

EVALUATION OF MECHANICAL PROPERTIES OF COIR FIBER REINFORCED POLYETHYLENE COMPOSITES

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Abstract

Environmentally friendly application of coconut husk as coir fibre reinforced composite can prevent the coconut husk wastes from constituting health and environmental menace. This study therefore examined the potential of using coconut husk as reinforcement in polyethelene composite. The effects of 10, 20 and 25% coir fibre weight fractions on the mechanical properties of the coir fiber composite were studied. The results indicated that the mechanical properties of composites reinforced with coir fiber were dependent on the weight fraction of coir fibers with 10% coir fiber weight fraction showing a significant result compared to high fiber loading composites.. The statistical analysis of the results indicated that there was no statistical significant difference between the properties of the composites and the properties of the 100% polyethylene resin which indicates the potential of coir fiber reinforced polyethylene composite to be used as substitute for 100% polyethylene resin without any significant change in property.

Keywords: coir, polyethylene, mechanical property, wastes utilization, Renewable resource

1. Introduction

Application of composite materials in virtually all areas of life has increased dramatically due to the qualities of the composites which include weight saving, low cost, easy availability, low density, CO₂ neutrality, recyclable and biodegradability, among others. However, the usage of the composites is still limited because some of the composite materials are still not cost effective and durable enough in tough conditions to replace traditional materials such as plastics, rubber, ceramics, and alloys, among others. Accordingly, new composites are currently being developed to overcome the challenges aforementioned, and therefore suitable for applications such as wind mill blades, shafts, gas cylinders, support beams, armoured fighting vehicles, among others (Verma et al. 2013). Besides, most of the new composites being developed are reinforced with biodegradable natural fibres from agriculture wastes, to address the environmental concern of non-biodegradability of the polymeric materials used for day-to- day activities. The influence of natural fibres including coir, sisal, jute, oil palm fibres on properties of composites depends on the type, quantity, and orientation of the fibers, among others.

Coir, which is scientifically known as *Cocos nucifera*, is a natural fibre of the coconut husk extracted from its outer shell (Ray 2005, Ali 2011). Although there are brown and white fibres got from ripe and unripe coconuts, respectively; brown fibres are mostly used in engineering applications (Aggarwal 1992, Agopyan et al. 2005, Ramakrishna and Sundararajan 2005, Li et al. 2007, Munawar et al. 2007, Corradini et al. 2008). Coir fibres have many beneficial properties including flame retardant, moisture and microorganism attack-proof, good thermal and sound insulator, durability, toughness, as well as elasticity properties. These properties of coir fibres have encouraged their usage in various applications including construction, ropes, rugs, textiles, insulation panels, and packaging, caulking boats, mats, mattresses and brushes, among others. Meanwhile, coir fibres from different coconut plants may have different properties due to varying quantities of the fiber major constituents which include cellulose, hemi-cellulose and lignin. The quantities of the fiber major constituents depend on age and variety of husk, season, local farming practices and seasonal conditions, among others (Menon 1935, Meenatchisundarm 1979).

Previous research studies on coconut fibre reinforced composites are available in various literatures. Regarding study on cement paste composites, tensile strengths of the composites for different lengths

(25, 38 and 50 mm) and volume fractions (2 to 6 %) of coconut fibres were investigated (Aziz et al. 1981). The coconut fibres with a length of 38 mm and a volume fraction of 4% gave maximum tensile strength (2.8 MPa) of cement paste composite. Another study conducted on tensile strength of coir fibre reinforced cement sand mortar indicated that though the tensile strength of fibre reinforced mortar was greater than the mortar without any fibre; a decrease in strength of fibre reinforced mortar was observed with an increase in fibre content (Slate 1976). Furthermore, in the study carried out on the mechanical properties (flexural strength, fracture toughness and fracture energy) of epoxy polymer concrete reinforced with natural fibres (coconut, sugarcane bagasse and banana fibres, the mechanical properties of coconut fibre reinforced polymer concrete were higher than that of other fibres reinforced polymer concrete (Reis 2006). In another study to investigate the effect of presence of coir fibre in composites (Baruah and Talukdar 2007), the increments in compressive strength, splitting tensile strength, modulus of rupture and shear strength of coir fibre reinforced concrete with 2% fibre volume fraction when compared to those of plain concrete were 13.7, 22.9, 28.0 and 32.7%, respectively. In a study conducted on the mechanical behavior of coconut shell reinforced polyethylene composite (Olumuyiwa et al 2012), the results showed that though the composite hardness increased with increase in coconut shell content, other properties including tensile strength, modulus of elasticity, impact energy and ductility of the composite decreased with increase in coconut shell content, In this study, the objective was to evaluate the effects of coir fibre weight fraction on the mechanical properties of coir fiber reinforced polyethylene composites at room temperature. The significance of this study could be related to the associated benefits of coir fibre application for reducing composite production cost, improving composite quality regarding the safety and environmental requirements.

