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PARTIAL REPLACEMENT OF FINE AGGREGATE WITH EGG AND SNAIL SHELLS IN THE PRODUCTION OF CONCRETE

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ABSTRACT

Egg and snail shells are agricultural waste materials generated in abundance from hatcheries, homes, and food industries. They contribute continuously to environmental and disposal problems. This study examined the suitability of egg and snail shells to replace fine aggregate (sand) partially in concrete for effective disposal of these materials and to reduce environmental problems. Powdered shells as fine were added in proportions 2½%, 5%, 7½%, 10%, 12½%, and 15% to replace fine aggregate in the mix ratio 1:2:4. The two shells composed of compounds of calcium which is very similar to that of cement. Results showed that both egg and snail shells influenced the compressive strength of concrete. The compressive strength of concrete modified with eggshell decreases as the percentage replacement increases. However, an appreciable increase in compressive strength at 2.5% replacement was observed when snail shell was used up to the 14th day. Maximum compressive strength 14.08 N/mm^2 (eggshell) and 18.12 N/mm^2 (snail shell) were recorded on the 28th day for 2.5% replacement was used for concrete modified with egg and snail shells. The positive effects of snail shell on the compressive strength of the concrete revealed that snail shell contains an appreciable percentage of calcium carbonate more than eggshell and the particle size distribution and texture of snail shell could be contributory factors to a better performance of concrete modified with snail shell than that of concrete with eggshell.

Keywords: Eggshell powder, Snail shell powder, Aggregates, Particle size distribution, Compressive strength.

INTRODUCTION

The number of wastes generated increases on daily basis and it is a reflection of growth in the world population. Most of the wastes produced are non – biodegradable resulting in a waste disposal crisis. Most of these materials finally ended up in rivers, lakes, and coastal waters by erosion and thereby causing a health hazard to the populace by contaminating water resources and polluting the environment (Praveen et al., 2015).

Eggshells and snail shells are agricultural waste materials obtainable in abundance from hatcheries (Eggshells), homes and food industries. These shells contribute immensely to environmental pollution. Some of the challenges associated with the disposal of eggshells include cost, availability of disposal sites, odor, flies, and abrasiveness (Pliya and Creed, 2015). Karthick, *et al*., (2014) reported that the main constituent of the eggshell is calcium carbonate which is much better than limestone used in the production of cement.

This shell is comprised of a network of protein fibers, associated with crystals of calcium carbonate ($CaCO_3$), magnesium carbonate ($MgCO_3$), calcium phosphate ($Ca_3(PO_4)_2$), organic substances, and water. $CaCO_3$, the major constituent of the eggshell, is an amorphous crystal that occurs naturally in the form of calcite (hexagonal crystal) (Oliveira, *et al.*, 2013). Besides, Bee (2011), established that the composition of an eggshell is very similar to that of human bones and teeth. Also, according to Akinnusi *et al.,* 2018, in a snail shell, calcium is more pronounced with the highest concentration varied between 260.75 – 279.68 mg/100 g followed by Phosphorus which varied between 196.27 mg/100 g and 206.08mg/100 g. However, several pieces of research have shown that these wastes can be turned into useful raw materials for construction in so many ways if well processed. According to Ihom *et al.,* (2013), eggshell waste has confirmed its usage as an enhancer in the carburization of mild steel to improve its hardness value in place of calcium carbonate because it serves as an energizer during the carburization process by raising the carbon potential of the carburization mixture. It has also been used in the treatment of water and wastewater (Udeozor and Evbuomwan, 2014) and as a useful stabilizer for road works to improve the properties of both stabilized lateritic soil (Amu and Salami, 2010, Olanrewaju *et al.,* 2011) and cement - stabilized lateritic soil resulting from its chemical composition (Okonkwo *et al.*, 2012). Freire and Holanda (2006) carried out an investigation and affirmed the usage of eggshell waste as an alternative raw material in the production of wall tile materials. In addition, when the eggshell powder is mixed with fly ash and rice husk ash the constituents can be used as a partial replacement for cement (Jayasankar *et al.*, 2010*)*. However, for further research, the suitability of recycling these materials to replace fine aggregate in concrete was investigated.

