Journal of Inventive Engineering and Technology (JIET)
ISSN: 2705-3865
Volume-6, Issue-1, pp-27-33
www.jiengtech.com
Research Paper Open Access

Development of Decking Boards from Carbonized Walnut shell Ash Particulate/Epoxy Resin

Chidume N. Nwambu[1], Unegbu Chukwudi[2], Chilee M. Ekwedigwe[3]

[1,3]Metallurgical and Materials Engineering Department, Faculty of Engineering, Nnamdi Azikiwe University, Awka, Nigeria
[2]Shell Nigeria Exploration and Production Company, Lagos, Nigeria

Corresponding author: [1]cn.nwambu@unizik.edu.ng

Abstract

The conversion of agricultural wastes into possible raw materials for industry has recently received much interest. As a result, a decking board has been developed that uses carbonized walnut shell ash particulate as a filler and Resin Epoxy as a binder. The filler (walnut shell ash particle) was carbonized and sieved into three grades: 100µm, 355µm, and 710µm. Press time, pressure, temperature, and filler-to-epoxy resin ratio were the independent variables used to create twenty experimental samples. Thermal conductivity, water absorption, thickness swelling, and density tests were performed on the generated samples, and the results formed the basis for the Central Composite Design. Response Surface Methodology was used to assess the experiment's outcomes, and Analysis of Variance (ANOVA) was used for validation. The best values for the production parameters were 23.234% filer/epoxy resin, 10 minutes press time, 178oC press temperature, and 13.134MPa press pressure, resulting in a density of 673.456 g/cm3, 0.412% water absorption, 0.865% thickness swelling, and 0.456W/M.K thermal conductivity. This finding demonstrates that agro-waste breadfruit seed coat is an effective filler material in the manufacturing of decking boards. The results revealed that the finer the sieve size, the better the properties. The results achieved in this study were compared to those of commercial decking boards, which are very similar.

Keywords: *Composite, Walnut ash particulate, epoxy resin, agro waste, decking boards.*

I. INTRODUCTION

The demand for agricultural waste materials as an alternative to high-density, expensive, and environmentally hazardous organic reinforcement for composite materials has risen dramatically (Achebe et al., 2019; Ibezim et al. 2022; Chukwuneke et al. 2023). These naturally occurring wastes offer advantageous qualities such as high strength, lightweight, cost-effectiveness, and the absence of toxic substances during use (Olorunfemi et al. 2024). Natural waste materials have been shown in studies to be a reliable replacement for glass fiber for polymer reinforcement (Abdel-Salam et al, 2011; Nwoye et al., 2023). The introduction of agricultural waste materials will help to mitigate the hazardous threat of environmental contamination created by the use of synthetic materials like glass as reinforcement in composite production (Aigbodion et al., 2010; Ekwedigwe et al., 2023). Previous research has shown that composite materials reinforced with natural fibres have strong chemical resistance, superior acoustic insulation, and good thermal and electrical properties (Fono-Tano, 2014; Nwambu, 2022; Nwankwo et al. 2024). Deepika et al. (2013) found that the emergence of composite materials was caused by recent technological advancements, which led to an increase in demand for materials with certain unique features. These factors have also contributed considerably to the recent demand for composites in a variety of industries, including automotive, aircraft, and sports (Aderiye et al., 2014; Edokpa et al., 2014; Nwambu et al., 2022). In composite manufacture, the matrix acts as a solvent and the reinforcement as a solute. The reinforcement could take the form of particles, fibres of various orientations, or sheets. The matrix could be made of ceramics, metal, alloys, or polymers (Mohammed et al.2018; Anyanwu et al. 2019). The "hard" reinforcement is spread in a continuous phase (the matrix), and the matrix forms a percolating network,

becoming embedded with the reinforcements to build a new material (Yawas et al., 2013; Ezenwa et al. 2022). The reinforcements are much stronger than the matrix, thus they are bound to it to improve its strength, hardness, and wear qualities. Because the reinforcements are insoluble in the matrix, they are placed beside it. As a result, there is a requirement to improve the wettability of the reinforcement to the matrix to achieve effective bonding and improved characteristics (Xavier, 2022). Several studies have used natural fibres to strengthen epoxy resins (Ezenwa et al. 2019). Their findings show that composites reinforced with natural fibres have higher tensile and flexural strength than composites reinforced with particles. Furthermore, composites reinforced with particles are more durable and resistant to damage than composites reinforced with fibers. (Yawas et al., 2016, Achebe et al., 2019; Okoye et al., 2023). Rice husk (Oladele et al., 2009; Suleiman et al., 2013; Madu et al., 2018), breadfruits (Ezenwa et al., 2019), and banana fibres (Stephen et al., 2014) have all been used to make ceiling boards. Even though numerous agro-wastes have been employed in manufacturing ceiling boards, the production of decking boards is not recorded in the literature, creating the knowledge gap that this study intends to fill.

