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Utilization of bioresources such as coir-pith, saw dust and palmyra fiber as reinforcement material in polyester matrix

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ABSTRACT

This paper deals with the study of mechanical properties of the composite sandwich plates made up of coir industry waste, the pith / the timber industry waste the saw dust as the fillers in the form of core and the Palmyra fiber as skin. Coir pith being a waste disposed from the coir factories, pose the danger of pollution and health hazard. This can be used as filler material in polymer composites. Sandwich plates were prepared with general polyester resin matrix by varying the coir pith /saw dust content keeping the palmyra fiber content constant. Specimen were cut as per ASTM standard and tested in Instron machine. The mechanical properties such as tensile, bending, shear and impact strength were studied. 10%, increase in tensile strength, 14% in shear strength and 40% increase in impact strength were observed due to the addition of 10g coir pith / saw dust as core material.

KEYWORDS

Palmyra fiber;
Sandwich;
Tensile;
Bending;
Shear;
Impact.

INTRODUCTION

Use of natural fibers such as oil palm, sisal, flax, coir, jute and as reinforcement in polymer matrix was studied by several researchers in the recent years[1-10]. Natural fibers are easily available and biodegradable. Use of natural fiber as reinforcement provides an opportunity for the utilization of agricultural product. The composites with natural fibers as reinforcement in polymers give good mechanical properties with low specific mass. Abundantly available fillers, inexpensive and possessing good mechanical properties, when used with fibers reduce total cost of the composites. Also the filler-fiber combination in composites reduces the amount of matrix material required and enhances its specific properties. Fillers such as calcium carbonate, clay, mica, glass micro spheres and fly ash are generally added to the polymer composites to improve the properties. Wood–Plastic Composites (WPCS) are being used increasingly for nonstructural applications in the automotive, furniture, and building industries. Mechanical Properties of polymer matrix filled with Wood flour was studied by several authors[11-15]. Li et al. studied the impact behavior of sawdust / recycled PP composites and observed the fracture energy to decrease with the presence of sawdust filler in a recycled PP matrix and fracture toughness was reported to increase by 32% for 40% by weight loading of the sawdust[14]. Sombatsompop et al studied the effect of wood sawdust content on rheological and structural changes and thermo-mechanical properties of PVC-Sawdust composites[15]. Effect of Coupling Agent, Polybutadiene Isocyanate, on Mechanical Properties of hardwood aspen fiber/polypropylene (PP) composites was carried out by Amir Nourbakhsh et al.[16]. Tensile strength value of 24.75 MPa for pure PP and 22 MPa for the composite containing 40wt% unmodified fibers were reported. These results indicate that wood fiber behaves merely as filler when incorporated into PP and has no reinforcing effect. Addition of 3% MAPP and 5% PBNCO to this produced composites with tensile and impact properties of 30 MPa and 22 J/sqm, respectively. R.Viswanathan and L.Gothandapani[17] studied the strength characteristics of particle board made of coir pith in phenol formaldehyde resin and urea formaldehyde resin. The optimum levels of the variables such as proportion of resin, curing temperature and curing duration of 16·7%, 138°C and 26 min respectively for phenol formaldehyde resin and 20·4%, 139°C and 17 min respectively for the urea formaldehyde resin were reported. Viswanathan et al.[18] reported the water absorption and swelling characteristics of coir pith - phenol formaldehyde and urea formaldehyde resins particle board. The water absorption, swelling along surface and thickness are ranged from 30% to 133%, 0.7% to 3.7% and 24% to 112.6% respectively. Also the water absorption and swelling were least for the board made from largest-size particles and phenol–formaldehyde resin. Coir pith as low cost filler in microcellular soles based on natural rubber–high styrene resin was studied by Srilathakutty et al.[19] and reported that the coir pith can be used as filler in amounts up to 50 phr without much reduction in properties.

In this experiment, skin core type composite sandwich plates are prepared with the waste materials such as wood sawdust, coir pith (waste obtained during coir fiber separation).coir pith and sawdust are used as fillers in the form of core and the Palmyra fiber as skin in the polyester resin matrix. Composites were prepared by sandwiching the above wastes between the unidirectional Palmyra fiber mats. Tensile, bending, shear and impact tests are carried out to study the mechanical properties.

EXPERIMENTAL

Materials

Coir pith of low calorific value is abundantly available and subsequent disposal creates environment-linked problems. Approximately 180 grams of coir pith is obtained from the husk of one coconut. Coir pith contains Carbon: Nitrogen in the ratio of 112:1 and contains 75 per cent lignin which does not permit natural composting as in other agricultural wastes. Recent studies by Viswanathan et al.[18] indicate that this can be used as fillers in the thermoplastic composites.

