Chapter 17
Experimental Testing and Evaluation of Coconut Coir/Rice Husk Fiber Reinforced with Polymer Composites

P. N. E. Naveen, R. V. Prasad and D. Rajendra

Abstract Coconut coir fiber blended with rice husk reinforced in polyester composites manufactured by hand layup method shows better properties than the other natural fibers and extended many applications due to their low weight, high strength, and anti-corrosive nature. In this paper, the effect of chemically treated fibers (silane) on mechanical properties with different volume fractions 5, 10, 15, 20, 25, and 30% is reported. Chemically treated natural fibers show better mechanical properties than the untreated fibers due to removal of the waxy layer on the fiber and improvement of the interfacial bond between the fibers and polyester; after conducting all the treatments, it is proved that silane-treated fibers give better results than the other chemical treatments. The mechanical performance of the composite under dry and wet conditions and water absorption behavior of the composite are investigated by using computerized universal testing machine. The results finally concluded that 5% volume fraction composites play the best performance than the other ones because of their bonding strength and dispersion in the structure of the matrix.

Keywords Silane treatment · Mechanical properties · Coconut coir · Rice husk · Tension · UTM

P. N. E. Naveen (✉)
Department of Mechanical Engineering, SVPEC, Visakhapatnam, Andhra Pradesh, India
e-mail: pne.naveen@gmail.com

R. V. Prasad
Department of Mechanical Engineering, Methodist, Hyderabad, Telangana, India

D. Rajendra
Department of Mechanical Engineering, Sri Padmavathi Mahila, University,
Tirupati, Andhra Pradesh, India

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17.1 Introduction

Natural fiber-reinforced composite materials plays a major role in their application due to their properties when compared to other synthetic fiber composites. A combination of two or more materials gives the different structures than the individual one which is used to change the behavior of a material especially suitable for engineering applications. Composites are hybrid materials composed of resin and fibers; the strength of a composite always depends upon the type of fiber, bonding between the fiber and the resin, and fiber orientation in the matrix. The most common natural fibers are coir, sisal, banana, rice husk, jute, hemp, etc., having better mechanical strength when reinforced into the polymer resin. The current paper describes the manufacturing method of coconut coir/rice husk fiber reinforced into the polymer resin and its mechanical properties in dry and wet conditions. Here, chemically treated fibers were mixed with the polymer and, by using hand layup process, specimens were prepared in different volume fractions of coconut coir and rice husk in order to obtain more accurate results.

17.1.1 Chemical Treatment of the Fiber

The chemical treatment is used to improve the bonding strength between the fiber and the resin such that mechanical properties will increase and the water absorption level of the fiber will decrease depending upon the adhesion characteristic of the material. Out of the available chemical treatments, here we are using silane treatment. Silane solution which means 95% of ethanol and 5% of distilled water, after that solution was stirred for 4 h with 70 °C temperature and then the solution is washed with distilled water to attain pH value of 6 to turn the acidic solution into neutral. After the filtration of fibers, all are collected in a crucible to remove moisture content of fibers and placed in a vacuum for 8 h and the silane-treated fibers are collected from the solution.

$$\mathrm{Si} + 3\mathrm{HCl} \rightarrow \mathrm{HSiCl_3} + \mathrm{H_2}$$

$$4\mathrm{HSiCl_3} \rightarrow \mathrm{SiH_4} + 3\mathrm{SICL_4}$$

Thus, the process of silane directly affects the cellulosic fiber and the degree of polymerization and the pulling out the lignin and hem cellulosic compounds. This treatment has two effects on fibers.

(1) Surface roughness is increased to result good mechanical properties
(2) It effects fiber strength and stiffness of it.

17.2 Literature Review

Jartiz et al. [1] Composites are multifunctional materials that provide characteristics not obtainable from any discrete material and cohesive structures made by physically combining two or more materials, they are different in composition and characteristics.

Kelly et al. [2] said that the composites are not a simple combination of two materials and the combination has their own unique properties. The composite strength, hardness, and resistance to heat are always better than those of the individual components.

Berghezan et al. [3] defined that "The composites are compound materials which differ from alloys and the individual components having their won characteristics but are so incorporated into the composite as to take advantage of their attributes and not of their shortcomings."

Van Suchetclan et al. [4] stated that the composite materials as heterogeneous materials consist of two or more solid phases, having contact with each other on a microscopic scale and also considered as homogeneous materials on a same scale at any portion of it will have the same physical property.

Water absorption behavior indicated that hybrid composites offer better resistance to water absorption.

