

Article

Mechanical Properties of Hybrid Periwinkle and Rice Husk Filled CNSL Composite

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Abstract: In recent years, hybrid biocomposite materials have replaced many conventional ones, such as wood and metals in many applications. The reason is due to the advantage of hybrid biocomposite over the conventional materials. The objective of this study was to develop and determine the mechanical properties of a hybrid biocomposite made of periwinkle shell, rice husk and cashew nut shell liquid (PWS/RH/CNSL). The growing concern of resource depletion and environmental pollution poses a serious challenge to engineers and scientists in the world. Therefore, the need to develop new materials relying on renewable sources has led to research of biocomposite materials. The composite in this research work was prepared using ASTM standard. Mechanical properties such as tensile strength, tensile modulus and flexural strength were determined at different percentage of filler content. The results obtained show that for a 10 to 20% increase in filler content, the tensile strength increased by an average of 32%. The increase in percentage of filler content and particle size led to a uniform decrease in tensile strength and a slight increase in tensile modulus. The impact strength decreases for increase in particle size and increases as the percentage of filler content is increased. Similarly, a reduction in percentage elongation and a slight increase in flexural strength were observed for increase in particle size, which converge at 30 % filler content. The result indicates that variation in particle size and filler content influences the mechanical properties of the composite.

Keywords: filler content; particle size; periwinkle-shell; rice husk; CNSL resin; mechanical properties.

1. Introduction

Glass fibre is an engineering material that is widely used for reinforcement of plastics because of its low cost and good mechanical properties. Despite these advantages, glass fibre has its drawbacks, which includes health risk to the body when inhaled, high-energy consumption during processing, abrasion to machines, high toxicity, non-renewability and recyclability and non-biodegradable. The drawbacks of this fibre and other petroleum fibres have given room for the need to develop alternative materials that relies on renewable sources. Extensive applications of natural fibres have been demonstrated in the previous works [1-4]. Epoxy and polyester resins like glass fibre are widely used, especially in the automobiles and aerospace industries. The two resins have been characterized for their low impact strength, high brittleness and poor resistance to crack [5,6]. The need to take care of these set back resulted into the utilization of natural resin. Furthermore, fillers are added to matrix among other things to improve the properties of the emerging composite. The successive utilization of rice husk, calcium carbonate (CaCO_3), silica and black carbon as fillers have been reported [7-9]. Similarly, Jacobson et al. [10] reported that for all filler sizes, the mechanical properties of PP and kaolin composite decreased with increasing filler content. The addition of fly ash into PP matrix was found to improve the tensile modulus, with a decrease in tensile strength, impact strength and elongation at break for increasee in filler loading [11-13]. Clay, kaolin, rice husk ash, and fly ash have been used for the reinforcement of plastics [14].

Periwinkles (*Turritella communis*) are small edible species of medium-sized sea snails of the marine *gastropod mollusks*. Research into properties of periwinkles shells has been on the possible usage as concrete replacement. The work of Adewuyi and Adegoke [15] compared a total of 300 concrete cubes of size $150 \times 150 \times 150 \text{ mm}^3$ with different percentages by weight of crushed granite to periwinkle shells as coarse aggregate in the order 100:0, 75:25, 50:50, 25:75 and 0:100, which were cast, tested and their physical and mechanical properties were determined. Compressive strength from their tests showed that 35.4% and 42.5% of the periwinkle shells in replacement for granite was quite adequate with no compromise in compressive strength requirements for concrete mix ratios 1:2:4 and 1:3:6. This corresponds to savings of 14.8% and 17.5% for 1:2:4 and 1:3:6 concrete mixes, respectively. Similar research is found in the works of other persons [16,17], who researched on the mechanical properties of quaternized polysulfone/benzoyl periwinkle shells blends. Furthermore, attempt on the use of natural renewable matrix is not common in literatures. This research intends to investigate the mechanical properties of hybrid composite made of perewinkle shells (PWS), rice husk (RH) as reinforcing fillers using cashew nut shell liquid (CNSL) resin composite as the matrix. The effect of the addition of these fillers on the tensile, flexural and impact properties of the resulting composites as well as the matrix will be examined.

2. Materials and Methods

2.1. Source of Material

Periwinkle shells were purchase from the local market of Calabar and rice husk (RH) was supplied by local rice mill in Ugep, both in Cross River State, Nigeria. Cashew nuts were obtained from Obollo-Afor cashew plantation in Udenu local government area of Enugu State, Nigeria. All

chemicals, saline solution constituents, catalyst (methyl ethyl ketone peroxide/MEKP), accelerator (cobalt naphthanate (CDA-4301)), PVA, wax and NaOH pellets used were all of commercial grade.

