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Assessment of Physico-Chemical Properties of Periwinkle Shell Ash as Partial Replacement for Cement in Concrete

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Abstract— *This paper reports on the assessment of physico-chemical properties of periwinkle shell ash as a replacement for cement in concrete. Physical properties like specific gravity, fineness, bulk density and moisture content of the periwinkle shell ash were determined and compared with the specification of American society of testing and material. The chemical composition of the ash was determined and compared with the specifications of American society of testing and material. Compressive strength of percentage replacement of cement with periwinkle shell ash of 0, 10, 20, 30 and 40% at 28 days of curing was also determined with mix ratio of 1:1:2 and 1:2:4. Periwinkle shell ash calcined at 800 and 1000 ˚C shows satisfactory result in terms of fineness, chemical composition and 28 days compressive strength activity index and could be used as partial replacement for cement in concrete preparation.*

Keywords— *Assessment, cement, compressive strength, concrete, and periwinkle shell ash, physico-chemical properties, replacement, water requirement.*

I. INTRODUCTION

In Nigeria, the magnitude of fishing activities in the riverine areas has led to the production and accumulation of greater quantities of sea shells as wastes along the dump sites, market areas, coastal regions. According to [8], [14] stated that the fleshes of the species are processed and consumed while the hard shells are dumped at open sites resulting in environmental pollution, while [1] looked into the suitability of sea shells, like periwinkle shells as partial or full replacement for granite in concretewith satisfactory compressive test results at appropriate concrete mix ratios. According to [7], periwinkle Shells are agricultural waste which is dumped when the edible part (flesh)have been removed. The waste is stockpiled in open fields thereby causing a menace on the environment, and managing it has become a difficult challenge because of high generation of this waste daily. According to [14], one of the ways to disposeperiwinkle shell would be using it as constructionmaterials as this would help to lower the rate ofdepletion of natural resources such as granite and gravel and to maintain ecological balance.Accordingly, [7] reported that researchers in Nigeria in recent times have made use of periwinkle shell both for construction and non-construction purposes; [4] uses the physiochemical properties of periwinkle shell ash burnt at 300°C for 2 hours and sieved with 180µm sieve in the removal of lead ion and copper from industrial waste waters, [1], [2], [6], [9], and [15] made use of periwinkle shells (*Tympanotonus Fuscatus*) to replace coarse aggregates in lightweight concrete, [12] employed the periwinkle shells as hybrid bio-composite material, while [7] reported that [17] employed the cementitious properties of the periwinkle shell ash as a filler for partial replacement of lateritic soil in lateritic blocks production, [18] had compressive strength values that varied between 12.12 Nmm^{-2} and 25.67 Nmm^{-2} at 28 days which depend on factors ranging from mix proportion, type of coarse aggregate and water/cement ratio, while [6] obtaineda compressive strength characterustics of 18.64 N/mm^2 using water Cement ratio of 0.8, and [1] obtained a compressive strength characteristics of 21 Nmm^{-2} and 15 $Nmm^{-2}$for concrete mixes 1:2:4 and 1:3:6 respectively, [2] got 13.05 $Nmm^{-2}$for the periwinkle-gravel concrete. Using mix ratios of 1:1:2, 1:2:3 and 1:2:4, [16] achieved compressive strength characteristics of 25.67 Nmm^{-2}, 19.50 Nmm^{-2} and 19.83 Nmm^{-2} at 28 days hydration period, respectively. Periwinkle shell used mostly has been *Tympanotonus Fuscatus* and *Nodilittorina radiata* species in investigating the compressive strength of the concrete. This study examines the physico-chemical properties of periwinkle shell ash in comparison with that of cement to ascertain its full replacement potential in concrete.

TABLE 1. Main compounds in Portland cement.

Name of compound	Oxide composition	Abbreviation
Tricalcium silicates	$3CaO.SiO_2$	C3S
Dicalcium silicates	$2CaO.SiO_2$	C_2S
Tricalcium aluminates	$3CaO.Al_2O_3$	C_3A
Tetracalcium-aluminoferrite	$4CaO.Al_2O_3.F_{e2}O_3$	C_4AF

Source: [12]

TABLE 2. Approximate oxide composition limits of ordinary Portland cement.

