



Effect of Egg Shell Composition on the Flexural and Hardness Properties of Epoxy Resin/ Egg Shell Particles Composite

I. C. C. Iloabachie¹, O. T. Ajina¹ and A. C. Chime^{2*}

¹Department of Mechanical Engineering, Institute of Management & Technology, Enugu, Nigeria.

²Department of Agricultural & Bio-Environmental Engineering, Institute of Management & Technology, Enugu, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The effect of calcined egg shell particles on the mechanical properties of epoxy resin had been studied. The egg shell was sun dried for 3 days and calcined at 800°C in an electrically fired furnace model KGVB. The calcined egg shell was ground in a locally fabricated pulverized machine and sieved using Sieve Model 567924/173281Endecotts in accordance with ASTM standard. Microwave digestion system and an inductively coupled plasma mass spectrometer (ICP-MS) were used to determine the chemical composition of the egg shell. The egg shell particles were mixed with epoxy resin to develop a composite casted by open mold casting. The flexural and hardness properties of the developed composite was determined using Universal Testing Machine model TUE-C-100, observing ASTM D790 standard and Rockwell Scale K hardness testing machine according to ASTM D785 respectively. The results showed that the calcined egg shell contained mostly CaO. Maximum flexural strength of 12MPa was observed at 25 wt. % egg shell particles. The highest hardness value of HRN 393 was observed at 20 wt. % egg shell particles. The produced composites may be applied where moderate strength is required.

*Corresponding author: Email: achime@imt.edu.ng;

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1. INTRODUCTION

Over the years, research all over the world has been tailored towards developing new materials to meet various human needs using natural or synthetic materials. In this regard, though, breakthrough has been recorded in developing new / alternative or substitute products for industrial and domestic application, however, more still needs to be done in utilizing agro wastes to accomplish similar feat.

Engineering composites Iloabachie, [1] stated are combinations of traditional materials with improved properties using new ideas, methods and technologies. Usually, they are developed based on a thorough understanding of the composition, processing technique, microstructure, and properties relationship and are applied to improve both their mechanical and functional properties, with a view to increasing their robustness and application Iloabachie, [1] observed.

Egg shells are available in abundance in tropical countries as a waste product after consumption of egg white and yoke. Such abundance can fulfill the demand for durable natural reinforcement based composites while reducing waste. Hunton [2] and Toro et. al, [3] opined that eggshells are naturally occurring structural composites; forming an embryonic chamber that houses developing chicks. In addition, eggshell provides mechanical protection and exchange of gas for the chicks. Chaithanyasai et al. [4] stated that egg shell contains about 95% calcium carbonate and 5 % organic materials. Though many attempts to use egg shell in many applications have been made, Chaithanyasai et al. [4] argued that it is potential filler in polymer composites.

Abdel-Salam [5] and Powrie stated that eggshells contain mainly calcium and trace amounts other elements like magnesium, sodium, phosphorus, boron and carbon. King'ori [6] identified poor management of eggshells as one of the causes of environmental hazards especially in countries where large quantities of eggs are consumed either domestically or industrially. Agunsoye et al., [7] argued that eggshell can be processed into useful materials such as fertilizer for enhancing crop growth; human and animal nutrition; building materials and particulate powder for metal and polymer reinforcement in composite development.

Epoxy resins (ER) Potter [8] observed is considered one of the most important classes of thermosetting polymers widely employed as matrices for fiber-reinforced composite materials and as structural adhesives. Zhikai [9] stated that epoxy resins are amorphous, highly cross-linked polymers making these materials possess various desirable properties such as high tensile strength and modulus, uncomplicated processing, good thermal and chemical resistance, and dimensional stability. These properties notwithstanding, epoxy resins still needs to be improved to enhance its inherent properties. To achieve such successfully, Yorkitis [10] and. Bucknall [11] suggested incorporating a second phase of dispersed rubbery particles into the cross-linked polymer (epoxy resins) as one of the methods of improving the toughness of epoxy resin. Durowaye et. al, [12] reported little developments in utilizing natural fiber or particulates as reinforcement materials for polymeric composite, despite findings showing that natural fillers reinforced polymeric materials provide materials engineers with a new group of materials that can offer exceptional combinations of mechanical properties making them equivalent to steel applications.

