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Properties of Concrete Produced with a Blend of Groundnut Shell Ash and Periwinkle Shell Ash as a Binder, Partially Replacing Ordinary Portland Cement

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ABSTRACT
The current global issues of pollution, environmental degradation and global warming of which construction activities contribute a large percentage has become so serious that construction practices and materials are being reviewed to minimize the danger that could result from this. The use of renewable or waste materials for construction work will lessen energy consuming activities as well as allow for proper waste disposal. Groundnut shell and Periwinkle shell, as natural materials, are obtained as waste. Chemical analysis of Groundnut Shell Ash (GSA) and Periwinkle Shell Ash (PSA) was carried out and identified as having desirable pozzolanic and cementitious properties. The study, therefore, investigated the effect of a blend of Periwinkle Shell Ash (PSA) and Groundnut Shell Ash (GSA) as partial replacement for cement in concrete production. The Specimens were designed to attain to target strength of $20N/mm^2$. A concrete grade M20 with a mix of ratio 1:1.5:3 was used for this research work with the introduction of GSA and PSA in 10%, 20%, 30%, and 40% of the total weight of the concrete constituents. The test cube specimens used in the research was of 150mm moulds. Compressive strength was tested at 7, 14 and 28 days. The result obtained showed that optimal replacement level of 30% will produce concrete with acceptable compressive strength. The study concluded that a 30% blend of GSA and PSA content is suitable replacement for cement in structural concrete

INTRODUCTION

Concrete is a composite construction material made primarily with aggregate, cement, water and admixtures when required. There are many formulations of concrete which provide varied properties and this makes concrete the most-used man-made product in the world. Concrete is widely used for making architectural structures, foundations, brick/block-walls, pavements, bridges/overpasses, motorways/roads, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Olusola and Umoh (2012) observed that considerable efforts are being taken worldwide to improve on the strength and durability performance of concrete through the use of pozzolanic materials. They further observed that in continuing the quest for more cost-effective and environmentally acceptable materials, recently, there has been a growing interest in the use of agricultural waste as pozzolans. Many agricultural waste ash such as rice husk, corn cob ash, groundnut shell ash and periwinkle shell ash have been individually researched and used as pozzolans but a review of blending various pozallans in concrete to further improve the quality of pozzolans, increase availability and reduce cost is becoming apparent. This necessitated the research of blending Periwinkle Shell Ash PSA and Groundnut Shell Ash GSA as partial replacement for cement in concrete production.

Periwinkle is a group of marine snails. Their shells are typically mottled grey, white and black and taper to a straight sided or rounded cone with an obtuse point. Periwinkles inhabit the littoral zone, the region between low and high tides. Although they must live near the ocean and spend part of their time under water, they prefer to be partially exposed to air. In the riverine areas of Nigeria, Periwinkles are extremely useful. Apart from the fact the snails are consumed for food, their shells are also useful for soil stabilization, concrete production, beads production, poultry birds feed, decorations etc (Soneye et al 2016). Olutoge, Okeyinka and Olaniyan (2012) reported that Periwinkle shell is a waste product generated from the consumption of a small greenish-blue marine snail (periwinkle), housed in a V shaped spiral shell, found in many coastal communities within Nigeria and world-wide, it is a very strong, hard and brittle material. These snails called periwinkle are found in the lagoons and mudflats of the Niger Delta between Calabar in the East and Badagry in the West of Nigeria, the people in this area consume the edible part as sea food and dispose the shell as a waste, though few people utilize the shell as coarse aggregate in concrete in areas where there are neither stones not granite for purposes such as paving of water logged areas.

