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Mechanical Properties of Granite / Pulverized Coconut Shell Particulate Hybrid Reinforced Epoxy Composites

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Abstract: Mechanical properties of particulate granite and pulverized coconut shell hybrid reinforced epoxy composites were studied in this research, with the aim of converting agro-waste and natural occurring element to develop a new composite material for engineering applications. The stir cast method was used to produce the composites. The hybrid composites were developed by adding varying weight percentage of fine granite/coconut shell particles as reinforcement to epoxy matrix and the effect of the particles on the mechanical properties of the composite produced was investigated. The result revealed that the tensile strength ranges between 14.44 – 22.78 MPa, tensile modulus ranges between 300.52 – 718.47 MPa, flexural strength and flexural modulus varies between 43.03 – 77.19 MPa and 1009.35 – 1820.81 MPa, respectively; impact strength varies between 33 – 54 Joules and the hardness varies between 30.14 - 46.14 HRC. Finally, from the investigation, it is evident that the selection of percentage of filler content suitable for the polymer composite depends on the required properties for various engineering applications.

Keywords: Agro waste; coconut shell; granite; hybrid; new material; particulate.

I. Introduction

Modern producing industries are rapidly getting advance, creating an expanse for the development of new various materials. The author [1] investigated the characteristics of composites developed with nano-scale vapor grown carbon fiber and mentioned that "composites have been used in modifying the shortcomings of monolithic material". The concept of composite in construction has been in existence since ancient times such as the construction of pillars and beams, which are done with a combination of steel and concrete. Concrete serves as the matrix and is reinforced with steel to achieve high strength of the pillar and beam.

In Nigeria, with a population of over a 200 million; proper disposal and general management of agricultural wastes remain a major problem despite the concerted effort of waste management authorities, most of this agricultural waste contributes to the pollution of the environment. Thereby, causing an environmental hazard, in which if not checked may cause a reduction of population. There are huge loopholes to be filled in terms of utilization by way of recycling through processing some of these wastes to be useful for engineering purposes, for the benefit of mankind. Coconut shell is one of the common agricultural wastes which are readily available in local communities and commonly found in tropical regions.

Coconut shells occur naturally, acting as an outer protective chamber for the coconut meat and water. Coconut shell particles (CSPs) are made from the coconut shell after being

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pulverized, which enables the use as particle reinforcement to matrix. They are readily available, renewable, cost efficient, and possess good mechanical properties; all these make CSPs ecologically attractive alternatives to man-made filers [2].

Granites in powder form are natural reinforcing materials to composite materials which are common type of felsic intrusive igneous rock. They are durable and also have a good matte finish. The granite is granular, visible in texture, and hard. The constituents of granite chiefly contain quartz, alkali feldspar (containing sodium and calcium), mica and hornblende [3].

Polymeric materials in automobiles have undergone an apparent increase in the last twenty years, and their application is increasing rapidly with a propensity of further growth [4]. This is a global achievement in the cycle of innovation and results in better recycling efficiency. Previously, almost all products were made of metal or metal alloys and presently polymer or plastic in general are used in majority of the applications and the achievement is rapidly growing. For example; in 1990 there was reduction in the automotive average weight by 9 %, due to reduction of utilization of steel and iron by automobile industry [5]. Epoxy resins are significant polymeric or semi polymeric/oligomer materials of the thermosetting family and play a significant character in composites. A composite is a multiphase material that unites the properties of its constituents to get better properties when compared to its parent components.

The composite contains matrix and reinforcement(s), both serving different purposes. The reinforcement provides support to the structural load and improves the mechanical strength, while the matrix provides adhesion, making it possible for union with reinforcement. Hence, the mechanical properties of pulverized coconut shell and granite hybrid reinforced epoxy composites have been assessed to institute the possibility of using it as a pristine material. This paper present reports on the mechanical properties of pulverized coconut shell and granite hybrid reinforced epoxy composites.

