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Mechanical Performance of Bio Particulated Natural Green Husk Coir Fiber-Vinyl Ester Composites

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Abstract: The tensile, flexural and impact properties of various bio particles impregnated natural green husk coir fiber reinforced vinyl ester composites were compared in order to introduce a new platform for the development of bio particulated natural fiber-polymer composites. The thermal conductivity of bio-particulated coir-vinyl ester composites were measured using Lee's disc method. The problem of matrix cracking for the quick failure of natural fiber reinforced polymer composites was solved using matrix strengthening by bio particulate inclusion and the inter laminar bond between constituents of composites were studied using SEM images in this investigation.
Keywords: Rice husk: particulate; coir fiber; vinyl-ester; scanning electron microscope.

Introduction

The natural fiber reinforced polyester composites were developed to replace the synthetic fiber and petroleum based plastics, due to their high cost and environmental degradation[1]. Among the different natural fibers, some of the natural fibers such as sisal, banana and coir etc. were proved as better reinforcements in polymer applications[2]. The short coir fibers and boiled egg shell particles were used as reinforcement materials in vinyl ester composites and better mechanical behaviors were obtained in earlier studies[3]. In order to improve the mechanical properties of composites further, the particles such as alumina, calcium carbonate were added and desirable properties were tested[4, 5]. The best and simple way of improving mechanical behaviors of coir-polymer composites are by strengthening matrix system by particulate inclusion. Among the synthetic and natural particles, the bio particles attract the researchers in recent years, addition of fillers as fly ash, red mud along with natural fiber such as sisal and jute fiber have reported better mechanical properties[6,7,8,9]. The effective utilization of bio waste particles has been emphasized in society for environmental and economic concerns. The bio particulates are used in the fiber reinforced composites for producing the desired mould shape and to reduce the manufacturing cost of composites and also to enhance the mechanical behaviors of the composites[10].The bio waste such as rice husk used as reinforcement in polymer applications proved the better mixing of matrix and rice particulates leading to better mechanical properties[11,12,13,14,15].The present investigation is focused on the development of bio particulates such as rice husk, boiled egg shell, alumina, groundnut shell and termite mound soil impregnated coir fiber-polymer composites by evaluating mechanical and thermal conductivity behaviors.

Materials and Methods

Materials

The natural short green husk coir fibers along with bio particles were used as reinforcement materials in this investigation. The bio particles such as termite mound soil, rice husk, groundnut and boiled egg shell particles were obtained from the south region of Tamilnadu. The chemical composition of bio particles used in this investigation is listed in Table.1.

Table.1 Chemical composition of bio particles

Composition (%)	Termite mound soil	Rice husk	Groundnut shell	Boiled egg shell
Cellulose %	28.3	35.7	31.3	32.7
Hemi Cellulose %	16.5	18.7	24.3	26.7
Lignin %	35.4	30.2	14.3	19.5
Ash %	4.3	5.9	23.5	13..7
Pectin %	9.1	9.5	6.6	9

Since alumina has ability to improve the mechanical performance of the vinyl ester composites, it is also used along with coir fiber to reinforce the vinyl ester matrix. Also addition of alumina helps in preventing the crack propagation in the matrix when subjected to sudden load. The collected particles were sieved finely to obtain particle size of 75 µm and are added individually with vinyl ester resin reinforced with coir fibers. The use of particles with size of 75 microns helps in improving the bindability of particles with vinyl ester resin[16]. The matrix system used in this investigation, consist of unsaturated vinyl ester resin along with 1.5 % cobalt Octane accelerator, 1.5 % Methyl Ethyl Ketone Peroxide (MEKP) catalyst and 1.5% of Di-methyl Aniline (DMA) promoters.

Composite fabrication

A 30 Ton capacity ACE make hydraulic compression molding machine was used to fabricate the bio particulated composite plates for the dimensions of 300 × 300 × 3 mm. The short coir fiber length was varied from 10 to 50 mm for five levels. The particulate weight content of bio particulates were varied from 5 % to 25 % at five levels; correspondingly the fiber weight content was varied from 35 % to 15 % for five levels. The particle content range was selected based on the previous studies[17, 18] which reported feasible mechanical properties within this specified range. The appropriate weight content of reinforcement and matrix was mixed using mechanical stirring and maintained with pressure of 2.0 MPa and temperature of 80°C for 45 minutes to facilitate uniform curing of composite sheets. The atmospheric conditions of 29^0 C temperatures and Relative Humidity of 55 % were recorded during the composite manufacturing.

Thermal conductivity and mechanical testing

The Lee's disc method based on the principle that the quantity of heat conducted through the bad conductor is equal to the quantity of heat radiated by the disc at the steady state condition. The coefficient of thermal conductivity of prepared composites was determined experimentally using Lee's disc method. The method was adopted based on the past studies which used Lee's disc apparatus for measuring thermal conductivity[19, 20]. This method is familiarly applied to study the effect of incorporating particles on the thermal conductivity of PTFE/glass fiber fabric used for conveyor belts in food processing industries. The steady state temperature of the chamber (Φ_1) and the temperature of the lower disc (Φ_2) were maintained at 99^0 C and 89^0 C respectively.

