



## Characterizations of some discarded shells particles polymer-based composites for ceilings and particles board applications

Mufutau A. Salawu<sup>a,\*</sup>, Ibrahim K. Ayinla<sup>b</sup>, Mashood A. Salahudeen<sup>c</sup>, Joshua A. Adeoye<sup>a</sup>, Peter T. Jegede<sup>a</sup>, Sabastine C. Ezike<sup>d</sup>, Oluwatoyin O. Olanmi<sup>a</sup>, Francis O. Omoniyi<sup>a</sup>, Aderemi B. Alabi<sup>a</sup>

<sup>a</sup>Department of Physics, University of Ilorin, Ilorin, Nigeria

<sup>b</sup>Department of Chemistry/Industrial Chemistry, University of Ilorin, Ilorin, Nigeria

<sup>c</sup>Department of Mechanical Engineering, Kwara State Polytechnic, Ilorin, Nigeria

<sup>d</sup>Department of Physics, School of Physical Sciences, Modibbo Adama University of Technology, Yola, Nigeria

### ARTICLE INFO

#### Article history:

Received: 04 September 2023

Received in revised form: 25 Oct. 2023

Accepted: 01 November 2023

Available online: 28 November 2023

**Keywords:** PVA, Thermo-gravimetric, Acrylic, Isophoromediamine, Bisphenol-A-diglycidyl ether poly

DOI:10.61298/rans.2023.1.2.17

### ABSTRACT

Sea-shells, periwinkle-shells, and snail-shells were pulverized into 35.5  $\mu\text{m}$  particle sizes. Using a two-roll Rheomixer with a rotor speed of 60 rpm for 10 minutes, the particles were thoroughly mixed with the binders in ratio 2:1 and placed in the compression mold of dimension 15 cm by 3 cm by 3 cm using a force of 1.5 kN. The Rockwell hardness tester on scale B with a 1.56 mm steel ball, optical microscope and Flexural tester were used to characterize the composites. Thermo-gravimetric analyzer and Fourier Transform Infrared (FTIR) Spectrometer were used to characterize the shell particles. According to the results, epoxy resin (bisphenol-A-diglycidyl ether poly) and hardener (isophoromediamine) composites containing periwinkle shell particles had the highest hardness number of 48 and could withstand maximum flexural load of 5.5 MPa with a maximum flexural extension of 0.05 mm. The epoxy resin (bisphenol-A-diglycidyl ether poly) and hardener (isophoromediamine) proved to be the best epoxy resin. All the shell particles functional groups were visible in the FTIR analysis with varying transmittances at their respective wavenumbers. Optical micrographs of the composites showed uniform distribution of the reinforcement and the matrix, thermo-gravimetric analyses demonstrated good thermal stability of the shell-particles up to 250 °C.

© 2023 The Author(s). Production and Hosting by FLAYOO Publishing House LTD on Behalf of the Nigerian Society of Physical Sciences (NSPS). Peer review under the responsibility of NSPS. This is an open access article under the terms of the Creative Commons Attribution 4.0 International license. Further distribution of this work must maintain attribution to the author(s) and the published article's title, journal citation, and DOI.

### 1. INTRODUCTION

Since the dawn of history, new materials have been essential to human expansion, wealth, security, and quality of life, ranking among the greatest achievements of all time [1]. In any field, whether it's civil, chemical, construction, nuclear, aeronautical,

agricultural, mechanical, biomedical, or electrical engineering, new materials are always key to developing new technologies. The need for innovative materials such as carbon fiber reinforced polymers (CFRP), titanium alloys, silicon carbide, alumina ceramic, Inconel and hastelloy to offer a suitable balance of strength, toughness, wear resistance, high temperature performance, and corrosion resistance is growing every day. As a result, scientists are concentrating on combining two or more materials to create new composites for a variety of purposes [1].

\*Corresponding author: Tel.: +2348030788553;  
e-mail: salawu.ma@unilorin.edu.ng (Mufutau A. Salawu)

In coastal regions and nations that generate a lot of seafood, seashells and periwinkle shells are being discarded as garbage [2]. Even if they have not yet found widespread use, a sizable deposit of shells has accumulated in a number of areas throughout the years [3]. A significant fraction of them, including snail shells, are nevertheless thrown out as wastes. Due to problems with landfill management and water pollution, seashell trash causes environmental deterioration and emissions [5]. According to several studies, shell debris in landfills produces an unpleasant odor, contaminate public water surface management, and affect the ecosystem [6, 7].

Other research [8–11] show that discarded shells may be used to make Portland cement, coarse aggregates, and concrete, among other building materials. For particular uses, other researchers have also experimented with various materials as composites [12–14]. Particleboard was originally created from wood, rice husks, sycamore leaves, citrus branches, beech twigs, and ordinary agricultural waste, according to the work mentioned [15–24]. This study investigates the characteristics of the shells that have been discarded (periwinkle shells, seashells, and snail shells) for their applications as roof ceilings and particle board utilizing various polymer binding agents.