Periwinkle Shell Ash (PSA) is obtained from the burning of periwinkle shells which is a by-product of periwinkle shell at a temperature of 800℃ (Olusola and Umoh 2012). PSA in binary blended system in concrete have been reported to enhance concrete strength and durability with replacement level of up to 10% (Job et al 2017). Groundnut is an important cash crop in the tropics; cultivated in most parts of the central and northern states of Nigeria. Groundnut Shell is a form of fuel in sweet manufacturing units and oil mills. The groundnut shell after being used as fuel generates ash which can be used as a replacement material for cement (Lakshmi and Sagar, 2017). Mahmoud et al (2012) obtained GSA by burning groundnut shell in an electric kiln at a temperature of 550 ℃ and Lakshmi and Sagar, (2017) obtained similar results by burning groundnut shell on an iron sheet, in open air, at a measured temperature of 650℃. The ash is a useful pozzolanic material and the compressive strength of concrete has been shown to increase when the replacement of cement with GSA up to 10% replaces by weight of cement (Lakshmi and Sagar, 2017)

MATERIALS AND METHODS

Materials

Cement: The ordinary Portland cement used is of the Dangote (Obajana) brand and was obtained from Katako market, Jos. Test results on cement are presented in Table 1 in accordance to BS 812, Part 2 (1975).

Periwinkle Shell Ash (PSA): The periwinkle shell were obtained from Akwa- Ibom state, they were free of dirt and organic matter. The periwinkle has been removed from the shells. The shell were properly dried and burnt at a temperature of 800℃ in a kiln at Abubakar Tafawa Belawa University Bauchi, Bauchi state and thereafter grinded to fine particle. The resulting ash was then sieved through British standard sieve size 75μm to fine powder. The ash retained on the sieve was then grinded and sieved again. The results of chemical analysis carried out on PSA is presented in Table 2.

Groundnut Shell Ash (GSA): The groundnut shell was obtained from farmers within Jos East, Plateau State, Nigeria free of charge after threshing/separating the shell from the nut using mechanical method. The shell were properly dried and burnt at a temperature of 500 ℃ in a kiln at Abubakar Tafawa Belawa University Bauchi, Bauchi State and thereafter sieved through British standard of 75μm. The ash retained on the sieve was then grinded and sieved again. Results of chemical analysis carried out on PSA is presented in Table 2

Fine Aggregates

Fine aggregates conforming to specification of BS 882: 1992 was locally obtained from a river of the Jos, Plateau State, and metropolis. The sand was free from clay, silt and organic impurities. Results of sieves analysis, bulk density and specific gravity carried out on fine aggregate used is presented in Table 3.

Coarse Aggregate

Machine crushed angular gravel in accordance with BS 822: 1973 were used. The gravel was free from clay, silt and organic impurities. The results of sieves analysis, bulk density and specific gravity carried out on fine aggregate used is presented in Table 4.

Table 1: Properties of Binding Materials

Material	Bulk Density	Specific Gravity
Cement	1440	3.15
PSA	930 Kg/m^3 (uncompacted) 1057 Kg/m^3 (compacted)	2.12
GSA	930 Kg/m^3 (uncompacted) 1057 Kg/m^3 (compacted)	2.12

Table 2: Chemical composition of PSA and GSA

Constituent	Percentage Composition by weight in PSA (%)	Percentage Composition by weight in GSA (%)
Na_2O	0.402	0.671
MgO	0.917	8.285
Al_2O_3	11.111	10.050
SiO_2	35.410	28.327
P_2O_5	0.114	3.455
SO_3	0.588	2.371
Cl	0.280	0.721
K_2O	0.149	25.010
CaO	40.042	12.713
TiO_3	0.033	1.760
Cr_2O_3	0.000	0.000
Mn_2O_3	0.226	0.324
Fe_2O_3	1.081	6.111
ZnO	0.006	0.082
SrO	0.510	0.120

Table 3: Properties of fine aggregate

S/No.	Properties	Test Result
1.	Uncompacted Bulk Density	1562.96 Kg/m^3
2.	Compacted Bulk Density	1725.50 Kg/m^3
3.	Mean Specific Gravity	2.50
4.	Mean particle size	4.75mm-150μm
5.	Appearance	Spherical