17.3 Design Manufacturing and Testing

The composite material was made of a polymer matrix reinforced with coconut and rice husk fibers. They were arranged in discontinuous random orientation in the resin. Basically, coir fibers were obtained from coconut husk, which was abstracted from coconut fruit and rice husk from the rice mills; these fibers will be dried at 80 °C with the help of oven to minimize the moisture content in the fibers. The chemical treatment is used to improve the bonding strength between the fiber and the resin such that mechanical properties will increase and the water absorption level of the fiber will decrease; depending upon the adhesion characteristic of the material, in this we used the silane treatment out of the existed methods.

17.3.1 Production of Test Specimen

The test specimen panels of 5–30% coconut coir and the rice husk fiber content were produced by hand layup process. Curing was done in an oven operated at 100 °C. The specimens were removed from the oven after 30 min and were conditioned. The example of the calculations is as follows:

Fig. 17.1 Coir fiber-reinforced polyester composite tensile test specimen

i. The total volume of the sample as shown in Fig. 17.1 is calculated.
ii. Five percent of the total volume which is occupied by the fiber is determined, and then, the volume of the fibers is converted to fiber weight using equation:

$$\text{Density P} = m/v$$

where m is the mass of the fibers and v is the volume occupied by the fibers.

iii. Fibers are then mixed with polymer resin, and they are mechanically stirred to produce homogenous mixture.

17.4 Mechanical Testing

Tensile test is used to determine the mechanical properties of materials such as strength, ductility, toughness, elastic modulus, and strain hardening. There are five samples for each fiber volume fraction, and the average values obtained from those samples were determined. The sample used for tensile test was ASTM D638 Type 1 as shown in Fig. 17.1. The tests consisted of applying 10 KN capacity operated at a crosshead speed of 5 mm/min (Figs. 17.2 and 17.3).

Fig. 17.2 Material required for preparing the components

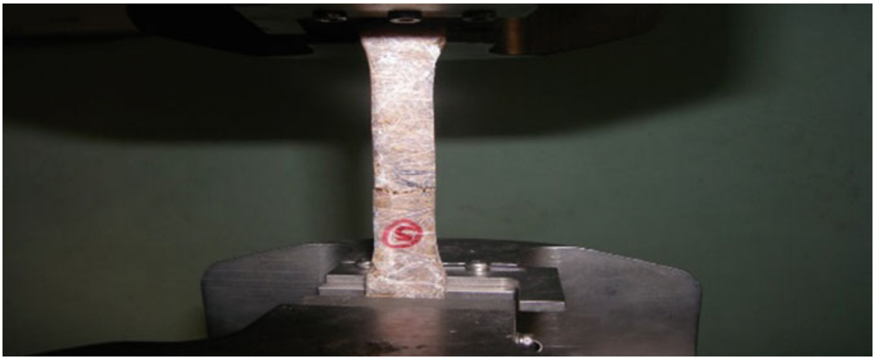

Fig. 17.3 Specimen subjected to UTM

17.5 Results and Discussion

The results of some mechanical strength properties and correlation of treated coir and rice husk fiber reinforced polymer composite panels are shown in (Tables 17.1, 17.2 and Charts 17.4, 17.5).

Table 17.1 Tensile properties of the specimen with different volume fractions

Volume fraction	Composition	Tensile values	Failure strain	Young's modulus
5%	Coir	25.2	3.4	633
	Rice husk	23.5	3.5	800
5% (4 + 1%)	Coir/rice husk	28	2.8	938.5
10%	Coir	21.4	4.6	148.2
	Rice husk	21	5.1	1000
10% (7 + 3%)	Coir/rice husk	23	3.7	1125.4
15%	Coir	17	5.5	318.8
	Rice husk	16	5.8	1020
15% (10 + 5%)	Coir/rice husk	18	3.2	1200
20%	Coir	15.3	6.8	209.1
	Rice husk	14.5	7.2	1080
20% (12 + 8%)	Coir/rice husk	15	6.4	1210
25%	Coir	13.8	7.9	110
	Rice husk	12.2	9.0	1200
25% (15 + 10%)	Coir/rice husk	12	6.8	1300
30%	Coir	11.5	7.9	40
	Rice husk	10.8	9.0	1500
30% (15 + 15%)	Coir/rice husk	12	6.8	1508.1

Table 17.2 Water absorption properties of the specimen with different volume fractions