Presently in Nigeria, the federal government's resolve to transform the mono-economy oil dependent foreign exchange earner led to economic diversification program aimed at opening up other sectors of the economy. As a result, poultry farming has become booming industry in Nigeria. With greater number of the poultry farms centering in egg production, egg consumption has significantly increased with increased consequent of egg shell production. Egg shell becomes a waste product after the consumption of egg with virtually no second hand importance.

Being non bio-degradable, it litters the environment and constitutes a very big environmental challenge. The need to create an efficient and effective means of consuming this waste continues to agitate the minds of researchers.

This research work therefore is aimed at evaluating the mechanical properties and wear resistance behavior of eggshell/epoxy resin composite for industrial applications. It will also alleviate the problems associated with poor

management of eggshell by converting the waste into wealth which on a large scale production will enhance technological development and economic growth.

2. MATERIALS AND METHODS

2.1 Materials

The following materials were used in this research work are egg shell, epoxy resin, LY 556 (Bisphenol-A-Diglycidyl-Ether) having density 1.2g/cm³ at 25°C, curing agent i.e. hardener HY-951 [NN0 (2-amineethylethane-1, 2- diamin)] with density 0.99g/cm.

2.2 Methods

2.2.1 Drying of egg shell

The egg shell was sundried for six hours per day for 3 days and calcined at 800°C

2.2.2 Calcinations of egg shell processing

The egg shell was packed in an earthen pot, covered with a lid and heated in an electrically fired furnace model KGVB kohaszatgyarepítővállalat, Type –Koo 80/50-120 “Temperature -950°C 513-4124 -0730/B at a temperature of about 500°C with a heating rate of 10°C per minute and a soaking time of two hours to form calcined egg shell.

2.2.3 Grinding of egg shell

The calcined egg shell was crushed to different particle sizes using a pulverizing machine and a locally fabricated grinding machine.

2.2.4 Sieving of ground egg shell

A particle size analyzer in accordance with ASTM standard was used to obtain particle sizes. The ground egg shell particle was sieved using a set of sieves arranged in descending order of fineness. Sieve Model 567924/173281 Endecotts Test Sieves, Ltd. London, England was used to sieve the ground egg shell to different particle sizes.

2.2.5 Determination of chemical composition of egg shell

Chemical composition of the egg shell in raw and calcined form was done to determine its chemical

(CaCO₃) content by the application of a microwave digestion system and an inductively coupled plasma mass spectrometer (ICP-MS). Powdered samples of raw and calcined egg shell were digested in 65 wt. % concentrated nitric acid (HNO₃) at 200 °C in a closed vessel employing a microwave digestion system (Model CEM Corporation Mars 6, United States of America). Approximately 1800 watts microwave energy at a frequency of 2450 MHz. ICP-MS (Agilent 7700x ICP MS, Japan) was used to determine elemental composition.

2.3 Preparation of Composite Samples

150 mm × 50 mm × 5 mm wooden mold with a glass base was used for casting the composite sheets. Calculated amount of epoxy resin and hardener (ratio of 10:1 by weight) was thoroughly mixed with 5%, 10%, 15%, 20% and 25% of calcined egg shell particles and properly stirred with a mechanical stirrer for uniform distribution of the egg shell particulates. The mixture was poured into the mould. Care was taken to avoid formation of air bubbles and loss during manufacturing. 35 kg load was applied for 24 hours to ensure proper curing at room temperature. For quick and easy removal of the molded composite sheet, a mold release sheet was kept over the glass plate and mold sides. After curing, the laminate produced was trimmed and cut into required size using a hack saw for different tests to be carried out.

2.4 Hardness Test

Hardness represents the internal resistance of a composite material against cutting, wear, scratching or indentation or resistance to permanent deformation. Rockwell hardness test usually carried out by specimen indentation was done. It helps to achieve macro-in materials with heterogeneous structure. The hardness tests were performed according to ASTM D785 standard using Rockwell Scale K hardness testing machine.