## 2. MATERIALS AND METHOD

From the Oron waterside in Akwa-Ibom State, sea shells, periwinkle shells, and snail shells were collected and ground into  $35.5 \mu\text{m}$  particle sizes using a grinding machine and sieve. The sea shell, periwinkle, and snail shell powders were combined separately with the binders in a ratio of 2:1 and thoroughly stirred using a two-roll Rheomixer device for 10 minutes at a speed of 60 rpm. The composites were then placed into an aluminum mold with dimensions of 15 cm by 3 cm by 3 cm and compressed with a force of 1.5 kilo-newton using a compression machine. The procedure was repeated for the three distinct shell particles and binders which included acrylic, polyvinyl alcohol (PVA), epoxy resin (bisphenol-A-diglycidyl ether poly), and hardeners (isophoromediamine). The produced composites were allowed to dry before being analyzed with a Flexural tester, an optical microscope, and a Rockwell hardness tester on scale B with a 1.56 mm steel ball. Both the modulus of rupture (MOR) and the modulus of elasticity (MOE) were calculated. Additionally, the Fourier Transform Infrared (FTIR) Spectrometer and thermo gravimetric analyzer were used to characterize the shell particles. Figure 1 shows the schematic diagram describing the synthesis of these composites.

## 3. RESULTS AND DISCUSSIONS

### 3.1. INDENTATION HARDNESS ANALYSES

The most effective and popular mechanical test for determining a material's characteristics is the indentation hardness test. A material's hardness is frequently regarded as its resistance to becoming permanently indented. The purpose of the hardness test is to evaluate the appropriateness of a material for a given application.

The average hardness number of the three shell particle polymer-based composites with various binders is shown in Figures 2-4. Periwinkle shell epoxy/hardener composites had the highest average hardness number of 48, followed by sea shell

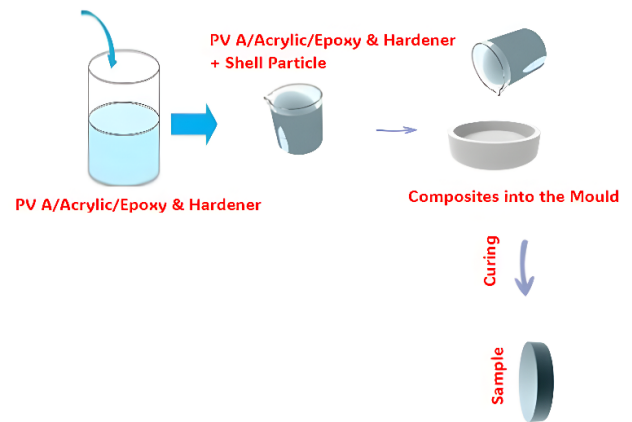


Figure 1. Schematic diagram describing the synthesis of these composites)

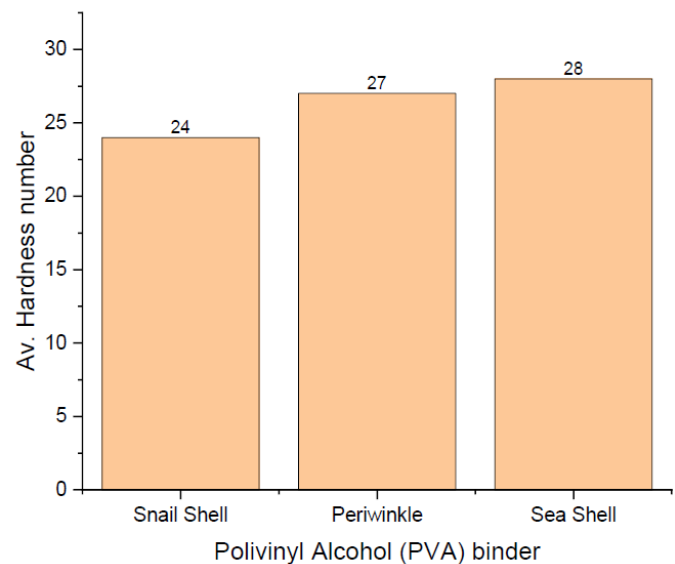
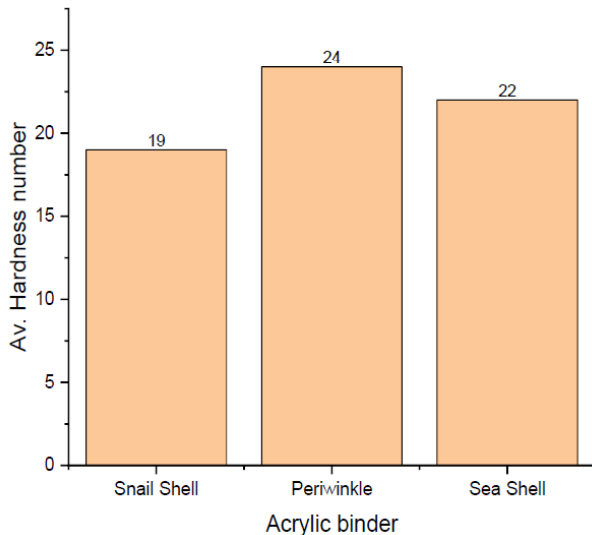