II. MATERIALS AND METHODS

A. Materials and Fabrication

Walnut shell ash particles, steel dust, silicon carbide, graphite, and epoxy adhesive. A 30-kg quantity of walnut shells was collected from a local farm in the Izi community in Ebonyi state. The walnut shell was carbonized and sieved through apertures of 600µm, 300µm, and 100µm according to Chukwuneke et al. (2023) and Ezenwa et al. (2022). In decking board composition, use a set of BS 410 standard sieves (Olorunfemi et al. 2024). The samples were manufactured with a compression molding machine and counter molding was used in compression moulding to close the mould after it had been saturated (Mohammed et al. 2018). Walnut shell ash particles, steel dust, graphite, silicon carbide, and epoxy resin were combined in varying compositions and sieve grades (600µm, 300µm, and 100µm). The combination was thoroughly dry mixed in a mixer for 40 minutes to establish homogeneity before being transferred to a mould in a hot platen press at 2000C and 100KN/cm2 pressure for 5 minutes (Mohammed et al. 2018). Following removal from the hot press, the composite products were cured in an oven at 120oC for 8 hours. The product was then allowed to cool to ambient temperature. The ingredients' composition analysis is as follows: 55% sawdust, 12% steel dust, 11% graphite, 10% silicon carbide, and 17% epoxy resin. The samples were characterized by grinding with 600, 400, and 300 grit papers, respectively (Olorunfemi et al. 2024; Mohammed et al. 2018). After dry polishing these samples, a metallurgical microscope was used to investigate their internal architecture.

B. Mechanical Tests

The samples' wear rate was evaluated by sliding a pin-on-disc machine over a cast iron surface at a load of 10N, 125 rev/min, and 2000m. All tests were carried out at ambient temperature. The initial weight of the samples was obtained using a single-pan electronic weighing equipment with an accuracy of 0.01g ((Mohammed et al. 2018). During the test, the pin was forced against its counterpart revolving against a cast iron disc (hardness 65 HRC) with a counter surface roughness of 0.3µm by providing a load. A friction-detecting arm coupled to a strain gauge supported and placed the pin samples vertically into the rotating hardened cast iron disk. After running through a set sliding distance, the samples were removed, cleaned with acetone, dried, and weighed to evaluate the weight loss caused by wear (Chukwuneke et al. 2023; Ezenwa et al. (2022). The weight discrepancies observed before and after tests indicate the wear of the samples.

$$Wear\ rate = \frac{\Delta W}{S} \qquad (1)$$

Where ΔW is the weight difference of the sample before and after the test in mg, S is the total sliding distance in m.

The compressive strength was measured using a Tensometric Machine (Olorunfemi et al. 2024). Samples with a diameter of 29.40mm were subjected to compressive force and loaded continuously until failure occurred. The load at which the failure occurred was then documented.

According to Ibezim et al. (2022), and Veeman et al. (2023), the composites' resistance to indentation was measured using Brinell hardness testing equipment to BS240, using a Tensometer (M500-25KN, Gunt Hamburg Hardness Tester, and WP300) pushing a hardened steel ball with diameter D into a test specimen. According to ASTM specifications, a 10 mm diameter steel ball was employed, and the applied load P was held constant at 3000 kg. The indentation's diameter, d, was measured in two perpendicular directions using an optical micrometer screw gauge. The mean value was taken and incorporated into Equation 2 to obtain the Brinell Hardness Number (BHN) (Mohammed et al. 2018).

BHN $= 2P \div \pi D\,(D - \sqrt{D^2 - d^2})$ (2)

Where P is the load applied, D is the diameter of the hardened steel ball into a test specimen and d is the diameter of indentation.

The density of the samples was calculated by weighing them on a digital weighing machine and dividing by their volumes (by liquid displacement).