The static tension test samples were cut for prepared composite plates according to ASTM D 638-10 standard for the dimensions of 165 × 25 × 3 mm and the tensile behavior of bio particulated coir-vinyl ester composites were tested using Computerized Universal Testing machine (Tinius Olsen H50K).The three point flexural test samples were cut according to ASTM D 790-10 for the rectangular test pieces of 125 × 12.5 × 3 mm were used. The impact test was carried out using Tinius Olsen Impact Tester (Model: Impact 104) with the specimen size of 60 × 12.5 × 3 mm as per ASTM D 256-10 standard. Testing conditions of 23 ± 2^0C temperature and relative humidity of 50 ±5 % were followed and five samples in each combination in each test were tested in order to derive statistical significance of results.

Results and Discussion

Thermal conductivity behavior of bio particulated coir- vinyl ester composites

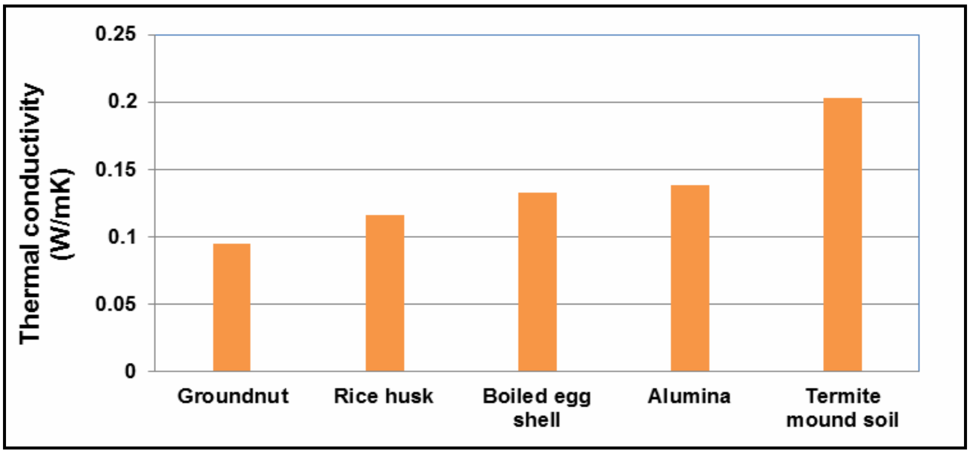

Figure 1. Effect of particle content on thermal conductivity of coir fiber-vinyl ester composites.

The thermal conductivity for various bio particulated coir-vinyl ester composites was evaluated. The Figure 1. shows the effect of particle content on thermal conductivity of coir fiber-vinyl ester composites.Thermal conductivity of particulated coir fiber-vinyl ester composites was found to better with composites reinforced with termite mount soil. The better conductivity of termite mound soil reinforced coir-vinyl ester composites (0.203 W/m K) is due to the presence of ferrous particles in the termite soil mount soil. The presence of alumina, calcium and silica content in the particulates had also played a leading role in improving the thermal conductivity of the bio-particulates fiber reinforced polymer composites. The alumina, boiled egg shell, rice husk and groundnut particulates impregnated coir-vinyl ester composites exhibited thermal conductivity of 0.138 W/m K, 0.133 W/m K, 0.116 W/m K and 0.095 W/m K respectively.

Mechanical behaviors of bio particulated coir-vinyl ester composites

The experimental result confirmed the role of particulate impregnation in improving the mechanical properties of the coir fiber reinforced vinyl ester composites. Figure 2. shows the effect of particle content on tensile strength of coir fiber-vinyl ester composites.

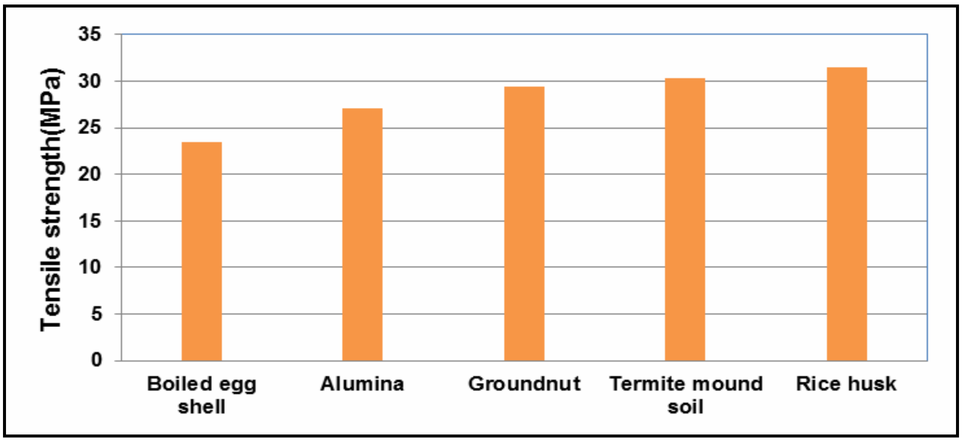

Figure 2. Effect of particle content on tensile strength of coir fiber-vinyl ester Composites.