Concrete is one of the oldest and the most widely used construction material which depletes materials leading to environmental concerns in terms of utilization of raw materials. The composite material mainly consists of both coarse and fine aggregates and cement pastes mixed with water. Often, additives and reinforcements are included in the mixture to achieve the desired physical properties of the finished material. It is widely used in different areas like buildings, bridges, highways, and runways. The amount of concrete used worldwide, ton for ton is twice that of steel, wood, plastics, and aluminum combined while it is only exceeded by that of naturally occurring water (Cement Trust, 2013).

In this study, the interest was to use these agricultural waste materials as cost-effective construction materials in replacement of fine aggregates partially in concrete production to match the societal need for safe and economic disposal.

MATERIALS AND METHODS

Samples collection and Preparation

Egg and Snail shells were obtained in large quantities from food centers stock dumped at the Student Union Building of Federal University of Agriculture Abeokuta (FUNAAB) and a canteen in Ibara, Abeokuta, respectively both in Ogun State, Nigeria.

These shells were washed, sun-dried, ground to the required size (between 0.06 mm – 0.2 mm) equivalent to sand size with the aid of a milling machine. Ordinary Portland cement was used bought from the local market to prepare concrete while fine and coarse aggregates were also sourced locally and made to satisfy BS 882: 1992 and BS 812: 1990 Part 110 specifications.

Testing and Evaluating of Samples

Testing of shells (Snail and Eggshells)

Sieved analyses were carried out on the shells to determine their grading, using a set of sieves with the largest diameter at the topmost to the smallest diameter at the bottom, the mass of samples retained by each sieve was recorded. The grain size distribution curves were drawn on the semi-log graph.

Evaluation of Shells

The chemical compositions of snail and eggshells were determined and the specific gravity for each also was calculated under BS 1337:1996.

Determination of compressive strengths of concrete

Concrete mix 1:2:4 by volume was used and sand replacement with grinded egg and snail shells 0%, 2.5%, 5%, 7.5%, 10%, 12.5% and 15% each was done randomly. A water-cement ratio of 0.45 was adopted. Three (3) cubes (150 mm × 150 mm × 150 mm) were made for each percentage replacement. Slump and compressive strength were determined as specified in BS 1881:1983 Part 102 and BS 1881: 1983 Part 116, respectively. After 24 hours of casting, the molds were stripped and concrete specimens were taken to the curing stands inside the water tank. Compressive strengths were tested at 7, 14, 21, and 28 days after casting.

RESULTS AND DISCUSSION

Chemical Analysis

Snail and eggshells are mainly composed of compounds of calcium (98.1% and 94.5%, respectively) Table 1. This is in agreement with Winton (2003) and Odesina (2008) who presented eggshells as being composed mainly of calcium carbonate, one of the major raw materials in cement production (Oliveira *et al.*, 2013).

Table 1: Chemical compositions

Component (%)	Snail shell	Egg shell
$CaCO_3$	98.10	94.5
$CaPO_4$	0.15	1.0
$MgCO_3$	0.46	1.70
Others	1.29	2..80

Particle Size Distribution of Aggregates

The coefficient of curvature and coefficient of uniformity for each were 0.46, 7.0, and 1.81, 4.29 respectively (Figure 1). The two shells used were poorly graded. The size ranged from 0.0086 to 0.36 mm and 0.0086 to 0.072 mm. They fell within the silt and fine sand fractions i.e. from medium silt to medium sand and medium silt to fine sand for snail and eggshells, respectively (Figure 1).