Table 4: Properties of Coarse Aggregate

S/No.	Properties	Test Result
1.	Uncompacted Bulk Density	1414 Kg/m^3
2.	Compacted Bulk Density	1670 Kg/m^3
3.	Mean Specific Gravity	2.35
4.	Mean particle size	37.5mm-6.30mm
5.	Appearance	Angular

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Table 5: Material Quantities for Control Specimen

Material	Dry Bulk Densities 1:1.5:3	Ratio Weights With Respect to Cement	Material Quantities In 1m^3 (Kg/m^3)	Material Quantities per 150mm Cube Specimens (Kg)	Total Material Quantities in 45 Specimens (Kg)
Cement	1440.00	1	313.50	1.11	49.95
Fine Aggregate	2587.50	1.8	470.25	1.67	75.15
Coarse Aggregate	5010.00	3.5	940.50	3.34	150.30
Water	-	-	188.10	0.64	28.80

Table 6: Material Quantities used In Blended Concrete and the Slump Values.

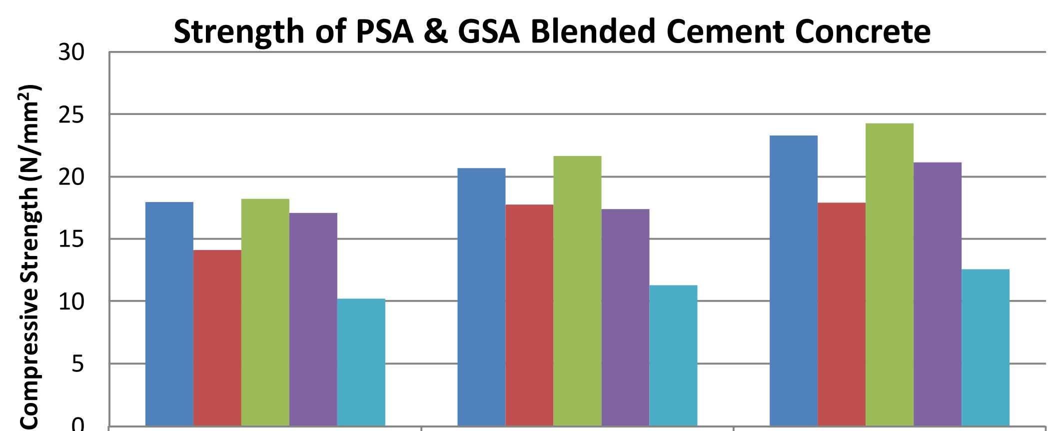
Percentage Replacement (%)	Cementitious Material (Kg)		Water Content (Kg)	Fine Aggregate (Kg)	Coarse Aggregate (Kg)	Slump (mm)
	Cement	PSA&GSA				
0	49.95	0	28.80	75.15	150.30	29
10	44.51	4.99	28.80	75.15	150.30	29
20	39.96	9.99	28.80	75.15	150.30	28
30	34.96	14.99	28.80	75.15	150.30	27
40	29.97	19.98	28.80	75.15	150.30	25

Table 7: Compressive Strength of PSA & GSA Blended Cement Concrete and Densities

Curing age (days)	PSA &GSA (%)	Compressive Strength (N/mm^2)			Mean Strength (N/mm^2)	Attainment of Design Strength (%)	Densities of Concrete (Kg/m^3)
		Spec. 1	Spec.2	Spec. 3			
	0	17.92	18.20	17.89	18.00	90.00	2528
	10	16.98	17.13	17.22	17.11	85.55	2545
7	20	18.10	18.30	18.26	18.22	91.10	2530
	30	14.14	14.11	14.15	14.13	70.00	2554
	40	10.20	10.25	10.21	10.22	51.10	2539

