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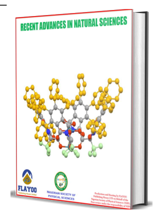

Characterizations of some discarded shells particles polymer-based composites for ceilings and particles board applications

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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 μm 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.

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].

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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 μm particle sizes using a grounding 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.

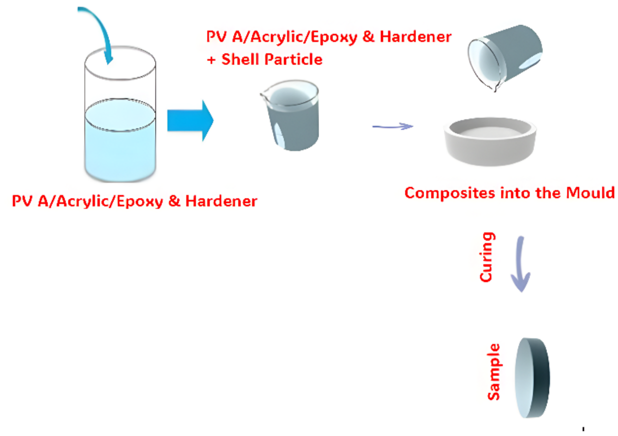


Figure 1. Schematic diagram describing the synthesis of these composites)

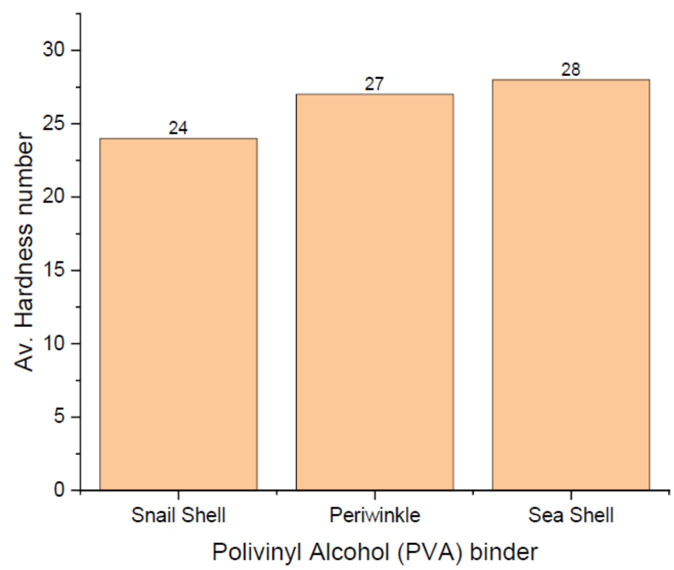


Figure 2. Average hardness number against PVA shells particles composites)

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 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-epoxyl 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,

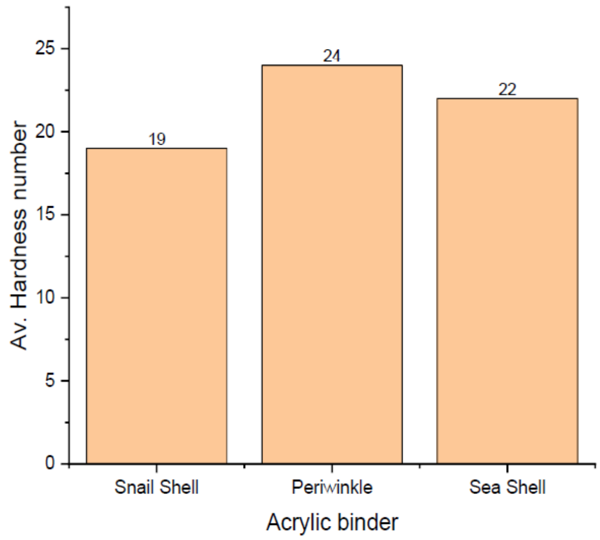


Figure 3. Average hardness number against Acrylic shells particles composites)

