Comparison of the Mechanical Properties of Charcoal Unsaturated Polyester Matrix Composite and Snail shell Unsaturated Polyester Matrix Composite

Madueke, Chioma Ifeyinwa[1*]; Bolasodun, Babatunde[2]; Umunakwe, Reginald[1]; Nwonah, Jennifer Nneka[3]

Abstract- This study focuses on the comparison of the mechanical properties of charcoal unsaturated polyester matrix composite and snail shell unsaturated polyester matrix composite. The ground charcoal powder and snail shell powder were of the same particle size of 625microns. The ground charcoal was introduced into the unsaturated polyester at different concentrations. The same concentrations of ground snail shell were incorporated into the same percentage of unsaturated polyester. The mechanical properties of the two resulting composites were compared. The mechanical properties tested include, ultimate tensile strength, tensile strain at maximum load, bending strength at peak, deformation at peak, hardness and impact strength. Significant findings showed that the flexural strength snail shell unsaturated polyester matrix composite at 20wt% reinforcement was better than that of the charcoal at the same concentration. Also, snail shell unsaturated polyester composite showed better hardness and impact strength than its charcoal counterparts and those of unreinforced unsaturated polyester. Therefore, where flexural strength, hardness and impact strength are of paramount importance such as in some automobile parts, snail shell reinforced unsaturated polyester composite should be given priority.

Keywords: Charcoal, snail shell, unsaturated polyester, mechanical, composite.

1. INTRODUCTION

Polymers have numerous applications ranging from domestic articles to their use as matrix in composite applications. It is a light weight alternative to most metals. The utilization of natural fibres and fillers as reinforcement for composite materials based on thermoplastic and thermosetting polymers such as polypropylene and polyester is gaining ground in sustainable research area in the polymer world. The major reasons for a huge growth in the area of polymeric composite materials are low weight, low price and minimization of environmental impact. Unsaturated polyester resins are versatile when it comes to properties especially because of its capability to cure at room temperature. Unsaturated polyester resin (UPR) matrix and talc filler were fabricated by simple cold press moulding, the flexural strength and modulus increased with increasing talc content, thermal stabilities of the composites also increased1. In the study of the mechanical properties of rice-husk fibre reinforced polyester composite, results showed that the tensile and flexural strength of the composite increased when the fibre weight fraction increased2. When bagasse/sugarca1ne fibre was used to reinforce unsaturated polyester material in order to assess the viability of the composite materials developed for engineering applications, results showed that the reinforcement enhanced the mechanical properties of the developed composite3. Eggshell particles have been used as reinforcement in polyester matrix and the results showed that the density and hardness values of the polyester/eggshell particulate composite increased steadily with increasing eggshell addition, flexural strength as well as impact energy, tensile and bending strengths also increased4. In the tensile properties characterization of okra-woven fibre reinforced polyester composite, the specific tensile strength and modulus of both treated and untreated okra fibre-reinforced polyester composite were higher than pure polyester specimen5. In the work on the effect of clay addition on the mechanical properties of unsaturated polyester/glass fibre composite, the tensile strength, flexural strength, and flexural modulus of the composites were increased in the presence of clay6. In the tensile behaviour and hardness of coconut fibre ortho unsaturated polyester composites, the result showed the tensile properties to be greatly enhanced7. Unsaturated polyester (UP) resins were filled with bentonites modified with silsesquioxanes; it was found that the mechanical properties of the cured resin improved8. The inclusion of castor seed shell into a polyester matrix composite led

• *Madueke, Chioma Ifeyinwa*
Department of Materials and Metallurgical Engineering, Federal University of Oye-Ekiti, Ekiti State, Nigeria
chioma.madueke@fuoye.edu.ng, +234 8023536748

• *Bolasodun, Babatunde*
Department of Metallurgical and Materials Engineering, University of Lagos, Nigeria.

• *Umunakwe, Reginald*
Department of Materials and Metallurgical Engineering, Federal University of Oye-Ekiti, Ekiti State, Nigeria
• *Nwonah, Jennifer Nneka*
Jexander Engineering and Consulting Company, Port-Harcourt, Rivers State, Nigeria.

to an increase in the strength of the composite9. A ceramic composite was prepared by adding ceramic particles to unsaturated polyester resin, from the investigation, filling the unsaturated polyester resin by CaCO3 and MgO filler particles led to an increase in the ultimate tensile strength10.