II. Materials and Methods

A. Materials

The materials used for this research include coconut shell that was obtained from west African tall cocos nucifera shell waste at Ado-Ekiti, Ekiti State, Nigeria. Other are granite powder from a local mining site at Akure, Ondo State and epoxy resin and hardener purchased from Malachy Enterprise Ltd., Lagos.

B. Methods

i. Preparation of Pulverized coconut shell particles (CSPs)

The coconut shells collected were washed properly with warm water, dried in open air for 48 hours and crushed with a jaw crusher for size reduction. The crushed coconut shell was charged into the pulverizing machine till a reasonable size was gotten and then charged into the ball mill for 30 minutes. The ground coconut shell was discharged from the ball mill and was introduced into set of sieves (700 microns, 500 microns, 350 microns, 230 microns, 180 microns, 109 microns and 50 microns) and then placed on the sieve shaker which was allowed to gyrate for 15 minutes.The particle sizes of undersize (50 microns) were collected. The coconut shell (CS) and the coconut shell particles (CSPs) are shown in Figures 1a and b, respectively.

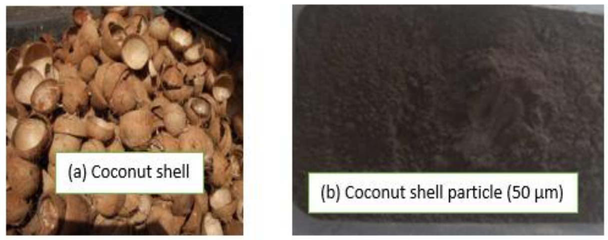

Figure 1: shows (a) coconut shell and (b) pulverized coconut shell particles

ii. Preparation of fine granite particles (FGPs)

The granite particles were washed thoroughly in water and allowed to dry in an open air for 48 hours and was charged into the pulverizing machine. The fine granite particles (FGPs) sizes of 50 microns were obtained using the procedure followed in obtaining CSPs. The FGPs is shown in Figure 2.

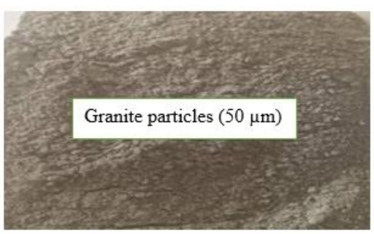

Figure 2: shows FGPs (50 µm)

iii Fabrication of the composites

The new hybrid composites and the control were produced by cast moulding method, adopting the formulation shown in Table 1. The mixture was poured into an aluminium mould of different cavities containing different dimension (impact, hardness, tensile and flexural mould cavity, according to the sample dimensions required for ASTM standards.) for various test analysis and was allowed to cure at room temperature. The matrix contains Epoxy and hardener in the mixing ratio 2:1, while the particles reinforcement contains CSPs and FGPs in ratio 1:1.

iv. Characterization of the hybrid composites using XRD spectrum

The CSPs and FGPs x-ray diffraction (XRD) pattern were carried out using diffraction machine (Bruker D2 Phaser®), with a copper Kα radiation source and the machine was operated at generator settings (30 kV, 20 mA and at 25 ^{0}C temperature). The present phases in the particulates were determined at the range of 2θ = 10–90° measurements. Software (PANalytical (v3.0e) X'pert Highscore) was used to analyse the patterns.

v. Hardness test

The hardness of the composites and control were determined using Adarsh Digital Rockwell hardness machine (model FS, serial no: 292/2018-19). A load of 15 kgf was applied to each specimen with 15 seconds dwell time.