2.5 Flexural Property Test

Flexural strength is the ability of the composite material to withstand bending forces applied perpendicular to its longitudinal axis. This test was carried out using Universal Testing Machine model TUE-C-100, observing ASTM D790 standard. The composite samples were tested at a three-point bending test at a cross head speed of 5 mm/min. The five specimens per test

condition was carried out for accuracy. The flexural stress was computed using the following equation:

$$\sigma_{\max} = \frac{3P_{\max}L}{bh^2} \quad \dots\dots (1)$$

Where, P_{\max} is the maximum load at failure (KN), L is the span (mm); b and h are the width and thickness of the specimen (mm) respectively.

3. RESULTS AND DISCUSSIONS

3.1 Chemical Composition of Egg Shell

Tables 1a and 1b illustrate the chemical compositions of raw and calcined waste egg shells. From Table 1a it is evident that the major constituent of waste raw egg shell is calcium trioxo-carbonate IV i.e. calcite constituting over 95% of raw egg shell. As was reported by Owuamanam [13] egg shell consists mainly of CaCO_3 in the form of calcite usually between 94 to 98 wt. % with minor traces of other elements like magnesium and phosphorus, and 3-4 wt. % organic matter.

Boronat et.al [14] had attributed this variation in calcite content of egg shell to the composition of feed consumed by the chicken and possible contamination from the inner membrane of the egg shell. Table 1b shows the chemical

composition of calcined egg shell at 800°C. It could be observed from Table 1b that the major component of calcined waste egg shell is calcium oxide, CaO. This constitutes about 88.37 wt% and its formation may be attributed to the decomposition of CaCO_3 . CaCO_3 usually decomposes at a temperature of 750°C and above. This result clearly shows that calcinations decompose CaCO_3 from egg shells powder to CaO at a given temperature. Jitjamnong [15] had reported a similar trend when waste egg shell was calcined at about 900°C.

3.2 Flexural Strength

This was done to further characterize the as-prepared composites and also establish their response to three-point bending. The flexural strength polymeric composites depend on the interfacial bonding between the reinforcement and the matrix Subita Bhagat and Pardeep Kumar Verma, [16] The flexural strength increased with increase in egg shell particles as can be seen in Fig 1. This increase could likely be due to strong interfacial adhesion between the egg shell particles and the epoxy resin matrix which enhances load transfer as Swain, [17] had earlier reported. Maximum flexural strength of 12MPa was observed at 25 wt. % egg shell particles. Better flexural behavior obtained may also be likened to even distribution of the egg shell particles within the matrix.

Table 1a. Chemical Composition of Raw Egg Shell

Compound	Concentration (wt %)
CaCO_3	95.35
Mg	0.5
Si	0.3
P	0.3
Sr	0.42
Organic compound	3.13

Table 1b. Chemical Composition of Calcined Egg Shell

Compound	Concentration (wt %)
CaO	88.37
MgO	1.01
SiO_2	0.045
P_2O_2	0.48
SO_3	0.29
SrO	0.10
Organic compound	9.705

Table 2. Flexural test results of calcined egg shell particles/epoxy composite samples

Weight percent (%)	Flexural Strength MPa
5	5.7
10	6
15	8.5
20	11.4
25	12

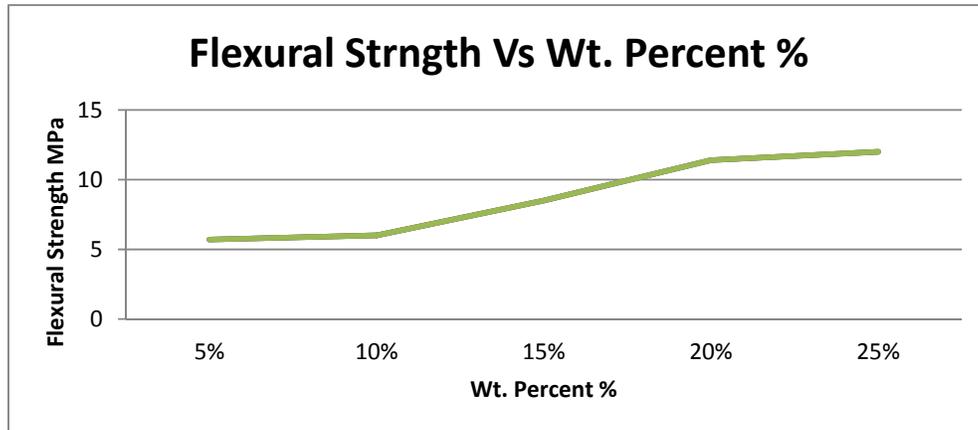


Fig 1. A graph of flexural strength against egg shell weight percent

Table 3. Hardness test results of calcined egg shell particles/epoxy composite samples