Calculation: Density (ρ) $= \frac{m}{V}$ (3)

Where m is the mass of the test piece (g) and V is the measured volume of the test piece (cm^3) by the liquid displacement method (Olorunfemi et al. (2024).

C. Water Absorption Test

According to Mohammed et al. (2018) and Ezenwa et al. (2022), the samples were weighed with a digital weighing machine and then immersed in room-temperature water for 48 hours. The samples were then extracted, cleaned with tissue paper, and weighed.

Calculation: Water Absorption = $\frac{m_2 - m_1}{m_1} X\ 100\ \%$ (4)

Where m_1 is the mass of the sample (g) and m_2 is the mass of the sample after absorbing water (g).

III. RESULTS AND DISCUSSION

A. Properties of the developed decking board with walnut shell ash particulate and epoxy resin

Figs. 1 to 5 illustrates how the particle size of walnut shell particulates influences the properties of decking boards manufactured with epoxy resin and walnut shell ash particles. The sample with 100µm particle size has the highest hardness value and compressive strength (121N/mm2) as shown in Figs. 1 and 2.

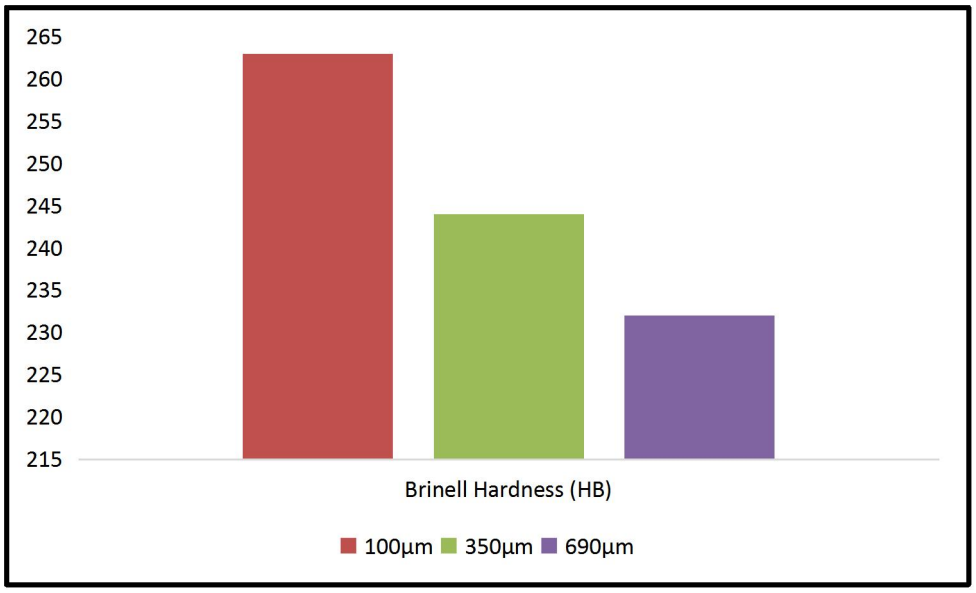

Fig.1: Brinell hardness against particle size of walnut shell particulate decking composite

The hardness ratings dropped as particle size grew. The high hardness values for 100µm particle size were produced by the reduced sieve grade of walnut shell ash particles (i.e. increased surface area), which resulted in enhanced bonding ability with resin. The consistent decrease in compressive strength as particle size increases can be attributed to the walnut shell particles' lower surface area and pore-packing capacities in the resin. This align with the finding of Mohammed et al. (2018) and Ezenwa et al. (2022)