Table 1: Formulation used for composite preparation

Sample wt%	Epoxy Resin (g)	Hardner (g)	Granite (g)	Pulverized coconut shell (g)
Control	233.33	116.67	___	___
3	226.33	113.17	5.25	5.25
9	212.33	106.17	15.75	15.75
15	198.33	99.17	26.25	26.25

vi. Impact energy test

Hounsfeld balanced impact testing machine (model: h10-3 and serial number: 3915) was utilized to determine the impact energy of the new hybrid composites and the control. The notched Izod impact test was conducted in accordance with [6]. The dimension of the test samples used is 65 × 10 x 4 mm.

vi. Tensile test

Tensile test of the composites and the control were carried out on a UTM (FS 300–1023, USA), the machine was operated at 6 mm/min speed, conducted at room temperature in accordance with [7]. The sample dimension was based on the Type IV specification with the length of 114 mm and thickness of 3 mm, results generated are recorded.

viii. Flexural test

Flexural test of the composites and the control were carried out using the same UTM used for tensile test, in accordance with [8]. Composite and control test samples are of dimension of 150 x 50 x 3 mm and results are taken.

III. Results and Discussion

Plate1a; shows x-ray diffraction of the coconut shell particle. The result shows that most of the main material in the crystalline phase present in the coconut shell particles is silicon oxides (SiO_2). The major diffraction intensity peaks indicated at 2θ angle of 34.3°. Also, the minor peaks confirmed the presence of Al in form of Alumino-silicate (Al_2SiO_3), Fe in form of Iron oxide (Fe_2O_3), Carbon and an intermetallic compound (CaO/MgO).

Plate 2, shows the x-ray diffraction for the fine granite particle. The result shows that the main material in the crystalline phase of the granite particle is quartz. The major diffraction intensity peak indicated at 2**θ** angle of 27°**.** It was also observed that most of the peaks confirmed the presence of quartz in its various states, magnetite, albite and biotite.

From Figure 3, there was enhancement in the hardness of new composites. It was observed that the hardness of the pulverized coconut shell/granite hybrid reinforced epoxy composites increases with increase in coconut shell/granite particle content within the matrix of the composites, which implies there was an enhancement in the hardness of the composites compared with that of the neat.

HRC, because of Fe_2O_3, Al_2SiO_3 and intermetallic of CaO/MgO fine particles detected in CSPs/FGPs as shown in plates 1 and 2, respectively.

