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Experimental Investigation of Sisal, Coir and Sugarcane Fibre Reinforced Polymer Matrix Composites

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ABSTRACT:

The natural fibre-reinforced polymer matrix composites can be used both in industrial applications and in research field. These polymer matrix composites are low cost, renewable and completely or partially recyclable. In this study, hand layup method has been used with the combinations of coir, sisal fibre and sugarcane skin to fabricate composite specimens for tension, compression and flexural strength tests. From the test results, the sisal fibre composites have shown the promising tensile and compressive strengths. Further, it is also shown that the sugarcane fibre has good flexural strength compared to sisal and coir fibre reinforced polymer composite specimens.

KEYWORDS:

Natural fibres; Epoxy resin; Polymer matrix composites; Flexural strength; Sugarcane fibre

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1. Introduction

Polymer can be defined as a long molecular structure made of many units where the basic units are made of carbon, hydrogen and oxygen. Polymers are produced from raw materials such as petroleum, natural gas and derivatives of fossil fuel [1]. Generally, petro chemicals for polymer synthesis are produced on large scale from an important substance known as naphtha [3]. From naphtha, other olefins are produced such as ethylene, propylene, benzene and toluene [1-4]. Ethane is a component of natural gas that produces ethylene. Once the polymer materials are synthesised, they are channelled in to major consuming industries such as, textiles and paints, or to highly diverse processing sectors producing commercial products in construction, packaging, automobile, agriculture, furniture and electrical appliances [6-8].

Now a days, natural fibres have attracted the attention of many researches due to their merits such as light weight, eco-friendly, strong, fully biodegradable, abundantly available, renewable and low cost. Compared to glass, carbon and aramid, natural fibres are light in weight [6]. Natural fibres can be classified into three main categories: vegetable fibres, animal fibres and mineral fibres. Natural fibres derived from plant-based fibres are preferred as reinforcement by the automotive industry for structural applications due to their high fibre strength properties [5-12]. These types of natural fibres can be used to reinforce both thermosetting and thermoplastic resin matrices. Thermosetting resin such as epoxy, polyester, polyurethane and phenolic are commonly used in composites requiring higher performance applications [2-3, 13]. In this paper, natural fibre composites are fabricated using coir, sisal and sugarcane fibres reinforced with epoxy matrix and then tested to characterise their mechanical strengths.

Sisal is a hair like material similar to pieces of thread. Fibre is extracted by a process known as decortication where leaves are crushed and beaten by rotating wheels set with blunt knives. Sisal fibre is traditionally used for rope, twines and many other uses. Coir is a natural fibre extracted from the husk of coconut. It is found between the hard internal shell and outer coat of coconut with thick walls made of cellulose [5]. This is used for making finer brushes, string rope and fishing nets. Sugarcane is commonly used as a bio fuel and in the manufacture of pulp and in building materials, and it often used as a primary fuel source in the sugar mills [1]. The amount of cellulose presents in the natural fibres is listed in Table1. The mechanical properties of natural fibres are listed in Table 2. The natural fibres with higher cellulose content have higher values in tensile strength and Young's modulus [8].

Table 1: Cellulose content in selected natural fibres

Fibre type	% Cellulose
Sisal	65.5
Coir	19.9-36.7
Sugarcane	28.3-55

Table 2: Mechanical properties of natural fibres

Fibre type	Density (g/cm^3)	Elongation (%)	Tensile strength (MPa)	Young's modulus (GPa)
Sisal	1.3-1.6	1.9-15	400-700	8.5-40
Coir	1.2-1.6	14-30	170-230	3.0-7.01
Sugarcane	1.1-1.6	6.3-7.9	170-350	5.1-6.2

2. Specimen preparation and test setup

Hand layup moulding is used to fabricate the natural fibre composites. The base plate is fixed inside the frame for fabrication. The natural fibre and 50% resin hardener mixture are used for moulding process. The roller is used to impregnate the fibre with resin. Another layer of resin and reinforcement is applied until a suitable thickness is achieved. Table 3 gives the dimensions of the fabricated test specimens and their test standards. Respective photographs of specimens before testing are shown in Figs. 1 to 3. Fig. 4 shows the arrangement of three point bending test. The flexural test specimen is placed on two supports with a span of "L" and the actuator is applying the force "P" at the mid-span. The maximum flexural strength (σ) of the specimen is obtained using,

$$\frac{dP}{dw_0} = \frac{48EI}{L^3} \quad (1)$$

Where E is Young's modulus, I is the second moment of inertia and w_0 is the displacement at the mid-span.

