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# SYNTHESIS AND CHARACTERISATION OF ABRASIVE MATERIALS PRODUCED FROM SNAIL SHELLS AND SILICA

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## ABSTRACT

Surface finishing operation is a very vital aspect of the manufacturing process and would not fully be achieved without abrasives such as emery paper. Some materials used in the production of abrasives like alumina ($Al_2O_3$), and Boron Carbide ($B_4C$) are expensive thereby limiting their usage. This work is aimed at producing abrasive materials from snail shells, silica ($SiO_2$), and epoxy resin while melamine formaldehyde acts as a hardener. The raw materials used were sieved according to ASTM E11-20 standard to obtain an average particle size of 400 µm. The composites were produced by varying different amounts of the epoxy resin as well as the other materials. The samples were analysed using physical, mechanical, and microstructural characterization techniques. An analysis of the results showed that as the content of the epoxy resin in the composite increased, the hardness values increased. The wear rate of the samples containing snail shell powders are higher than those containing only silica. The morphology of the samples obtained through microstructural tests revealed that the silica-based abrasive has better interfacial bonding which helped to confer strength. Therefore, silica can be used to produce abrasives with the required mechanical properties comparable to those of conventional abrasives.

**KEYWORDS:** Abrasive, Snail Shell, Silica, Epoxy, Wear.

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## 1. INTRODUCTION

Grinding process is necessary for surface finishing of metallic and wood product, also for cleaning rust materials. These operations uses abrasives. The abrasives are called emery cloth or sand paper. Sand papers and emery clothes are sometimes referred to as flexible abrasives (Birhanu et al., 2018).

Emery paper is a general term used to describe flexible sheets of paper or cloth coated with natural or synthetic abrasive particles. An abrasive paper can be used to mechanically clean and smoothen a surface. So an abrasive is any material that can wear softer materials (Ibrahim et al. 2019). The importance of abrasives in the fabrication and furniture industries for surface finishing operations as well as surface preparation for the microstructural examination cannot be over-emphasized. These activities cannot be achieved without abrasives such as emery paper Sa'ad H (et al., 2021).

Surface finish is one of the properties that determine the quality of any product (Sandak et al. 2004). A good surface finish is usually achieved by carefully applying the appropriate type of abrasive paper. Regardless of whether the work will be done by hand or by machine, all abrasives should be properly selected for the job both as to the coarseness of the grit and the type of abrasive selected (Zhong and Venkatesh 2008). The raw materials used in the production of these abrasives are scarce thereby making the cost of the final product to be high (Brecker, 2006). The demand for high quality at a cheaper cost has motivated a lot of people to research local materials that can serve as an alternative to abrasive materials.

Wai and Lilly (2001) manufactured abrasive paper from quartz, using epoxy resins as the hardener. The samples were produced through the hand spray method and tested for various properties. A series of quality control analyses were carried out to reach international standards and based on the success of the work, the manufacturing process was recommended for small-scale industries.

Obot et al. (2015) developed abrasive materials using periwinkle shells. The effects of particle size and concentration of the periwinkle on the matrix (polyester resin) were investigated. The samples that had the composition with 87 wt.% periwinkle shell, 12 wt.% resin, and 0.5 wt.% each for methyl ethyl ketone peroxide hardener and cobalt naphthalene gave the required properties and were believed to be appropriate for the production of abrasive. Obot et al. (2016), analytically compared two abrasive sandpapers made from materials obtained domestically i.e. periwinkle and palm kernel shell. They studied both the physical and mechanical properties of the composites and discovered that periwinkle shell (PWS)/resin composites had higher bulk density, hardness, and compressive strength compared to the palm kernel shell/resin composite. The formulation used for abrasive production was 87 wt.% of both palm kernel shell and periwinkle shell to 12 wt.% of resin. A comparison of the product with the commercially available abrasives showed that the properties were similar.

Odior et al. (2013) researched the use of five domestic raw materials as substitutes (sodium carbonate, quartz, sodium chloride, sawdust, and coal) for silicon carbide abrasives. An optical preparation of silicon carbide abrasives by searching systematically using the Taguchi method was achieved while the formulation and production of silicon carbide abrasives were accomplished. The produced abrasives were tested and the properties met the necessary standards.