Owing to the wide application of polymer composites nowadays, therefore it is a very promising effort to study on the utilization of local cheap renewable sources of fibres or fillers available in our country for the production of polymer composites. In this research, the influences of filler loading of unsaturated polyester/snail shell composite and unsaturated polyester/charcoal composite have been studied.

MATERIALS AND METHOD

Materials:

The charcoal and snail shell reinforcements used in casting were obtained from a local market in Ikorodu Lagos Nigeria. Polyester resin (unsaturated), methyl ethyl ketone peroxide (catalyst), cobalt naphthanate (accelerator) were bought from Ojota Chemical market, Lagos

Preparation of the charcoal filler and the snail shell filler

The charcoal was sun-dried for three days, ground and sieved with a hand sieve of 625microns in the Metallurgical and Materials Engineering laboratory of the University of Lagos. The snail shells were cleaned to remove dirt, dried under the sun for three days and then ground to a powder; it was thereafter sieved with a hand-sieve of 625microns in the same laboratory.

Preparation of the unsaturated polyester composite

The required materials were weighed out using an electronic weighing balance. Two sets of unsaturated polyester matrix composites were produced with varied weight fractions of particulate charcoal and snail shell filler. The weight percentages of the constituents are shown in tables 1 and 2. In synthesizing the reinforced polyester composites, the mass of the polyester was varied with that of the reinforcement to give a total of 100grams. The filler is added into the polyester resin and stirred continuously with a glass rod for about two minutes until a uniform mixture was observed. Thereafter, 1g of catalyst was added with the help of disposable syringe and stirred for about two minutes, after which 0.5g of accelerator was also added and stirred for about two minutes. The mixture was poured into a mould already coated with paper tape as a mould release agent and allowed to cure for two hours. This procedure was repeated for other specimen as shown in tables 1 and two with changes in the weight percentages of the particulate fillers. A control sample was produced without the addition the particulate snail shell filler. After curing, the samples were removed from the mould.

Table 1. Formulations of particulate snail shell/ polyester composite

Specimen	Composition (g)			
	Particulate snail shell filler	**Tere-phtallic unsaturated polyester**	**Methyl ethyl ketone peroxide (catalyst)**	**Cobalt naphthanate (accelerator)**
A_1	5.0	95.0	1.0	0.5
B_1	10.0	90.0	1.0	0.5
C_1	15.0	85.0	1.0	0.5
D_1	20.0	80.0	1.0	0.5
E_1	25.0	75.0	1.0	0.5
F_1	30.0	70.0	1.0	0.5
Control	0.0	100.0	1.0	0.5

Table 2. Formulations of particulate charcoal/ polyester composite

Specimen	Composition (g)			
	Particulate charcoal filler	**Tere-phtallic unsaturated polyester**	**Methyl ethyl ketone peroxide (catalyst)**	**Cobalt naphthanate (accelerator)**
A_2	5.0	95.0	1.0	0.5
B_2	10.0	90.0	1.0	0.5
C_2	15.0	85.0	1.0	0.5
D_2	20.0	80.0	1.0	0.5
E_2	25.0	75.0	1.0	0.5
F_2	30.0	70.0	1.0	0.5
Control	0.0	100.0	1.0	0.5

Figure 1: Weighed samples of particulate charcoal filler reinforcement

2.4. Mechanical Test on the Specimens

2.4.1. Tensile test

Instron Universal Testing Machine operated at a cross head speed of 10mm/min was used for the tensile testing of the samples. The tensile test specimen preparation and testing procedures were conducted in accordance with the American Society of Testing and Materials D412 (ASTM D412).

2.4.2. Flexural test

Three points flexural testing was conducted using Testometric Testing Machine with serial number 25257 and capacity M500-25KN at Federal Institute of Industrial Research, Oshodi (FIIRO) in Lagos. The flexural test was carried according to ASTM D7264 at a cross-head speed of 20mm/min, maintaining a span of 100mm. This test was conducted at room temperature. The flexural test specimens were of 120 X 50 X 10 mm.