Oxide	Percent Content
CaO	60 – 70
SiO2	17 – 25
Al2O3	3.0 – 8.0
Fe2O3	0.5 – 6.0
MgO	0.1 – 4.0
Alkalis (K2O AND Na2O)	0.4 – 1.3
SO3	1.3 – 3.9

Source: [17]

II. MATERIALS AND METHODS

2.1 Source of Material

The periwinkle shell used for the study was sourced from Odiok Itam, a riverine community in Itu Local Government, Akwa Ibom State. It was carefully washed and sun-dried for

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seven days. The fine aggregate (lateritic soil) was sourced from a borrowed pit in Ajebandele along ife-Ibadan express road, granite chippings from a quarry along Ondo road Ile-Ife Osun State while Portland cement was purchased from a cement store in Ile-ife, Osun State

TABLE 3. Chemical composition of periwinkle shell ash obtain by other researchers.

Oxides%	Umoh (2012)	Job *et al.* (2009)	Koffi (2008)	Badmus *et al.* (2007)
SiO_2	33.84	59.4	32.68	60.20
Al_2O_4	10.20	18.5	17.49	20.50
Fe_2O_3	6.02	7,6	19.92	7.00
CaO	40.84	3.2	26	3.70
MgO	0.48	1.1	1.7	1.12
SO_3	0.26	-	-	1.37
K_2O	0.14	2.2	0.86	-
Na_2O	0.24	-	-	2.30

2.2 Specimen Preparation

Periwinkle shells were divided into three with each division weighing 15Kg. There were calcined at 600, 800 and 1000˚C with a gas furnace at the firing chamber of the ceramic section in department of Fine and applied Art, Obafemi Awolowo University Ile-ife Osun State. Physical characterization of the periwinkle shell ash was carried out at the Material testing laboratory in the Department of Agricultural and Environmental Engineering Obafemi Awolowo University Ile-ife, while the chemical characterization was carried out at the Larfarge cement factory in Ogun state. The calcine periwinkle shell ash was ground with a hammer and a burr mill in other to have fine particle size.

2.3 Physical Properties

2.3.1 Sieve Analysis

Periwinkle shell ash wascarefully sieved using the mechanical sieve apparatus with different sieve sizes and the residues obtained with a sieve size of 45µm was used for this study.

2.3.2 Specific Gravity

An empty beaker was weighed and its weight taken as w_1, some quantity of periwinkle shell ash was poured into the beaker to a volume of 300ml and the weight taken as w_2, an equal volume of water was also measured and the weight taken as w_3. The values were estimated thus

$$\text{Specific gravity} = \frac{W_2 - W_1}{W_3}$$

2.3.3 Bulk Density

The mass of a quantity of periwinkle shell ash (W_S) was measured and an equal volume (V_S) was also measured and the bulk density was calculated thus

Bulk density = W_S / V_S

2.3.4 Moisture Content

An emptycan was weighed and the weight taken as w_1, some quantity of wetted periwinkle shell ash was poured into the can and weighed and the weight taken as w_2, the wet periwinkle shell ash was oven dried at 110˚C for 6 hours and weighed and the weight taken as w3. Moisture content was estimated thus

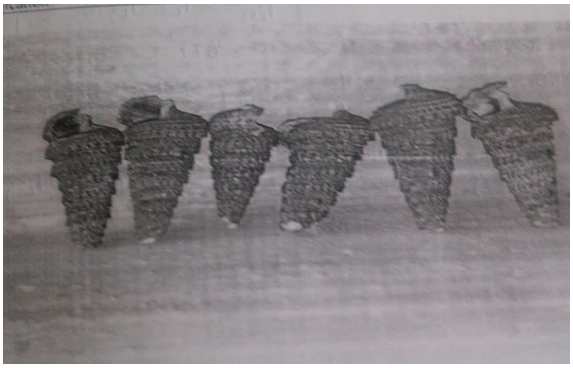
$$\text{Moisture content} = \frac{W2 - W1}{W3 - W1}$$

2.4 Chemical Properties

500g of periwinkle shell ash calcined at 600, 800 and 1000 ˚C were passed through an x-ray fluorescent machine and the values of the chemical composition in its oxide state were obtained.

2.5 Compressive Strength

Compressive strength test was carried out on periwinkle shell ash laterized concrete with two mix ratio of 1:1:2 and 1:2:4 at five replacement level (0, 10, 20, 30 and 40%) of cement with periwinkle shell ash cured and tested at 28 days.



(a). Periwinkle shell.

(b). Calcine periwinkle shell ash.

III. Result and Discussion

Physical Properties of Periwinkle Shell Ash

The physical properties of periwinkle shell ash calcined at different temperature levels of 600, 800 and 1000˚C are presented in table 3. The fineness of the ash retained on 45µm sieve as express in percentages are 25%, 62.5%, and 25% for 600, 800 and 1000 ˚C respectively. Only ash calcined at 800 ˚C met the required maximum 34% as Stipulated byASTMC618 (2008). Periwinkle shell ash caicined at 800 ˚C recorded the lowest specific gravity of 0.4 while ash at 1000 ˚C recorded a value of 0.64 and ash at 600 ˚C with the highest value of 1.42. This shows that the heat application on the periwinkle shell has an effect on the fineness of ash produced.