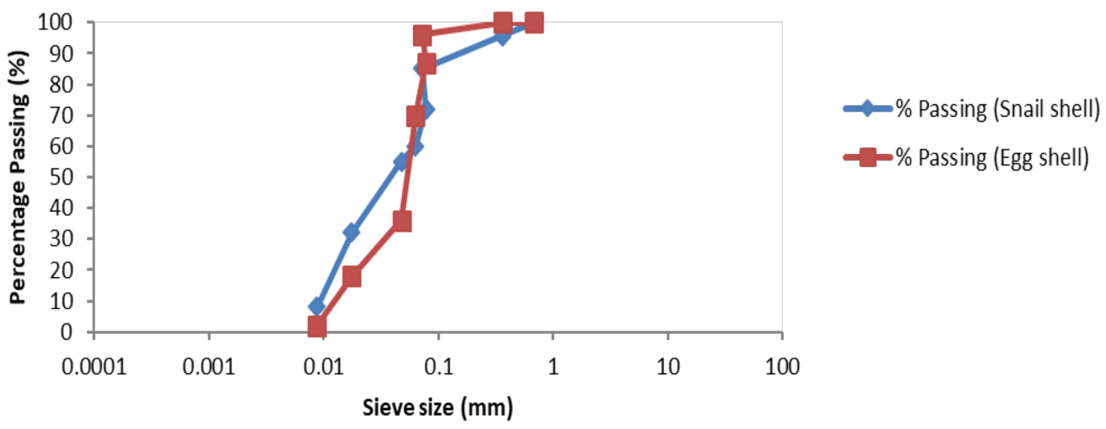

Figure 1: Particle Size Distribution for Snail and Egg shells

Workability of the Concrete

Both snail and eggshells influenced the workability of the concrete (Table 2). The slump test results that measured the workability of the concrete were within the true fall value (that is ≤ 125 mm). Workability of concrete decreased as percentage replacement of snail shells and eggshells increased. The workability of concrete with snail shell replacement was generally greater than that of concrete with eggshell replacement except at 2.5%. At this percentage replacement, the snail shell had a lower value (111 mm) while the eggshell was 113 mm and this established that the snail shell had better workability than the eggshell (Table 2).

Table 2: Slump Tests for Snail and Egg shells

% Replacement	Snail shell	Eggshell
0	124	124
2.5	111	113
5.0	105	99
7.5	102	93
10.0	98	90
12.5	96	87
15.0	92	84
100	83	77

However, as percentage replacement increased, the concrete became more rigid and since these materials are siliceous and pozzolanic, finely divided in form, and being in the presence of moisture, they could react chemically with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. These materials when used with ordinary Portland cement formed the glue of the concrete matrix and occupied the voids between aggregate particles, thereby keeping the matrix together. These however refined the pore size and eventually led to dense and less permeable concrete which is in line with ACI, (1994).

Compressive Strength

The average compressive strength of the concrete with snail shell increased generally up to 2.5% replacement with the highest value (18.12 N/mm^2) recorded at age 28 day (Figure 2). This value was greater than the control concrete (17.20 N/mm^2), though less than the targeted strength (20 N/mm^2) by 5.1%.