Barbara (2015) reviewed the qualities of abrasive grits as well as a selection of grit, and highlighted the most necessary grit qualities for grinding tools concerning tool functioning and production. Some of these qualities include grit toughness, size, and shape, and concluded that more clear grit sorting techniques and quality indicators for abrasive grits help stakeholders like grit producers, tool manufacturers, and tool users. The demand for grinding tools with higher sustainability and recyclability is increasing. Due to the increase in demand for high-quality and cost-effective abrasives, the objective of this research to synthesize and characterize abrasive materials from locally sourced easily available materials such as snail shells, silica (sea sand), epoxy resin (binder), and melamine formaldehyde (hardener).

## 2. MATERIALS AND METHODS

The raw materials used for this research include Snail shells, Silica, baking paper, and epoxy resin together with its hardener. The snail shells were sourced from a local market in Oyingbo, Lagos, while the silica was obtained from a beach in the Lekki area of Lagos, and the backing paper was gotten from a market in Mushin, Lagos. The epoxy and melamine formaldehyde (hardener) were gotten from a market in Ojota, Lagos, Nigeria.

The silica and snail shells were washed thoroughly several times to remove traces of dirt. The silica was subsequently cleaned with dilute hydrochloric acid (HCl) prepared in the volume ratio of 500 $cm^3$ of acid to 1000 $cm^3$ of water to remove impurities like clay and ions. The washed silica and snail shells were sun-dried for three days after which they were oven-dried at 100 $^{o}$C for three hours to remove any traces of moisture. They were first ground with a crushing machine, and subsequently with a grinding machine. Thereafter, the powder was sieved according to ASTM E11-20 ( *American Standard Test Methods for woven wire test sieve cloth and test sieves')* using a sieve of particle size p40 (400 µm). This was done to categorize the ground silica and snail shells into abrasive grit of the P40 based on the Federation of European Producers of Abrasive (FEPA) standard.

## 2.1. MATERIAL PREPARATION

Different amounts of the silica and snail shells powders were weighed with a weighing balance. The formulation for the powder and epoxy resin used to prepare the abrasive materials are shown in Table 1**.** For easy reference, the samples have been given the nomenclature A to E to represent the different compositions of the prepared abrasives.

**Table 1. Formulation used in the preparation of the abrasive samples.**

| Samples | Silica (wt. %) | Snail Shell powder (wt. % | Epoxy Resin wt. (%) | Hardener wt. (%) |
|---|---|---|---|---|
| **A** | 95 | 95 | 4 | 1 |
| **B** | 93 | 93 | 6 | 1 |
| **C** | 91 | 91 | 8 | 1 |
| **D** | 89 | 89 | 10 | 1 |
| **E** | 87 | 87 | 12 | 1 |

Each formulation was blended in a mechanical mixer for 5 mins to form a thick paste. The samples were produced using the compression method. The pastes were compressed into different moulds using a manual compression machine, to form solid shapes of height 50 mm and diameter 60mm. The compression was carried out at room temperature with a pressure of 12.5 MPa. The produced samples were dried at room temperature for 10 days to attain full strength before carrying out the physical and mechanical tests. The produced samples are as shown in Figs. 1 and 2**.**

**Fig. 1. Silica/epoxy composite.**

**Fig. 2. Snail Shell/epoxy composite.**

The sieved silica and snail shell powders of size 400 µm equivalent to the P40 standard respectively were poured into separate containers. The epoxy resin with hardener in the ratio of 2:1 was then rigorously mixed for 5 minutes and applied on the surface of the backing paper gently using the brushing method. Then the sieved silica and snail shell were sprayed manually on the same surface to the adhesive. The pictures of the produced samples are shown in Figs. 3a and 3b.

**(a)** **(b)**

**Fig. 3. Abrasive materials produced from (a) epoxy resin and snail shell powder and (b) epoxy resin and silica shell powder. Both abrasives have an average particle size of 400 µm.**

Each sample was subjected to standard tests which include; water absorption, Density, Hardness, Wear resistance, visual examination of the wood specimen, and microscopic examination.

