Mechanical and Dimensional Properties of Bamboo (*Gigantochloa Scortechinii*) Fiber – Thermoplastic Composite

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ABSTRACT

Bamboo fibres, retained at the screen size of 1.0 mm were used in the production of bamboo plastic composites at three different plastic: bamboo ratio (30:70, 50:50 & 70:30 w/w). Two plastic material namely high density polypropylene (HDPP) and low density polyethylene (LDPE) and a 3% maleated anhydride polypropylene (MAPP) on the total weight were used as the compatibilizer. Both plastic material and plastic: bamboo ratio had significant effect on all the board properties (except for plastic: bamboo ratio on MOR). Higher fibre content increases the board stiffness but with acceptable modulus of rupture (MOR) and tensile (TEN) strength values. However, higher fibre content decreased the WA and TS properties. Thermoplastic boards with polypropylene as the matrix shows better strength but lower dimensional properties compared with boards blended with polyethylene.

Keywords: *thermoplastic composite, bamboo – polypropylene, plastic content*

Introduction

For the past two decades, newer materials and composites that have better strength, economic and environmental benefits are being considered in the automotive, building, construction, furniture and packaging industries. The composites used are usually plastic based. Many types of mineral fillers and fibres have been used extensively in the plastics industry to achieve desired properties and also to reduce the cost of the finished product. These are the reinforced thermoplastic composites and they used non-renewable fillers or fibres such as glass fibres. However, these fibres require high temperature and tend to be abrasive towards processing equipment and also increase the density of the plastic composite. In the early 1990s, researchers all over the globe have shown great interest in the development of industrial and household products that combine lignocellulosic fibres and other raw materials such as plastics, gypsum, cement to form composite products with unique properties and emphasising on cost benefits. Youngquist (1995) reported that the primary impetus in developing these products are due to the following reasons: to reduce material costs by combining low cost material with a high-cost material, to develop products using recyclable materials and to produce a composite product that have superior properties when compared to either the components material alone.

Before 1990, work on lignocellulosics in thermoplastics are concentrated on wood-based flour and significant advances have been made by a number of researchers such as Woodhams et. al. (1984), Klason & Kubat (1986), Kokta *et al.* (1989) and Bataille et. al. (1989). Recent research on the use of lignocellulosics fibres suggests that these fibres have potential for use as reinforcing fillers in thermoplastics (Sanadi et. al. 1994). The use of wood flour/fibre in thermoplastic is well known, however, the use of bamboo fibres as reinforcing agent in thermoplastic has yet to be reported. This paper examines the mechanical and dimensional properties of bamboo fibres-polypropylene and polyethylene-composites. The effects of plastic material and plastic: bamboo ratio are also discussed.

Materials and Methods

Materials

Plastic materials used are commercially available. High density Polypropylene (HDPP) used had a MFI (230ºC, 2.16 kg) 8.0 g/10 min and low density polyethylene (LDPE) a MFI (190ºC, 2.16 kg) 4.0 g/10 min. The coupling agent used was maleated anhydride polypropylene (MAPP) an anionic powdered form of Epolene-43, from Eastman Chemical Products, USA.

The bamboo fibres were first prepared by steaming the chips for 10 minutes under pressure and at a temperature of 190ºC. The steamed chips were then fed into the pressurized refiner to produce fibres. The fibres were then oven dried in the oven at 80°C for 48 hours to achieve a moisture content of below 5%. The dried fibres were then screened into > 2.0, 1.0-2.0, 0.5 - 1.0 and < 0.5 mm screen sizes. Only the 1.0 mm fibres were used in the study.

Blending, Board-making and Evaluation

Blending was carried out in a dispersion mixer with a capacity of 1 kg. Polypropylene (PP) was first melted in the mixer at a temperature of 185°C for about 10 minutes. A 3% maleated anhydride polypropylene (MAPP) as the compatibilizer was then added followed by the bamboo fibres. The mixture was allowed to stay in the mixer for another 15 - 25 minutes to ensure proper blending. The blended samples consists of 3 plastic: bamboo ratio (30, 50 & 70% plastic). Upon blending the mixture was extracted manually using a scraper out of the mixer and rolled into thin sheets with a iron pipe. The thin sheets were then crushed in a crusher into small granules. The granules were then placed in a chrome-plated mould and press into thin boards with a size of 2 x 150 x 150 mm for tensile and water absorption test. Bending samples were made using mould with a size of 6 x 150 x 25 mm. A total of 6-8 boards and 10-12 bending samples were produced at each variable. All test samples were produced at a target density of 1000 kg/m^3. The board was cut into test samples for tensile and water absorption (WA) according to BS 3872 (Anon 1993). All the test samples are conditioned and tested according to the BS test standards.

