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Utilization of Snail Shell Ash (Mollusca Gastropoda) as a Local Sourced Material for Cement Production

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Abstract— *Production of cement using snail shell ash and clay soil obtained from locally sourced materials has been presented in this work. The major raw materials, which are snail shell ash and clay soil, were obtained locally and prepared for the cement production. Physico-chemical analysis using Atomic Absorption Spectrophotometer (AAS) showed the elemental composition of the formulated cement and comparison with Dangote and Bua cements was made. The formulated cement was mixed with aggregates to form cubes which was further tested to know the strength for 7, 14 and 21 days curing. The result obtained was compared with that of two Portland Cement (Dangote and Bua) which were also used to produce cubes. The results of the comparison showed reasonable agreement with British standard, which makes the formulated cement acceptable for use and as an alternative to limestone in cement production.*

Keywords— *Snail Shell Ash, Clay Soil, Cement, Gypsum, Limestone, Physico-Chemical Parameters.*

I. INTRODUCTION

Ordinary Portland cement (OPC) is the major construction material throughout the world. The production rate in Nigeria is not enough due to high cost of production since about 75% of the raw materials for cement production is imported to meet up the demand. If alternative cheap cement can be produced locally, the demand for Portland cement will reduce and ultimately reduce the cost with lower energy demand without compromising output. The search for suitable local raw materials to produce cement was therefore intensified and it was discovered that, snail shell, which is an agro waste, is a potential substitute for production of cement. Most of the increase in cement demand will be met by the use of supplementary cementing materials, and the pollution of this agro waste in the environment will be drastically reduced. Cement is the second largest volume materials used by human being after water as reported by Wan et al., (2017). It plays the role of a binder, a substance that sets and hardens and might bind alternative materials along. Production of cement using locally sourced material such as snail shell ash is a notion that opens way for other materials apart from limestone to be used in cement production. Snail shells are high potential materials that can act as an alternative to limestone and filler in concrete. This is because the calcium carbonate ($CaCO_3$) in the snail shell is high and is similar to that of calcium carbonate in the limestone dust that been used in the Portland cement production. Impressively, the crystal structures of snail shell are largely composed of calcite and aragonite, which have higher strengths and density than limestone powder. In addition, the particle size of snail shell is between 36μm to 75μm and are similar to the particle size of Portland cement. Snail shell ash is gotten by washing, drying, burning and grinding snail shell. Snail belongs to the class Gastropodia, a Latin word meaning Gastro (stomach) and Podia (foot), phylum mollusca and kingdom animalia. Snail species have much greater diversity and biomass. There are about 70,000 different species in the Gastropod family worldwide. These include all terrestrial, marine and freshwater snails and slugs. Of those 70,000 species, about 5,000 live in the seas, oceans, brackish water and freshwaters; the remaining species live on land. As herbivores animals, Gastropod can be found living everywhere around the world from the tropics to the Artic and Antarctic. In short, Gastropod range second only behind insects when it comes to the number of named species. The snail species used is 'Helix pomatia' also called semi slugs. They are found in very large quantity all over Nigeria both on land and in water. Their shells are brownish yellow in color with dark markings and is up to 10cm in length. It is used for protection, as it is hard and rich in various minerals like calcite etc. Snail shell is an agro waste which is discarded when the edible part has been removed. However, a large amount of these shells are still disposed as waste of which disposal constitutes a problem to the environment. Its ash has pozzolanic properties that enables it to react with other materials i.e. clay, gypsum etc. It also has many other properties including its high percentage of chemical composition which is similar to the chemical composition of other raw materials used in cement production. Hence, it can he used as a complete replacement material of limestone in the cement industry as it is a low cost and environmentally friendly raw material at the same time fueling the economic growth of the nation, which is one of the reasons of this work. Research conducted by scientist and engineers all over the world to determine the effect of snail shell ash on the properties of concretes and cement is still ongoing in other to further improve the properties of snail shell for other advanced usage. In using snail shell ash as a raw material in cement production, there will be conversion of waste to wealth, which will in turn create job opportunities in the society.

II. MATERIALS AND METHODS

2.1 Materials

The materials used in this research are, snail shell, clay, sharp sand, water, chippings. Additives like gypsum, apparatus/equipment like furnace, crushing machine, 75µm

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sieve, batch reactor, ball mill, spatula, sealed containers, mold, weighing balance, mixer and Atomic Absorption Spectrophotometer (AAS).

