Laboratory Study On The Compressive Strength Characteristics Of Concrete Containing Periwinkle Shell Ash Under Harsh Environmental Conditions

Oke O. L., Aluko O. G., Akinkurolere O. O.
Department of Civil Engineering,
Ekiti-State University
Ado-Ekiti, Ekiti-State, Nigeria
*[a] seyioke@hotmail.com [a]aatobi2002@yahoo.com, ,

Awolusi T. F.
Department of Civil Engineering,
Landmark University
Omu- Aran, Kwara-State, Nigeria
temitopeawolusi06@gmail.com

Abstract*-Before any unconventional construction material could be fully integrated as an alternative to the conventional one, it is required that such should meet the minimum standards set for the industry. This facilitates provision of economical structures without compromising safety, functionality, aesthetics and constructability requirements. One of such unconventional materials is concrete containing periwinkle shell ash as part replacement for cement. Previous works on this material have recommended it for use as an alternative to the conventional material i.e. normal concrete, without ascertaining its performance under harsh environmental conditions they would normally be subjected to in service. To this end, an investigation was initiated to fill this identified gap in knowledge. Periwinkle shells were sourced from Igbokoda, Ondo State, cleaned and calcined in a kiln furnace at 1000^{0}C and sieved through BS sieve (75 microns) to fine ash. Preliminary tests comprising sieve analysis, setting time and fineness were conducted on the Periwinkle Shell Ash (PSA) and Ordinary Portland Cement (OPC) used in the study. Slump test was carried out on the fresh concrete produced. The study also examined the compressive strength of concrete containing PSA as part replacement for cement. The concrete was immersed in magnesium sulphate (with concentrations of 1000 ppm and 2000 ppm) and hydrochloric acid (with concentrations of 1000 ppm and 2000 ppm) solutions in order to examine the performance of the concrete under harsh environmental conditions. The cement replacement with the PSA was done at 0%, 10% and 20%. A total of 108 cubes were cast and 36 cubes were cured in water while others were immersed in magnesium sulphate and hydrochloric acid solutions. The crushing of the concrete cubes was carried out at 7 days, 14 days, 28 days and 56 days. The results showed that the slump decreased with increasing PSA content. The initial and final setting times increased with increasing proportion of PSA. The compressive strength of concrete specimens decreased as the percentage of PSA increased while the crushing strength increases as the age of curing increases for each of the percentage replacements. However, concrete with 10% replacement of cement with PSA compared well with concrete with 0% replacement of cement with PSA i.e. the control mix. Under acid attack, concrete containing PSA performed better than the control mix, while under magnesium sulphate attack, the control mix performed better than mixes containing PSA.

Keywords—Concrete, Periwinkle shell ash, Setting Time, Harsh Environmental Conditions

I INTRODUCTION

Increase in the world's population has placed a great demand on existing facilities such as housing, transportation, waste disposal etc which either requires maintenance or construction of new ones to cater for this growth. The increasing construction cost for the provision of facilities for the comfort of the human race in both developed and developing countries has placed a constraint on the government of various countries as to which project to embark on per time. This has increased the interest of researchers all over the world at bringing down the cost of construction. One of these ways is the utilization of agro-waste in construction. It is observed that billions of tons of agricultural wastes are generated yearly across the globe with its majority being unutilized in the developing countries. A vivid example is the periwinkle shell. Periwinkle shell can be regarded as left over from consumption of the small greenish proteinous marine snail. The material has also been described by Badmus *et al.*[1] as a small marine snail with spiral cone, shaped shell having round opening and dual interior. It has been reported by Powell et al. [2]; Job [3]; Jamabo and Chinda [4]; Mmom and Arokoya [5] that periwinkle is massively harvested within communities in Rivers, Cross River, Lagos and Delta States, of Nigeria.

The full integration of this material into the construction industry either in its unrefined form as coarse aggregate or refined in form of ash to be used as part replacement for cement is still being studied by various researchers. The material in its ash form is referred to as a pozolana and is essentially silicious or aluminous in nature. This material possesses no cementitious properties in its finely divided form and in the presence of water, reacts with calcium hydroxide, liberated in the hydration process of cement to form compound having cementitious properties. Other pozzolanic materials of agricultural origin that have been investigated by researchers like Sumaila and Job [6]; Zhang and Malhotra [7]; Adesanya [8]; etc include sawdust ash, rice husk ash, corn cob ash, palm oil fuel ash with recommendation in favor of these materials. Olutoge *et al.* [9] investigated periwinkle shell ash (PSA) as part replacement for Ordinary Portland Cement (OPC), with the percentage of replacement varied from 0% to 25% and concluded that the material contains all the main chemical constituents of cement though in lower percentage compared with that of OPC which means it will serve as a suitable replacement if the right percentage is used. The use of PSA will not only produce an economical concrete as the quantity of cement required for construction is reduced, it will also provide a platform in which heap of accumulated periwinkle shell can be reused thereby reducing environmental pollution.