Results and Discussions

Mechanical and Water Absorption Properties

Table 1 (refer next page) shows the mechanical and water absorption properties of the bamboo fibre-plastic composites according to plastic matrix and plastic: bamboo fibre ratio.

For thermoplastic board blended with PP, a plastic ratio of 70% showed the highest MOR (47.90 MPa) and tensile stress (26.31 MPa). However, boards with 30% PP showed the highest MOE (5614 MPa), lowest TEN (11.65 MPa), highest WA (4.36%) and TS (7.18%). With PE as the matrix, the mechanical properties of MOR (26.92 MPa) and MOE (4393 MPa) was highest for boards with 30% PE. However, the board also showed the lowest TEN (9.94 MPa) and, the worst WA (2.87%) and TS (3.47%). In general for both thermoplastic boards, the lower plastic:bamboo ratio produced boards with higher strength properties but lower dimensional properties. Boards with 100% plastic had the best dimensional properties.

Table 1: Strength and Dimensional Properties of Thermoplastic Composites at Different Plastic to Bamboo Fibre Ratios

Plastic type	Bamboo (%)	MOE (MPa)	MOR (MPa)	TEN (MPa)	WA (%)	TS (%)
PE	0	682	21.41	12.47	0	0
	30	2545	23.92	19.55	0.43	0.18
	50	2200	21.95	14.42	0.71	0.34
	70	4393	26.92	9.94	2.87	3.47
PP	0	3176	46.02	24.05	0	0
	30	4598	47.90	26.31	0.91	2.26
	50	4943	46.36	19.29	1.22	3.14
	70	5614	35.31	11.65	4.36	7.18

Values are averages of 9 determinations
Note : MOE = Modulus of elasticity, MOR = Modulus of rupture, TEN = Tensile strength, WA = Water absorption after 24 hrs, TS = Thickness swelling after 24 hrs

Table 2 shows the ANOVA of the board properties. All the board properties are shown to be highly significantly affected by the plastic material used. Plastic:bamboo ratio did not had any effect on MOR. The main variables showed highly significant effects on the board properties.

Table 2: Summary ANOVA on the Thermoplastic Composite Properties

SOV	Df	MOE	MOR	TEN	WA	TS
Plastic type (P)	1	5.43E7**	4969**	465.60**	4.60**	55.36**
Ratio (R)	3	1.89E7**	47.09ns	300.38**	30.25**	62.80**
PXR	3	1.34E6**	191.03**	51.19**	1.16**	7.48**

Note: SOV - source of variance, Df - degree of freedom, ns - not significant at $p < 0.05$ and ** - highly significant at $p < 0.01$

Effects of Plastic Material

The effects of plastic material (PP or PE) on the strength and dimensional properties are shown in Figure 1 and 2, respectively. Figure 1 shows that thermoplastic board with PP matrix gives better strength properties compared to PE as the matrix. However, the WA and TS are higher for PP thermoplastic boards (Figure 2).