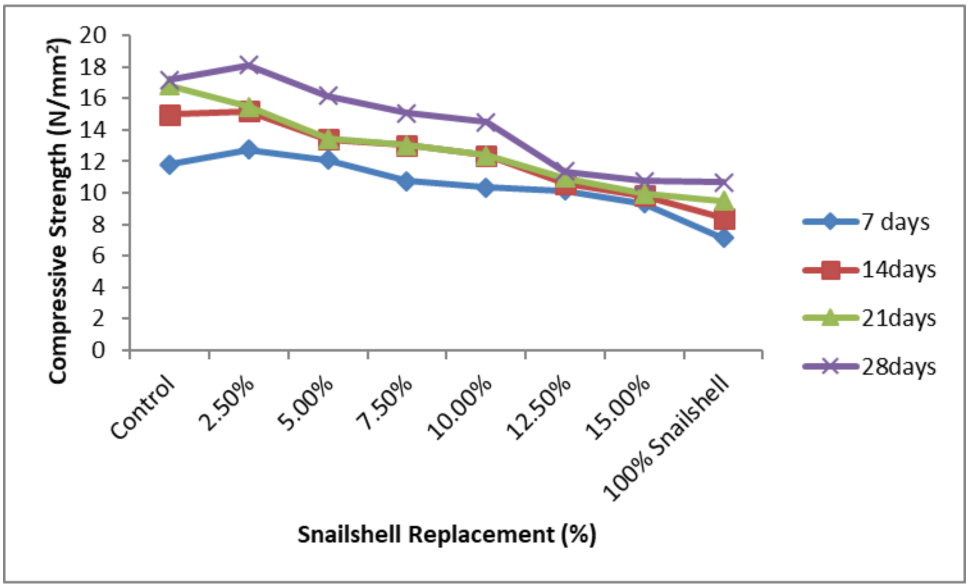

Figure 2: Variations of Compressive Strength with Snail shell

The compressive strength of concrete decreased generally as percentage replacement with eggshell increased (Figure 3). The highest value (14.08 N/mm^2) was also recorded on the 28th day when 2.5% replacement was used. Snail shells increased the compressive strength of concrete more than eggshells. The value obtained when 10% replacement with snail shell (14.51 N/mm^2) at 28th day was greater than the highest value recorded for concrete with eggshell at the same age (14.08 N/mm^2) for 2.5% replacement by 2.96% (Figure 3). The positive effects of the snail shell on the compressive strength of the concrete revealed that the shell contains an appreciable percentage of calcium carbonate more than the eggshell. Besides, the particle size distribution and texture of snail shells could be contributory factors to a better performance of concrete modified with snail shells than that of concrete with eggshells.

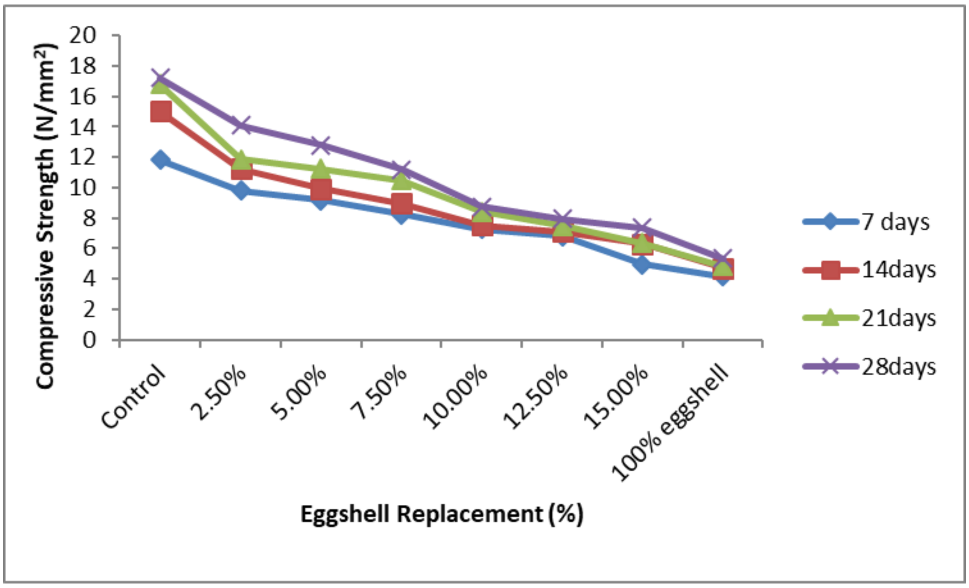

Figure 3: Variations of Compressive Strength with Snail shell

Concrete Weight

The specific gravity of the snail shell was greater than that of the eggshell by 7.07% (Table 3). This showed that the snail shell is more of good quality and suitable as a construction material than the eggshell because an increase in specific gravity increases both shear strength (Roy and Dass, 2014) and the California bearing ratio of materials used in road construction (Roy, 2016).