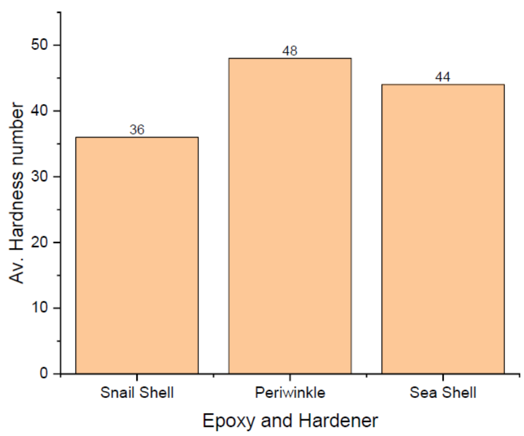
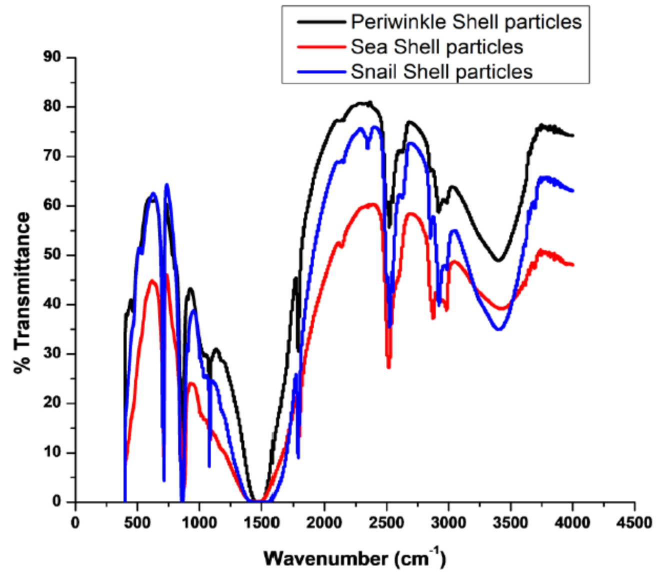


Figure 4. Average hardness number against shells particles of Epoxy/hardener based composites.

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 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 components. 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.



FTIR

of the shells particles

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 (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

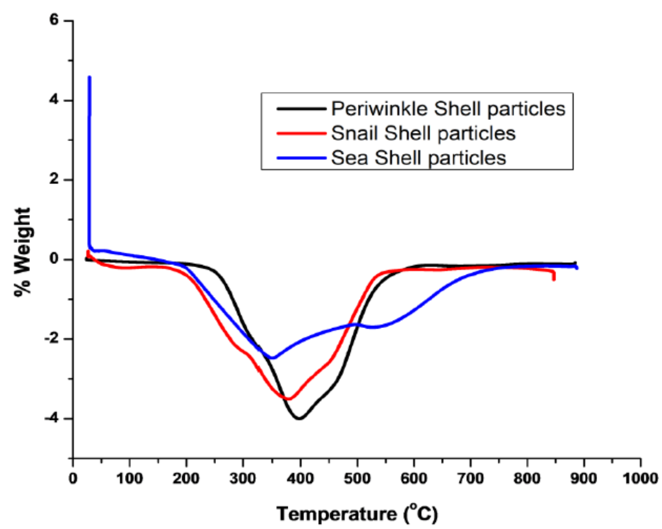


Figure 6. Thermo-gravimetric (TGA) analysis of shell particles)

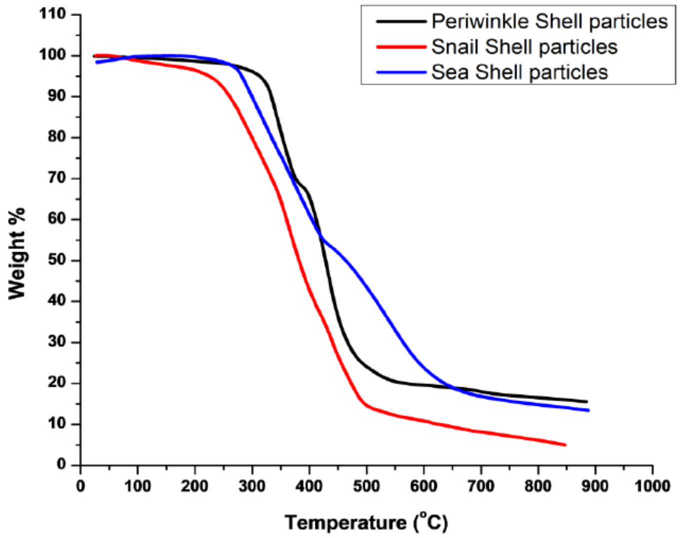


Figure 7. Topological Data Analysis (TDA) of shell particles)