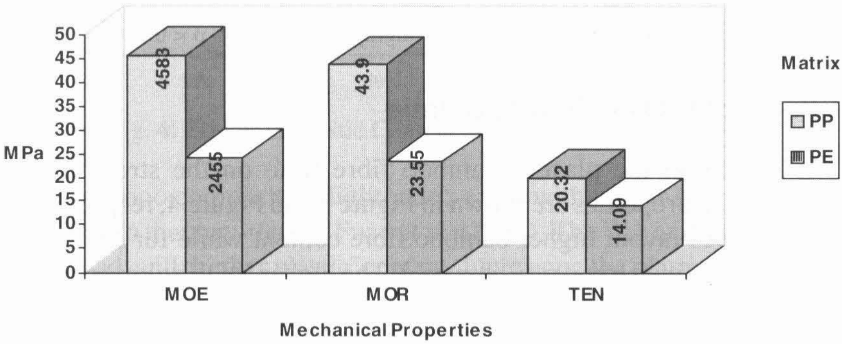

Fig. 1: Effects of Plastic Matrix on the Mechanical Properties

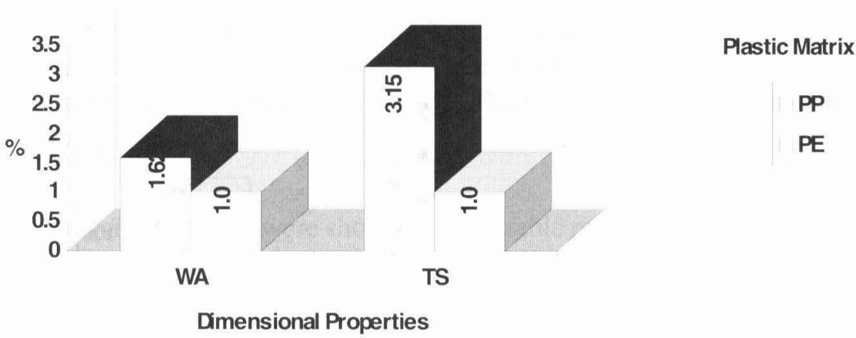

Fig. 2: Effects of Plastic Matrix on the Dimensional Properties

Table 4 further reveals that the plastic material used are positively correlated with MOR, MOE, TEN and TS. The WA was found to be uncorrelated. The correlation analysis (Table 4) further revealed that only TEN (r = 0.49) was positively correlated with plastic: bamboo ratio. The MOE (r = -0.67), WA (r = -0.81) and TS (r = -0.74) were all negatively correlated. MOR was, however, uncorrelated with the variations in the plastic: bamboo ratio.

Table 4: Correlation Coefficients of Board Properties with Plastic Type and Ratio

Variable	MOR	MOE	TEN	WA	TS
Plastic type	0.68 **	0.86**	0.53**	0.21ns	0.44**
Plastic ratio	-0.67**	0.08ns	0.49**	-0.81**	-0.74**

Note : ns - not significant at $p < 0.05$, ** - highly significant at $p < 0.01$

Effects of Plastic: Bamboo Ratio

The effects of the plastic: bamboo fibre ratio on the strength and dimensional properties are shown in Figure 3 and Figure 4, respectively. MOE values favour higher bamboo fibre content while for MOR and TEN an indefinite trend was observed. The higher MOE at lower plastic ratio could be due to the higher amount of bamboo fibres which are known to have high strength properties. The higher value of modulus with fibre/filler addition is a common occurrence in thermoplastic boards (Bigg 1987, Fuad et. al. 1995). According to Fuad et. al. (1995), the incorporation of filler/fibre to a polymer matrix may increase or decrease the tensile strength of the resulting composites. Usually fibre type fillers improve tensile strength as the fibres are able to support stresses transferred from the polymer. Figure 3 shows that the tensile strength of