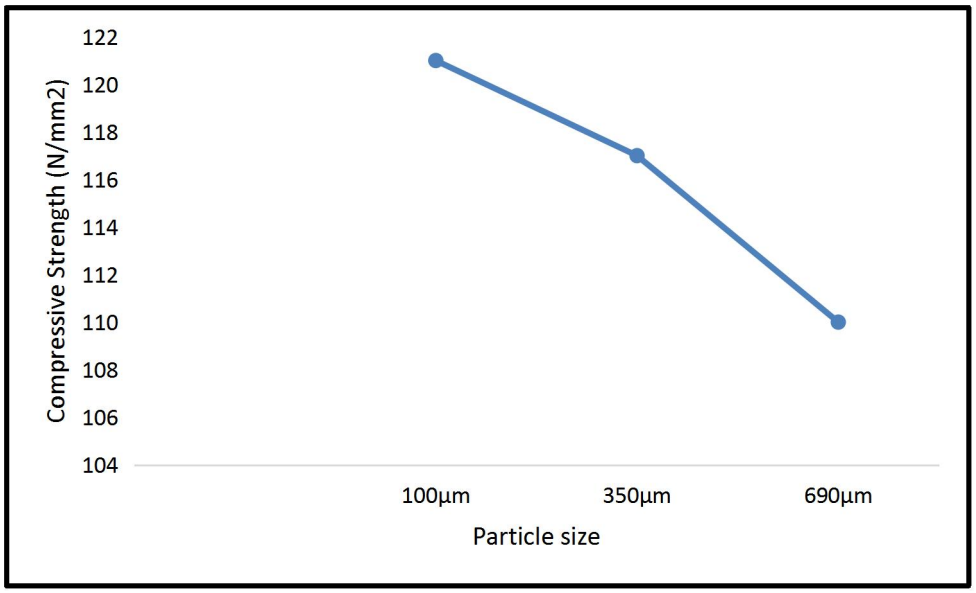

Fig.2: Compressive strength against particle size of walnut shell particulate decking composite

Fig.2 depicts the compressive strength of walnut shell ash particles rises with decreasing particle size. Additionally, the data demonstrates that as particle size increases, the ash content decreases, which could be related to an increase in pores. The sample with a 100µm sieve grade exhibited the best properties due to its significant dispersion of tiny particles.

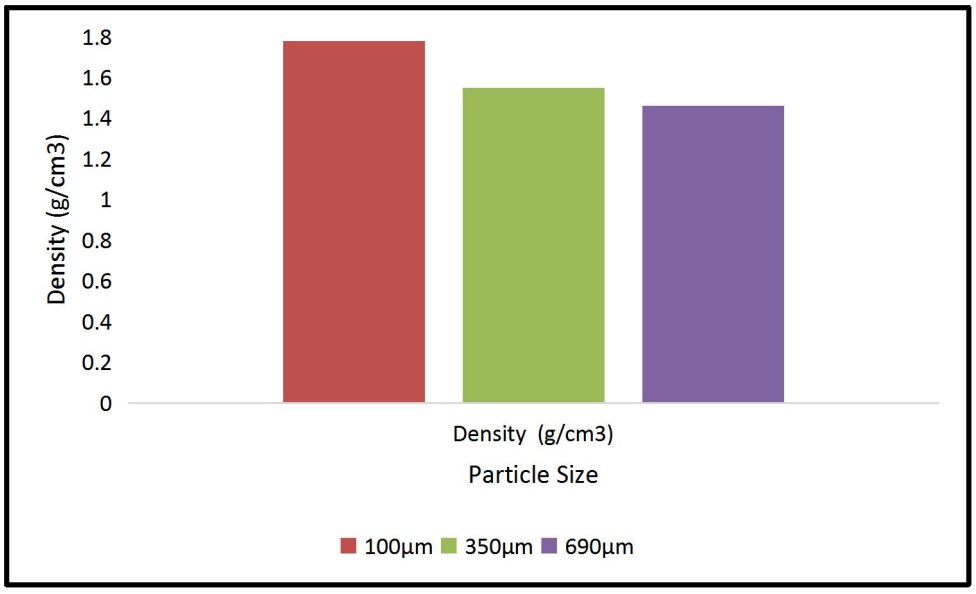

Fig.3.:Density against the particle size of the walnut shell particulate decking composite

Similarly, Fig.3 shows that the density of the walnut shell ash particles falls as its particle size grows in composition. The decrease in density can be due to the increased particle size. The sample with 100µm sieve grade has the highest density due to closer packing of walnut shell ash particulate, resulting in higher uniformity throughout the composite body.