### 2.1.1. Water Absorption

This was carried out after determining the dry weight ($W_0$), the samples were soaked in hot (boiling) water of density ($\rho_w$) for 3 hours. Thereafter, the soaked weight ($W_1$) was taken and the water absorption was calculated using Equation 1

$$Water\ Absorption = \frac{W_1 - W_0}{W_0} \times 100 \qquad (1)$$

### 2.1.2. Density

The density was calculated using Equation (2) after measuring the mass with the device in Fig. 4.

$$\text{Density } (\rho) = \frac{Mass}{Volume} = \frac{M}{V} \quad (2)$$

**Fig. 4. Analytical weighing balance.**

### 2.1.3. Hardness

The hardness test was carried out using Vickers Micro Hardness testing machine as shown in Fig. 5.


**Fig. 5. Vickers Micro Hardness Tester.**

The values were calculated using the formula for Vickers hardness in Equation 2.

$$HV = \frac{2FSin\frac{136}{2}}{d^2} \tag{3a}$$

$$HV = 1.854\frac{F}{d^2} \tag{3b}$$

Where HV stands for Vickers hardness value

*F*= Load in kgf

*d* = Arithmetic mean of the two diagonals, *d1* and *d2* in mm

### 2.1.4. Wear Resistance

The wear rate of the abrasive specimens was carried out at a speed of 250 rev/min for 30 s, 60 s, 90 s, and 120 s respectively under a load of 1,150 g. Using the device as shown in Fig. 6.

**Fig. 6. Wear Grinding machine and the load.**

The wear Rate is calculated using Equation 4.

$$Wear\ Rate = \frac{W_1 - W_2}{D} = \frac{\Delta W}{D} \tag{4}$$

Where ΔW, is the weight difference of the sample before and after the test in mg, and

D = Total sliding distance in metres, $W_1$ = Initial weight of sample,
$W_2$ = Final weight of the sample.

#### 2.1.5. Microscopic Examination.

The micro structural examination of the samples is also carried out using ASPEX 3020 variable pressure Scanning Electron Microscope (SEM)/ Energy Dispersive X-ray (EDX) as shown in Fig. 7.

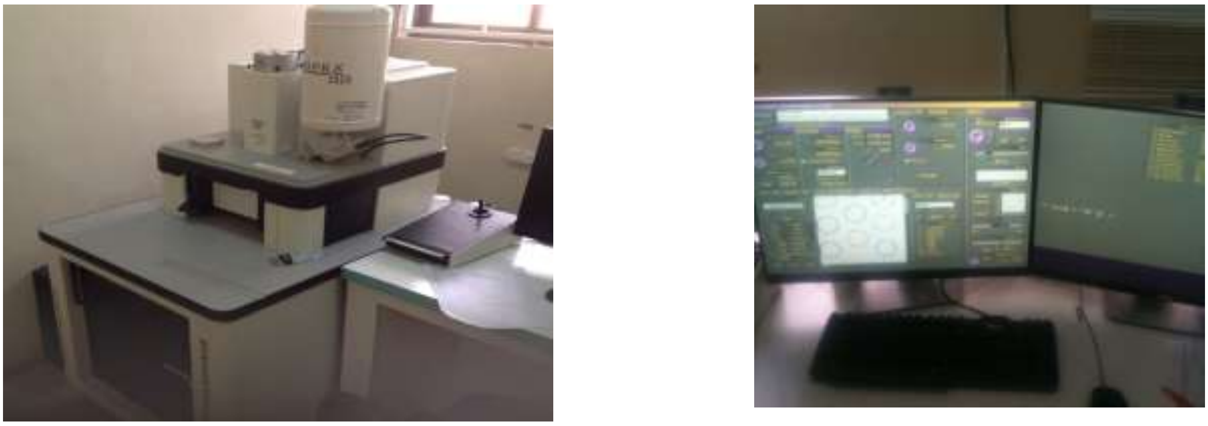


**Fig. 7. ASPEX 3020 variable pressure Scanning Electron Microscope (SEM)/ Energy Dispersive X-ray (EDX) machine.**

## 3. RESULTS AND DISCUSSION

### 3.1. MECHANICAL PROPERTIES

#### 3.1.1. Hardness Test

The results of hardness tests for the abrasives made from snail shell and silica with different amounts of epoxy/hardener are represented in Fig. 8.