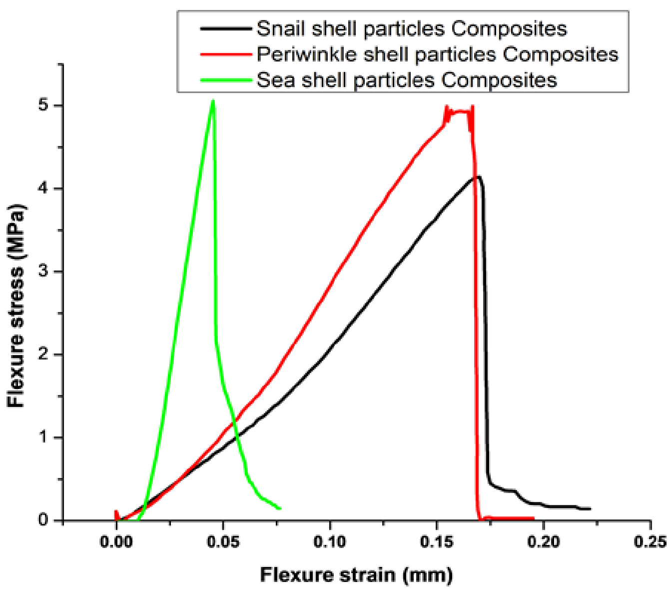


Figure 8. Flexure extensions (mm) of the PVA shells particles composites)

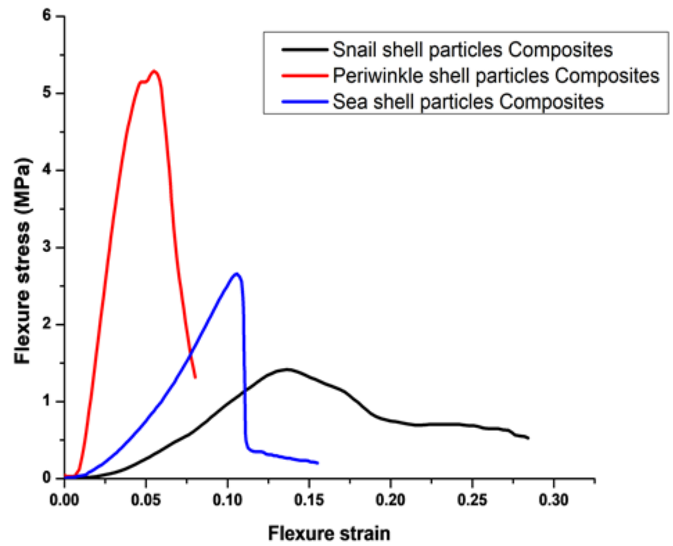


Figure 9. Flexure extensions (mm) of the Acrylic shells particles composites)

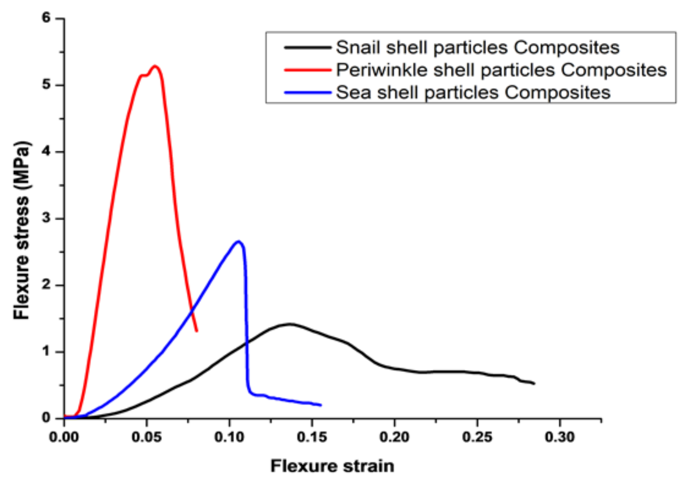


Figure 10. Flexure extensions (mm) of the epoxy/ hardener shells particles composites)