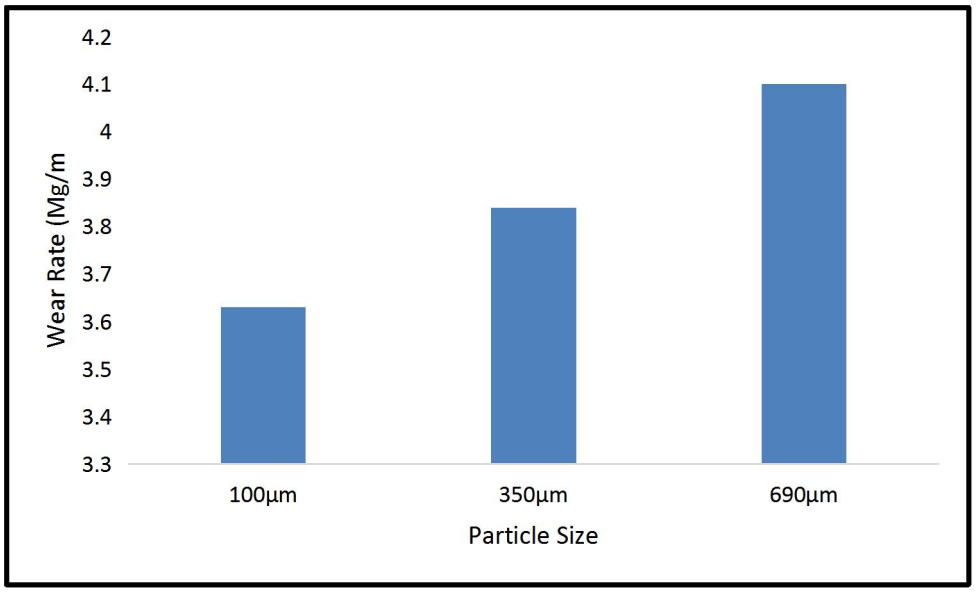

Fig. 4. Wear rate against particle size of walnut shell particulate decking composite

Furthermore, the Fig.4 shows an increase in wear rate as the size of the walnut shell ash particles increases. This is owing to the denser packing of walnut shell ash particles, which has a stronger bonding impact inside the combination. This could be due to the increased hardness and compressive strength of the materials as particle size decreases.

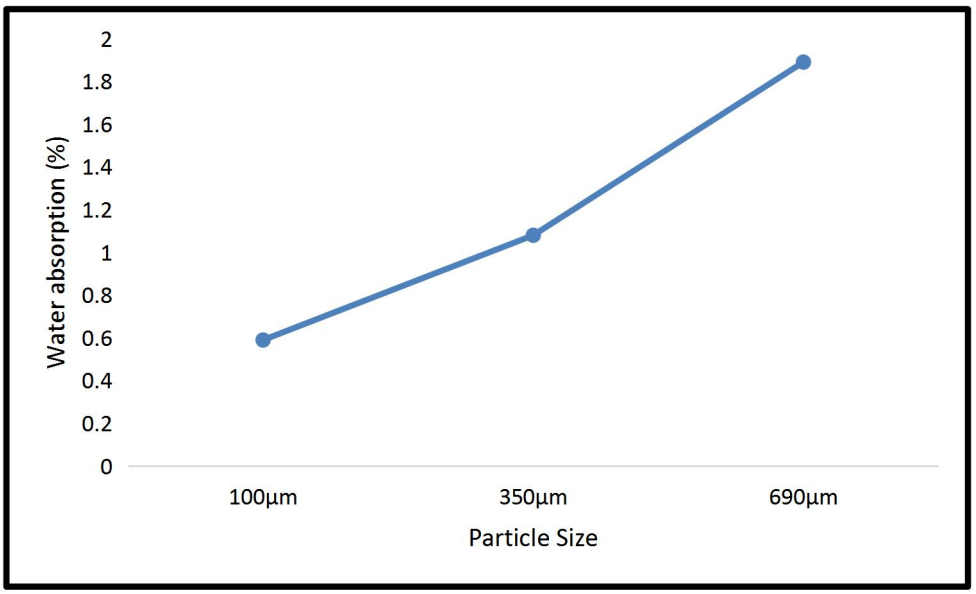

Fig.5: Water absorption against particle size of walnut shell particulate decking composite.

Water absorption increases with particle size as shown in Fig.5, possibly due to the increased number of pores. These results are consistent with previous observations. The sample with 100µm sieve grade had the best property due to improved dispersion of walnut shell ash particulate particles. This led to improved interfacial bonding between the resin and walnut shell ash particulates.