2.2. Preparation of the Composite

The composite was prepared by compression moulding technique after pre-treatment of the fillers periwinkle shells and rice husk, while cashew nut shell resin (CNSL) was extracted using the “hot-oil-bath” method as described below. The cashew nut was broken into two halves to remove the edible part. The shells are poured in a vat pan containing n-hexane, allowed to soak for 24 hours after which the solution is filtered and heated to distil n-hexane leaving behind CNSL only. Oxalic acid and CNSL were mixed (ratio 1:32 g/mL) in a three neck 500 mL reactor equipped with stirrer and water-cooled condenser. The solution was purge with nitrogen for 10 minutes, heated to 70 °C with formaldehyde added slowly, and heated continuously for about 2 hours to a temperature of 150 °C to remove water living cardanol novolak resin as condensate. Furthermore, a mole of cardanol novolak, glycidylmethacrylate (GMA) and 0.8% of benzyltriethyl ammonia chloride were mixed in a 500 mL three neck reactor equipped with stirrer and water-cooled condenser. The mixture is purge with nitrogen for 10 minutes and heated to 105 °C with GMA added and allowed to heat for about 10 hours, forming a resin.

The periwinkle shells (PWS) were first soaked in detergent for 24 hours, and then washed thoroughly with wire brush to remove dirt's and odour, dried in an oven at 80 °C overnight, and then milled. The milled PWS powder was mixed with NaOH solution for about 3 hours at room temperature, thoroughly washed with deionised water, dried again in an oven overnight at 70 °C. The RH was first soaked in water to remove sand and other impurities dried in the sun and later in an oven at 70 °C overnight before treated with NaOH. The dried RH was immersed in NaOH solution for 3 hours at room temperature, washed thoroughly with deionised water and air dried. On drying 400 µm, 600 µm and 800-µm sieve were used to get different particle sizes of both PWS and RH. Sample specimens were produced at 10, 20 and 30 % filler content at a ratio of 1:1 by weight of PWS and RH.

2.3. Mechanical Testing

Tensile strength, tensile modulus, flexural strength and percentage elongation were measured using Universal Testing Machine - UTM (Instron 5567) while RAY-RAN Universal Pendulum Impact System for Izod-Charpy-Tension and Puncture was used for impact test. Tensile test specimen were made according to ASTM D638M, while flexural strength test samples were made according to ASTM D790M and impact strength test specimen were made according to ASTM D256M. Five samples were tested for each filler content and average results were used. A crosshead speed of 5 mm/min was used. All specimens were conditioned at a temperature of 23 ± 2 °C and 50 ± 5 percentage relative humidity for 48 hours before testing.

3. Results and Discussion

Figure 1 shows the powdered periwinkle shell of different microns (400, 600 and 800) and rice husk used for the preparation of the composite. The powdered PWS look milky white with some dark

particles. The dark particles are due to the dark outer surface of this sea shell. Fig. 2 shows the graph of tensile strength of the composite at different filler content of PWS/RH. Fig. 3 shows the tensile modulus of the composite at different filler content and particle sizes. Fig. 4 shows the increase in percentage elongation as the filler content increases from 10 to 30 %, while Figs. 5 & 6 show the flexural and impact strength of the composite at different filler content.

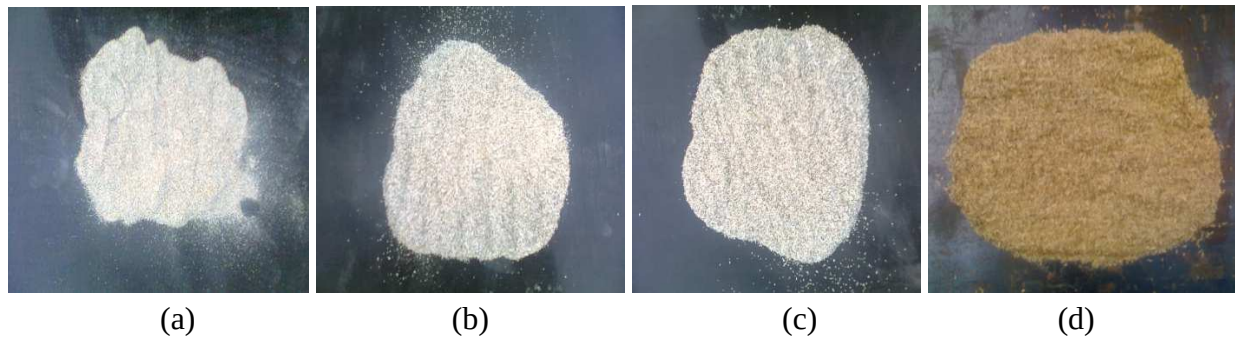


Figure 1. Powered periwinkle shells (a) 400 μm , (b) 600 μm , (c) 800 μm and (d) rice husk filler