2.4.3. Hardness test

The hardness test was carried out at Obafemi Awolowo University, Ife. The hardness of a polymeric material is a complex property related to mechanical property such as modulus, strength, elasticity and plasticity. This relationship to mechanical properties is not usually straight forward, though there is a tendency for high modulus and strength values to correlate with higher degrees of hardness within classes of materials. The hardness test was carried out on the polymeric material composite at different filler content at 0, 5, 10, 15, 20, 25 and 30 wt% of filler content.

2.4.4. Impact test

This test was also carried out at Obafemi Awolowo University, Ife. Impact test is a standard method of determining the impact resistance of materials. An arm held at a specific height (constant potential energy) is released. The arm hits the sample and breaks it. From the energy absorbed by the sample, its impact energy is determined. A notched sample is generally used to determine impact energy and notch sensitivity. Impact test are used in studying the toughness of a material. A material's toughness is a factor of its ability to absorb energy during plastic deformation.

RESULTS AND DISCUSSIONS

The results of the mechanical tests on the various composite samples are shown in table 3.

Flexural properties

Bending strength at peak /break

From figure 2, it was observed that bending strength at peak/break for the two reinforcements fell at 0% filler concentration. As for the charcoal reinforcement, it had its maximum bending strength at peak at 5wt% filler concentration after which it continually dropped because the increase in weight percent of filler reduced the deformability of the matrix, and in turn reduced the ductility of the composite thereby forming a weak structure. The reduction in the bending strength at peak of the charcoal reinforcements could be attributed to controlled mobility of matrix by filler particles. As the amount of reinforcement increases, there is reduction in total surface area available for matrix-filler interaction.

The snail shell reinforced composite shows its highest bending strength at peak at 20wt% filler concentration after which it undulates. It is also worth noting that the total area for deformation stress also has an important role to play in the behavioural pattern of this result.

Deformation at peak

Figure 3 shows the deformation at peak of the two reinforcements showing an undulating/sinusoidal pattern. The two reinforcements show a steady decrease in deformation at peak between 15wt% and 30wt%.

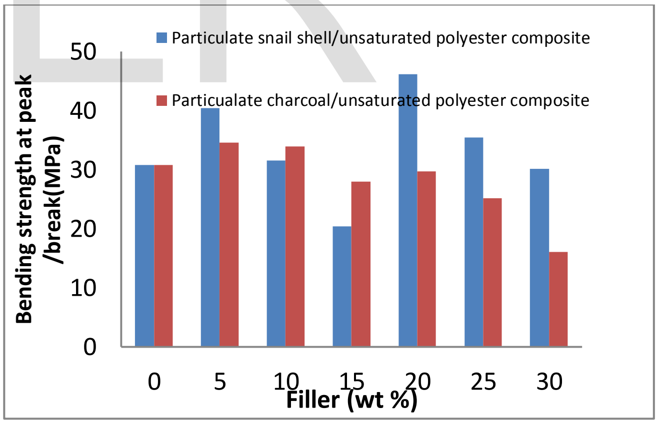

Figure 2. Chart of bending strength against filler concentration

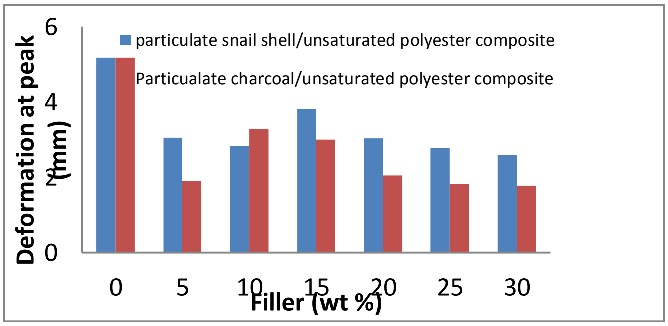

Figure 3. Chart of deformation at peak against filler concentration

Table 3: Result of mechanical tests on the samples with varying percentages of snail shell and charcoal reinforcements