2.2 Methods

2.2.1 Sourcing for raw materials

Snail Shell: The snail shells used for this research were obtained from Abua, Rivers State, Nigeria and the edibles were removed. The shells were made free from any organic and inorganic matter by soaking in water and washing severally. The snail shells were spread in sunlight to dry.

Clay: The clay (Kaolin) used was collected from a fresh water swamp in Yeghe community in Gokana Local Government Area in Rivers State, Nigeria.

2.2.2 Heating

Snail shell: The dried snail shells were calcined at 700°C to weaken the strength of the shell for crushing. The shell recorded weight loss after heating.

Clay: Dehydration of the clay was done at various temperature to reduce moisture content. The clay recorded weight loss after heating.

2.2.3 Crushing and sieving

The dried snail shells and clay where each subjected to a crusher where they were crushed to fine particles. After crushing, the snail shell ash and clay ash were then sieved with a sieve of aperture size 75μm.

2.2.4 Material characterization

The experimental raw materials, clay soil (CS) and snail shell ash (SSA) were characterized and the morphology of pulverized samples were observed using Atomic Absorption Spectrometer: Accordingly, suitable blends of SSA and CSA should be able to conveniently replace cement in building blocks, since cement contains reasonable amounts of both CaO and SiO_2.

2.2.5 Raw mix preparation

The snail shell ash and clay ash were proportioned through a weighing machine in the percentage ratio of ninety is to ten (90:10), eighty is to twenty (80:20), seventy is to thirty (70:30), sixty is to forty (60:40) and fifty is to fifty (50:50). The proportioned quantity was discharged into a ball mill which mixed the mixture properly to a homogeneous state at 20 minutes intervals. The ratio of these mixture was necessary so as to checkmate the proper ratio the formulated cement can be produced using snail shell ash and clay soil.

2.2.6 Raw mix heating/kilning

The raw mix was sent to the furnace for kilning. The raw mix in the kiln was heated to different temperature at different time intervals. The raw mix was still in powdered form after heating. This process was done for the five different mixture ratio of snail shell ash and clay soil.

2.2.7 Addition of additives

Gypsum is a white powdery substance that contains minerals composed of crystalized calcium sulphate and water ($CaSO_4.2H_20$). It is used to regulate setting time or to correct hydration rate. Gypsum has other characteristics such as resistance to fire. Gypsum as an additive was added to the different ratio of the raw mix for mixture of ratio of snail shell ash and clay soil of (90:10), (80:20), (70:30), (60:40) and (50:50). These mixtures were also discharged to a ball mill for homogeneous mixing. Silicate is responsible for strength impart to cement. It forms hard silicate compounds when it reacts with calcium. It is added in fine particle size.

The result that best gives a good combination of raw mix to additive is eighty percent (80%) Snail shell ash to twenty percent (20%) clay soil which gives a tot& of hundred percent (100%) of the raw mix. A measurement of seventy percent (70%) of the raw mix was added to twenty percent (20%) Gypsum and ten percent (1 0%) Silicate.

2.2.8 Mixing/Blending

The additives were mixed/blended into the cement to fine particle size with the use of ball mill to give the formulated cement, which was removed and stored.

2.3 Chemical Composition of Raw Mix

Samples of Snail shell ash and clay soil ash, which were labelled sample S and C respectively were analyzed using Atomic Absorption Spectrophotometer (AAS). The result of the analysis detects the elemental percentage composition for both samples. Elements such as Calcium, Silicon. Aluminum, Iron, Magnesium and Sulphur were detected as the major constituents alongside other minor constituents.

2.4 Production of Cubes

The formulated cement was mixed with water, sharp sand and chipping/gravel to form concrete which was used for making the cube. It is important that the water used for making the concrete and curing should be free from harmful impurities such as oil, acids etc. In general, the water fit for drinking should be used. The cubes (150mm x 150mm x 150mm) were produced and each samples of cubes tested and analyzed for the formulated cement and its result was compared to that of other cement to find out the uniqueness of the produced cement in terms of its strength and other properties.

Ratios of 1:2:4

Using the standard mixing ratio above in the weight of 3.2:6.4:12.8 j.e. Cement: Sharp sand: Chippings, with an estimated volume of 170Cl for fresh water. Where A = Cement, B = Sharp sand, C = Chippings and D = Water. It means that for the formulated cement (1)

$A_1 + B + C + D$

For Bua Cement (2)

$A_2 + B + C + D$

For Dangote Cement (3)

$A_3 + B + C + D$

2.5 Cube Testing

The cubes casted were tested for 7, 14, and 21 days curing. The freshly cast specimen will be left in the molds for 24 hours before being de-molded and then cured in water with temperature of 27± or 2 °C until it was 30mins prior to testing time when it will be removed. The weight of the cubes will be determined so as to calculate the densities of the cubes. Compressive strength of the cube will also be determined with the use of a compression machine.