Chemical Composition of Periwinkle Shell Ash

The summary of the chemical composition of periwinkle shell ash calcined at different temperatures are presented in table 5. Ash calcined at 800 ˚C has the highest silica Oxide with a value of 33.85 followedby ash calcined at 1000 ˚C and

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then by ash calcined at 600 ˚C with values of 30.80 and 23.32 respectively. BS EN 197-1 (2009) stipulate 25% silica content for a pozzolan to be considered to have cementitious composition. This means that ash calcined at 800 and 1000 ˚C met the required standard for their silica content. The sulphur trioxide (SO_3) does not satisfy the requirement stated by ASTMC618-2008 which specifies a range of values of 4 – 5% as the recorded values ranges from 0.15 – 0.25%. For calcium oxides, the result indicates that its percentage increases as the temperature of calcination increases. This single out this periwinkle shell ash as a high lime pozzolan due to its high calcium oxides and silica oxides content, hence they act like mineral cementitious materials though may not be as reactive as cement. Due to this description, they could be classified as class C pozzolan. Ash calcined at 800 and 1000 ˚C met the requirement of ASTMC618-2008 for loss of ignition (LOI) which stipulates a valueof not more than 10%, with recorded values of 7.08 and 6.28 respectively. This shows that periwinkle shell ash will become a more active pozzolan when calcined to a temperature of 800˚C and above. For the combine acidic oxides (SO_3 + Al_2O_3 + Fe_2O_3), only ash at 800˚C met the requirement of ASTMC618-2008 for class C pozzolan with a value of 50.34%. From the analysis, it could be deduced that 800 ˚C is the optimum temperature for calcination of periwinkle shell since its silica and combine acidic oxide records the highest values and these values met the limit for high lime fly ash. According to [17] chemical composition of pozzolanic materials varies from one anotherand also within the same pozzolan, there is variability in the composition. This variability in the periwinkle shell ash may be attributed to place of source, type of shell, geological condition and also the method of processing.

Strength Activity Index

Figure 1 shows the strength activity index with Portland cement at 28 curing age for a mixed ratio of 1:1:2. The activity index is seen to be decreasing as the level of replacement of periwinkle shell ash with Portland cement increases. At 10% replacement level, periwinkle shell ash calcined at 800 ˚C has the highest activity strength index of 91.4 N/mm^2 followed by periwinkle shell ash at 1000 ˚C with 87.5 N/mm^2 while at 600 ˚C the strength index was 78.6 N/mm^2. It could be noted that in all other level of replacement of periwinkle shell ash, the ash calcined at 800 ˚C recorded the highest strength activity index.

For the mixing ratio of 1:2:4, test strength was recorded for 10 and 20% replacement level only while the 30 and 40% replacement level specimen recorded a zero strength value. As shown in figure 2, the highest strength activity index was recorded with the 1000 ˚C calcined periwinkle ash at 10% replacement level and the strength activity index was found decreasing with increase in the replacement level.

Water Requirement

The waterrequirements for periwinkle shell ash calcined at three different temperature levels for the two mixing ratios are expressed in figure 3 and figure 4. According to ASTMC618 (2008) which states the standard water requirement range of 105% to 115% of the control, Figure 1 shows that for mixing ratio of 1:1:2, periwinkle shell ash calcined at 800 and 1000 ˚C met the standard requirement as it ranges from 107% to 113% at all level of replacement, while that of 600 ˚C is less than the 105% for class F and C pozzolans. For the mixing ratio of 1:2:4, ash at 800 ˚C with 20, 30, 40% replacement and ash at 1000 ˚C with 30 and 40% replacement met the standard water requirement.

TABLE 4. Summary of the physical properties of periwinkle shell ash calcined at different temperature.

Parameters	Temperature (˚C)		
	600	800	1000
Fineness (% retained on 45µm sieve)	25	62.5	25
Specific Gravity	1.42	0.40	0.64
Bulk density	1.37	0,39	0.62
Moisture content	1.5	1.1	1.3

TABLE 5. Summary of chemical composition of periwinkle shell ash calcined at different temperatures.