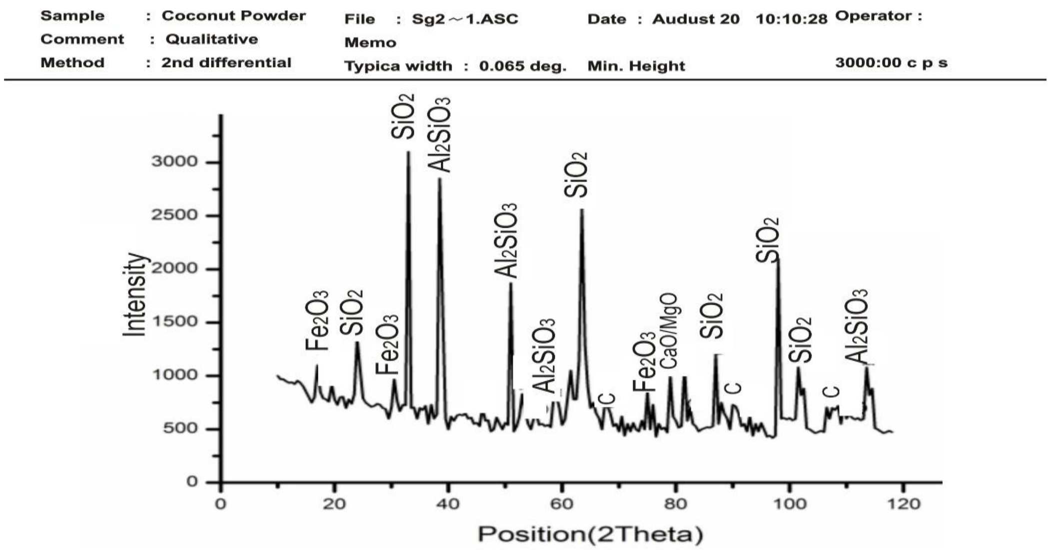

Plate1: X-ray diffraction of pulverized coconut shell particles

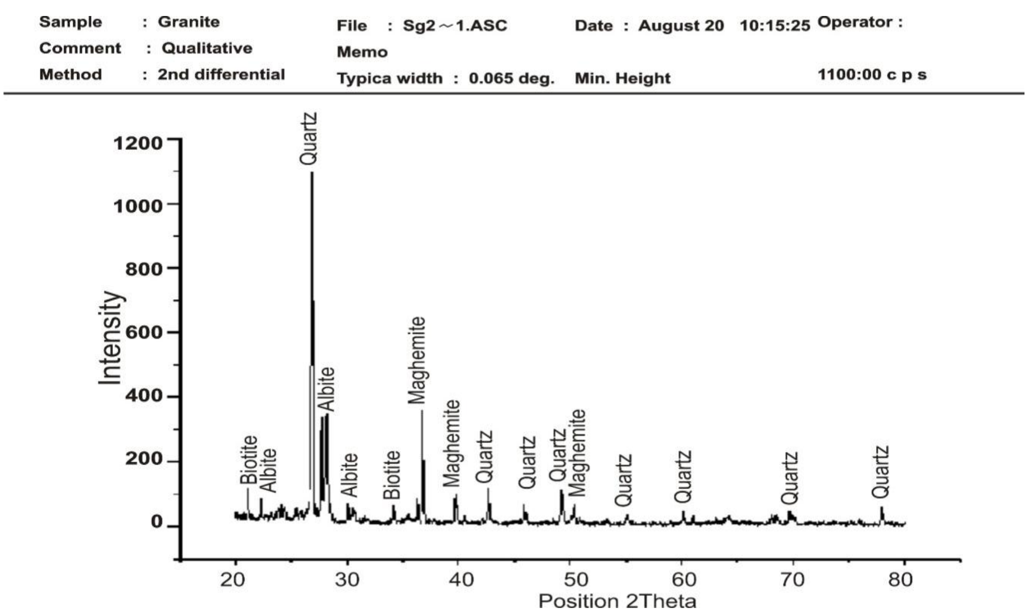

Plate 2: X-ray diffraction of fine granite particles

The composite with 15 % reinforcement displayed the highest hardness value of 46.14. It can be observed that as the reinforcement composition increases in the new composites, there is corresponding increase in hardness. This is in line with the findings of [9].

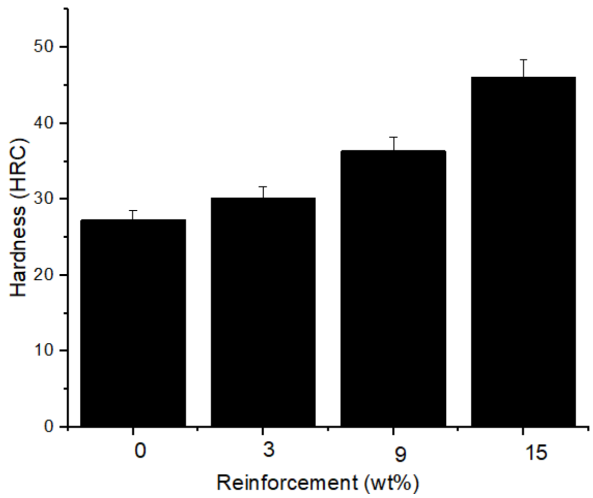

Fig. 3. Plot of hardness of pulverized coconut shell/granite composites and the control.

From Figure 4, it is shown that all the composites were all enhanced compared with the control, this is due to the size of 50 μm of reinforcement particles used, and in accordance with the findings of [10]; that reinforcement particle size less than 200 μm tends to increase mechanical properties. It was observed that the tensile strength of 3 wt% reinforced composite had the highest value of 22.78 MPa, followed by 9 wt% reinforcement with tensile strength of 22.06 MPa, while the least of 16.16 MPa was exhibited by hybrid composite with 15 wt% reinforcement. This trend is expected, since silicon oxide compounds and quartz compounds are the major constituents of the reinforcing materials (Plate 1a and b) used are reinforcement. This trend is expected, since silicon oxide compounds and quartz compounds are the major constituents of the reinforcing materials (Plate 1a and b) used are hard and brittle; hence the strength of the composites decreases as the quantity of the reinforcement decreases, as shown in Figure 4. Thus, the tensile strength of the new composites is inversely proportional to the weight percentage of the reinforcement; this is in line with the findings of [11].