The result of the Vickers hardness test carried out showed an increase in hardness with increasing epoxy content. The abrasive made from silica and epoxy showed higher hardness values compared to that from snail shells. The possible explanation for the increasing hardness could be attributed to better interfacial bonding between the epoxy resin and the powder particles (silica and snail shell) as revealed by SEM results. The abrasive containing 12 wt.% epoxy resin gave the highest hardness value of 26.48 Hv

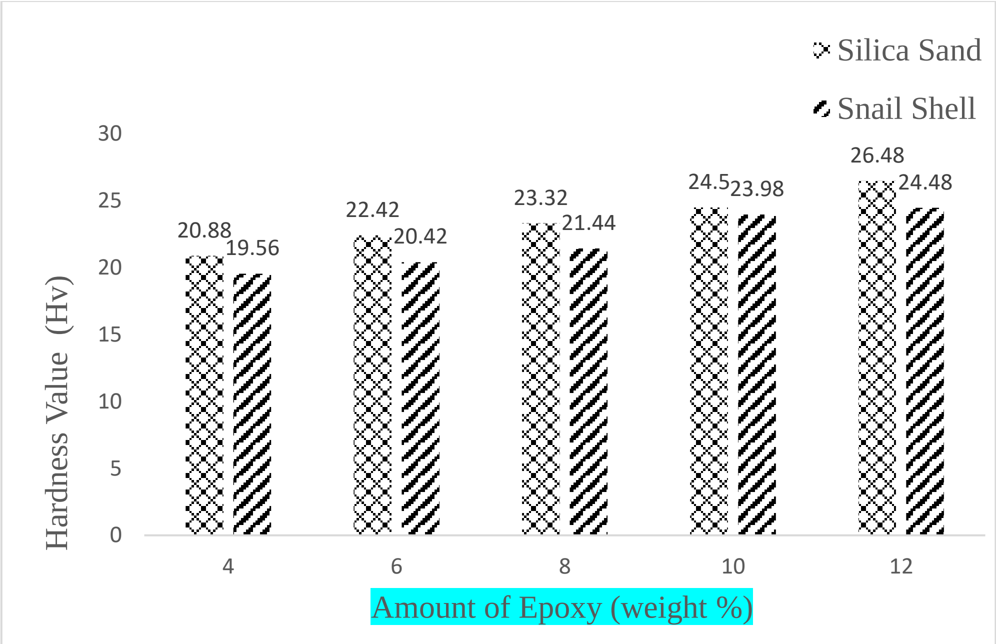



**Fig. 8. Hardness Value of the silica and Snail Shell with Epoxy.**

### 3.1.2. Wear Resistance Test

The results of the experiments are shown in Figs. 9a and 9b.

It was observed that the wear rate of the samples decreased with the increasing amount of epoxy resin. As the time used for the experiment increases, it was expected that the wear rate should increase but this was not entirely the case. The composite containing snail shell powder was found to wear faster.

