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Chemical resistance and tensile properties of polycarbonate (PC) toughened epoxy-bamboo fibre composites: Surface modification, varied fibre lengths and varied fibre orientations

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Abstract: Polycarbonate (PC) toughened epoxy-bamboo fibre composites were developed using varied fibre lengths and fibre orientations. The variation of tensile strength with varied fibre length was studied and optimum length of fibre was identified in this experimental study. The variation of tensile strength with varied fibre orientations was also studied. Tensile strength was maximum when the orientation angle (è) was zero and minimum when 90° to the stress direction. The chemical resistance test indicated that the composite materials were resistant to some acids, alkalis, solvents and water.

Key words: Bamboo fibre, chemical resistance, epoxy resin, fibre orientation, polycarbonate, tensile strength.

INTRODUCTION

Several studies on the composites made from thermoset materials and natural fibres like jute, wood, bamboo, sisal, cotton, coir, wheat straw, palmyra, *etc.* have been reported in the literature. In order to improve the properties of such composites, several methods have been adopted. Modification of matrix is one of these avenues. Toughening of epoxy resins can be achieved by mixing the resin with elastomers or even with ductile thermoplastics before curing. Chen *et al.* (1992) studied the miscibility and fracture behaviour of epoxy resin/polycarbonate blend. They indicated that the blend is miscible and has better mechanical properties. Though bamboo is

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extensively used as a valuable construction material from time immemorial (because of its high strength and low weight), studies on reinforced plastics using this fibre are meager. In the present investigation, the epoxy resin was toughened with a thermoplastic, namely bisphenol-A polycarbonate, and this blend was used as the matrix. The present paper explains the development of polycarbonate toughened epoxy-bamboo fibre composites and their chemical resistance and tensile properties.

MATERIALS AND METHODS

Bamboo fibres

Bamboo fibres (*Dendrocalamus strictus*) procured from Tripura in dried form, were soaked in 5 per cent NaOH solution for 2 hr to remove the soluble hemicellulose and lignin. The fibers were washed thoroughly with distilled water and dried under the sun. The fibre cross-section was rectangular with breadth and thicknesses varying from 0.1 to 0.6 mm. Fibres with thickness of 0.1 mm were selected for the study. For studying the tensile properties and chemical resistance, the fibres were cut to different lengths.

Chemicals

For chemical resistance test, glacial acetic acid (8%), concentrated nitric acid (40%), concentrated hydrochloric acid (10%), ammonium hydroxide (10%), aqueous sodium carbonate (20%), aqueous sodium hydroxide (10%), benzene, toluene, carbon tetra chloride and water were used.

The epoxy resin LY-556 and hardener HY-951 (Huntsman Advanced Materials) and polycarbonate (Viral Rasayan Mv = 25000) were used as the matrix components. To make the blend, the epoxy resin was added with polycarbonate dissolved in dichloromethane. The mixture was then kept in vacuum until the entire solvent got evaporated. To this mixture, required quantity of hardener was added and mixed thoroughly. A mixture containing 10 per cent polycarbonate was used as the matrix.

Sample preparation

For making the composite, a glass molding box with 150 mm × 150 mm × 3 mm dimensions was used. The mold cavity was coated with a thin layer of aqueous solution of polyvinyl alcohol, which acted as a good releasing agent. Further, a thin coating of hard wax was laid over it and finally another thin layer of polyvinyl alcohol was coated. Each coat was allowed to dry for 20 min at room temperature. The prepared mold of 3 mm depth was evenly filled with fibre and matrix mixture containing 100 parts of matrix, 10 parts of hardener by weight and fibre in random orientation. The wet mould was allowed to cure at ambient temperature for 24 hr. To ensure complete curing, the composite and matrix sheets were post-cured at 100 °C for 3 hr. For each

length of the composite, the fibre content was maintained at 0.40 volume fraction of the composite. The various fibre lengths used were 5, 10, 15, 20, 25, 30, 35, 40, 45, 50 and 55 mm.

For studying the effect of fibre orientation, specimens with the fibre axis making angles of 0°, 15°, 30°, 45°, 60°, 75° and 90° with respect to the stress direction were prepared. A fibre content of 30 per cent weight was used for all orientations.

Specimen samples were prepared by cutting the cast sheets into strips of 100 mm × 15 mm × 3 mm (Fig. 1). The gauge length of 20 mm and width of 10 mm were maintained as described by Jindal (1986). For chemical tests, the specimens were cut into blocks of 10 mm × 5 mm × 3 mm dimensions as per ASTM Standards (1989). For comparison sake, the specimens for matrix material were also prepared in similar lines.

Measurement of tensile strength

The tensile strength was determined using Instron Universal Testing Machine (Model 3369) at 22 °C and 50 percent RH. Samples were tested at a cross-head speed of 10 mm/min. In each case, at least five specimens were tested and mean tensile strength was recorded.