Figure 2. Average hardness number against PVA shells particles composites)

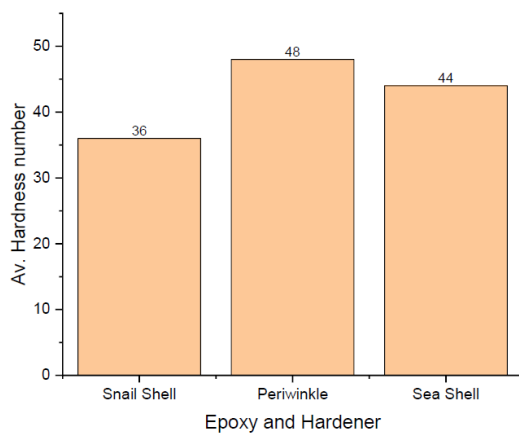
epoxy/hardener composites with a value of 44. The hardness number demonstrated the materials resistance to persistent indentation. In comparison to the snail shell epoxy/hardener composite, periwinkle and sea shell epoxy/hardener composites had considerably improved mechanical performance. The ability of the periwinkle-epoxy/hardener combination to adhere well to each other was responsible for mechanical performance. Proper adhesion prevents delamination and enhances the overall strength. Epoxy/hardener performed better than the PVA and Acrylic binders among the three binders examined. The particle boards' hardness is mostly determined by the inherent properties of the particles, their sizes, their uniform distributions, and their mixing with resins.

### 3.2. FOURIER TRANSFORMS INFRARED SPECTROSCOPY ANALYSES

Figure 5 depicts the Fourier transform infrared spectroscopy absorptions of periwinkle shell, sea shell, and snail shell particles,



**Figure 3.** Average hardness number against Acrylic shells particles composites)

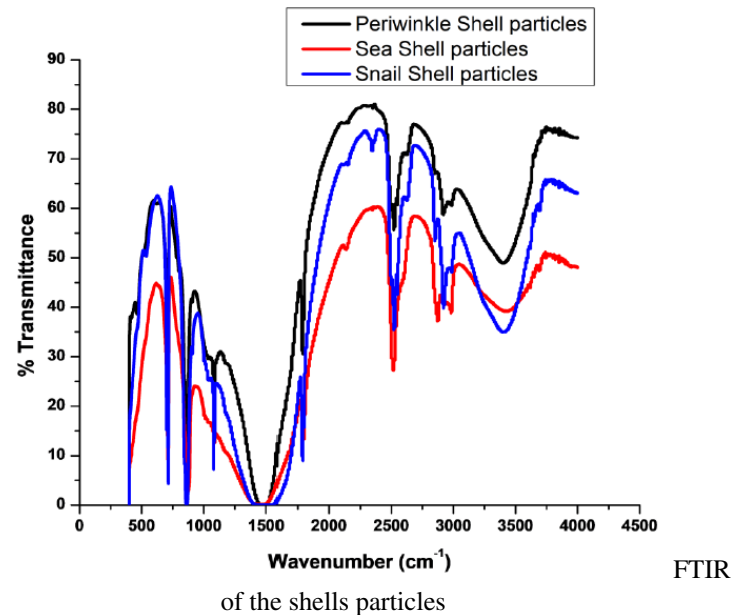


**Figure 4.** Average hardness number against shells particles of Epoxy/hardener based composites.

respectively, by frequency regions. The shell particles created nitro compounds (N-O stretching), hydroxyl compounds (O-H stretching), and primary amine compounds (N-H stretching) at their respective wave numbers with variable levels of transmittance, as shown from the spectra. Within the wavenumber (500 - 4500  $\text{cm}^{-1}$ ), the periwinkle shell, sea shell, and snail shell particles display symmetrical spectra patterns. Table 1 provides a summary of the wavenumber, compound class, and assignment of the shell particles under investigation.