Elemental Oxide (%)	Calcination Temperature (˚C)		
	600	800	1000
SiO_2	23.32	33.85	30.80
AAl_2O_3	9.62	10.24	10.84
Fe_2O_3	5.01	6.25	5.58
CaO	38.62	40.63	46.39
MgO	0.36	0.83	0.73
SO_3	0.15	0.25	0.18
Na_2O	0.24	0.15	0.27
K_2O	0.13	0.26	0.27
Mn_2O_3	0.00	0.00	0.00
P_2O_5	0.01	0.01	0.00
TiO_2	0.02	0.05	0.23
LOI	22.50	7.08	6.28
(SiO_2 + Al_2O_3 + Fe_2O_3)	37.95	50.34	47.22

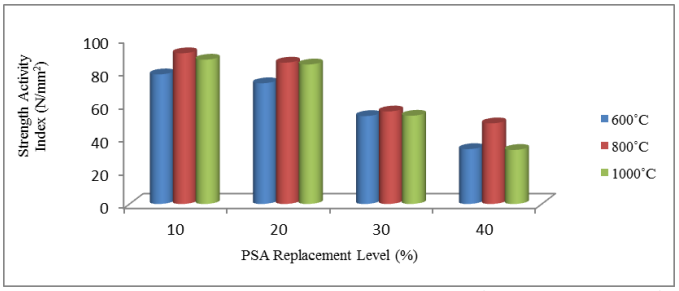

Fig. 1. 28 Days Compressive Strength Activity Index for a Mixing Ratio of 1:1:2.

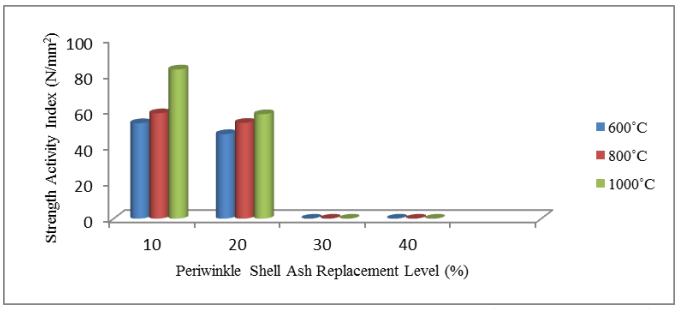

Fig. 2. 28 Days Compressive Strength Activity Index for Mixed Ratio of 1:2:4.

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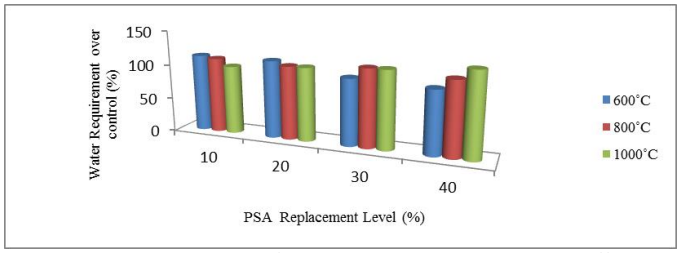

Fig. 3. Water Requirement of Periwinkle Shell Ash Calcined at Different Temperatures for Mix Ratio of 1:1:2.

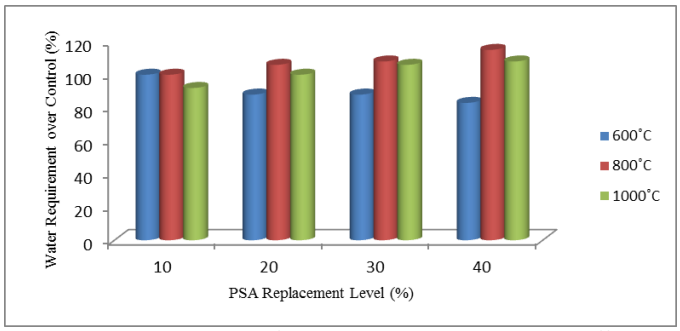

Fig. 4. Water Requirement of Periwinkle Shell Ash Calcined at Different Temperatures for Mix Ratio of 1:2:4.

IV. CONCLUSION

a. Periwinkle shell ash calcined at 800 ˚C met the required maximum 34% as stipulated by ASTMC618 (2008) for its fineness compared with that of cement. This shows that the heat application on the periwinkle shell has an effect on the fineness of ash produced.
b. The calcium and silica content of the periwinkle shell ash also met the required standard. This single out this periwinkle shell ash as a high lime pozzolan due to its high calcium oxides and silica oxides content, hence they act like mineral cementitious materials though may not be as reactive as cement.
c. The strength activity index of periwinkle shell laterized concrete recorded a highest strength index values with 800 and 1000 ˚C calcined periwinkle shell ash. Hence, periwinkle shell ash calcined to a temperature range of 800 to 1000 ˚C is suitable for use as partial replacement for cement in concrete.

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