Table 3: Specific Gravity of Materials

Material	Specific Gravity
Cement	3.1
Coarse Aggregate	2.66
Fine Aggregate (River Aggregate)	2.61
Snail shell	1.98
Egg shell	1.84

Variation in weight was observed for all the percentage replacements both in snail shells (Table 4) and eggshells (Table 5). A decrease in weight was observed as percentage replacement increased up to 2.5% and also from 10% to 15% across the age of the concrete and percentage reduction ranged from 0.28% to 10.45% when eggshell was used. An increase in weight was observed as percentage replacement increased up to 12.5% across the age of concrete to 14 days ranging from 0.76 to 4.33% for snail shells.

There was an appreciable decrease in the weight of the concrete replaced by snail shell and eggshell on the 21st day for all the percentage replacement (Tables 4 and 5). However, variation in weight observed could be as a result of the particle size distribution, specific gravity, and texture of both snail and eggshells materials.

Table 4: Concrete weight (SS) of materials

Age for Testing	Weight of Cube (kg)	Weight of Cube (kg)	Weight of Cube (kg)	Weight of Cube (kg)	Weight of Cube (kg)	Weight of Cube (kg)	Weight of Cube (kg)
	0%	2.5%	5%	7.5%	10%	12.5%	15%
7 days	7.92	7.98	8.00	8.26	8.25	8.08	8.13
14 days	8.08	8.23	8.23	8.10	8.35	8.43	7.93
21 days	8.80	8.08	8.48	8.25	8.38	8.40	8.18
28 days	8.28	8.50	8.13	8.50	8.38	8.05	8.20

Table 5: Concrete weight (ES) of materials

Age for Testing	Weight of Cube (kg)	Weight of Cube (kg)	Weight of Cube (kg)	Weight of Cube (kg)	Weight of Cube (kg)	Weight of Cube (kg)	Weight of Cube (kg)
	0%	2.5%	5%	7.5%	10%	12.5%	15%
7 days	7.92	8.03	8.23	7.78	7.96	7.91	7.58
14 days	8.08	8.00	8.23	7.75	7.90	7.90	7.93
21 days	8.80	8.40	8.13	8.13	8.28	7.88	7.88
28 days	8.28	8.26	8.38	8.33	8.10	8.05	8.20

CONCLUSION

Snail and eggshells are agricultural waste materials that can be turned into useful raw materials for construction. They can be used to replace fine aggregates partially in concrete production to match the societal need for safe and economic disposal. Based on results obtained and discussion made in this study, the following conclusions were made:

(i) Workability of concrete with either snail shell or the eggshell is a function of its chemical composition, texture, and particle size distribution. Both snail and eggshells are pozzolanic materials and thereby enhance the workability of concrete, although concrete with snail shells had better workability than that of eggshells.

(ii) The highest compressive strength of concrete modified with snail shell and eggshell was recorded with 2.5% replacement on the 28th day. Besides, the particle size distribution and texture of snail shells could be a contributory factor to an increase in compressive strength observed than concrete with eggshells.

(iii) The weight of the concrete with eggshells was lighter than that of concrete with snail shells. In the light of the above observation, 2.5% of either eggshell or snail shell can be used partially to replace fine aggregate where lightweight concrete is required.

REFERENCES

ACI Committee 232 1994. Proposed Report: Use of natural pozzolans in concrete. *ACI Materials Journal* 91(4): 410–427.

Akinnusi, F.A.O., Oni, O.O. Ademolu, K.O. 2018. Mineral composition of giant African land snail's (*archachatina marginata*) shells from six south West States, *Nigeria Nigerian J. Anim. Sci* 20(4): 485-489.