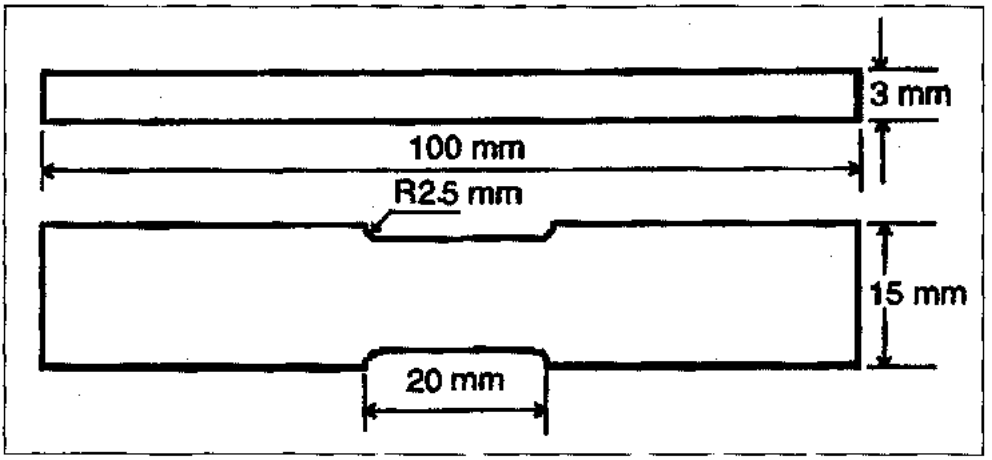

Figure 1. Tensile test specimen

Measurement of chemical resistance

The chemical resistance tests of the composites were carried out in accordance with ASTM D 543-87 (1989). In each case five pre-weighed samples were dipped in respective chemicals for 24 hr, removed and immediately washed with distilled water and then dried by pressing them between filter papers. The samples were then weighed and the percentage weight loss (-)/weight gain (+) was determined. The percentage weight loss (-)/weight gain (+) during immersion was calculated to the nearest 0.0001 value.

RESULTS AND DISCUSSION

The tensile strength values of the composites with varied fibre lengths are presented in Table 1. It is evident that the tensile strength of bamboo fibre reinforced composites increased with the increase of fibre length up to 30 mm. Further increase of fibre length resulted in decreased tensile strength of the composites. It indicates that the optimum fibre length to get maximum tensile strength for the system under study was 30 mm.

Variation of tensile strength with varying fibre orientations is given in Table 2. It is clear that the tensile strength was maximum when orientation angle (è) was zero and minimum when è = 90 ° to the stress direction. The tensile strength values for other angles were intermediate between these values. It indicates that the tensile strength is a function of cosine of the orientation angle.

The percent weight gain (+)/weight loss (-) when the composites and matrix materials were immersed in different chemicals and water is presented in Table 3. From the Table it is seen that weight gain was observed for almost all chemical reagents and water. This clearly indicates that in the composite materials swelling was due to gel formation rather than dissolution in the chemical reagents. This is understandable as

Table 1. Tensile strength of polycarbonate toughened epoxy-bamboo fibre composites with varying fibre length

Sample No.	Fibre length (mm)	Tensile strength (MPa)
1	5	22.39
2	10	25.46
3	15	33.57
4	20	37.78
5	25	40.92
6	30	42.47
7	35	39.99
8	40	34.26
9	45	29.86
10	50	24.57
11	55	20.64

Table 2. Tensile strength of polycarbonate toughened epoxy-bamboo fibre composites with varying fibre orientation

Sample No.	Angle of orientation fibre (degrees)	Tensile strength (MPa)
1	0	53.07
2	15	47.63
3	30	44.33
4	45	39.42
5	60	34.18
6	75	30.33
7	90	24.96

Table 3. Weight loss (-)/gain (+) of the composites and matrix on immersion in chemicals for 24 hours

Chemicals	Matrix	Composite
Conc. nitric acid (40%)	+0.8189	+3.3217
Conc. hydrochloric acid 10%)	+0.5511	+2.1278
Acetic acid (8%)	+0.1832	+2.8222
Sodium hydroxide (10%)	+0.1416	+4.1169
Sodium carbonate (20%)	+0.0168	+1.8421
Ammonium hydroxide (10%)	+0.1631	+4.3287
Benzene	-0.0623	+0.1804
Toluene	+0.1093	+0.0537
Carbon tetrachloride	+0.1740	+3.4734
Water	+0.7246	+2.7860

* % change in weight after immersion for 24 hours

cross-linked systems form three dimensional gel networks which are chemically more stable. As the present system was cross-linked, it had good chemical resistance. A slight weight loss for matrix was observed in the case of benzene. This may be due to removal of polycarbonate which is slightly soluble in certain solvents. From Table 3, it is further observed that when the composites were immersed in water for 24 h, a maximum of only 2.7860 per cent weight increase was observed. It indicates that the composite under study was water resistant.

REFERENCES

ASTM 1989. Annual Book of ASTM standards. ASTM Publishers, Philadelphia 8: 128p.

Chen, M.C., Houston, D.J. and Sun, W.B. 1992. Miscibility and fracture behavior of an epoxy resin Bisphenol-A polycarbonate blend. *Eur. Polym. J.* 28: 1471-1475.

Jindal, U.C. 1986. Development and testing of bamboo fibre reinforced plastic composite. *J. Compos. Mater.* 20: 19-29.