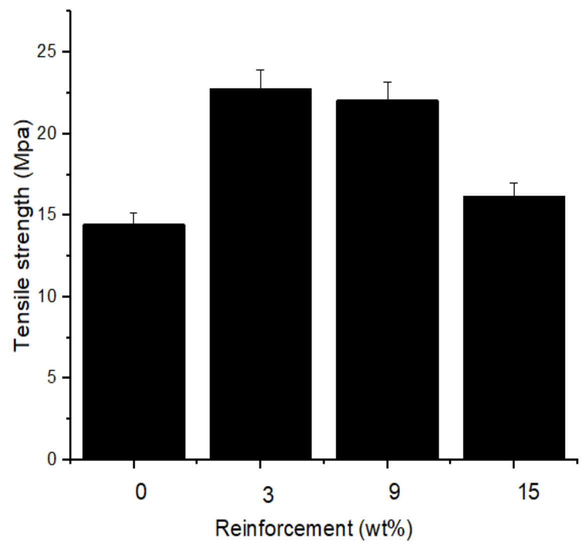

Fig. 4. Plot of tensile strength of pulverized coconut shell/granite composites and the control.

From Figure 5, it showed an improvement in the young modulus of the new hybrid composites, except 15 wt% reinforced composites of young modulus value of 300.51 MPa. Hybrid composite with 9 wt% reinforcement exhibited the highest young modulus of value of 718.47 MPa, followed by 3 wt% composites with value of 497.24 MPa. The reason for the enhancement exhibited by 3-9 wt% reinforced composites may be due to the good bonding between CSPs/FGPs and the epoxy matrix, which is in accordance with the findings of [12-13]. The decrease of young modulus exhibited by 15 wt% may be due to formation of poor bonding.

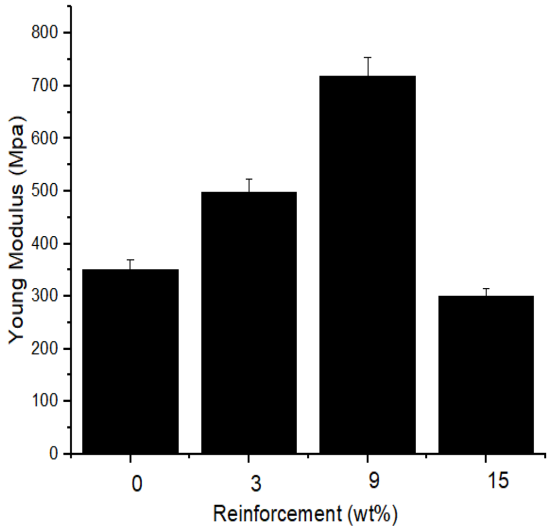

Fig. 5. Plot of young modulus of pulverized coconut shell/granite composites and the control.

From Figure 6, it was observed that the flexural strength of the new hybrid composites was all enhanced because of the particle size of 50 μm reinforcement used, which is less than 200 μm and this is in accordance with the findings of [10]. It was also observed that 3 wt% reinforced composite has the highest value of flexural strength of 77.19 MPa, next is 9 wt% reinforced composites (47.25 MPa) and followed by 15 wt% reinforced composites (43.03 MPa).

Figure 7 showed that the flexural modulus of the reinforced composites was all enhanced, due to the use of 50 μm particles of CSPs/FGPs used as reinforcement [10]. 9 wt% of reinforced composite have the highest value of flexural strength (1280.51 MPa), followed by 15 wt% and 3 wt% reinforced composites, values of 1042.88 MPa and 1009.35 MPa, respectively. This trend is in accordance with findings of [11].