Table 3: Dimensions of the testing samples

Tests	Dimensions (mm)	Test standard
Flexure	250×30×10	3-point bending
Tension	250×30×10	ASTM D3039
Compression	25×25×25	ASTM D5467

Fig. 1: Sisal fibre reinforced epoxy specimens before test

Fig. 2: Coir fibre reinforced epoxy specimens before test

Fig. 3: Sugarcane fibre reinforced epoxy specimens before test

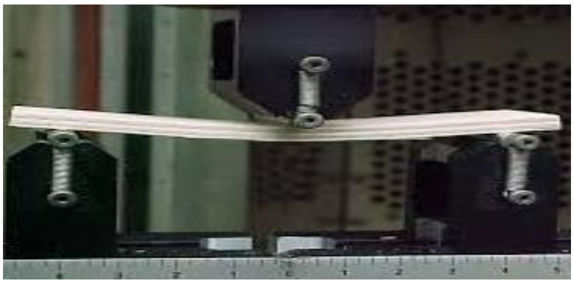

Fig. 4: Three point bending test setup

3. Results and discussion

Testing for flexural, tensile and compressive strengths for the fabricated sisal, coir and sugarcane fibre reinforced composite specimens were carried out using respective test standards as per Table 1. For tension test, the specimens are placed in the grips of a Universal Test Machine at a specified grip separation and pulled until failure. A typical tensile test speed of 2 mm/min is used. A strain gauge is used to determine elongation and tensile modulus. In compression test, the loading introduces the compressive force into the specimen through shear at the wedge grip interfaces. The load transfer differs from the procedure in test method ASTM D695. The photographs of specimens post-test are shown in Figs. 5 to 7. Respective strengths determined by post-processing the load vs. displacement data are plotted in Figs. 8 to 10 respectively for flexural strength, tensile strength and compressive strength. Sugarcane fibre reinforced composite has the highest flexural strength when compared with other fibre reinforcements. Sisal fibre reinforced composite has the highest tensile and compressive strengths when compared with other fibre reinforcements.

Fig. 5: Sisal fibre reinforced epoxy specimens after test

Fig. 6: Coir fibre reinforced epoxy specimens after test

Fig. 7: Sugarcane fibre reinforced epoxy specimens after test

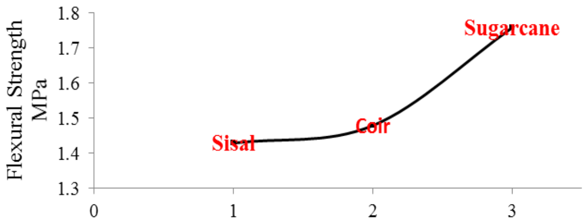

Fig. 8: Flexural strengths of natural fibre composites

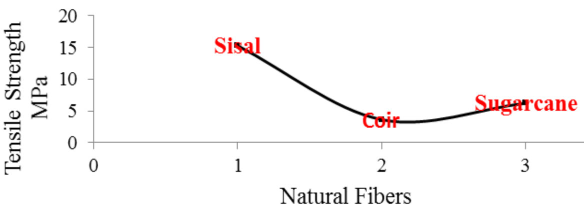

Fig. 9: Tensile strengths of natural fibre composites

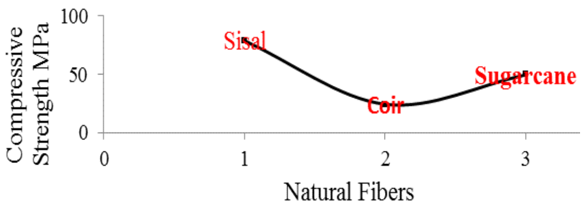

Fig. 10: Compressive strengths of natural fibre composites

4. Conclusions

The natural fibre composite manufactured by hand lay-up process provides an opportunity of replacing existing materials with a higher strength, low cost, alternative eco-friendly natural fibres. From this experimental investigation, sisal fibre reinforced epoxy composites have shown the promising results for tensile and compressive strengths. It is also shown that the sugarcane fibre reinforced epoxy composites have good flexural strength compared with sisals and coir fibre reinforcements.

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