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 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	45.833.33
9	I (Snail shell/ Epoxy and Hardener)	1.5	125	12.500

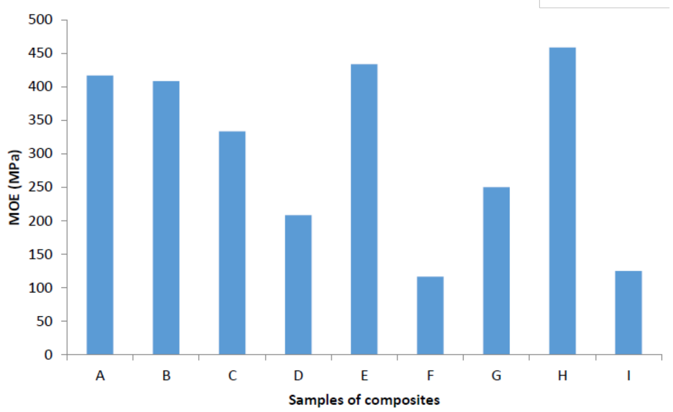


Figure 11. Modulus of elasticity against samples of composites)

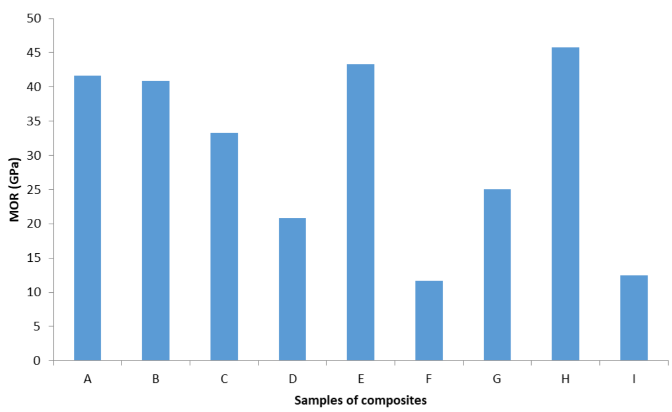


Figure 12. Modulus of rupture against samples of composites)

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 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.

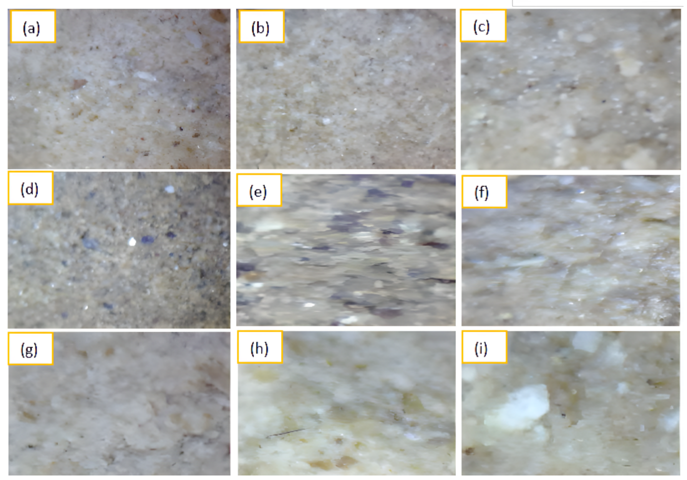


Figure 13. Optical micrographs of shells based polymer composites. (a) Snail shells/PVA. (b) Snail shells/Acrylic composite. (c) Snail shells/Epoxy/hardener composite. (d) Periwinkle shells/PVA composite. (e) Periwinkle shells/Acrylic composite. (f) Periwinkle shells/Epoxy/hardener. (g) Seashells/PVA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

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.

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