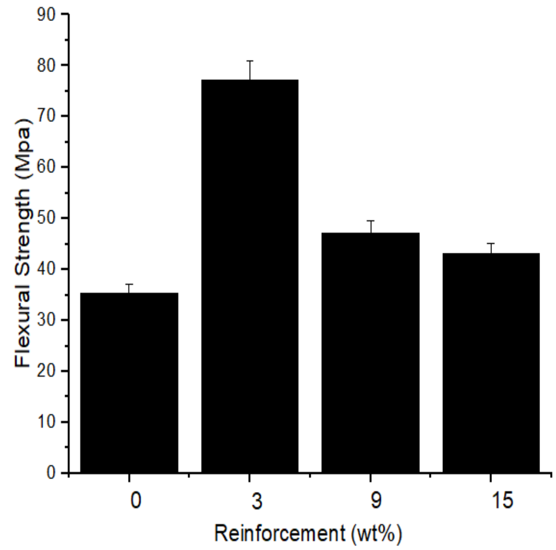

Fig. 6. Plot of flexural strength of pulverized coconut shell/granite composites and the control.

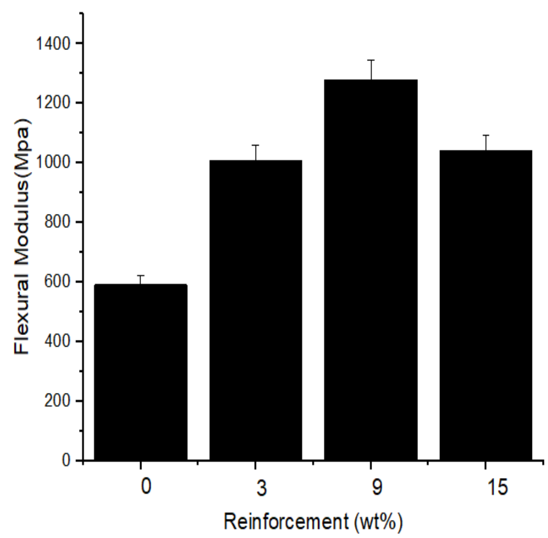

Fig. 7. Plot of flexural modulus of pulverized coconut shell/granite composites and the control.

From Figure 8, there were enhancements in impact energy of 3-15 wt% reinforced composites; due to the size (50 μm) of CSPs/FGPs used [10]. It was observed that impact energy was lowest in the control and highest in 15 wt% samples, respectively. The 15 wt% reinforced composites had 54 J, which is 93% increase in impact energy strength compared with that of the neat (28 J). 9 wt% reinforced composites have impact energy strength of value 45 J, while 3 wt% composites have impact energy strength value of 33 J. it was also observed that increase of filler weight percent increases the impact energy strength of the reinforced composites, this is in accordance with findings of [10].

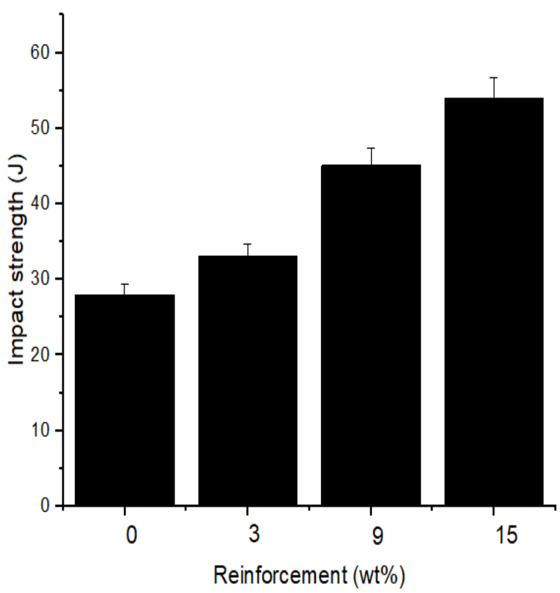

Fig. 8. Plot of impact energy strength of pulverized coconut shell/granite composites and the control.