The result of the test in Figure 2 shows that the tensile strength increased by an average of 32 % for 10 to 30 % increase in filler content. For each percentage filler content and increase in particle size, there is a uniform decrease in tensile strength. Furthermore, the percentage decrease in tensile strength at 10, 20 and 30 % filler contents was 2.5, 4.2 and 4.3%, respectively. As the particle size increases irrespective of the percentage filler content, there is an increase in interfacial area, this increase in interfacial area results into poor interfacial bonding and inefficient stress transfer between filler and matrix polymer. This poor bonding decreases the tensile strength as shown in Figure 1(a-d). The absence of porosity, void, good interfacial bond and better dispersion of PWS/RH/CNSL may have contributed to the good tensile properties recorded here.

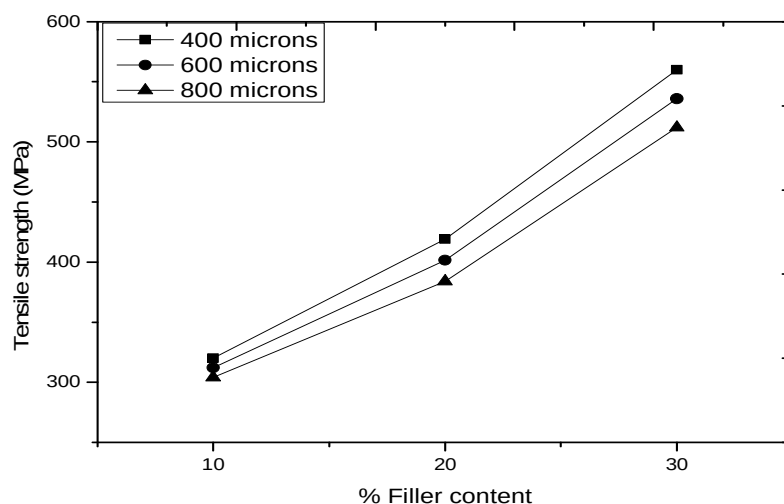


Figure 2. Tensile strength properties of PWS/RH/CNSL

Figure 3 shows the tensile modulus of the composite at different filler content and particle sizes. There was no significant increase in tensile modulus irrespective of the particle size at given filler content but gradually increases between 19 and 33 percent as filler content increases. This increase occurs at all the particle sizes. Fig. 4 shows an increase in percentage elongation as the filler

content increases from 10 to 30 %. For any given filler content with increase in particle size, there is a gradual decrease in percentage elongation an indication that PWS/RH inhibits molecular mobility or deformability of CNSL matrix. In addition, the reduction in elongation and discontinuity at failure could be because of discontinuous morphology and extended surface area due to increase in particle size