2. Methodology

Coconut husks, of ripening age of eleven months in order to obtain the best quality coir, were obtained from the farms of metallurgical training institute Apata Ibadan Oyo State while a bag of low density polyethylene pellet size was purchased from Plastic making Companies.

2.1. Coconut fiber extraction from coconut husk

The coconut husks were first subjected to retting process by immersing in water-filled concrete tank for about six months to expose the husks to microbial degradation action which helped the partial separation of the husk pulp into coir fibers and a residue called coir pith. The husks were later removed from the water-filled concrete tank and washed. The outer skin of the coconut husk was peeled off before the husk was placed on wooden surface and beaten with a wooden malletto separate the fibers from the pith. The fibers obtained were dried in the sun for two days after which the dried coconut fibers were cut into small sizes and manually hammered to generate fibers of length 0.5-1.0mm and some powders. These were safely kept for later use

2.2. Production and property examination of coir fibre reinforced composite

Low density polyethylene pellets were measured in various quantity of 1kg, 0.9 kg, 0.8kg, 0.75kg on a sensitive electrical beam balance. Various weights, including 0kg, 0.1kg, 0.2kg, and 0.25kg of coconut fibers that have been reduced in length and into powdered form, were also taken. The polyethylene pellets and coconut fibers were mixed to form various units of mixtures including Extrudate 1, Extrudate 2, Extrudate 3, and Extrudate 4, such that each unit of mixture was of one hundred percent (100%) weight. The various units of mixtures were fed into the extruder with the extrusion started with low temperatures first before proceeding to high temperatures. The extruded strands were pelletized using scissors and cutters as the strands cooled down. Each of the pelletized strands were packed separately as strands from Extrudate 1, Extrudate 2, Extrudate 3, and Extrudate 4 and were labeled as sample A, sample B, sample C and sample D, respectively. The four samples were each moulded in a moulding machine into unique shapea in such a way that their mechanical properties could be examined using compression, abrasion and hardness test equipment at the Information Computer Technology Laboratory of Polymer and Textile Department, Yaba College of Technology

,Lagos Nigeria.

Compression test equipment was used for testing the compressive performance of the composites. It was used to determine the material strength or behavior of the composites under compressive pressure loads. The compressive test equipment used was a Universal Testing Machine (UTM) of Batch No-01 with test Speed of 100mm/min, the Denier- 01. The composite samples/specimens tested were of length 60.00 mm, thickness 3.50 mm, diameter 15.00 mm, and area 0.525 mm². The specimen used were broken at the center while specimens/samples that broke on the grips were discarded. Abrasion test equipment was used to test the abrasive resistance of the composites which could help to predict the lifetime of the composite. The abrasion test equipment used was DINA ABRASION TESTER- FE05000. The diameter of the equipment roller used was 150 mm. The number of revolutions of roller of the machine was taken as 40 rev/ minutes and the abrasion distance used was 40 m. The abrasion time used was 120 seconds while the magnitude of the load used was approximately 10 N. Regarding the hardness test equipment, it was used to evaluate the strength, ductility and wear resistance of the composites. The test was used to provide information on the suitability of the composites for the required purposes. The hardness test equipment used was Rex Durometer of Model OS-2H.

3. Results and Discussion

The results of the study on the evaluation of mechanical properties of coir fiber reinforced polyethylene composites are presented in Table 1. From the table, it could be observed that the tensile strength increased from 0% fiber content until 10% fiber content was reached. From 10% fiber content to 25% fiber content and above, the tensile strength continuously decreased to 25%... The value of hardness of composite also increased from 0% fiber contents to 10% fiber content. The hardness value then decreased through 20% to 25% fiber contents. The maximum load at break of a composite could be observed to increase from 0% to 10% fiber contents for the three determinant temperatures and then declined through 20% to 25%, fiber contents.