	0	20.63	20.89	20.58	20.70	103.50	2553
	10	17.82	17.78	17.74	17.78	88.90	2461
14	20	21.66	21.69	21.69	21.68	108.40	2560
	30	17.10	17.60	17.50	17.40	87.00	2534
	40	11.33	11.43	11.23	11.33	56.65	2490
	0	23.29	23.33	23.30	23.31	116.55	2578
	10	21.16	21.17	21.21	21.18	105.90	2533
28	20	24.28	24.26	24.27	24.27	121.35	2593
	30	17.87	17.92	17.94	17.91	89.55	2504
	40	12.63	12.59	12.58	12.60	63.00	2444

Figure 1: Compressive Strength of PSA & GSA Blended Cement Concrete



	7days	14days	28days
Series 1	18	20.7	23.31
Series 2	14.13	17.78	17.91
Series 3	18.22	21.68	24.27
Series 4	17.11	17.4	21.18
Series 5	10.22	11.33	12.6

METHODS

Specimen Preparation and Testing

Specimens were prepared using a 150mm cubes. The specimens were cast in wooden moulds according to BS EN 12390-2:2009 specifications. The specimens were stored for 24 hours away from direct sunlight after which they were demoulded and submerged in water to cure at room temperature until about two hours before testing at 7, 14 and 28days. Specimens were designed to attain target strength of 65%-75% (13N/mm^2-15N/mm^2) at 7 days, 90% (18N/mm^2) at 14 days and 99%-100% (19.8N/mm^2-20N/mm^2) at 28days. The concrete specimens were tested for compressive strength according to BS EN 12390-3:2009. Three specimen cubes of each mix were tested for compressive strength at 7, 14 and 28days and their mean value was computed; a total of 45 concrete cubes were tested for compressive strength.

2.2.2 Batching of Materials

The absolute volume was adopted for the computation of the various quantities of material required. The volume of compacted concrete is equivalent to the sum of the absolute volume of the materials that make up the concrete (Job et al, 2017). By first obtaining the volumes of materials required and by conversion, batching was done by weight of material according to the properties of each material as determined and shown in Table 5 and 6. A grade M20 1:1.5:3 blended concrete mix was prepared with a water to cement ratio (w/c) of 0.6 for 0%, 10%, 20%, 30% and 40% partial replacement of Portland Cement with PSA and GSA. Computation of batching of each material is shown on Table 6. The formula for calculation of materials for the required volume of concrete is given by

$V_C = \frac{Weight\ of\ material}{Specific\ gravity\ of\ Material}$ and also

$$V_C = \frac{W}{1000} + \frac{C}{1000S_c} + \frac{F_A}{1000S_{Fa}} + \frac{C_A}{1000S_{Ca}}$$

where W = Weight of Water, C = Weight of cement, F_A = Weight of fine aggregate, C_A = Weight of coarse aggregate and S_c, S_{Fa}, and S_{Ca} are specific gravities of Cement, Fine aggregate and Coarse aggregate respectively. 2% was assumed for entrained air to arrive at a value of 1 - 0.02 = 0.98m^3 as volume of 1m^3 of compacted concrete. Also 5% was allowed to compensate for wastage in computing weight of materials. From computations of the values on table 10, an absolute volume of 0.1439m^3 was obtained and by dividing the compacted volume of concrete with this value, 6.27 bags of cement was obtained for production of 1m^3 of concrete. Therefore the various quantities required for production of concrete in 1m^3 and in cube specimens was computed and shown in tables 5 and 6 respectively.

RESULTS AND DISCUSSIONS

Physical Properties

The specific gravity of both PSA and GSA obtained was 2.12. This is less than that of OPC (3.19) and lies between 2.0-2.40 conforming to the requirement stipulated for pozzolana. The loose bulk density of PSA and GSA was found to be 930kg/m3 and compacted bulk density of 1057kg/m3. The ratio of the loose to compacted bulk density is 0.88, which lies between 0.86 - 0.96 as stipulated for non-light materials. 26.6% of the PSA and GSA was retained on the 75µm sieve, which conforms to the requirement.