### 3.3. THERMO-GRAVIMETRIC AND TOPOLOGICAL ANALYSES

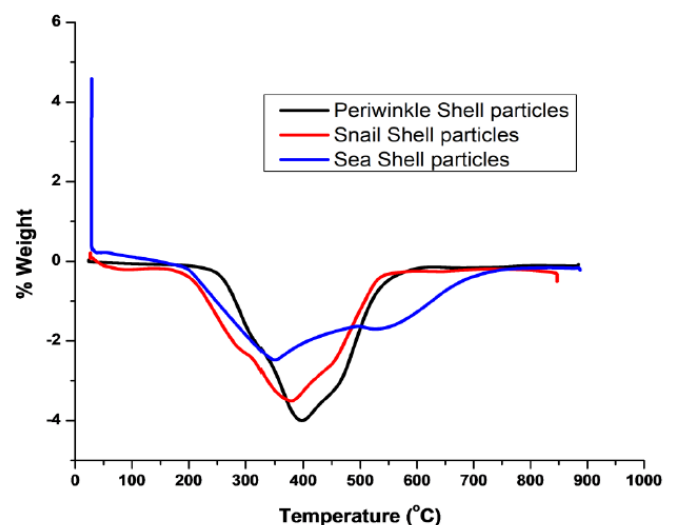
Thermo-gravimetric analysis is a technique for thermal analysis that measures the mass sample's weight and changes it in relation to temperature. The thermo-gravimetric analysis (TGA) and topological data analysis (TDA) of the under-researched shell particles were shown in Figures 6 and 7. These figures indicate that by observing the weight change that takes place while the materials are heated at a constant rate, the % weight samples demonstrate thermal stability and their fraction of volatile com-



**Figure 5.** Average hardness number against shells particles of Epoxy/hardener based composites)

**Table 1.** Structure and chemical composition of the synthesied graphene oxide material

S/N	Wavenumber ( $\text{cm}^{-1}$ )	Compound Class	Assignment
1	1500	N-O stretching	Nitro compound
2	2500	O-H stretching	Hydroxyl compound
3	3500	N-H stretching	Primary amine



**Figure 6.** Thermo-gravimetric (TGA) analysis of shell particles)

ponents. Prior to the weight reduction of the three shell particles, the results showed that the three shell particles are thermally stable up to 250 °C. This suggests that the shells particles have good potential for use in board and ceiling applications.

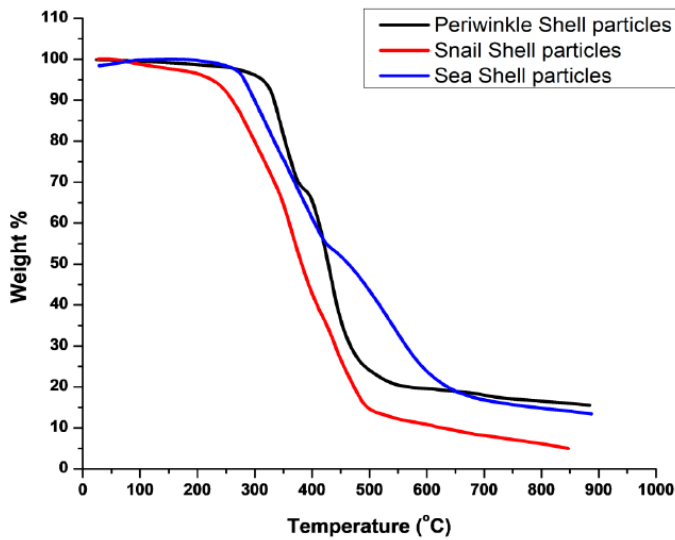


Figure 7. Topological Data Analysis (TDA) of shell particles)

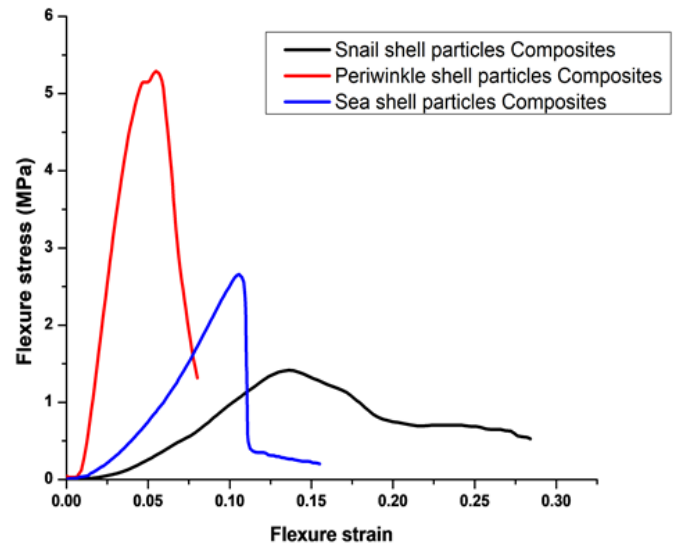


Figure 9. Flexure extensions (mm) of the Acrylic shells particles composites)