The palmyra tree (Borassus flabellifer) is found in abundance in southern part of Tamil Nadu. Rich quantities of fibers are available in leaf stalk of the palmyra tree and the fiber obtained from it is shown in figure 1. They are separated by crushing the stalk either manually or mechanically and then by combing. As reported by Velmurugan et al.[10], the density of the fiber is around 0.4-0.6 g/cc and strength is in the range of 110-280 MPa.This fiber is used as reinforcement in polyester resin matrix in this study.

Sandwich construction

Structural members made of two strong skins separated by a lightweight core are known as sandwich

Figure 1 : Fiber

Figure 2 : Sandwich structure

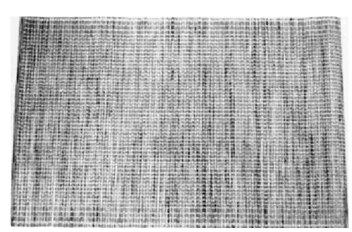

Figure 3 : Unidirectional fiber mat

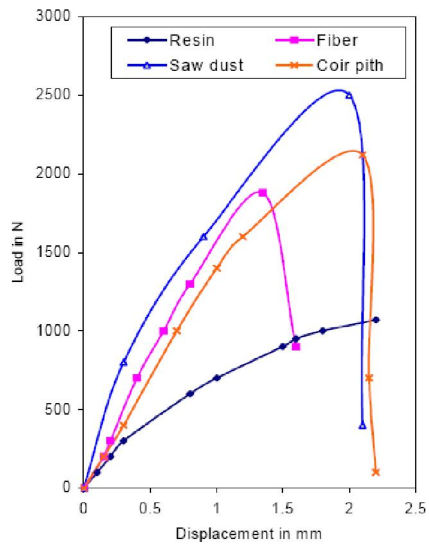

Figure 4 : Load deflection curve for tensile loading

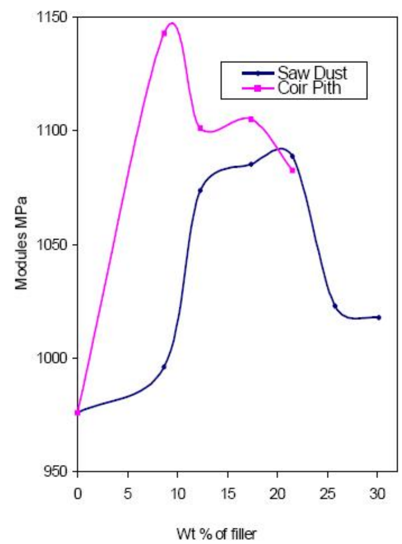

Figure 5 : Variation of tensile modules

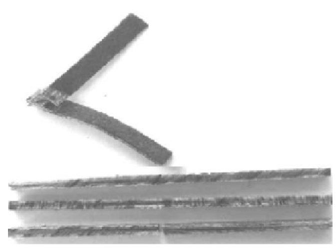

Figure 6 : Specimen showing the poor absorption of resin

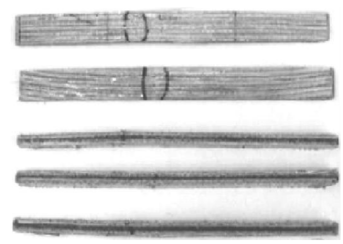

Figure 7 : Specimen tested on tensile loading

plates. The mechanical properties of the sandwich structures depend upon the materials and the thickness of the core and skin. In this experiment the palmyra fiber was used as skin material and the sawdust / coir pith as core material. The cross section of the sandwich plate prepared for this study is shown figure 2.

The palmyra fiber was cleaned, dried and a unidirectional fiber mat was prepared as shown in figure 3. A mould of 150×150×5mm was prepared in mild steel. The mould surface was coated with wax for easy removal of the composites plate from the mould. Weighted quantity of the filler material sawdust / coir pith was spread uniformly in between the two metal sheets and compressed to get a single mat preforms. Two unidirectional fiber mats were placed in the mold such that the fibers are oriented opposite direction to each other. The compressed coir pith saw dust preform was placed over the fiber mat, which forms the core. Another two layers of the fiber mat were placed over the core as said above. The general polyester resin mixed with accelerator and catalyst was poured over the fiber and the mold was then closed. Sufficient pressure was applied till the mould closes completely and allowed to cure at room temperature for four hours. The cured plates were removed from the mould and the test specimens were prepared as per the ASTM standards and tested in the Instron Universal Testing machine.In the present experiment the tensile, bending, shear and impact tests were conducted to study the mechanical behaviour of the composites. To study the effect of core material on the mechanical properties, composite plates with 10g, 15g, 20g, 25g, 30g and 35g (9, 12, 17, 21, 25 and 30 wt%) saw dust and coir pith core were prepared.