IV. CONCLUSION

The findings indicate that walnut shell ash particles satisfied the requirements for usage as a decking board material (i.e., as a substitute for wood and other non-locally derived materials) because they provided results within the decking board test range. The study discovered that 100µm walnut shell ash particles can successfully replace wood or non-locally sourced materials in decking board manufacture. As a result, the properties of walnut shell ash particles improve as the particle size decreases. The compressive strength, hardness, density,

ash content, and water absorption of the resultant samples decreased with increasing particle size. The wear rate increased as the particle size grew.

Acknowledgement

The authors acknowledge funding from the Tertiary Education Trust Fund (Tetfund) with reference number TETF/ES/DR&D/CE/UNI/AWKA/IRR/2023/VOL.1. The authors also thank the following; Metallurgical and Materials Engineering Department Workshop of Nnamdi Azikiwe University Awka, Anambra State where we did our fabrication and testing job, We remain indebted to all.

REFERENCES

Abdel -Salam S., Metwally M. S., Abdel- Hakim A. A., El B. S. and Elshafie E. S. (2011) Effect of mineral fillers on rice straw fiber/high-density polyethylene composites. Nature and Science, 9(12):116-124.

Achebe C, Obika E, Chukwuneke J, et al. Optimization of hybridised cane wood-palm fruit fibre frictional material. Proc Inst Mech Eng Part L J Mater Des App 2019; 233: 2490–2497.

Aigbodion, V.S., Agunsoye, J.O. (2010). Bagasse(Sugarcane waste):Non-Asbestos Free Brake Pad Materials. LAP Lambert Academic Publishing, Germany, ISBN 978-3-8433-8194-9.

CI Nwoye, CC Emekwisia, CN Nwambu, OR Opetubo (2023) Response of PZT-rod Periodicity in piezoelectric polymer structure based on density of the composite and volume percent PZT in composite, Journal of Inventive Engineering And Technology, 4 (2), 21-28.

Ekwedigwe, C., Nwambu, C., Nnuka, E.,(2023) Effects of rice straw fibre and walnut shell ash particulates on the mechanical behavior of epoxy composite. Unizik Journal of Engineering and Applied Sciences 1 (1), 69-77.

Bono, S.G., Dekyrger, W.J. (1990). Auto Technology, Theory and Service, 2nd ed. DELMAR Publishers, New York, 45–48.

Deepika, K., Bhaskar, Reddy C., Ramana, Reddy D. (2013). Fabrication and Performance Evaluation of a Composite Material for Wear Resistance Application.International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 6.

CN Nwambu, CM Ekwedigwe, FO Osakwe, KO Iyebeye (2023) Raffia Nut Powder Reinforcing Filler in Unsaturated Polyester Resin, Journal of Inventive Engineering And Technology (Jiet) 4 (2), 83-86.

Blau, J. P. (2001). Compositions, Functions and Testing of Friction Brake Materials and their Additives.Being a report by Oak Ridge National Laboratory for U.S. Dept. of Energy. http://www.Ornl.- gov/-webworks/cppr/y2001/rpt/112956.pdf, 78–80.

C I Nwoye, C C Emekwisia, C.N Nwambu, O.R Opetubo (2024) Reliability Level In The Functional Evaluation Of Energy Density From The Activity Responses Of Average Wind Speed And Power Density. Journal of Inventive Engineering And Technology 4 (1), 49-57.

NE Nwankwo, CN Nwambu, CC Emekwisia, FO Osakwe, OJ Chukwu and CI Nwoye, (2024) Response of flexural strength of hazelnut shell polystyrene composite to the input concentration ratio of its constituent materials, International Journal of Research in Civil Engineering and Technology, 5(1): 17-24.

Yawas, D. S., Aku, S. Y., Amaren, S. G. (2013). Morphology and properties of periwinkle shell asbestos-free brake pad. Journal of King Saud University – Engineering Sciences.

Aderiye Jide (2014). Kaolin Mineral Material for Automobile Ceramic Brake Pad Manufacturing Industry: International Journal of Technology Enhancements and Emerging Engineering Research, Vol. 2, Issue 3. ISSN 2347-4289.

Edokpia, R. O., Aigbodion, V. S., Obiorah, O. B., Atuanya, C. U. (2014). Evaluation of the Properties of Ecofriendly Brake Pad Using Egg Shell Particles–Gum Arabic.ScienceDirect®, Elsevier B.V. DOI: 10.1016/j.rinp.2014.06.003

Fona, R.S. and Koya, O.A. (2013).Characteristics of Pulverised Palm Kernel Shell for Sustainable Waste Diversification.International Journal of Science & Engineering Research Volume 4.

