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Full Length Research Paper

Preparation and characterization of epoxy filled snail shell thermoset composite

Kolawole, S. A.*, Zakariyaw A. A., and Omoniyi, A. O.

Department of Chemistry, University of Abuja, Gwagwalada- Abuja, Nigeria.
*Corresponding Author E-mail: sunday.kolawole@uniabuja.edu.ng

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Researches are being conducted across the world with regards to the use of renewable materials as a source of composites reinforcement; this comes in the form of natural fibre or natural source of particulate filler. Against this background, this study has been carried out with a view to exploring the use of snail shell as filler for epoxy resin. The composite samples were prepared using hand lay-up method by mixing epoxy resin with varying (10, 20, 30, 40 and 50) wt % snail shell powder of particle size 150 µm in a fabricated glass mould. Mechanical tests were carried out on the prepared composites to determine the tensile properties, flexural properties and impact strength. The result showed significant decrease in tensile strength, flexural strength, impact strength and elongation at break with increase in filler content. While tensile modulus and flexural modulus increased with an increase in the filler content. The maximum tensile modulus was observed to be 430.10 MPa at a 40% filler ratio while the flexural modulus was 2.62 GPa at a 30% filler ratio. The prepared composite may be of use in the production of a table top, tiles for wall, ceiling.

Keywords: Renewable materials, reinforcement, mechanical test, tensile properties and flexural properties

INTRODUCTION

The use of polymer matrix composite has found wide application in our modern world. This is as a result of the combination of properties which these materials possess. Some of these properties of polymer matrix composite include: strength, high modulus, good fracture and fatigue properties as well as corrosion resistance (Agunsonye, 2013). These materials offer most important advantages such as their ability to liberate volatiles during cross-linking and their ability to be moulded using low pressures at room temperature (Crawford, 1998). Natural filler-reinforced polymers provide increase in degradability capability of the resulting product (Fakhrul and Isram, 2013). Fibres like oil palm, empty fruit bunch, as well as several particulate such as rice husk, egg shell have been used as reinforcing agents of different thermoplastics and thermosets plastic resins (Ahmad et al., 2010). There is an overwhelming interest in filler and natural fibre reinforced polymers owing to their ease of processing and low cost as some of these fillers are regarded as waste (Hassan et al., 2012).

Composite material is made by combining two or more materials to give a unique combination. In bulk form, the constituent materials work together but remain in original forms. The final properties of composite materials are better than constituent material properties (Mallick, 1993).

Thermoset resins

Thermoset materials form three-dimensional molecular chains called cross-linking. Due to these cross-linkings, the molecules are not flexible and cannot be re-melted and reshaped. The higher the number of cross-linkings, the more rigid and thermally stable the materials will be. Thermosets are brittle in nature and are generally used with some form of filler reinforcement (Composites Fabricators Association, U.S.A, 2000).

Epoxy

The ability of the epoxy ring to react with a variety of substrates gives the epoxy resins versatility. Treatment with curing agents gives insoluble and intractable thermoset polymers. Some of the characters of epoxy resins are high chemical and corrosions resistance, good mechanical and thermal properties, outstanding adhesion to various substrates, low shrinkage upon cure, good electrical insulating properties, and the ability to be processed under a variety of conditions (May, 1988). Epoxy resins are normally prepared by the base-catalyzed reaction between an epoxide such as epichlorohydrin and a polyhydroxy compounds such as bisphenol A (Figure 1):

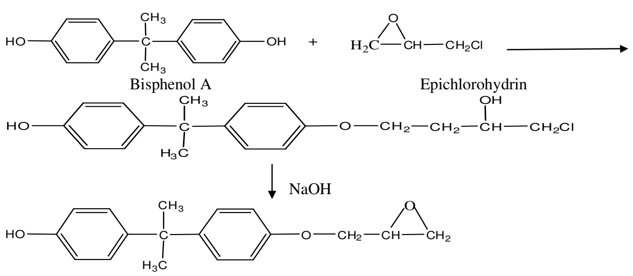

Figure 1. Synthesis of epoxy resin.