Weight (%) of reinforcement	Particulate Reinforcement type	Bending strength at peak/ break (MPa)	Deformation at peak (mm)	Impact strength (Joules)	Brinell Hardness (BHN)	Ultimate Tensile Strength (MPa)	Tensile strain (mm/mm)
0	Snail shell	30.85	5.1750	3.81	24.87	12.0539	0.0395
	Charcoal	30.85	5.1750	3.81	24.87	12.0539	0.0395
5	Snail shell	40.48	3.0520	5.13	31.20	5.7765	0.0342
	Charcoal	34.65	1.8910	3.30	20.10	5.1984	0.0194
10	Snail shell	31.54	2.8280	3.10	29.47	4.4247	0.0261
	Charcoal	33.97	3.2880	3.60	16.70	1.7217	0.0117
15	Snail shell	20.43	3.8250	4.20	24.20	7.2458	0.0178
	Charcoal	28.00	2.9960	3.50	19.20	0.8276	0.0811
20	Snail shell	46.24	3.0320	4.80	21.06	5.4060	0.0161
	Charcoal	29.72	2.0540	3.20	17.10	2.5499	0.0145
25	Snail shell	35.43	2.7780	4.24	20.52	5.4324	0.0153
	Charcoal	25.17	1.8290	3.15	20.21	2.9364	0.0136
30	Snail shell	30.21	2.5880	3.60	20.10	8.2354	0.0322
	Charcoal	16.16	1.7820	3.10	21.40	3.2257	0.0183

Impact properties

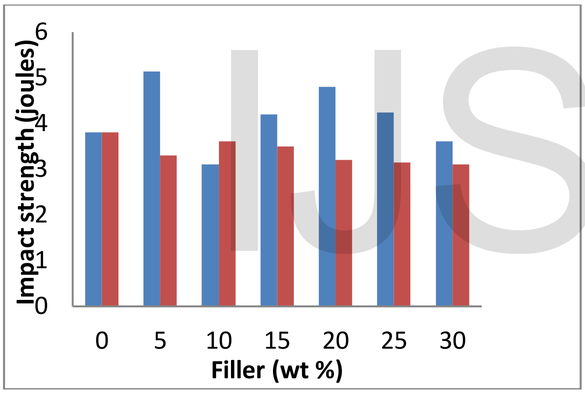

Figure 4: Chart of Impact strength against filler concentration

Figure 4 shows the amount of energy the samples can absorb prior to fracture. It was observed that the snail shell reinforced composite absorbs maximum energy at 5% while the charcoal absorbs maximum energy at 10% filler concentration.

However the maximum amount of energy absorbed was by snail shell at 5% reinforcement. The impact strength decreases as the filler content increases. This is mainly due to the reduction of elasticity of the material due to filler addition and thereby reducing

the deformability of matrix. An increase in concentration of filler reduces the ability of matrix to absorb energy and thereby reducing the toughness, so impact strength decreases.

Hardness

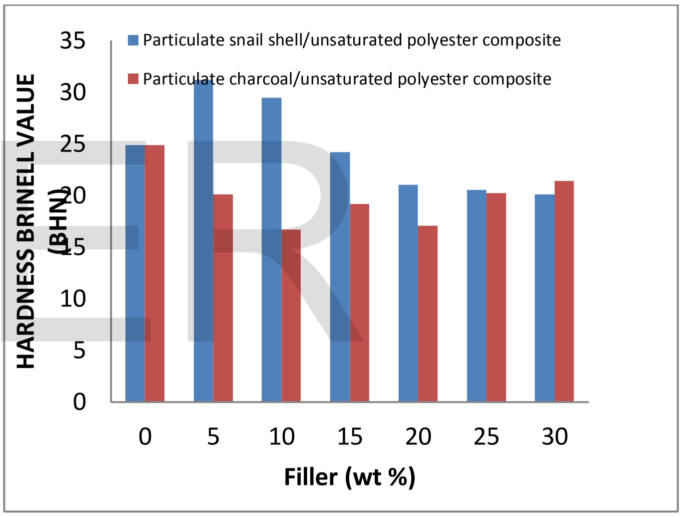

Figure 5. Chart of Brinell hardness against filler concentration

From figure 5, the composite exhibited the highest hardness at 5wt% snail shell reinforcement. The irregular/unpredictable pattern of the hardness may be attributed to the poor interfacial bonding or surface adhesion of the fillers and polyester resin.