Concrete can be exposed to harsh environmental conditions in form of acid attack on purpose or accidentally. These acids include sulphate, hydrochloric acid, etc. Sulphate attack is the most common occurrence in natural or industrial situation. Solid sulphates do not attack the concrete severely but when in solution, they find entry into porous concrete and react with the hydrated cement products. Of all the sulphates, magnesium sulphate causes maximum damage to concrete. A characteristic whitish appearance is an indication of sulphate attack. Shetty [10] has reported that the incorporation of or replacing a part of cement by a pozzolanic material reduces the sulphate attacks. It will be worthwhile therefore to investigate the performance of PSA in concrete subjected to magnesium sulphate and hydrochloric acid at 28 and 56 days as it will further provide acceptability of PSA in construction. The research is designed to investigate the compressive strength of concrete produced using PSA as part replacement for cement under harsh environmental conditions.

II MATERIALS AND METHODOLOGY

A. Materials

The Dangote brand of Ordinary Portland Cement obtained from a cement shop in Ado-Ekiti was used. The cement conformed to BS 12: 1978 for Portland cement. The periwinkle shell used to produce PSA was obtained from Igbokoda, Ondo State. Remnants and dirt were washed away from periwinkle shell and sun dried before ashing in a kiln furnace at a temperature of 1000^{o}C, to produce ash powder passing through BS sieve 600µm. This was done at the Glass and Ceramics laboratory of the Federal Polytechnic Ado-Ekiti, Nigeria. The specific gravity of the ash produced was determined as well as the fineness using Blaine air-permeability method. The fine aggregate used was sharp sand passing through sieve size 4.75mm; while the coarse aggregate used was crushed granite of maximum size 20mm collected from a construction site within the Ekiti State University. Water used for mixing and curing was potable water suitable for domestic purpose as available in the laboratory. Also, the chemicals i.e. magnesium sulphate and hydrochloric acid used for curing was obtained from a chemical shop in Ado-Ekiti.

B Proportioning, Mixing of Constituents and Specimen Preparation

The batching of the concrete was done by weight for mix 1: 2: 4; 1 part by weight of cementitous material (cement and periwinkle shell ash) 2 parts by weight of fine aggregate (sharp sand) and 4 parts by weight of coarse aggregate (granite) for concrete with a design strength of 20N/mm^2 and a constant water cement ratio of 0.45. The percentage of cement replaced with PSA was varied at 0%, 10% and 20% respectively. The mixing process was carried out manually. The materials were laid in uniform layers, one on the other in the order–coarse aggregate, fine aggregate and cementitious material. Dry mixing was done manually to obtain a uniform colour by using shovel as presented in Figure 1. The required quantity of water was added gradually until a thorough mix was obtained. The slump, initial and final setting times for the freshly mixed concrete were determined. The concrete was filled into already clean and oiled 150mm by 150mm by 150mm steel moulds in approximately 50mm layers with each layer given 30 strokes of the tamping rod. The concrete specimen was stored under damp sacks for 24hours in the laboratory before de-moulding. All specimens were prepared in triplicate and a total of 108 cubes were cast.