III. Results and Discussion

3.1 Chemical composition analysis of snail shell ash and clay soil ash was conducted using Atomic Absorption Spectrophotometer (AAS) is shown below:

3.1.1 Snail shell ash

Table 1 shows the analysis carried out on snail shell ash using Atomic Absorption Spectrophotometer AAS.

Table 1: Elemental Composition in Snail Shell Ash

Elements	Snail Shell Content
SiO_2	10.75291
Al_2O_3	2.03654
Fe_2O_3	2.49246
CaO	43.70381
SO_3	0.90523
KO_2	0.31164
TiO_2	0.97284
Mn_2O_3	1.25621
P_2O_5	0.03187
MgO	1.14218

The chemical analysis was performed in Austino Research and Analysis Laboratory Nigeria LTD. Along UPTH Road Alakahia, Port Harcourt, Rivers State. From the result in Table 1, we observe that the snail shell ash contains the main chemical constituents of cement which are CaO, SiO_2, Al_2O_3, Fe_2O_3 which are present in the ordinary Portland cement.

3.2 Clay Soil Ash

For samples of clay soil which was tested, the result of the analysis is shown in the Table 2.

Table 2: Elemental Composition Present in Clay Soil Ash

Elements	Snail Shell Content
Silicon (Si)	15.94320
Aluminum	2.18057
Iron (Fe)	3.05038
Calcium (Ca)	52.07421
Sulphur (S)	0.82170
Potassium (K)	0.13526
Titanium (Ti)	2.94110
Zinc (Zn)	0.17482
Lead (Pb)	1.56381
Mananese (Mn)	0.83192

From Table 2, it is seen that silicon, aluminum, iron, and calcium, which are the main constituents for silicate and alumina formation in the production of cement, are available in clay soil. Hence, clay soil is a perfect match for the production of cement with snail shell ash.

3.3 Chemical Composition of Bua Cement, Dangote Cement and Formulated Cement

The chemical composition of Dangote cement, Bua cement and the formulated cement was determined using Atomic Absorption spectrometer.

3.3.1 Dangote cement

Table 3 shows the result obtained from the analysis of Dangote Cement in Atomic Absorption spectrometer.

Table 3 shows the Dangote cement percentage elemental composition. From Table 3, it is seen that there is a high percentage of calcium, silicon, Sulphur and Aluminum in Dangote cement, with calcium being the major constituent.

Table 3: Dangote Cement Percentage Elemental Composition

Elements	Content%
Silicon (Si)	5.4426
Aluminum (Al)	2.0343
Iron (Fe)	1.4887
Calcium (Ca)	66.7244
Sulphur (S)	4.3281
Potassium (K)	0.0000
Copper (Cu)	0.0090
Zinc (Zn)	0.0238
Magnesium Mg)	0.6721
Phosphorus (P)	0.4459

3.3.2 Bua cement

Table 4 shows the result obtained from the analysis of Bua cement in Atomic Absorption spectrometer.

Table 4: Bua Cement Percentage Elemental Composition

Elements	Snail Shell Content
Silicon (Si)	3.3732
Aluminum	1.3338
Iron (Fe)	1.0592
Calcium (Ca)	62.518
Sulphur (S)	0.9295
Potassium (K)	3.5816
Copper (Cu)	0.0111
Zinc (Zn)	0.0233
Magnesium (Mg)	0.0000
Phosphorus (P)	0.2996

Table 4 shows the Bua cement percentage elemental composition. From Table 4, it is seen that there is a high percentage of calcium, silicon, Sulphur and Aluminum in Bua cement, with calcium being the major constituent.

3.3.3 Formulated cement

Table 5 shows the formulated cement produced with the best raw mix ratio of 90% snail shell ash and 10% clay soil. From the analysis carried out using AAS, the formulated cement contains 61.72% CaO, 18.54% SiO_2 and 8.03 Al_2O_3.