Reinforcements

Reinforcements are important constituent of a composite material and give all the necessary stiffness and strength to the composite. Reinforcements for composites can be fibers, fabrics particles or whiskers (Astön, 1997). Fibers are essentially characterized by one very long axis with other two axes either often circular or near circular (Nielsen, 1974). Particles have no preferred orientation and so does their shapes. Whiskers have a preferred shape but are small both in diameter and length as compared to fibers (Tjong, 1997).

Particulate/fillers

The essence of adding fillers to polymer is to alter its properties and to add bulk to the material e.g Tensile Strength, Acoustic Properties, Sorption Properties etc. (Wypych, 2000). An essential point to note is that properties of composites depend upon the volume percentage of fillers added (Wypych, 2000; Shenoy, 1999). The properties of a composite are usually in between those of component materials. Several properties such as density modulus and yield strength can be predicted by the rules of mixtures, according to the volume fraction of each component (Baker et al., 1987). Particulate fillers are usually in powdery form with particle size measured in micrometers. Examples of particulate fillers are talc, hollow glass microspheres, rice husk powder, hollow sphere from fly ash, snail shell powder, hollow polymer microsphere, calcium carbonate, seashell and eggshell powder, coconut shell powder etc. (G. Fourty, Proceedings of Moffis 1991).

Snail shell powder as particulate filler

Snail shell contains about 85% calcium carbonate ($CaCO_3$) (Vermeij, 1993). Calcium carbonate is the most widely used inorganic filler. It is available in a variety of particle sizes, especially for composite applications. They assist in reducing shrinkage of the moulded parts. Owing to the high level of calcium carbonate in snail shell, the powder can be considered suitable as particulate filler for reinforcement of composites. The research work aim is to prepare and investigate the mechanical properties of snail shell reinforced epoxy composite.

MATERIALS AND METHODS

Material collection

The epoxy resin and hardner were purchased from a chemical store in Lagos, Nigeria. The epoxy resin has a density of 1.17 g/cm^3, while the density of the hardner is 1.03 g/cm^3. The snail shell (*Achatina fulicia* specie) was obtained from Gwagwalada market, Abuja, Nigeria (Figure 2a and b).

Figure 2. (a) Snail Shell (b) Glass Moulds

Filler preparation

The snail shell was thoroughly washed with water to removed dirty particles such as sands and other contaminants and sundried. It was then pulverized to a fine powder and hand sieved with a sieve of mesh size 150 µm, the powdered shell was dried in an oven for 4 h at about 100°C to reduce moisture content.

Composite preparation

The composite was compounded by adding the required volume of the epoxy with that of the filler (snail shell) for each formulation. This was done for particulate composition of (10, 20, 30, 40 and 50) wt%. The required filler ratio of the snail shell particulate is added to the resin and stirred manually with a glass rod and mixed thoroughly until a good mixture is obtained. Thereafter, the required volume of the hardner is added to the mixture and stirred thoroughly. The volume ratio of epoxy to hardner is 2:1. The mixture was poured into a mould covered with releasing agent (aluminium foil), and allow to cure for 24 h. After curing, the composite block is stripped from the mould. This procedure was repeated for all samples produced with variations in the particulate ratio. The samples were machined into a dimension of 140 × 20 × 4 mm.

Tensile test (ASTM D3039)

The tensile testing was performed using the Universal Testing Machine (TIRA test 2810) in accordance with ASTM standard D3039 operated at crosshead speed of 20mm/min.

Tensile strength and tensile modulus were expressed as:

Tensile strength (MPa) = $\frac{P}{bh}$, Where, P = Pulling force (N) b = Specimen Width (m)

h = Specimen thickness (m), Tensile modulus (MPa) = $\frac{\sigma}{\varepsilon}$

Where, σ = Stress (N/m^2)

ε = Strain

Flexural test (ASTM D790)

Three points flexural were conducted using Universal Testing Machine (TIRA test 2810) in accordance with ASTM D790 at crosshead speed of 20 mm/min. The flexural strength of composites was found using the following equation.