Chemical Properties

According to BS EN 450.1 and ASTM 618, the major requirements for a material to be classified as pozzolana are that the total percentages of Al_2O_3, SiO_2 and Fe_2O_3 must not be less than 70%. The values obtained from the chemical analysis of PSA are Al_2O_3

= 11.111%, SiO_2 = 35.410%, Fe2O3 = 1.08% and the values obtained for GSA are Al_2O_3 = 28.327%, SiO_2 = 10.05%, Fe_2O_3 = 6.111%. The total values of Al_2O_3, SiO_2 and Fe_2O_3 in PSA and GSA are 47.601% and 44.488% respectively. However, both materials have a high value of calcium oxide i.e 40.042% and 12.713% for PSA and GSA respectively. Abdelatif et al, (2020) researched on the "Evaluation of Calcium Oxide (CaO) Nanoparticles from Industrial Waste on the Performances of Harden Cement Paste" and opined that adding a level of 15% by wt of pure CaO is nearly acceptable and suitable for all parameters of hardened cement paste. Though the levels of Al_2O_3, SiO_2 and Fe_2O_3 are less than 70%, the high level of CaO is perhaps desirable and the low level of SO_3 percentage in the ash, which is under 5%, conforms to requirement for pozzolana.

Workability of Fresh Concrete

The result of trial mix indicated that cementitious materials replacements for cement needed a greater water requirement than that for the control mix in order to enable workability comparable to a cement only concrete; this can be attributed to the fineness of PSA and GSA which will have a greater specific surface to be wetted and lubricated as observed by Kolapo and Akaninyene, 2012. Therefore a water cement ratio of 0.6 was adopted rather than the generally accepted 0.5-0.55 water cement ratio for an M20 concrete grade. However, while workability of the PSA and GSA blend mix was enabled, the lower strength of the control mix can be attributed to the higher w/c ratio. Tables 6 shows that the values of slump test obtained falls within the stipulated range of slump which is between 10mm-30mm for low workability concrete.

Compressive Strength

As expected, the result of the compressive strength test as given on Table 7 and shows that concrete strength increased consistently in all specimens as curing age increased. However, the results of 90:10% replacement of cement with PSA and GSA blend showed a drop in strength from the control specimen while the 80:20% replacements shows increase in strength above that of the control specimen. This result is similar to the findings of the work done by Kolapo and Akaninyene (2012) on PSA and the research of Lakshimi and Sagar, (2017) on GSA. The result at 7 days shows that specimens with10-30% cement replacement attained the stipulated target strength of 65-75% of an M20 grade concrete. At 14 days, the 10% cement replacement was short of the stipulated 90% grade M20 target strength by 1.1%. This is acceptable considering the slow reactivity of pozollans. The 20% cement replacement specimens where already showing excellent results at 108.40%. This exceeded the 20N/mm^2 target strength for M20 concrete grade. The results of the control specimen were also noted to exceed the 100% target strength and this is consistent with works done by previous researchers.

At 28days hydration period the results of the control specimen, 10% and 20% cement replacement was 23.31N/mm^2, 21.18N/mm^2 and 24.27N/mm^2 and this was an increase of 116.55%, 105.90% and 121.35% respectively over the 100% target strength of an M20 grade concrete. The result of the 30% cement replacement was 89.55N/mm^2 and did not attain the target strength. However, Kolapo and Akaninyene (2012) showed/. That at 30% replacement of cement with PSA, compressive strength increased from 75% at 28days to 100.35% at 120 days, representing a 25.35 % strength increase. Therefore it means that where later age strength is required at 120 days hydration, a 30% cement replacement with a blend of PSA and GSA may be adequate.