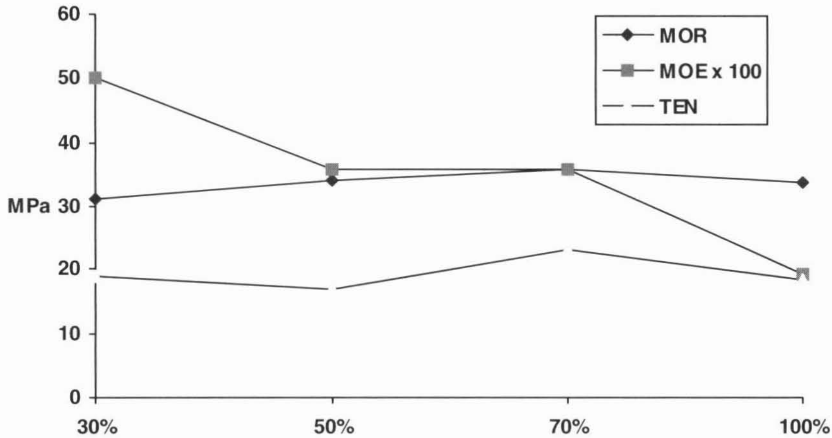

Fig. 3: Effects of Plastic Content on the Strength Properties

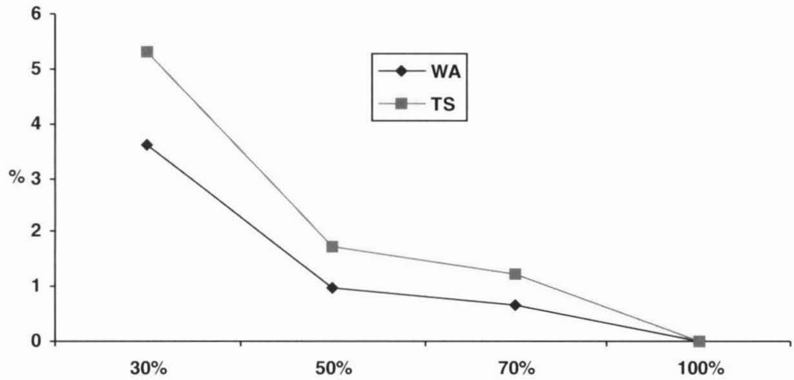

Fig. 4: Effects of Plastic Content on the Dimensional Properties

the bamboo composites slightly decreases with higher bamboo content similar to that reported by Fuad et al. (1995). The WA and TS are greatly reduced with higher plastic content. Increasing the plastic content from 30% to 50% a decrease of 73.5% in WA and 67.3% in TS was observed. Sanadi et. al. (1994) researching with Kenaf fibre found that 50% fibre content in the thermoplastic composite showed only a 0.95% in 24 hr WA comparable to the 0.96% obtained for the 50% plastic: bamboo fibre ratio used in this study. The lower WA and TS at higher plastic ratio is related to the presence of interfacial bonding and wood fragment encapsulment that reduces water uptake.

Conclusion

The bamboo fibres were shown to be suitable reinforcement material in the production of thermoplastic boards. Plastic material and the plastic: bamboo ratio had significant effects on the board properties. Polypropylene was shown to be a better matrix compared to polyethylene for better strength properties of the thermoplastic composites. Addition of bamboo fibres between 30 to 50% in the plastic matrix shows acceptable strength and dimensional properties.

References

Bataille, P., Ricard, L. & Sappieha, S. (1989). Effect of cellulose in polypropylene composites. *Polm. Compos.* (10): 103.

Bigg, D.M. (1987). *Polymer Composites*. (8): 115.

Fuad, M.Y.A., Ismail, Z, Ishak, Z.A.M &. Omar, A.K.M. 1995. Application of rice husk as fillers in polypropylene effect of titanate, zirconate and silane coupling agents. *Eur Polm. Journal*. (31): 885.

Klason, C. & Kubat, J. (1986). *Cellulose in polymer composites*. In Salmen,L., de Ruvo, A. (eds.). Elsevier Science, Amsterdam.

Seferis, J.C & Stark, E.B (Eds.). (t.t). *Composites systems from natural and synthetic polymers*. Elsevier Science, Amsterdam.

Kokta, B.V., Raj, R.G. & Daneault, C. (1989). Use of wood flour as filler in polypropylene. Studies on mechanical properties. *Polm.. Plast. Technology Engineering*. (28): 247.

Sanadi, A.R., Caulfield, D.F., Walz, K., Wieloch, L., Jacobson, R.E. and Rowell, R.M. (1994). Kenaf fibres – Potentially outstanding reinforcing fillers in thermoplastics. p 155-160. In *Conference Proceedings of the International Kenaf Association*, March 8 – 10th., New Orleans, Louisiana, USA.

Woodhams, R.T, Thomas, G. & Rodgers, D.K. (1984). Wood fibres as reinforcing fillers for polyolefin's. *Polm. Eng. Science*. (24): 1166.

Youngquist, J. A. (1995). Unlikely partners ? The marriage of wood and non-wood materials. *Forest Products Journal*. 45 (10): 25 - 30.

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