RESULTS AND DISCUSSION

Tensile test

Standard size specimens were cut from the plate and tested in the Instron-testing machine with the crosshead speed of 2mm per minute and the results are presented in TABLE 1. Incorporation of 28 weight % of fiber with out filler (14% in the length wise and 14% in transverse direction) results in an increase in strength value by 29.7% than that of resin. Addition of 10g of sawdust as a core results in increase in tensile strength by 14.6% and any further addition of sawdust say 15g, 20g, 25g, 30g and 35g (12, 17, 21, 25 and 30 wt%) results in little drop in strength and remains almost constant. Figure 4 shows the load deflection curves of the tensile tested specimens. No change in % of elongation is observed due to addition sawdust as filler.

TABLE 1 : Tensile properties of Palmyra fiber, coir pith/saw dust composites

Material	Core wt%	Resin wt%	% of elongation	Strength MPa	Modulus MPa	Composite weight in g
Saw dust (Core)	0	72	3 :02	42 :66	1421 :93	126
	9	63	3 :03	45 :98	1507 :49	115
	12	60	3 :04	45 :00	1500 :00	116
	17	56	3 :02	44 :94	1497 :93	115
	21	51	3 :21	46 :39	1449 :68	116
	25	48	3 :01	48 :21	1607 :00	116
	30	43	3 :01	47 :78	1587 :38	117
Coir pith (Core)	9	62	3 :42	52 :92	1556 :46	115
	12	61	3 :21	48 :16	1505 :05	115
	17	55	3 :01	46 :72	1557 :33	116
	21	52	3 :20	47 :65	1489 :06	117
	25	47	-	-		117
	30	42	-	-		116
Resin			4 :00	32 :33	808 :25	140

Addition of 10g (9 wt%) of coir pith as core in 28 weight % fiber composites results in increase in tensile strength by 23% than that of 28 weight % composites and further addition of coir pith results in little drop in tensile strength and is almost constant. Composites with 30g and 35g (25 &30 wt %) coir pith core was separated in to two half along the middle of the core when loaded axially and poor wetting of pith by the resin was observed at the failed surface. Specimens were also cut in the transverse directions and tested and almost similar results were obtained. The weight of the composite plates without core material was 126g and the weight with core material was 115g. Thus an 8% weight saving was achieved with out losing its properties. The % of elongation increases form 3.02 to 3.4 due to addition of 10 g (9 wt %) of coir pith.

The tensile modulus for various wt % of the core material is plotted in figure 5. Small increase in modules is observed due to the addition of 10g (9 wt%) sawdust and above that it is almost constant. In coir pith core, the composite plates made of 10g (9 wt%) core shows higher modules and for further addition of coir pith, little drop in modulus is observed and then it remains constant. 50% increase in modules than that of resin is achieved due to the fiber reinforcement. Figure 6 shows the failed surface of the composites, which is the evident of insufficient resin absorption and also observed that the all the samples tested were failed at the middle. The fiber is the major load-carrying element even after the addition of core material. Figure 7 shows tensile tested specimens. The mode of failure and crack propagation depends upon the sequence of stack. In this study the fibers are oriented opposite direction in alternate fiber layer and hence the crack is more localized and almost horizontal. Like in the unidirectional fiber composite the crack did not spread over the area as observed by velmurugan et al.[10]. Also a clear wider de-bonding of the core material was observed. Hence the failure could have initiated by the de-bonding of the core first and then followed by fiber failure. The load displacement curve pattern is almost similar for both fiber composite and fiber filler sandwich composite plates.

TABLE 2 : Flexural and shear properties palmyra fiber, coir pith/saw dust composites

Core material	wt %	Flexural modulus MPa	Flexural strength MPa	Shear strength MPa
Saw dust	0	2085 :82	63 :75	9 :79
	9	1933 :80	56 :42	10 :03
	12	1870 :00	56 :52	8 :22
	17	1853 :85	56 :85	8 :23
	21	1943 :95	56 :18	8 :14
	25	1950 :00	56 :29	7 :47
	30	1954 :00	56 :30	6 :09
Coir pith	9	1786 :80	55 :70	10 :09
	12	1761 :35	54 :52	8 :89
	17	1793 :10	52 :80	9 :04
	25	1921 :90	51 :23	9 :36
Resin		1324 :85	38 :54	4 :21