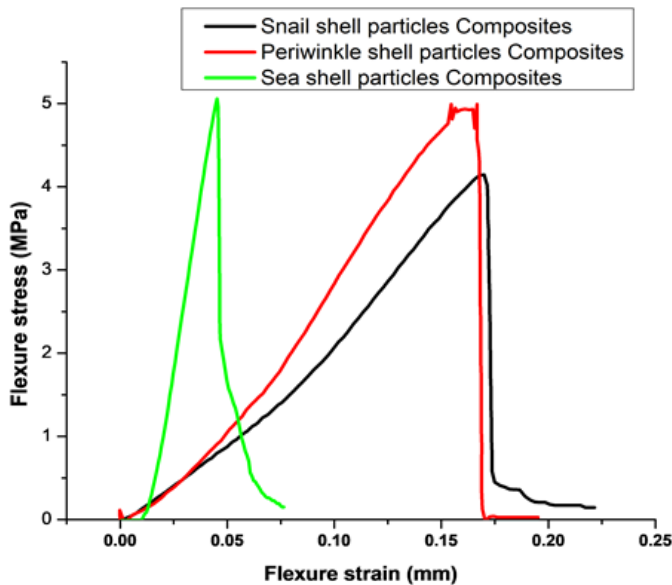


Figure 8. Flexure extensions (mm) of the PVA shells particles composites)

### 3.4. FLEXURAL STRENGTH ANALYSIS

It was determined whether the composite could sustain bending forces applied perpendicular to its longitudinal axis by examining the flexural strength of the shells' particles composites. By positioning the sample to be examined between two points or supports and applying a load using a third point, this can be done. Finding out what load will cause the composite to break is the main goal of this. Figure 8 shows the flexure stress against flexure extensions (mm) for polyvinyl alcohol composites made from shell particles with maximum flexure extensions of 0.04 mm, 0.17 mm, and 0.175 mm for seashells, periwinkle shells, and snail shells, respectively, when applying maximum loads of 5 MPa, 4.9 MPa, and 4 MPa. For the composites made of snail shell particles, a minor flexure stress of around 4MPa resulted in

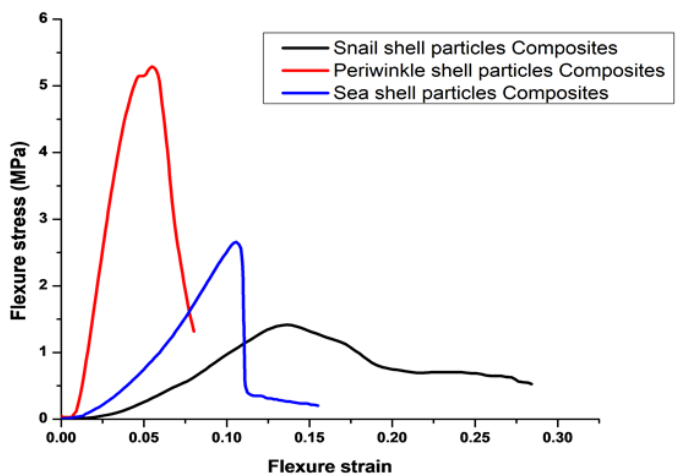


Figure 10. Flexure extensions (mm) of the epoxy/ hardener shells particles composites)

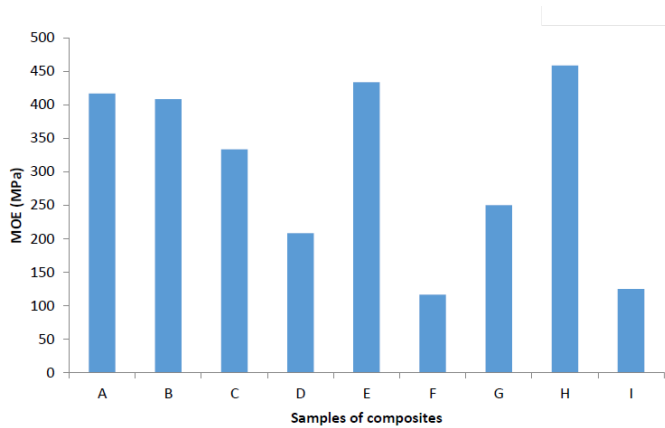
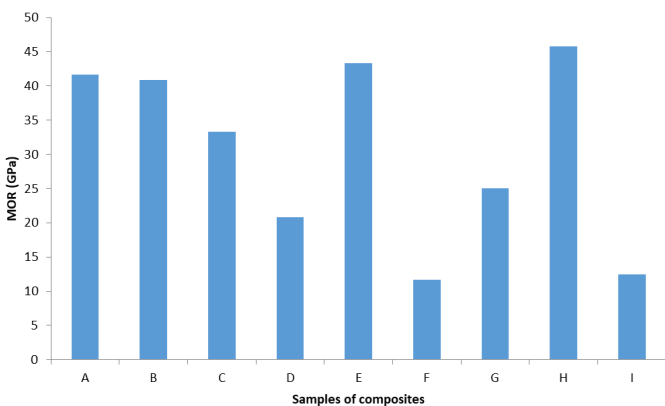
a maximum extension of approximately 0.175 mm before failure.