Volume fraction	Composition	1 h	24 h	72 h	120 h
5%	Coir	8	9	8	9
	Rice husk	4	5	5	6
5% (4 + 1%)	Coir/rice husk	7	7.2	7.5	7.8
10%	Coir	9	9	9.5	10
	Rice husk	8	8.1	8.5	8.7
10% (7 + 3%)	Coir/rice husk	8.3	8.5	8.7	8.8
15%	Coir	11	11	11.5	11
	Rice husk	8	8.2	8.8	9
15% (10 + 5%)	Coir/rice husk	9	9.1	9.1	9.3
20%	Coir	13	13.5	14	14
	Rice husk	10	10.4	10.6	10.8
20% (12 + 8%)	Coir/rice husk	9.9	10.2	10.4	10.6
25%	Coir	15	16	17.5	18
	Rice husk	12.2	12.8	13.1	13.4
25% (15 + 10%)	Coir/rice husk	11.2	11.5	11.8	12
30%	Coir	16	17	17.8	19
	Rice husk	13	16	16.8	17.4
30% (15 + 15%)	Coir/rice husk	13	13.5	14	14.8

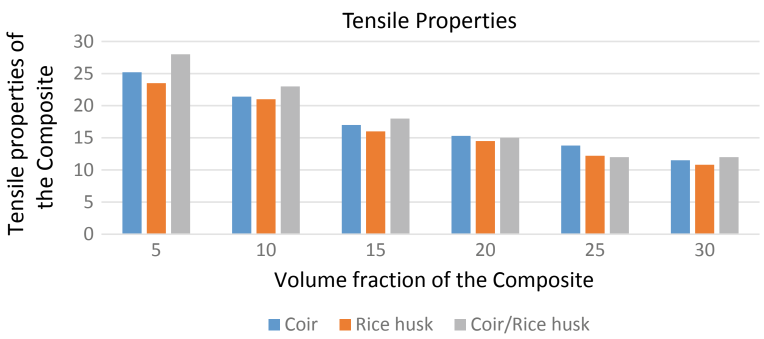

Chart 17.4 Tensile properties of the composites with different volume fractions

Water Absorption Test

The chemical treatment on coconut coir/rice husk is used to improve the bonding strength between the fiber and the resin such that mechanical properties will increase and the water absorption level of the fiber will decrease depending upon the adhesion characteristic of the material. Thus, chemical treatment of coir/rice husk fiber by using silane is environmentally friendly and produced composite materials are suitable to be applied in marine applications.

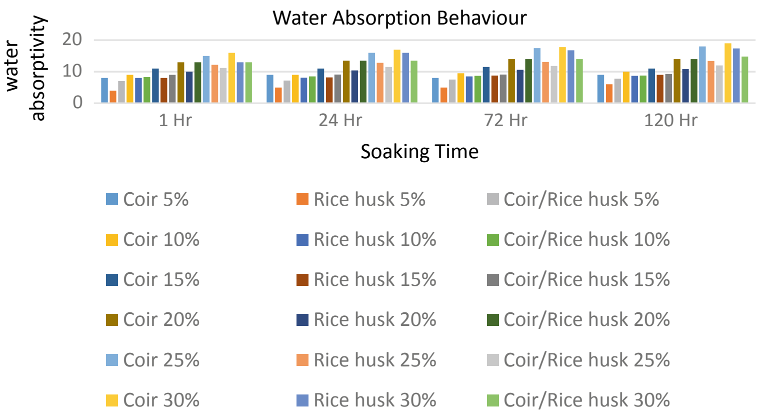

Chart 17.5 Water absorptivity of the composites with different volume fractions

17.6 Conclusion

Finally, this research is used to study the static and water absorption behavior of randomly oriented coir/rice husk fibers mixed with reinforced polymer composites. The volume fraction of the coir/rice husk fibers playing a major role on its mechanical properties of composites was studied, and depending upon this phenomenon, we calculated the water absorption behavior of the fibers reinforced in the polymer resin. From this research, we conclude that the composites having the volume of 5% coir/rice husk fiber showed the notable result when compared to high fiber loading composites due to the effect of material stiffness. When the fibers tested in water at different time intervals show a slight change in their tensile properties due to this reason we can use composites in different applications like turbine blades, marine application.

References

1. Jartiz, A.E.: Design, pp. 18 (1965)
2. Kelly, A.: Sci. Am. **217**(B), pp. 161 (1967)
3. Berghezan, A.: Non-ferrous materials. Nucleus **8**, 5–11 (1966)
4. Van Suchtelen, J.: Product properties: a new application of composite materials. Philips Res. Rep. **27**, 28 (1972)
5. Agarwal, B.D., Broutman, L.J.: Analysis and performance of fiber composites, pp. 3–12. Wiley, New York (1980)