Flexural strength = $\frac{3FL}{2bd^2}$ Where, F = Maximum load applied on test specimen (N),

L = Length of support span (mm) b = Width of specimen tested (mm), d = Thickness of specimen tested (mm)

The flexural modulus can also be found using the following equation:

Flexural modulus = $\frac{ML^3}{4bd^3w}$ Where, M = Maximum load applied on test specimen (N)

L = Length of support span (mm), b = Width of Specimen, d = Thickness of specimen

w = Deflection at maximum force

Impact test (ASTM D256)

The test was carried out using Impact testing Machine (Impats-15) with standard number ISO179. An arm held at 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.

RESULTS AND DISCUSSION

Tensile strength

Figure 3 shows the variation of tensile strength with filler content. It can be observed that the tensile strength of the composite exhibits significant decrease with increased in filler content. Adding 10% filler to the neat epoxy decreases the tensile strength by 29%. The decrease in tensile strength may be due to poor interfacial adhesion and distribution of snail shell filler within the matrix, thus increasing the brittleness as the filler content increased.

Tensile modulus

Figure 4 illustrates the effects of the filler content on tensile modulus of epoxy composites. It is observed that the tensile modulus of the composite increases with increase in filler content to 40 wt%. This observation highlights the fact that the incorporation of snail shell fillers into the polymer matrix improves the stiffness of the composites. At filler content of 50 wt%, there is decrease in tensile modulus. This may be due to insufficient wetting of the filler at higher concentration (Katz and Milewski, 1987).

Elongation at break

Elongation properties as seen in Figure 5 showed gradual decrease as the filler content increases. The decrease in elongation at break is an indication that the filler is incapable of supporting the stress transferred from the matrix to the filler. Again, the presence of the filler within the matrix decreased the elasticity of composite which leads to decrease in strength of composite.

Flexural strength

Figure 6 depicts the variation in flexural strength with varying filler content. The flexural strength decreases with increase in filler content. It is observed that increase in weight percentage of filler reduced the deformability of the matrix and in turn reducing the ductility of the composite thereby forming a weak structure.

Flexural modulus

As shown in figure 7, the flexural modulus of the composite increase as filler content increase, and shows

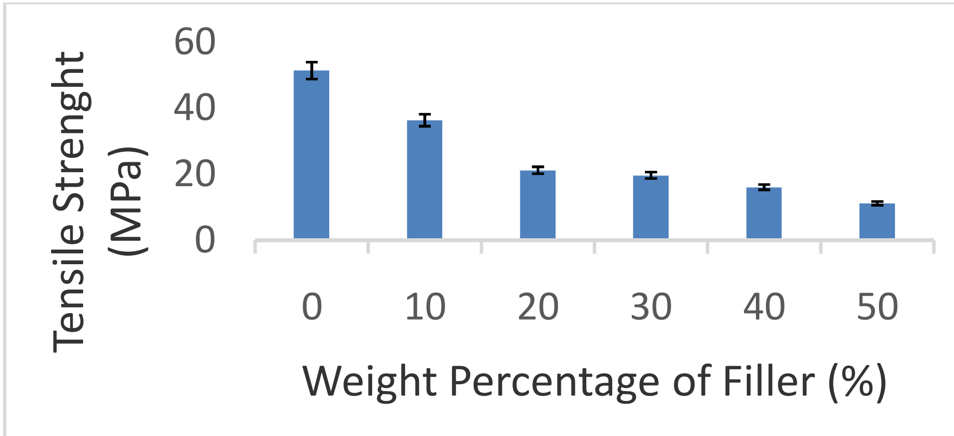

Figure 3. Effect of filler content on the tensile strength of snail shell powder reinforced epoxy.