The tensile strength of the composites was found to be better with rice husk particulate coir-vinyl ester composites. This because of the presence silicon content in rice husk particulate in a larger proportion (96.4%) and at the same time the tensile strength was found to decrease with the decrease in silicon proportion in the particulates. Similar behavior was inferred with flexural strength of the composites but change in order was observed with groundnut shell and termite mount soil, this is due to fact that the larger proportion of aluminum oxide present in groundnut shell particulates (26.98 %) has improved the bindability of the matrix with coir fiber. Effect of particle content on flexural strength of coir fiber-vinyl ester composites was shown in Figure 3.

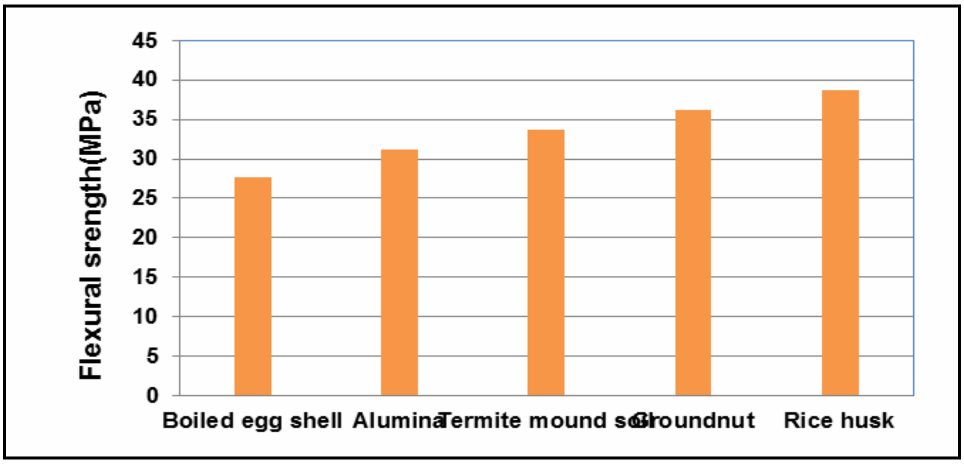

Figure 3. Effect of particle content on flexural strength of coir fiber-vinyl ester composites.

The presence of higher calcium content (95%) with boiled egg shall rendered ease of mould ability but reported poor mechanical properties compared to rice husk and termite mount soil impregnated coir fiber reinforced vinyl ester composites.Figure 4. shows the effect of particle content on impact strength of coir fiber – vinyl ester composites. The uniform shape and density of termite mount soil rendered uniform dispersion of particulate in matrix phase which in turn resulted in better Impact strength.

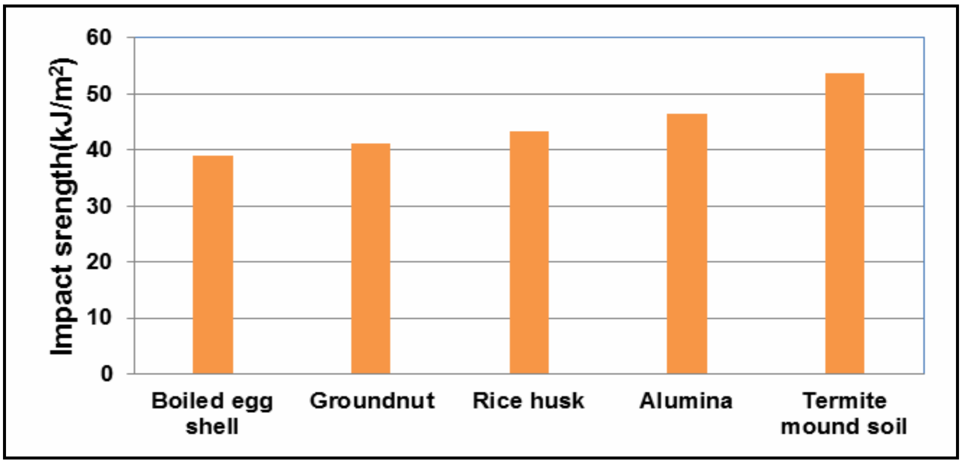

Figure 4. Effect of particle content on impact strength of coir fiber-vinyl ester composites.

Conclusion

The thermo-mechanical behaviors of various bio particulated coir-vinyl ester composites were evaluated. The better values of tensile strength of and flexural strength of were obtained in rice husk particulated coir-vinyl ester composites whereas better impact properties of 53 kJ/m^2 were obtained with termite mound soil impregnated coir-vinyl ester composites. The interlaminar bond and adhesion between constituents of composites were studied using SEM images. This specific investigation on thermal and mechanical behaviors of bio particulated coir-vinyl ester sets a new platform for the introduction of new variety of polymer composites in engineering applications.

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