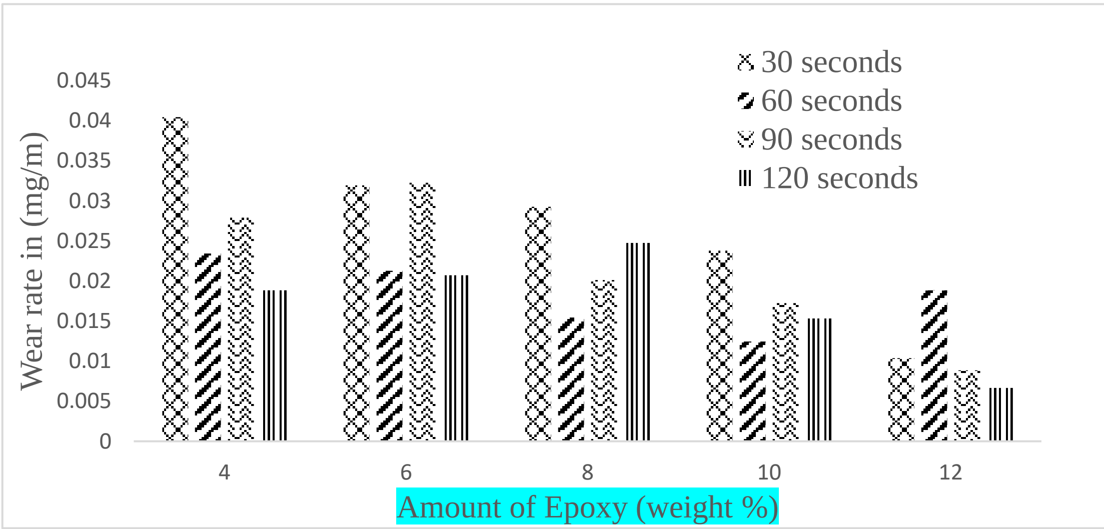



**Fig. 9 (a): Wear rate of the silica at different compositions of epoxy and different time regimes.**

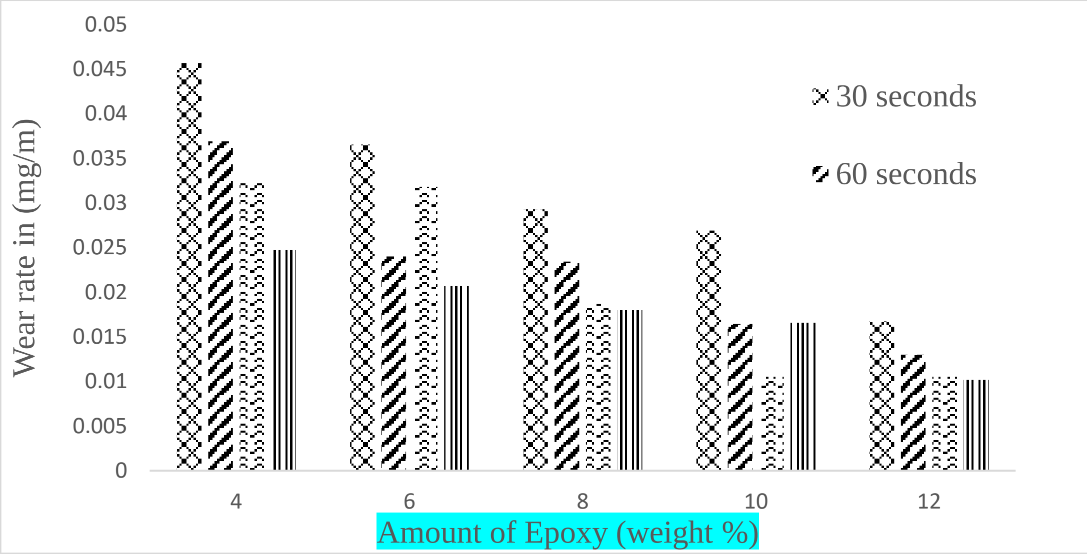



**Fig. (9b). Wear Rate of the composite from Snail shell powder at different amounts of epoxy resin and different time regimes.**

## 3.2. PHYSICAL PROPERTIES

### 3.2.1. Density Test

Fig. 10 shows the variation of density with different contents of epoxy resin for the snail shell and silica. It can be seen that density decreases with an increase in the amount of epoxy for both silica and snail shell. It is however more for the silica-based composite leading to a decrease in the packing density of the particles. This result is in conformity with (Ibrahim et al., 2019).

