.