Chidume Nnamdi Nwambu. Mechanical properties of asymmetric bouligand structured carbon fibre reinforced plastics, The University of Edinburgh, 2022/12/16,

CN Nwambu, GI Chibueze, EN Nwankwo, CM Ekwedigwe, (2023) Taguchi analysis of the tensile behaviour of unaged and hygrothermally aged asymmetric helicoidally stacked CFRP composites, Journal of Civil Engineering and Environmental Sciences 9 (2), 068-072.

C Nwambu, I Chibueze, K Iyebeye, C Ekwedigwe, (2023) Optimization of viscoelastic behaviors of bioinspired asymmetric helicoidal CFRP composites using Taguchi Method, Archive of Biomedical Science and Engineering 9 (1), 010-014.

CN Okoye, PC Okolie, BS Oluwadare, CN Nwambu (2023) The damage tolerance of Al-Si-Mg Alloy Reinforced with Periwinkle Shell and Mangifera Indica Particulates, Journal of Inventive Engineering And Technology, 4 (2), 64-72.

CI Nwoye, CC Emekwisia, CN Nwambu,(2023) Empirical Analysis of Ceramic Wear Shrinkage Based on the Operational Influence of Firing Temperature and Sustained Porosity. UNIZIK Journal of Engineering and Applied Sciences 2 (3), 315-323.

Ekwedigwe, C. Nwambu, C, F Osakwe, E Nnuka, (2023) Mechanical Properties of Hybrid Rice Straw Fibre and Walnut Shell ASH Particulate/Epoxy Composite. International Journal of Science and Engineering Invention, 01-07.

Ezenwa, O.N, E.N. Obika, C. Umembamalu, F.C. Nwoye. "Development of ceiling board using breadfruit seed coat and recycled low-density polyethylene", Heliyon, 2019

Akachukwu Ibezim, Raphael Onuku, Chidalu Ottih, Ifeoma Ezeonu, Efeturi Onoabedje, Karuppasamy Ramanathan, Ngozi Nwodo. "New sulphonamide-peptide hybrid molecules as potential PBP 2a ligands and methicillin resistant actives ", Journal of Biomolecular Structure and Dynamics, 2022

Chukwuneke Jeremiah Lekwuwa, Sinebe Jude Ebieladoh, Ezelue Anthony Emeka, Obika Echezona Nnaemeka et al. "Production and thermo-structural analysis of a hybridized natural fibre-based ceiling board for building applications", Advances in Mechanical Engineering, 2023

Dhinakaran Veeman, Jitendra Kumar Katiyar, Alessandro Ruggiero. "Tribo-mechanical performance of brake composite material: a comprehensive review", Tribology - Materials, Surfaces & Interfaces, 2023

Advanced Engineering Optimization Through Intelligent Techniques", Springer Science and Business Media LLC, 2020

Olorunfemi, B. J, D. O. Abegunde, O. T Oginni, A. O. Adesina, I. A. Olumoroti. "DEVELOPMENT OF COMPOSITE MATERIALS FOR TRICYCLE BRAKE PADS", UNIOSUN Journal of Engineering and Environmental Sciences, 2024

Romeo Sephyrin Fono-Tamo. "Agro-Waste Based Friction Material for Automotive Application", SAE International, 2014

Tiamiyu Ishola Mohammed, Olatunji Oladimeji Ojo, Olaitan Ezekiel Olufemi. "Laboratory Study of a Lignocellulosic Biomass as an Alternative Base Material for Brake Pads", Current Journal of Applied Science and Technology, 2018

Anyanwu, B.U, G.O. Olayinka, D.T. Ezeokeke, O.S. Fayomi, O.O. Oluwole. " Effect of Kenaf Core Fibre ( ) as one of the Dispersing Phases in Brake Pad Composite Production ", Journal of Physics: Conference Series, 2019

Obiora Nnaemeka Ezenwa, Echezona Nnaemeka Obika, Ignatius Echezona Ekengwu, Obiora Okafor. "Thermal Behaviour of Agro-waste Based Ceiling Board and Its Filler Material", Research Square Platform LLC, 2022

Sodagudi Francis Xavier. "Thermoplastic Polymer Composites" , Wiley, 2022