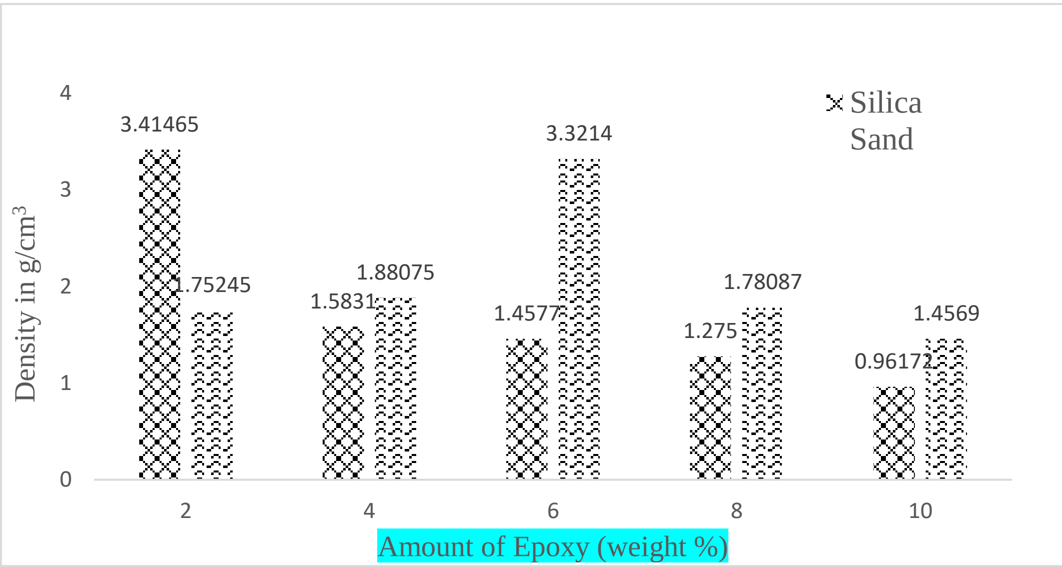



**Fig. 10. Variation in Density of Silica and Snail shell composites at different contents of epoxy resin.**

#### 3.2.2. Water Absorption Test

The water absorption result for the silica and snail shell composites was calculated using Equation 1 and is presented in Fig. 11. the level of water absorption in the silica composite is low compared to the snail shell composite and this is possibly due to poor interfacial bonding between the matrix and the epoxy fibre. It is believed the snail shell matrix has a poor bonding and this can be attributed to the poor bonding and subsequently poor water absorption relationship with epoxy resin.

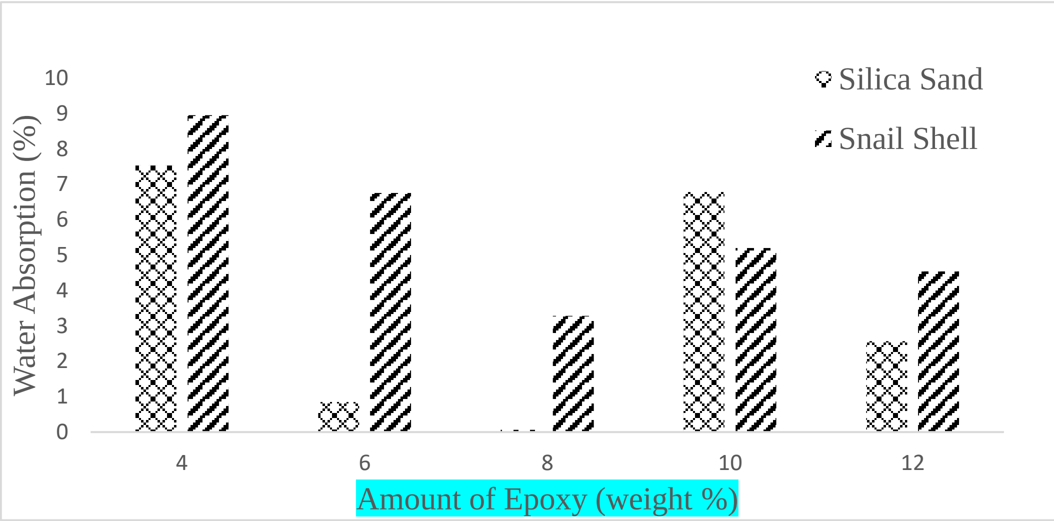
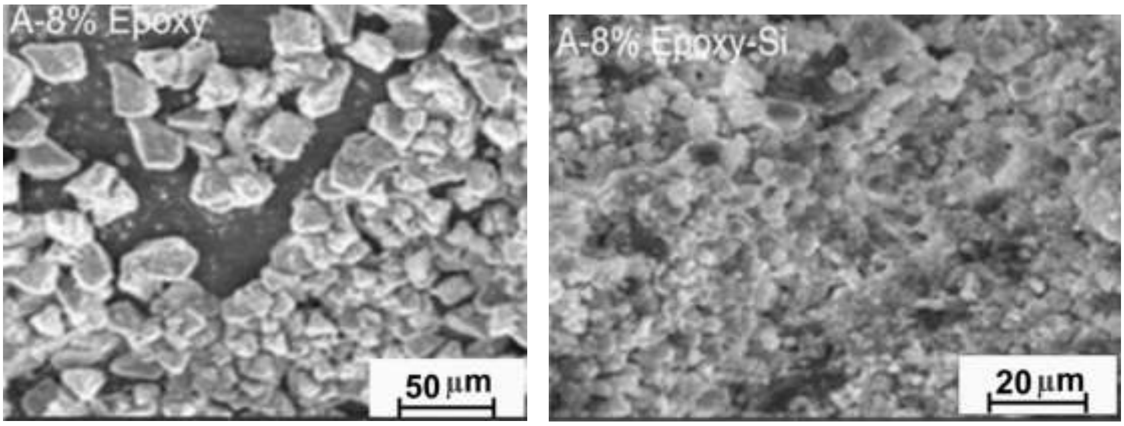