Figure 9 displays the shell-particle acrylic composites subjected to maximum flexural loads of 5.2 MPa, 2.5 MPa, and 1.4 MPa, respectively, with flexural extensions of 0.05 mm for periwinkle shells, 0.10 mm for seashells, and 0.14 mm for snail shells particles composites.

Under applications of maximum flexural loads of 5.5 MPa, 3 MPa, and 1.5 MPa, respectively, Figure 10 depicts the shells particles Epoxy/hardener composites with maximum flexural extensions of 0.05 mm for periwinkle shells, 0.10 mm for seashells, and 0.125 mm for seashells particles composites. According to the data, the largest values of average hardness numbers correspond to lower values of flexural extensions. Table 2 lists the flexure load, modulus of elasticity, and modulus of rupture for each of the composites being studied.

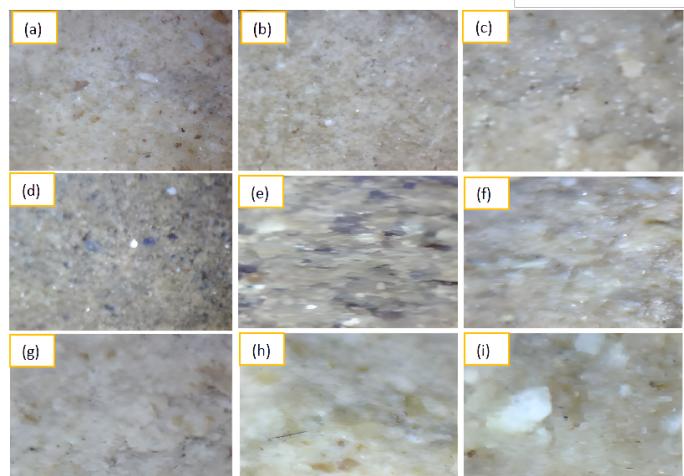
**Table 2. Mechanical properties of the shells composites**

S/N	Samples	Flexure Load (MPa)	MOE (MPa)	MOR (GPa)
1	A (Seashells/PVA)	5	416.6667	41.66667
2	B (Periwinkle shells/PVA)	4.9	408.3333	40.83333
3	C (Snail shell/PVA)	4	333.3333	33.33333
4	D (Seashells/Acrylic)	2.5	208.3333	20.83333
5	E (Periwinkle shells/ Acrylic)	5.2	433.3333	43.33333
6	F (Snail shell/ Acrylic)	1.4	116.6667	11.66667
7	G (Seashells/Epoxy and Hardener)	3	250	25
8	H (Periwinkle shells/ Epoxy and Hardener)	5.5	458.3333	45.83333
9	I (Snail shell/ Epoxy and Hardener)	1.5	125	12.500

**Figure 11.** Modulus of elasticity against samples of composites)**Figure 12.** Modulus of rupture against samples of composites)

### 3.5. MODULUS OF RUPTURE AND MODULUS OF ELASTICITY ANALYSES

Figure 11 shows the modulus of elasticity in comparison to composite sample. The findings demonstrated that particleboards are close to meeting JIS A 5908's requirements for board type 8. Periwinkle shells/Epoxy and Hardener composites and Periwinkle shells/Acrylic composites both had the greatest MOE values. It was claimed that MOE was affected by a number of variables, including adhesive content, adhesive type, and bonding effectiveness. The rupture modulus for the composite samples is displayed in Figure 12. Three varieties of particleboard, based on JIS A 5908:2003, were highlighted: types 8, 13, and 18 [19]. The

**Figure 13.** Optical micrographs of shells based polymer composites. (a) Snail shells/PVA. (b) Snail shells/Acrylic composite. (c) Snail shells/Epoxy/hardener composite. (d) Periwinkle shells/PVA composite. (e) Periwinkle shells/Acrylic composite. (f) Periwinkle shells/Epoxy/hardener. (g) Seashells/PVA composite. (h) Seashells/Acrylic composite. (i) Seashells/ Epoxy/hardener.

number of different types of flexural strength results increases with the particle board's mechanical qualities. All particleboards in this work had MOR values that were higher than what JIS type 18 called for. The range is between 12 and 46 GPa. Fine particles with a diameter of 35 microns were the reason why the MOR value was greater than expected. Particle size has an impact on the MOR value; smaller, finer particles have a greater MOR value. According to [25, 26], this result is consistent with other researchers' study.