Tensile properties

Ultimate Tensile Strength (UTS)

Figure 6 shows the graph of ultimate tensile strength of the two composite samples against their corresponding percentage reinforcement. It was observed that the snail shell composite at 30wt% filler concentration showed a higher UTS than the charcoal sample while the charcoal sample at 15wt% filler concentration showed the least UTS.

The ultimate strength of a composite depends on the weakest fracture path throughout the material. Hard particles affect the strength in two ways. One is the weakening effect due to the stress concentration they cause, and another is the reinforcing effect since they may serve as barriers to crack growth11. In this case (as seen in figure 6), the weakening effect is predominant and thus the composite strength is lower than the matrix. Prediction of the strength of composites is difficult. The difficulty arises because the strength of composites is determined by the fracture behaviours which are associated with the extreme values of such parameters as interface adhesion, stress concentration and defect size/spatial distributions. Thus, the load-bearing capacity of a particulate composite depends on the strength of the weakest path throughout the microstructure, rather than the statistically averaged values of the microstructure parameters.

The better tensile strength at higher filler content for snail shell reinforced unsaturated polyester composites could be attributed to better dispersion of the reinforcement in the polyester resin matrix, better wettability, absence of void or porosity and good interfacial bond. The lower tensile strength for charcoal reinforced unsaturated polyester composite could be attributed to inefficient stress transfer between the particle-matrix interface due to poor interfacial adhesion.

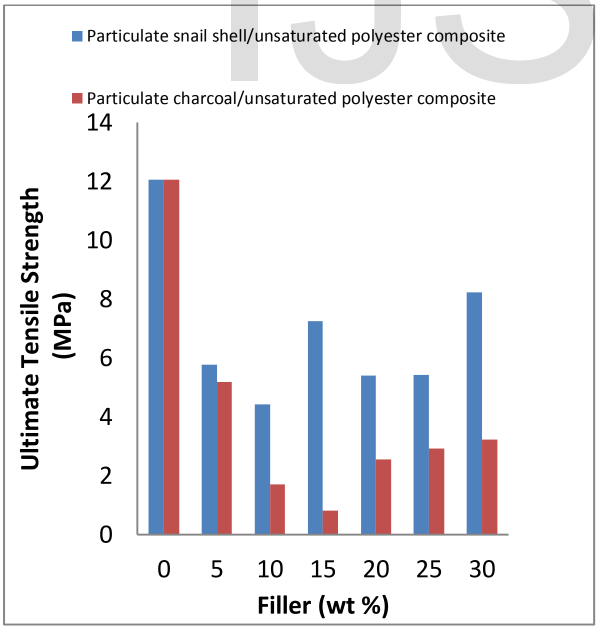

Figure 6. Chart of ultimate tensile strength against filler concentration

Tensile Strain at maximum load

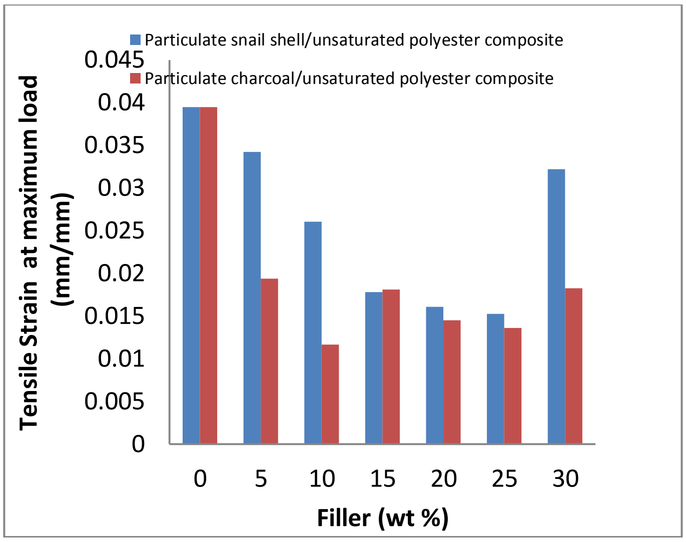

Figure 7. Chart of tensile strain against filler concentration

As shown in figure 7, the snail shell reinforced composite showed a higher tensile strain at maximum load at 5wt% than the particulate charcoal reinforced sample while the charcoal reinforced sample had the least tensile strain at maximum load at 10wt%. The graph showed that additional 5wt% snail shell filler concentration will not bring about any improvement on the strain.