Weight percent (%)	HRN Value
5	323
10	338
15	378
20	393
25	383

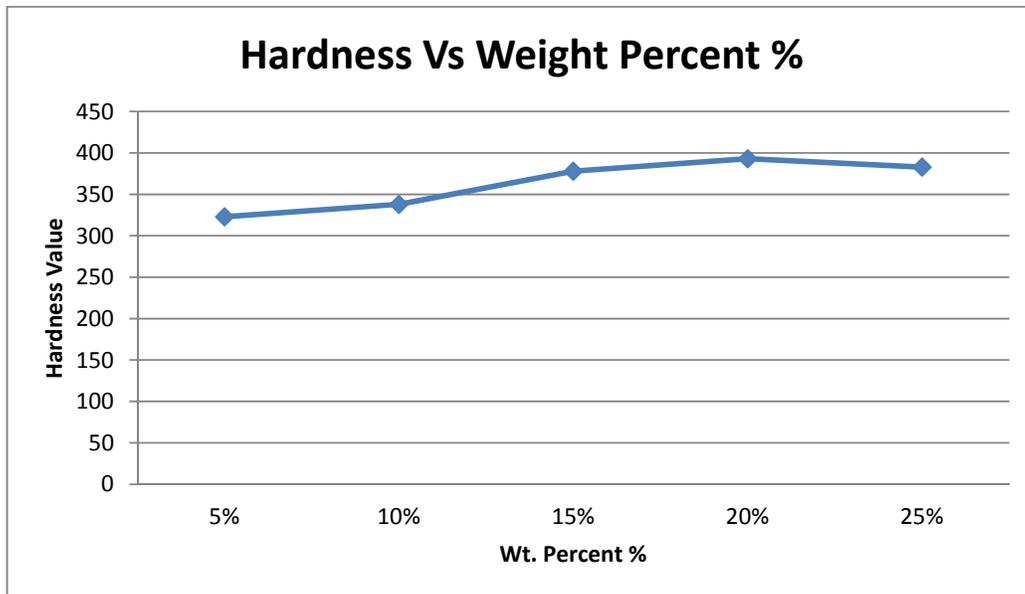


Fig. 2. A graph of hardness against egg shell weight percent

3.3 Hardness

Hardness represents the internal resistance of a composite material against scratching or indentation. Hardness strength usually, is a function of percentage composition of the reinforcement material i.e. eggshell powder in the polymer resin i.e. epoxy. As could be observed in Fig. 2, the hardness strength of the composite varies with increase in percentage composition of the eggshell powder. Increase in the hardness strength of the composite specimen was observed as the weight percentage composition of the egg shell increased. The highest hardness value of HRN 393 was observed at 20% and may be attributed to better dispersion of the egg shell particles within the epoxy resin matrix. The observed increase in hardness value may also be related to the increasing amount of the brittle egg shell particles in the polymer matrix and strong interfacial bond between the particulate and the matrix. The egg particles likely will resist deformation due to indentation. The decrease in hardness value observed at 25% egg shell particles may likely be as a result of poor distribution of the egg shell particles within the epoxy matrix due to increase in the egg shell particles.

4. CONCLUSION

- Calcination of egg shell particles at 800°C decomposes most of CaCO₃ in egg shell into CaO.
- Poor distribution of the egg shell particles in epoxy matrix reduces the hardness strength of egg shell particles/epoxy resin composite at 25 wt. %
- Similar behavior observed on the mechanical properties of the developed composites may be likened to even egg shell particles distribution within the matrix.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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