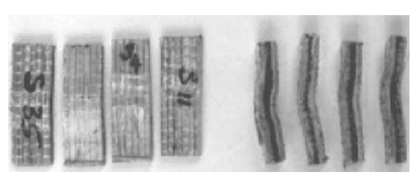

Figure 8 : Specimen tested on shear load

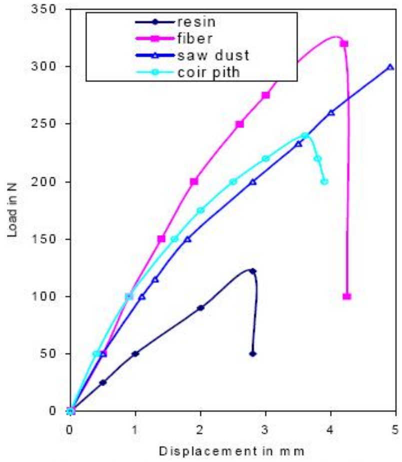

Figure 9 : Load deflection curve for bending

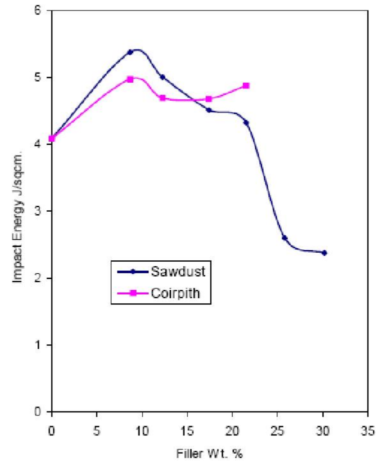

Figure 10 : Variation of impact strength

Shear test

The short beam shear test was performed with the crosshead speed of 2mm per minute and results were tabulated in TABLE 2. The specimens were cut with length of six times that of the thickness. The shear strength was calculated by the relation.

$$\tau_s = \frac{3W}{4bt} \quad (1)$$

Fiber reinforcement resulted increase in shear by 17% than that of resin. 10% increase in shear strength is observed due to the addition of 10g (9 wt %) saw-dust / coir pith. For any to further addition of either saw dust or coir pith the shear strength is almost constant. The tested specimens are shown in figure 9, which shows the crack on the core, debonding of laminate surface by a narrow line.

Flexural test

Standard size specimens were cut from the plate and tested in the Instron machine on three-point flexural test fixture with the crosshead speed of 2mm per minute and the results are given in TABLE 2. The flexural strength and flexural modulus was calculated by the following relation.

$$\sigma_b = \frac{3Wl}{2bt^2} \quad (2)$$

$$E_f = \frac{ml^3}{4bt^3} \quad (3)$$

where *m* - is the initial slope of the deflection curve, *b* - is the specimen width, *t*- is the specimen thickness and *W*- is the breaking load.

28% of fiber reinforcement (14% in each direction) increases the bending strength by 70% than that the matrix material. 11% drop in bending strength is observed due to the addition of 10g (9 wt%) sawdust, whereas in 10g (9 wt%) of coir pith it is 14% when compared to 28 wt% fiber reinforcement. There is not much of difference in bending strength observed due to any further addition of either coir pith or saw dust.

Impact test

Izod impact test was carried out on the unnotched specimens of standard size. Six specimens were tested for each case and the average value was considered. Figure 10 shows the impact resistance level for various composite plates. The polyester resin matrix without any reinforcement has very poor impact resistance of 0.23 J/sq cm. The fiber reinforcement increases the impact resistance of the polymer to 4 J/sqcm. Incorporation 10g (9 wt%) sawdust / coir pith in the form of core with 28 wt % fiber reinforced composite plates increases the impact resistance by 49%. urther addition of core material did not contribute much to the increase in impact resistant and there is a drop in the impact value for 25 and 30 wt% sawdust.

CONCLUSION

The use of coir pith and saw dust as filler in palmyra fiber reinforced composites was studied. Both coir pith and saw dust contribute increase impact strength. But their contribution to tensile strength was less, however there was little increase in strength and modules. Composites contain the coir pith had good shear properties than saw dust. Little drop in bending strength and modulus was observed for both coir and saw dust core. 8% of weight saving was also achieved without loosing its mechanical properties. This type of sandwich composite plates can be molded in to standard size and be used as interior panels for windows and shutters. Fiber damage and variation in fiber strength are the problems generally associated with natural fiber composites. The weight of the composite can also be reduced by sandwich construction without loosing its strength.

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