CONCLUSIONS AND RECOMMENDATIONS

Although chemical analysis of PSA and GSA show that the total Al_2O_3, SiO_2 and Fe_2O_3 percentage by weight was less than the 70% acceptable for pozollans, a high CaO content was recorded and has been shown to be desirable by Youssef A. et al, 2020. The impressive compressive strength recorded for PSA and GSA blended cement concrete may be due to both the reactivity of CaO together with Al_2O_3, SiO_2 and Fe_2O_3 in concrete. Further research is recommended to assess the role of CaO in Pozzolanic reactivity.

1. High slump values reveals that high water content is required to enable workability in PSA and GSA blended concrete. A 0.6 w/c ratio is recommended to maintain same level of workability as that expected for cement only concrete.
2. The compressive strength for 10% PSA and GSA blended cement concrete is lower than the control but at 28days 100% target strength was attained. The optimum level of PSA and GSA replacement is 20% which attained a strength of 24.27N/mm^2 (121.35% of design strength) and there are indications of continuous strength development. Therefore both 10% and 20% PSA/GSA blended cement concrete is recommended as suitable for use as a grade M20 concrete.
3. The continuous strength development with curing age indicates that 20% PSA/GSA blended cement concrete will attain strengths comparable to M25 grade concretes. It is therefore recommended that 20% PSA/GSA blended concrete be considered for use as an M25 grade concrete where late strength

attainment at 90 days or curing age is required. Further test and research is also recommended to confirm this assertion.

4. The results of 30% PSA/GSA blended cement concrete shows a strength of 17.91N/mm^2. This has a higher strength value than the target strength of an M15 grade concrete. It Is recommended that a 30% PSA/GSA blended cement concrete can be used for similar purposes as an M15 grade concrete is the cost benefit analysis of producing it is lower than an M15 grade concrete. Further research is also recommended to confirm this assertion.

REFERENCES

Olusola, K. O., and Umoh, A. A. (2012). Strength Characteristics of Periwinkle Shell Ash Blended Cement Concrete. *International Journal of Architecture, Engineering and Construction. Vol 1 No 4, 213-220*

Sonye, T., Ede, A. N., Bamigboye, G.O. and Olukanni, D.O. (2016). The Study of Periwinkle Shells as Fine and Coarse Aggregate in Concrete Works. *(CU-ICADI) International Confernce on African Development Issues, May 9-11 2016, Ota, Nigeria.*

Olutoge, F. A., Okeyinka, O.M. and Olaniyan, O.S. (2012). Assessment of the Suitabilty of Periwinkle Shell Ash (PSA) as Partial Replacement for Ordinary Portland Cement (OPC) in Concrete. *IJRRAS Vol 10 No 3, 428-434.*

Job, O. F., Barambu, Y.U., and Ishaya, A.A. (2017). Effects of Periwinkle Shell Ash on Water Permeability and Sorptivity Characteristics of Concrete Under Different Curing Conditions. *International Journal of Mordern Trends in Engineering and Research. Vol 4 No 11, 101-10*

Umoh, A. A., and Olusola, K.O. (2012). Compressive Strength and Static Modulus of Elasticity of Periwinkle Shell Ash Blended Cement Concrete. *International Journal of Sustainable Construction Engineering and Technology. Vol 3 No 4, 45-55.*

Lakshmi, N. V., and Sagar, P. S. (2017). Study on Partial Replacement of Groundnut Shell Ash with Cement. *Challenge Journal of Concrete Research Letters Vol 8 No 3, 84-90.*

Mahmoud, H., Belel, Z. A. and Nwakaire, C. (2012). Groundnut Shell Ash as a Partial Replacement of Cement in Sandcrete Blocks Production. *International Journal of Development and Sustainability. Vol 1 No 3, 1026-1032.*

Abedelatif, Y., Gaber, A., Fouda, A. and Alsoukarry, T. (2020). Evaluation of Calcium Oxide Nanoparticles from Industrial Waste on the Performance of Hardened Cement Paste: Physiochemical Study. *Processes, 8, 401; doi:10.3390/pr8040401, www.mdpi.com/journal/.processes*