Amu, O.O., Salami, B.A. 2010. Effect of Common Salt on Some Engineering Properties of Eggshell Stabilized Lateritic Soil, *APRN Journal of Engineering and Applied Science*, Asian Research Publishing Network 5(9): 64 - 73.

Bee, W. 2011. How to make calcium from eggshells. http://www.healing naturally. Downloaded from the internet on 30/09/2011.

British Standards Institution BS 1337: 1996. Methods of Test of Soils for Civil Engineering Purposes, BSI, London

British Standards Institution BS 1881 Part 102: 1983. Method for Determination of Slump. BSI, London.

British Standards Institution, BS 1881 Part 116: 1983. Method for Determination of Compressive Strength of Concrete Cubes. BSI, London.

British Standards Institution, BS 812 Parts 110: 1990. Method of Determination of Aggregate Crushing Value (ACV). BSI, London.

British Standards Institution, BS 882: 1992. Specification for Aggregates from Natural Sources for Concrete. BSI, London.

Cement Trust. 2013. What is the Development Impact of Concrete? Cement Trust Retrieved 10.

Freire, M.N., Holanda, N.F. 2006. Characterization of Avian eggshell waste aiming its use in a Ceramic wall tile paste, *Cerâmica* 52 (324).

Ihom, A.P., Nyior, G.B., Nor I. J., Ogbodo, N.J. 2013. Investigation of Egg Shell Waste as an Enhancer in the Carburization of Mild Steel, *American Journal of Materials Science and Engineering*, 1(2): 29-33.

Jayasankar, R., Mahindran, N., Ilangovan, R. 2010. Studies on Concrete Using Fly Ash, Rice Husk Ash, and Egg Shell Powder, *International Journal of Civil and Structural Engineering*, Integrated Publishing Services, 1 (3): 362-372.

Karthick, J., Jeyanthi, R., Petchiyamma, M. 2014. Experimental Study on Usage of Egg Shell as Partial Replacement for Sand in Concrete.

Odesina, I.A. 2008. Essential chemistry for senior secondary schools, 2nd edition. Tonad Publishers Limited, Ikeja, Lagos.

Olarewaju, A.J., Balogun, M.O., Akinlolu, S.O. 2011. Suitability of Eggshell Stabilized Lateritic Soil as Subgrade Material for Road Construction, *Electronic Journal of Geotechnical Engineering,* 16: 889-908.

Okonkwo, U.N., Odiong, I.C., Akpabio, E.E. 2012. The Effects of Eggshell Ash on strength properties of cement stabilized Lateritic, *International Journal of Sustainable Construction Engineering & Technology* 3(1):18 -23.

Oliveira, D.A., Benelli, P., Amante, E.R. 2013. A Literature Review on adding value to solid residues: Eggshells, Journal Cleaner Production, 46:42 -47.

Pliya, P., Creed, D. 2015. Limestone-derived eggshell powder as a replacement in Portland cement Mortar. *Construction and Building Materials* 95: 1-9.

Praveen, K.R., Vijaya, S.R., Jose, R.B. 2015. Experimental study on partial replacement of cement with eggshell powder. *International Journal of Innovation in Engineering and Technology* 5: 334-341.

Roy, S. 2016. Assessment of soaked California Bearing Ratio value using geotechnical properties of soils. *Resources and Environment* 6(4): 80-87.

Roy, S., Dass, G. 2014. Statistical models for the prediction of shear strength parameters at Sirsa, India. *I. Journal of Civil and Structural Engineering* 4(4): 483-498.

Udeozor, S.O., Evbuomwan, B.O. 2014. The Effectiveness of Snail Shell as Adsorbent for the Treatment of Waste Water from Beverage Industries Using H3 Po4 as Activating Agent. *Journal of Engineering* 4(8): 37-41.

Winton, A.L. 2003. Poultry eggs. Agrobios Publishers. Behind Nasrani Cinema, India.

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