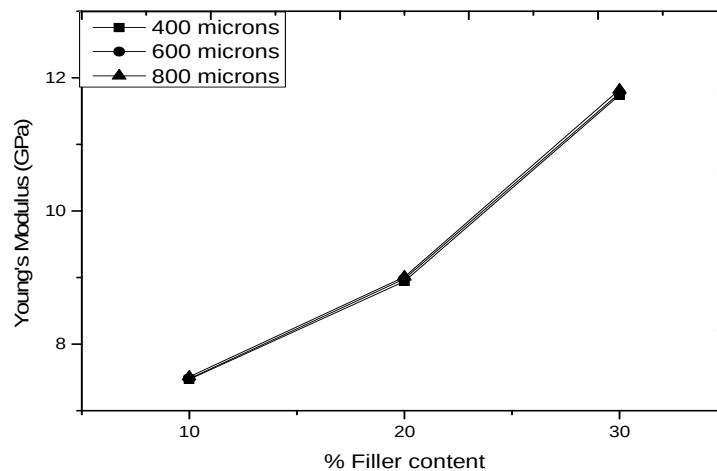


Figure 3. Tensile modulus properties of PWS/RH/CNSL

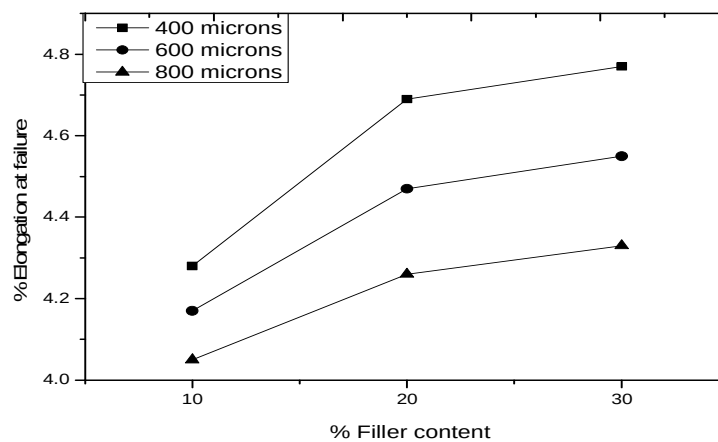


Figure 4. Percentage elongation of PWS/RH/CNSL

Fig. 5 shows the flexural strength of the composite at different filler content which covers at 30 % filler content. An average of 10, 12 and 13 % increase was obtained as the percentage of filler content increases for 400, 600 and 800 μm particle size, respectively. This increase is a confirmation of the assumption of controlled mobility of matrix by filler particles. As the particle size increases there is a reduction in the total surface area available for matrix filler interaction resulting into increase in mobility of matrix molecules. Fig. 6 shows the impact strength of the composite. The impact strength increases as the percentage filler content increases and decreases as particle sizes increases. The percentage increase is between 18 and 42 for 400 μm , 16 and 59 for 600 μm and between 14 and 90 for 800 μm while the average percentage decrease is between 13 and 27 across percentage filler content.

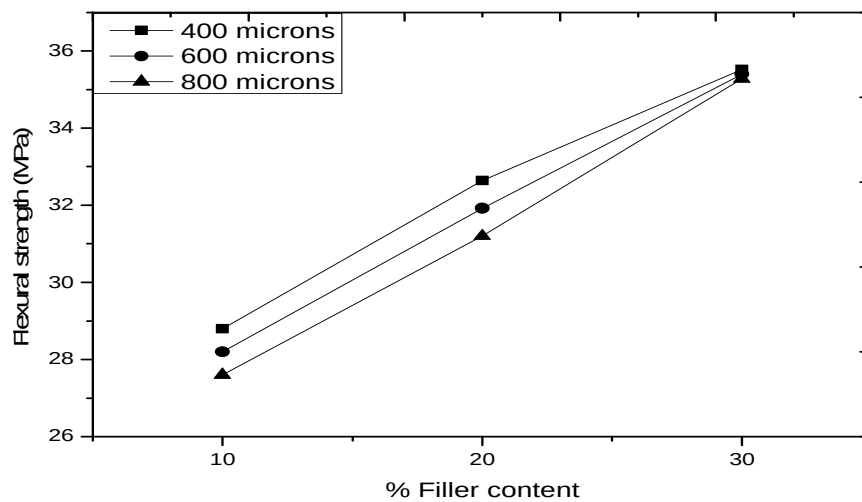


Figure 5. Flexural strength of PWS/RH/CNSL

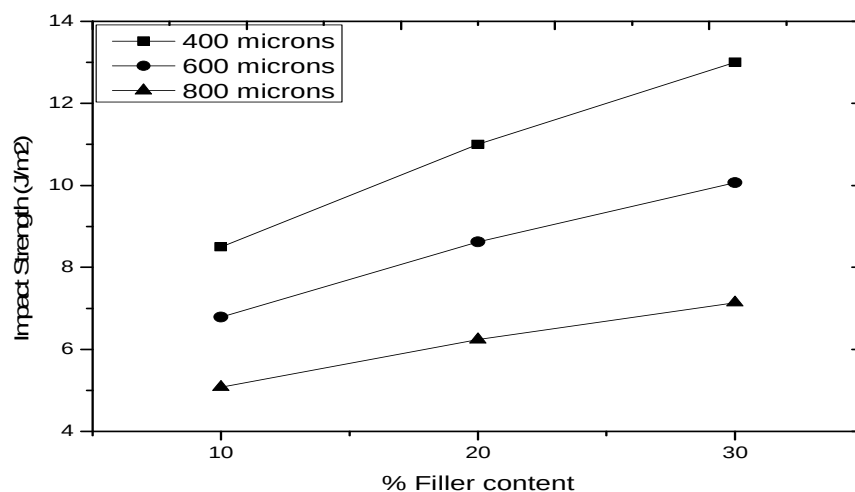


Figure 6. Impact strength of PWS/RH/CNSL

4. Conclusion

The mechanical properties of hybrid periwinkle and rice husk filled CNSL composite has been considered in this research. The results obtained show that the highest tensile and flexural strengths were obtained at 30% filler content and 400 μm particle sizes, and the highest tensile modulus and impact strength were obtained at 800 μm and 400 μm particle sizes, respectively, for same percentage of filler content. The flexural strength from the result converges at 30% filler content. This can however, be concluded that the optimum properties can be achieved at 30% filler content.

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