Table 5: Formulated Cement Percentage Chemical Composition

Elements	Content%
Silicon (Si)	15.93
Aluminum	6.17
Iron (Fe)	3.02
Calcium (Ca)	53.86
Sulphur (S)	1.13
Potassium (K)	0.82
Copper (Cu)	0.02
Zinc (Zn)	0.51
Magnesium (Mg)	0.34
Phosphorus (P)	0.08

Table 5 shows that the production of cement with snail shell ash as an alternative to limestone is a great one since calcium which is a major constituent in cement has the highest percentage. The close relationship between the formulated cement and that of Bua cement and Dangote cement is observed in the results of the AAS. There is a perfect similarity between the ranges of the elemental values of formulated cement to Dangote and Bua cements

3.4 Physical Properties of Formulated Cement

3.4.1: Setting time

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The result for the initial and final setting time of the formulated cement is shown in the Table 6. From the results, it is seen that the formulated cement sets at 9 hours.

Table 6: Initial and Final Setting Time of Formulated Cement

Penetration	15	30	45	1	2	3	4	5	6	7	8	9
	Mins	Mins	Mins	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs	Hrs
Time Interval on Addition of Water	12.43	12.57	1.12	1.27	2.27	3.27	4.27	5.27	6.27	7.28	8.28	9.28
Initial setting –time Reading	0.0	0.0	5.0	6.0	7.0	12.0	15.0	17.0	23.0	28.0	35.0	38.0
Final setting- Time reading												38.0

3.4.2 Fineness test

Table 7 shows the fineness test results of the formulated cement.

Table 7: Fineness of Formulated Cement

Sieve Aperture (μm)	75
Mass of cement (M)g	100
Mass of cement retained (R_m)g	5.00

% Fineness = $100 - (R_m/M) \times 100$
% Fineness = $100 - (5/100) \times 100$
% Fineness = 95.00

3.4.3 Compressive strength of cement concrete

Table 8 shows the result gotten from the determination of the compressive strength of the formulated cement compared with that of Bua Cement, Dangote cement and British standard for a period of 21 days.

Table 8: Compressive Strength of Dangote Cement, Bua Cement and Formulated Cement

Period (Days)	Dangote Cement (N/mm^2)	Bua Cement (N/mm^2)	Formulated cement (N/mm^2)	Minimum Values for British standard (N/mm^2)
7	18.67	24.00	16.84	16.00
14	24.89	25.78	18.53	19.00
21	28.44	26.67	23.11	21.00

Figure 1 shows the variation of Compressive strength with curing period for Bua Cement, Dangote cement, British standard and the Formulated cement within a period of 21 days. From the plot, it is seen that the higher the curing age (period), the higher the compressive strength of the cements under investigation.

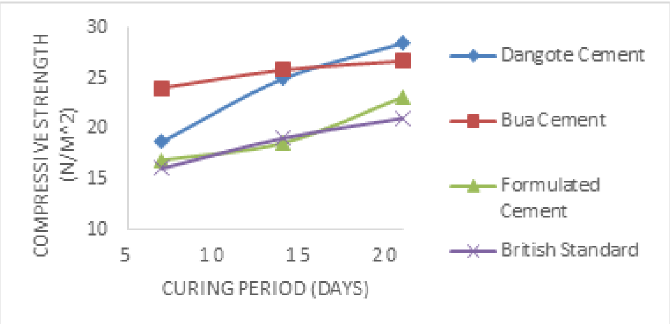

Figure 1: Variation of Compressive Strength with Curing Period

However, the compressive strength of the formulated cement was lower compared to that of Dangote and Bua cements, it is within the British standard minimum requirement.

IV. Conclusion

Production of cement using snail shell ash and clay soil obtained from locally sourced materials has been presented in this work. The major raw materials; snail shell ash and clay soil were obtained locally and prepared for the cement production. Different ratios of the raw mix of snail shell ash and clay soil (90:10), (80:20), (70:30), (60:40) and (50:50) were considered to determine the best mix for the production of cement. (90:10) ratio gave the best result for the formulated cement. Pysico-chemical analysis using Atomic Absorption Spectrophotometer (AAS) showed the elemental composition of the formulated cement and comparison with Dangote and Bua cements was made. The results of the comparison showed reasonable agreement with British standard which makes the formulated cement acceptable for use and also as an alternative to limestone in cement production. The chemical investigation of cement made with snail shell ash gives us a conclusion that the chemical composition of the snail shell ash and clay soil ash used for this research has the same properties as that of limestone satisfying the requirements. The high content of calcium, aluminum, and silicate found during the AAS analysis which are major constituent that gives the cement its strength and binding ability. Heat during the process of kilning also contributed to the cement formation and strength as silicates, aluminates and other elements are formed. From the setting time of the formulated cement, Dangote and Bua cement (OPC) cement sets faster than the formulated cement. The strength of the formulated cement concrete is less compared to that of Dangote cement concrete and Bua cement concrete but was within the acceptable range of British standard.

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