### 3.6. OPTICAL MICROGRAPHS OF THE COMPOSITES

To examine the appearances and uniform distributions of the shells particles and the polymer resins, optical micrographs of the shells particle-polymer-based composites were taken (see Figure 13).

Figures 13 (a to i) showed optical micrographs of shell particle polymer composites. In the micrographs, the shell particles and polymer binders were mixed uniformly to the highest degree.

## CONCLUSION

In Sub-Saharan Africa, abandoned shells have been transformed into useful materials that work well in their intended applications. Periwinkle shell particles Epoxy resin (bisphenol-A-diglycidyl ether poly) and hardener (isophoromediamine) based composites with minimum flexural extensions of 0.05 mm under the applications of maximum loads of 5.5 MPa were found to have a maximum average indentation hardness of 48. The thermogravimetric measurement demonstrated that the shell particles are thermally stable with their initial weight percentage up to 250 °C, demonstrating good results for the application intended.

## References

- [1] F. H. Tobins, O. K. Abubakre, R. A. Muiiana, S. A. AbdulRahman, "Snail shell as an inspiring engineering material in science and technology development: a review", *International Journal of Contemporary Research and Review* **9** (2018)20408. <https://doi.org/10.15520/ijcrr/2018/9/03/473>.
- [2] A. Tayeh, M. W. Hasaniyah, A. Zeyad & M. O. Yusuf, "Properties of concrete containing recycled seashells as cement partial replacement: a review", *Journal of Cleaner Production* **237** (2019) 117723. <https://doi.org/10.1016/j.jclepro.2019.117723>.
- [3] J. O. Afolayan, U. N. Wilson & B. Zaphaniah, "Effect of sisal fibre on partially replaced cement with Periwinkles Shell Ash (PSA) concrete" *JASEM* **23** (2019) 715. <https://dx.doi.org/10.4314/jasem.v23i4.22>
- [4] L. O. Ettu, O. M. Ibearugbulem, J. C. Ezeh, & U. C. Anya. "A reinvestigation of the prospects of using periwinkle shell as partial replacement for granite in concrete", *International Journal of Engineering Science Invention* **2** (2013) 54. [http://www.ijesi.org/papers/Vol\(2\)320\(Versio-3\)/I235459.pdf](http://www.ijesi.org/papers/Vol(2)320(Versio-3)/I235459.pdf)
- [5] G. O. Bamigboye, A. T. Nworgu, A. O. Odetoyan, M. Kareem, D. O. Enabulele & D. E. Bassey, "Sustainable use of seashells as binder in Concrete production: Prospect and challenges", *J. Build. Eng.* **34** (2021) 101864. <https://doi.org/10.1016/j.jobte.2020.101864>.
- [6] S. H. Saharudin, J. H. Shariffuddin, N. I. Nordin & A. Ismail, "Effect of aging time in the synthesis of biogenic hydroxyapatite derived from cockle shell", *Materials Today: Proceedings* **19** (2019) 1208. <https://doi.org/10.1016/j.matpr.2019.11.124>.
- [7] Y. Hou, A. Shavandi, A. Carne, A. A. Bekhit, T. B. Ng, R. C. F. Cheung & A. E. A. Bekhit, "Marine shells: potential opportunities for extraction of functional and health-promoting materials", *Critical Reviews in Environmental Science and Technology* **46** (2016) 1047. <https://doi.org/10.1080/10643389.2016.1202669>.
- [8] B. Safi, M. Saidi, A. Daoui, A. Bellal, A. Mechekak & K. Toumi, "The use of seashells as a fine aggregate (by sand substitution) in self-compacting mortar (SCM)", *Construction and Building Materials* **78** (2015) 430. <https://doi.org/10.1016/j.conbuildmat.2015.01.009>.
- [9] E. I. Yang, S. T. Yi & Y. M. Leem, "Effect of oyster shell substituted for fine aggregate on concrete characteristics: Part I. Fundamental properties", *Cement and Concrete Research* **35** (2005) 2175. <https://doi.org/10.1016/j.cemconres.2005.03.016>.
- [10] M. Olivia, R. Oktaviani & Ismeddiyanto, "Properties of concrete containing ground waste cockle and clam seashells", *Procedia Eng.* **171** (2017) 658. <https://doi.org/10.1016/j.proeng.2017.01.404>.
- [11] E. I. Yang, M. Y. Kim, H. G. Park, & S. T. Yib, "Effect of partial replacement of sand with dry oyster shell on the long-term performance of concrete", *Construction and Building Materials* **24** (2010) 758. <https://doi.org/10.1016/j.conbuildmat.2009.10.032>.