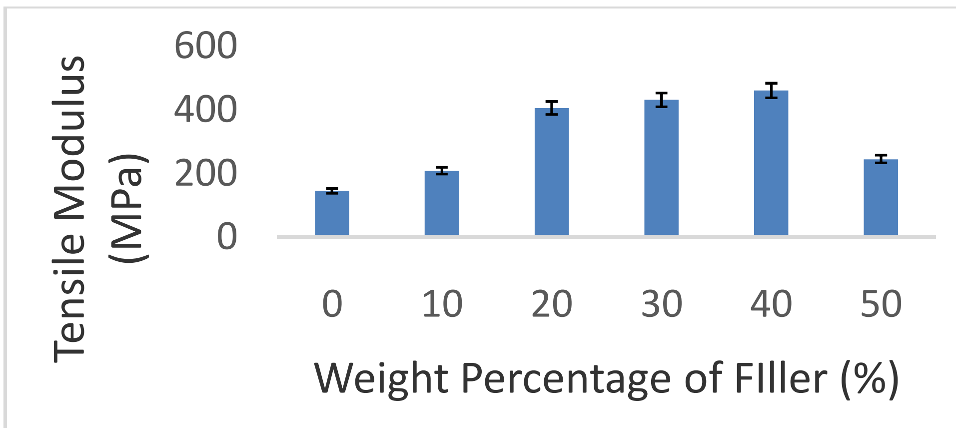

Figure 4. Effect of filler content on the tensile modulus of snail shell reinforced epoxy.

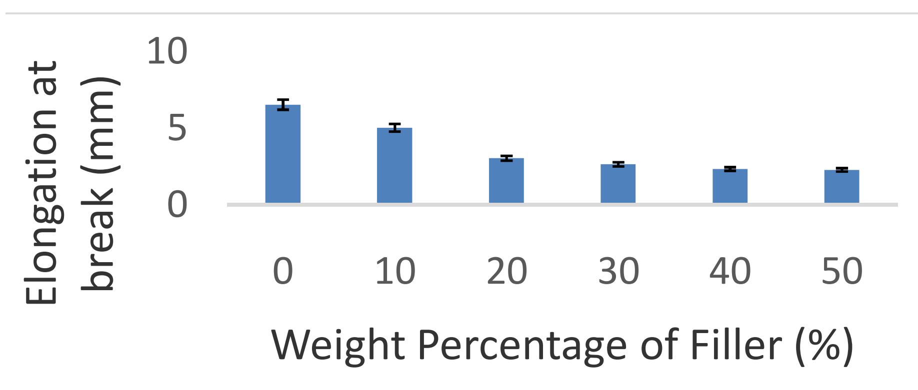

Figure 5. Effect of filler content on the elongation at break of snail shell reinforced epoxy.

a maximum value at 30 wt%. The decrease flexural modulus for the sample at 50 wt% is mostly due to agglomerate formation at higher concentration of the snail shell.

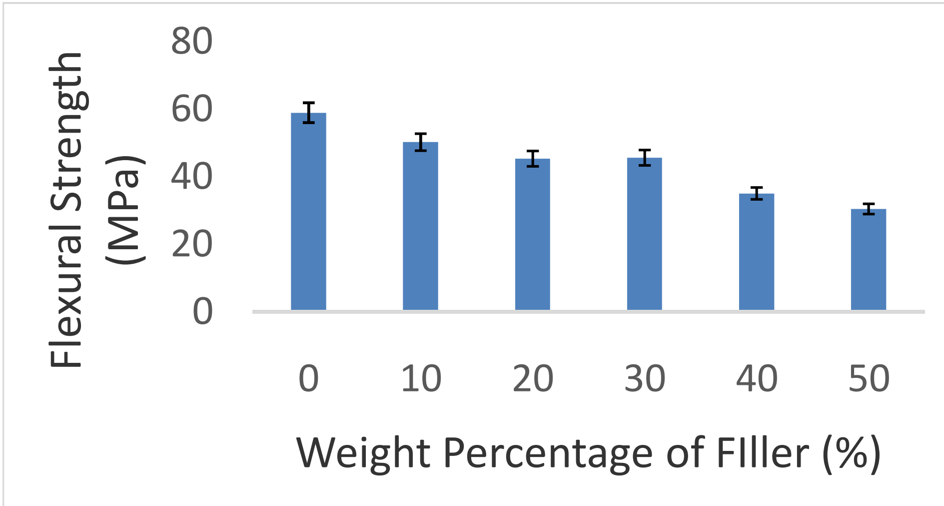

Figure 6. Effects of filler content on the flexural strength of snail shell powder reinforced epoxy.