Similarly, the tenacity value reached highest value at 10% fiber content from 0% content and then decreased through fiber contents of 20% and 25%. Regarding breaking load, the value increased from 0% fiber content to peak value at 10% fiber content and then declined from 20% to 25% fiber contents for the three temperatures of compression of composites. Abrasion value of the composites increased from 0% fiber contents to 10% fiber contents and decreased through fiber contents of 20% and 25%. The value of flexural strength of component increased from 0% fiber content to 10% fiber content. The value of the flexural strength, however, decreased from 10% fiber content for fiber contents of 20% and 25%. For the modulus of elasticity of composite, the value of the modulus also increased from fiber content of 0% and declined uniformly with further increase of fiber contents after reaching its peak value at 10% fiber content. From this peak value, modulus declined to the lowest value of 460 MPa at fiber contents of 25%.

The results of the statistical analysis of the data given in Table 1 are presented in Table 2. The Minitab paired t-test was used to analyze if there was significant mean difference between the mechanical property values of the coir fiber reinforced polyethylene composites (experimental group) and 100% polyethelene resin (control group). Nine mechanical properties including tensile strength at break, elongation at break point, hardness, load at break point, maximum load at break, tenacity, abrasion, flexural strength and modulus; were examined. Before paired t-test was conducted, the α -level = 0.05 was the criterion p-value selected to reject or accept the hypotheses. The hypotheses are Ho (the null hypothesis), the mean difference = 0, and H1 (the alternative hypothesis), the mean difference \neq 0. From the Minitab paired t-test output, the p-values of composite with 10, 20 and 25%, coir fibre weight fraction are 0.358, 0.587 and 0.306, respectively. It could be observed that all the p-values were greater than α -level = 0.05. As the p-values were greater than 0.05, it could be concluded that there was no statistical significant difference between the properties of the composites with coir fibre inclusion

and the properties of the 100% polyethylene resin without coir fibre inclusion. This indicates that the coir fiber reinforced polyethylene composites with 10, 20 and 30% coir fibre weight fractions can be used as substitutes for the whole 100% polyethylene resin without significantly affecting the properties originally exhibited by the 100% polyethylene resin.

4. Conclusion

This study has focused on the evaluation of the effects of coir fiber weight fraction in coir fiber reinforced polyethylene composites. The results showed that the mechanical properties of composites reinforced with coir fiber were dependent on the weight fraction of coir fibers. This might be due to the effect of material stiffness. The composites having a coir fibers of 10% showed a significant result compared to high fiber loading composites. The observed behavior, however, differed somewhat to the observation during the study on glass and carbon fibres where both the strength and modulus increase up to 20% loading. It may therefore be argued that reinforcing effect of this organic coir fibre may not be as pronounced as the inorganic glass and carbon fibres. Future studies will be conducted to establish this point of argument. Moreover, the effects of temperature variation on composite properties will be investigated. Meanwhile, it was observed that there was no statistical significant difference between the properties of the composites at the given temperatures and the properties of the 100% polyethylene resin which indicates the potential of coir fiber reinforced polyethylene composite to be used as substitute for 100% polyethylene resin without any significant change in property.

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Table 1. Result Analysis of Mechanical Properties of Coir Fiber Reinforced Polyethylene Composites

S/N	Fiber Composition (Wt. %)	Resin Composition (Wt. %)	Tensile Strength at break point (MPA)	Elongation at break point (MM)	Hardness (MM)	Load at break point (KGF)	Maximum Load at break point (KGF)
1	0	100	27.98	18.10.	74.10	44.20	54.20
2	10	90	25.20	10.25	70.20	37.44	50.23
3	20	80	21.40	6.22	66.44	32.01	35.10
4	25	75	20.80	4.20	60.43	30.32	32.12

Table 1. Result Analysis of Mechanical Properties of Coir Fiber Reinforced Polyethylene Composites (Cont'd)

S/N	Fiber Composition (Wt. %)	Resin Composition (Wt. %)	Tenacity (GMS / DERNIER)	Abrasion property (GRAM)	Flexural Strength (MPA)	Modulus (MPA)
1	0	100	35,000	29.0	3.4104	680
2	10	90	39,000	23.43	3.6355	620
3	20	80	35,111	20.33	2.6352	520
4	25	75	31,300	14.44	2.0346	460

Table 2. Results of statistical analysis of data presented in Table 1

S/N	Composites	95% CI for mean difference	T-Value	P-Value
1	10% Coir Fibre, and 90% Polyethylene	(-594, 1462)	0.97	0.358
2	20% Coir Fibre, and 80% Polyethylene	(-65.3, 39.6)	-0.57	0.587
3	25% Coir Fibre, and 75% Polyethylene	(-1385, 495)	-1.09	0.306