IV. Conclusion

Mechanical properties of granite/pulverized coconut particulate hybrid reinforced epoxy composites have been studied and discussed, the following conclusion can be drawn

1. The 50 μm particles size of CSPs/FGPs used as reinforcement enhanced the mechanical properties of the newly produced hybrid composites.
2. The highest mechanical properties of the hybrid reinforced epoxy composite were:
   i. Hardness (46.14 HRC at 15 wt%)
   ii. Tensile strength (22.78 MPa at 3 wt%)
   iii. Young modulus (718.47 MPa at 9 wt %)
   iv. Flexural strength (77.19 MPa at 3wt%)
   v. Flexural modulus (1280.51 MPa at 9 wt%)
   vi. Impact strength (54 J at 15 wt %)
3. The result will be utilized to develop an alternative lightweight, cheap and environmentally friendly material.

References

[1] Feng, L., Xie, N. and Zhong, J. "Carbon nanofibers and their composites: A Review of Synthesizing, Properties and Applications", *Materials*, 2014, DOI:10.3390/ma7053919.

[2] Alok, S., Savista, S. and Aditya, K." Study of Mechanical Properties and Absorption Behaviour of Coconut Shell Powder-Epoxy Composites". *International Journal of Materials Science and Applications,* vol. 2, no. 5, 2013, pp. 157-161.

[3] Wang, S., Yong, Y., Zhou, L. and Mai, Y. "Size Effect in Microcompression of Epoxy", *Micropillars,* vol. 47, no. 3, 2012, pp. 6047-6055.

[4] Bachtiar, D., Sapuan, S. M. and Hamdan, M. M. "Flexural Properties of Alkaline Treated Sugar Palm Fiber Reinforced Epoxy Composites", *International Journal of Automotive & Mechanical Engineering*, vol. 1, no. 1, 2010, pp. 79-90.

[5] Srivastava, V. and Srivastava, R. "Advances in Automotive Polymer Applications and Recycling", *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 2, no. 3, 2013, pp. 744-746.

[6] ASTM D256-10 (2018). "Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics", *ASTM International, West Conshohocken, PA*, 2018, https://www.astm.org retrieved on January 12, 2023.

[7] ASTM D-638-14. "Standard Test Methods for Tensile Properties of Plastics and Reinforced Plastics", *ASTM International*, *West Conshohocken, PA*, 2022, https://www.astm.org retrieved on January 12, 2023.

[8] ASTM D-790-03. "Standard Test Methods for 3-point Flexure test of Plastics", *ASTM International*, *West Conshohocken, PA*, 2011, https://www.astm.org retrieved on January 12, 2023.

[9] Agunsoye, J. O., Isaac, S. T. and Samuel, O. S. "Study of Mechanical Behavior of Coconut Shell Reinforced Polymer Matrix Composite", *Journal of Mineral and Materials Characterization & Engineering*, vol.11, no. 1, 2012, pp. 774-779.

[10] Sapuan, S. M., Harim, M. and Maleque, M. A. "Mechanical Properties of Epoxy/Coconut Shell Filler Particle Composites", *Arabian Journal for Science and Engineering*, vol. 28, no. 2, 2003, pp. 171- 183.

[11] Bhaskar, J. and Singh, V. K. "Water Absorption and Compressive Properties of Coconut shell Particle Reinforced-Epoxy Composite", *Journal of Material and Environment Science*, vol. 4, no.1, 2013, pp. 113-118.

[12] Oladele, I. O., Makinde., B. A., Adediran, A. A., Oladejo, M. O., Owa, A. F. and Olayanju, T. M." Mechanical and Wear Behavior of Pulverized Poultry Eggshell/Sisal fiber Hybrid Reinforced Epoxy Composites", *Material Resources Express* **7** 045304, 2020, pp. 1-10.

[13] Akindapo, J. O., Agov, E. T., Garba, D. K. and Ogabi, R. O. "Comparative Assessment ofMechanical Properties of Groundnut Shell and Rice Husk Reinforced Epoxy Composites", *American Journal of Mechanical Engineering*, vol. 5, no. 3, 2017, pp. 76-86.