CONCLUSION

The mechanical tests carried out in this study include; flexural test, impact test, hardness test, tensile test, using various proportions of snail shell and charcoal reinforcements in unsaturated polyester.

From figure 2, it is clear that the snail shell reinforced composite sample of 20wt% reinforcement showed the highest resistance before shattering relative to other samples when the flexural test was performed on them. The implication is that the snail shell reinforcement of 20wt% can be used instead of charcoal reinforcement for unsaturated polyester resin for applications where flexibility plays a major role.

From figure 4, it is clear that the snail shell reinforced composite sample of 5wt% reinforcement had the capacity to absorb the highest amount of energy before fracture, its impact strength is much better than that of charcoal reinforced composite. Therefore snail shell reinforcement of 5wt% is preferred to charcoal reinforcement for unsaturated polyester where impact strength is of utmost concern.

From figure 5, the snail shell reinforced composite sample of 5wt% reinforcement showed higher surface *hardness than charcoal reinforced composite and even pure polyester. Therefore, for applications where surface hardness takes the top priority, snail shell reinforcement should be used with unsaturated polyester.*

From figures 6 and 7, the performances of the two composites tested were poor when subjected to tensile loading. It can be seen that tensile strength and strain of the pure polyester reduced when it was reinforced. This means that these composites should not be considered in applications that would subject them to tensile loading.

From the results, snail shell reinforced unsaturated polyester composite has better mechanical properties than charcoal reinforced polyester composite.

REFERENCES

Akter, R., Sultana, R., Alam, Md. Z., Qadir, Md. Z., Begum, .H.A. and Gafur, Md.A. Fabrication and Characterization of Woven Natural Fibre Reinforced Unsaturated Polyester Resin Composite. International Journal of Engineering and Technology IJET-IJENS, 13(2), 122-128.

Surata, I.W., Suriadi, I.G. and Arnis. K. (2014). Mechanical Properties of Rice Husks Fibre Reinforced Polyester Composite. International Journal of Materials, Mechanics and Manufacturing, 2(2), 165-168.

Oladele, I.O. (2014). Effect of Bagasse Fibre Reinforcement in the Mechanical Properties of Polyester Composite. The Journal of the Association of Professional Engineers of Trinidad and Tobago, 42(1), 12-15.

Hassan, S.B., Aigbodun, V.S. and Patrick, S.N. (2012). Development of Polyester/Eggshell Particulate Composites. Tribology in Industry, 34(4), 217-225.

Srinivasababu, N., Rao, K.M.M. and Kumar, J.S. Tensile Properties Characterization of Okra woven Fibre Reinforced Polyester Composites. International Journal of Engineering, 3(4), 404 – 412.

Kusmono and Ishak, Z.A.M. (2013). Effect of Clay Addition in Mechanical Properties of Unsaturated Polyester/Glass Fibre Composites. International Journal of Polymer Science, 2013 (797109), 1-7.

Onuegbu, T.U., Umoh, E.T. and Okoroh, N.C. (2013). Tensile Behavior and Hardness of Coconut Fibre-ortho Unsaturated Polyester Composites. Global Journal of Science Frontier Research Chemistry, 13(1), 1-6.

Olesky, M and Galina, H. (2013). Unsaturated Polyester Resin Composites Containing Bentonites Modified with Silsesquioxanes. Industrial and Engineering Chemistry Research, 52(20), 6713-6721.

Nwigbo, S.C., Okafor, T.C. and Atuanya, C.U. (2013). The Mechanical Properties of Castor Seed Shell-Polyester Matrix Composites. Research Journal of Applied Sciences, Engineering and Technology, 5(11), 3159-3164.

Hanna, W.A., Gharib, F.E. and Marhoon, I.I. (2011). Characterization of Ceramic Filled Polymer Matrix Composite used for Biomedical Applications. Journal of Minerals and Materials Characterization and Engineering, 10(12), 1167-1178.

Fu, S- Y, Feng, X- Q, Lauke, B. and Mai, Y-W (2008). Effects of Particle Size, Particle/Matrix Interface, Adhesion and Particle Loading on Mechanical Properties of Particulate Polymer Composites. Composites: Part B, 39: 933–96