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Short communication

Tensile and flexural strengths of coconut spathe-fibre reinforced epoxy composites

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Abstract

Tensile and flexural strengths of coconut spathe and spathe-fibre reinforced epoxy composites were evaluated to assess the possibility of using it as a new material in engineering applications. Samples were fabricated by the *hand lay up process* (30:70 fibre and matrix ratio by weight) and the properties evaluated using the INSTRON Material Test System. Tensile and flexural strengths for the coconut spathe-fibre-reinforced composite laminates ranged from 7.9 to 11.6 MPa and from 25.6 to 67.2 MPa respectively, implying that the tensile strength of coconut spathe-fibre is inferior to other natural fibres such as cotton, coconut coir and banana fibres. However, fibre treatment may improve the interfacial bonding between fibre and matrix leading to better mechanical properties of the spathe-fibre-reinforced composite laminates.

Keywords: *Cocos nucifera,* mechanical properties, natural fibre composites

Natural fibre-composites have considerable potential to replace conventional materials like metal, plastics and wood in structural and non-structural applications, especially in furniture industry (Sapuan and Maleque, 2005). Such composites impart strength and stiffness to the product, besides having advantages such as low cost, environment friendliness, abundant availability and renewable nature. Coconut spathe, the covering of the coconut inflorescence, is an under-exploited material with considerable potential in this respect. Although substantial research has been carried out on other tissue-types of the coconut palm (*Cocos nucifera*), e.g., leaf bud sheath (Sapuan et al., 2001), coir (Lai et al., 2005), shell (Sapuan et al., 2003), reports on the use of coconut spathe as a source of fibre in composite materials are scarce. Furthermore, production of fibre-reinforced composite materials strengthens the bonding between fibre and matrix, so that it could resist the applied load. Hence coconut spathe-fibre and fibre-reinforced epoxy composites were tested in this study to determine the tensile and flexural strengths.

For testing the tensile properties of spathe, five sub-samples (1 to 1.2 mm thick and 225 mm long slices) were cut along the fibre-line from a five-month-old coconut spathe (Fig. 1). Fibre for the reinforcement media was extracted by crushing and hammering the spathe to give of long fibres, which were subsequently

Fig. 1: The coconut spathe

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dried in open field in dry sunny weather. The dry fibres were then repeatedly hammered to yield fine fibres (separate from one another), which was cut into short lengths to be used for preparing the composite laminates. Epoxy type *BBT–7893 A* was used as the matrix material and type *BBT–7893 B* as the hardener in view of their excellent bonding abilities. Specific gravity and viscosity of the epoxy resin type *BBT–7893 A* were 1.15 and 5500 cPs respectively.

To prepare the composite samples, a mould (285 x 230 x 7 mm) was fabricated by cutting glass according to the dimensions and then joining it using glass silicon. The epoxy and hardener were then mixed in the ratio of 5:1 (stirred to ensure proper mixing) and the composite laminates were produced in a *hand-lay up* process (fibre-to-matrix ratio 30:70 by weight). For this, a thin layer of resin was poured into the mould and the fibres were placed on top of the resin and flattened using a roller. Another thin layer of resin was poured on top of the flattened laminate as coating. The second layer of the composite lamina was prepared following the same procedure after the first lamina has dried up for 45 to 60 min. The process was continued until the desired thickness of the sample was achieved. The composite used for the present study consisted of three laminates. The fibre-reinforced composite laminate was then taken out of the mould in the form of a plate and was cut and machined to produce samples conforming to the ASTM standard D 638-99 for tensile testing and D 790-99 for flexural testing (ASTM, 2000). The dumbbell-shaped samples for tensile test and the rectangular samples for bend test were produced by milling followed by grinding. Servo-hydraulic controlled INSTRON 3142 Dynamic Material Testing System Model 8500 (Fig. 2) was used for tensile testing and Model 5566 for flexural testing (INSTRON Industrial Products, Grove City, PA, USA). The samples were prepared according to the Type I test procedures (7 mm or less thick and 165 mm long with a gauge length of 50 mm). In flexural testing, a jig was attached to the INSTRON machine. The lower part of the jig was mounted and set according to the span length of the sample before it was attached to the INSTRON machine and the suitable cross-section head speed was achieved after testing a few samples.

Fig. 2: The test set-up: INSTRON 3142 Dynamic Material Testing System (INSTRON Industrial Products, Grove City PA, USA)

Results of the tensile and flexural tests of the spathe samples and coconut spathe-fibre-composites are presented in Table 1. The highest maximum stress of spathe was 2.33 MPa, while the lowest maximum stress was 1.15 MPa. The corresponding vales for the coconut spathe-fibre composites were 11.59 and 7.87 MPa respectively. Flexural test values of maximum load applied during test ranged between 279.9 N and 106.8 N and stress at maximum load ranged between 25.6 and 67.2 MPa.

All the samples tested showed the same pattern of stress strain-curves before they were broken or failed. Although the samples were cut from the same spathe, there was a difference of more than one 1 MPa between the highest and lowest peak values of stresses for the spathe samples and approximately 3 MPa for the spathe-fibre-reinforced composites (Table 1). This can be explained by the varying thickness and change in alignment of fibre cut using manual tools. The mean strength of the thin specimens was 1.65 MPa and that of the spathe-fibre-reinforced composite was 9.33 MPa with mean strain of 0.0091%. Thus, by reinforcing the spathe fibre, the mean strength of the spathe can be increased by about six times.

Table 1: Tensile and flexural properties of coconut spathe and spathe-fibre-reinforced composites

Test/Parameter	Mean	Standard deviation	Min	Max
Tensile test of thin samples of spathe (n=5)				
Maximum load (N)	57.40	17.30	40.00	81.20
Strain at break (%)	2.44	0.77	1.22	3.28
Stress at maximum load (MPa)	1.65	0.50	1.15	2.33
Tensile test of spathe-fibre reinforced composites (n=3)				
Maximum load (kN)	1.25	0.27	1.05	1.55
Strain at break (%)	0.009	0.002	0.008	0.011
Stress at maximum load (MPa)	9.33	1.98	7.87	11.59
Flexural test of spathe-fibre reinforced composites (n=5)				
Maximum load (N)	183.3	65.2	106.8	279.9
Strain at break (%)	0.102	0.018	0.08	0.12
Stress at maximum load (MPa)	43.98	15.64	25.64	67.17

A comparison of the data presented in Table 1 also indicate that the tensile strength of spathe fibre reinforced composite was higher than the tensile strength of the spathe. This shows that incorporating the short spathe fibre within the epoxy resin will enhance the strength of the matrix. Despite this, the value of tensile strength of coconut spathe-fibre (1.15 to 2.33 MPa) is much lower than other natural fibres such as banana fibre (529 to 914 MPa; Sapuan and Maleque, 2005), cotton (350 MPa; Zan, 2004) and coconut coir (106 to 175; Lai et al., 2005), implying that coconut spathe fibre as reinforcement in a composite material is inferior to other natural fibres. The interfacial bonding between fibre and matrix, however, can be improved by fibre treatment. Hence research aimed to study the mechanical properties of coconut spathe-fibre should be undertaken to make it a potential candidate material for engineering applications especially since the material is available in plenty at little or no cost.

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