**Fig. 11. Variation of water Absorption of Silica and Snail shell at different Composition of Epoxy.**

### 3.3. STRUCTURAL ANALYSIS

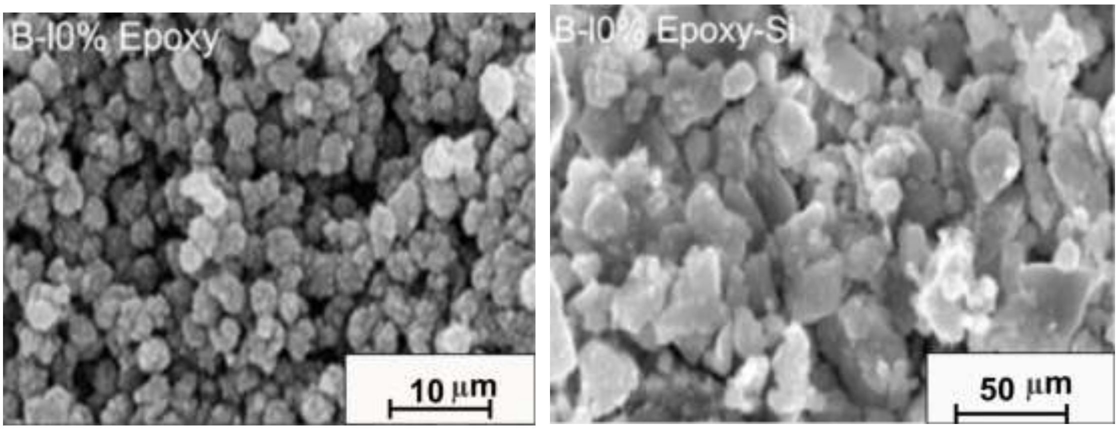
**Scanning Electron microscopy (SEM)**

The result of the microstructural examination of the snail shell and silica composites are shown in Figs. 12 and 13. In Fig. 12b**,** the composite sample with highest hardness shows better interfacial bonding which gives a better alignment to the grains, and it can also be noted that the increase in the epoxy content (reinforcement) in Fig. 13b increased the bonding of the silica particles which confer better strength and hardness, leading to better mechanical properties. Fig. 12a showed coarse grain sizes when compared to Fig. 12b which had finer grain sizes which exhibited higher strength similar to a literature report by (Umunakwe et al., 2017). Based on the results in Fig. 13, it can be concluded that the silica-based composite samples possess good strength properties due to their better bond formation and relatively smaller grain sizes.




**(a)** **(b)**

**Fig. 12. SEM micrographs of: (a) 8% wt. of Epoxy for Snail Shell (b) 8% wt. of Epoxy for Silica.**




**(a)** **(b)**

**Fig. 13. SEM micrographs of: (a) 10% wt. of epoxy for Snail Shell (b) 10% wt. of epoxy for Silica.**

## 4. CONCLUSION

This research investigated the effect of using locally available materials namely snail shells and silica to produce composites for abrasive applications. The results show a gradual increase in hardness value for the silica-epoxy resin composite compared to the snail shell composite. This increment is also related to the increase in the amount of epoxy resin from 4 to 12 wt. %. Although the wear from the composite produced with snail shells is lower than those from silica, their wear is constant even with increasing epoxy resin content. Uniformly sized grains were observed in the composites containing both snail shells and silica. As the amount of epoxy resin added to the composite increases, the bonding was found to be better. The level of bonding in the composite produced from silica was however found to be better than that from snail shell. This result gives an indication that silica and snails shells can indeed be used to produce abrasive papers for finishing operations.

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