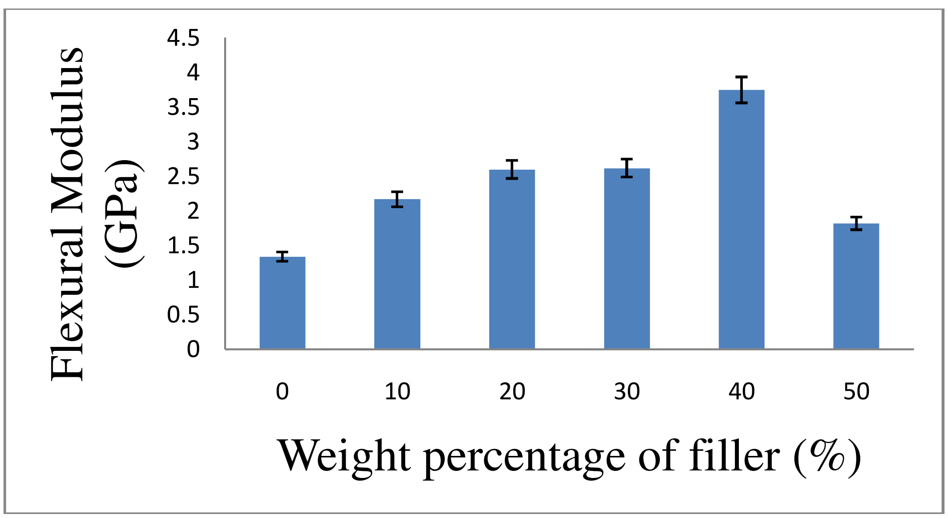

Figure 7. Effect of filler content on the flexural modulus of snail shell reinforced epoxy.

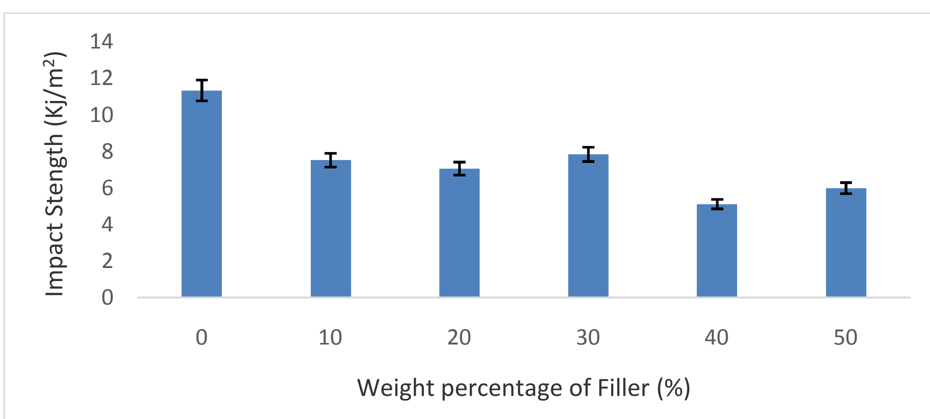

Figure 8. Effect of filler content on the impact strength of snail shell powder reinforced epoxy.

Impact strength

Figure 8 shows the variation of impact strength with filler content. The impact strength equally decreases with increase in filler percentage to 20 wt%, an increase in impact strength was observed at 30 wt%, then again decrease with further increase in filler content. This may be due to non-uniform level of stress concentration in the composites with resultant decrease and increase in impact strength as filler content increase.

Conclusion

Tensile strength, elongation at break and flexural strength decrease with increase in filler content; the impact strength shows alternate decrease and increase as filler content increase; while the tensile modulus and flexural modulus increases with increase in filler content. The incorporation of snail shell into the epoxy is seen to improve the rigidity while decreasing the elasticity of the matrix. This might be due to poor adhesion of filler particle to the matrix. It can also be due to the filler size use as smaller filler size could have increase the adhesion of the filler to the matrix. The prepared composite may be of use in the production of table top, tiles for wall.

Authors' declaration

We declared that this study is an original research by our research team and we agree to publish it in the journal.

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