- [12] M. A. Salawu, J. A. Gbolahan, A. B. Alabi, "Assessment of radiation shielding properties of polymer-lead (II) oxide composites", *Journal of the Nigerian Society of Physical Sciences* **3** (2021) 423. <https://doi.org/10.46481/jnsps.2021.249>.
- [13] A. B. Alabi, M. A. Salawu, R. A. Jimoh & T. Akomolafe, "Appraisal of mechanical properties of different particle sizes of palm kernel shell, coconut shell, and mixed palm kernel-coconut shells particles epoxy-filled composites", *Sri Lankan Journal of Physics* **21** (2020) 1. <https://doi.org/10.4038/sljpv.v21i1.8071>
- [14] Y. O. Saheed, M. A. Salawu & A. B. Alabi, "Mechanical evaluation and minerals phases identification of fine and coarse okelele block clay composites for furnace lining application", *Journal of the Nigerian Society of Physical Sciences* **4** (2022) 27. <https://doi.org/10.46481/jnsps.2022.252>
- [15] B.B. Hassan & O. O. Awopetu, "Production and characterization of particle boards from common agro wastes in Nigeria", *International Journal of Innovative Science and Research Technology* **4** (2019) 637. <https://ijisrt.com/wp-content/uploads/2019/02/IJISRT19JA425.pdf>.
- [16] O. O. Atoyebi, A. A. Adediran & C. O. Adisa, "Physical and mechanical properties evaluation of particle board produced from saw dust and plastic waste", *International Journal of Engineering Research in Africa* **40** (2018) 1. <https://doi.org/10.4028/www.scientific.net/JERA.40.1>.
- [17] H. Pirayesh, P. Moradpour, S. Sepahvand, "Particleboard from wood particles and sycamore leaves: physico-mechanical properties", *Engineering in Agriculture, Environment and Food* **8** (2015) 38. <https://doi.org/10.1016/j.eaef.2014.07.003>.
- [18] L. Muruganandam, J. Ranjitha & A. Harshavardhan, "A review report on physical and mechanical properties of particle boards from organic waste", *Int. J. ChemTech Res.* **9** (2016) 64. [https://sphinxsai.com/2016/ch\\_vol9\\_no1/1/\(64-72\)V9N1CT.pdf](https://sphinxsai.com/2016/ch_vol9_no1/1/(64-72)V9N1CT.pdf).
- [19] L. Astari, K. W. Prasetyo & L. Suryanegara, "Properties of particleboard made from wood waste with various size", *IOP Conf. Series: Earth and Environmental Science* **166** (2018) 1. <https://doi.org/10.1088/1755-1315/166/1/012004>.
- [20] E. A. R. Cuarán, N. N. Pimiento & C. A. T. Bueno, "Homogenization Analysis in Particle Boards with Rice Husk Reinforcement", *Tecnura* **26** (2022) 59. <http://www.scielo.org.co/pdf/tecn/v26n71/0123-921X-tecn-26-71-5.pdf>.
- [21] Z. Hussein, T. Ashour, M. H. Khalil , A. H. Bahnasawy and S. A. Ali, Mechanical Properties of Particleboard Panels made from Agricultural Wastes, *MISR Journal of Agricultural Engineering* **35** (2018) 319. <https://doi.org/10.21608/mjae.2018.96202>
- [22] G. Neml, "Effects of Some Manufacturing Factors on the Properties of Particleboard Manufactured from Alder (*Alnus glutinosa* subsp. *Barbata*)", *Turk. J. Agric.* **27** (2003) 99. <https://journals.tubitak.gov.tr/agriculture/vol27/iss2/6/>.
- [23] S. Bardak, G. Nemli & T. Bardak, "The quality comparison of particleboards produced from heartwood and sapwood of European Larch, *Maderas*", *Ciencia y Tecnologia* **21** (2019) 511. <https://doi.org/10.4067/S0718-221X2019005000407>.
- [24] M. Mehdi, R. Maraghi, A. Tabei & M. Madanipoor, "Effect of Board Density, Resin Percentage and Pressing Temperature on Particleboard Properties made from mixing of Poplar Wood Slab, Citrus Branches and Twigs of Beech", *WOOD RESEARCH*, **63** (2018) 669. <http://www.woodresearch.sk/wr/201804/12.pdf>.
- [25] S. Mohsen, Effects of Hardener Type and Particles Size on Formaldehyde Emission Pollution. *International Conference on Environment Science and Engineering* **8** (2011) 242. [https://hero.epa.gov/hero/index.cfm/reference/details/reference\\_id/5946626](https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/5946626).
- [26] A. B. Samson & R. Hans-Wolf, "Fibers of coffee husk and hulls for the production of particleboard", *Mater. Struct.* **43** (2010) 1049. <https://doi.org/10.1617/s11527-009-9565-0>.