Fig. 1. A mixture of the constituent of the concrete

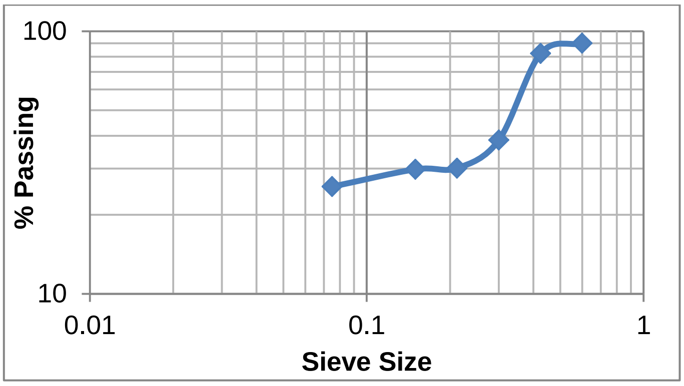

Fig. 2. Sieve Analysis for Periwinkle shell ash

C Curing and crushing

The de-moulded cubes were transferred into the three curing media considered in the study namely; water, magnesium sulphate (with concentrations of 1000 ppm and 2000 ppm) and hydrochloric acid (with concentrations of 1000 ppm and 2000 ppm) solutions. The cubes remained in their curing media for 7 days, 14 days, 28 days and 56 days as applicable until the crushing loads were determined. The values obtained were used to calculate the compressive strength.

III RESULTS AND DISCUSSION

A. Chemical and Physical Properties of Materials

The specific gravity of the material was determined to be 2.12. This agrees with Olusola and Umoh [11] who reported a specific gravity of 2.13. The result has shown that cement is weightier than PSA and as such more quantity of PSA will be required when used to replace cement. The result for the sieve analysis of PSA (Figure 2) shows the percentage passing through the various sieve sizes. Both results are similar to what was obtained by Olutoge et al. [9]. From the fineness test it was observed that over ninety percent (90%) of the PSA passed through BS sieve size 75 microns, and would thus provide a greater surface area for hydration. Habeeb and Mahmud ([12] in their study on rice husk ash (RHA) as pozzolanic material observed that reactivity is increased with increase in fineness.

B Determination of Initial and Final Setting Time

The initial and final setting time for PSA was observed to be more when compared with cement as shown in Table 3. This implies that PSA takes more time in setting, which has the advantage of eliminating false setting when used in concrete. The result agrees with Olutoge *et al.* [9] who observed that the initial and final setting time decreased with increase in PSA content.

TABLE 3. INITIAL AND FINAL SETTING TIMES OF PSA AND CEMENT

Mass (400 g)	Water/cement ratio of standard consistency (%)	Depth of penetration of initial setting time attachment (mm)	Depth of penetration of final setting time attachment (mm)	Initial setting time (minutes)	Final setting time(minutes)
PSA	30	45	43	97	206
Cement	28	44	41	100	209

C Slump Test

The slump values obtained for the various levels of cement replacement with PSA i.e.0%, 10% and 20%, were 26.5cm, 25.0 cm and 15.0cm respectively. From this result, it was observed that the slump decreased with increase in PSA content although the difference between 0% and 10% was just 1.5cm. This is in line with the report of Olusola and Umoh [11] slump values who recorded values ranging between 29 and 25 cm for PSA content varied from 0% - 40%.

D Compressive Strength Test

The concrete specimens cured in water were tested for compressive strength (BS EN 12390-3:2009) at ages 7, 14, 28days, while those immersed in magnesium sulphate (with concentrations of 1000 ppm and 2000 ppm) and hydrochloric acid (with concentrations of 1000 ppm and 2000 ppm) solutions were tested at ages 28 and 56 days. Three replicates of 150mm cubes were tested at each age for compressive strength and the mean values computed as shown in Tables 4, 5 and 6.

TABLE 4. COMPRESSIVE STRENGTH FOR CUBES CURED IN WATER

Curing Age (days)	PSA (%)	Compressive strength (N/mm^2)				Attainment of design strength (%)
		Sample 1	Sample 2	Sample 3	Mean ± SD	
7	0	16.67	16.22	15.56	16.15±0.46	80.75
	10	14.67	14.18	13.69	14.18±0.40	70.90
	20	11.96	11.56	10.89	11.47±0.44	57.35
14	0	18.00	17.78	16.89	17.56±0.48	87.80
	10	17.78	17.56	16.89	17.41±0.38	87.05
	20	13.33	12.67	12	12.67±0.54	63.35
28	0	20.67	20	18.87	19.78±0.75	98.90
	10	20.22	19.11	19.78	19.70±0.46	98.50
	20	15.11	14.22	12.58	13.97±1.05	69.85

It was observed from Table 4 that the compressive strength generally increased with curing age and decreased with increase in the content of periwinkle shell ash. The result at 7 days showed that in all the replacement levels, the attainment of the design strength ranged between 57.35%.and 80.75% These values satisfied the requirement of normal concrete strength development which is stipulated to be between 50-66% [13],[14].

The compressive strength at 14 and 28days followed similar trend as the design strength was observed to have varied between 63.35% and 87.80% and 69.85 and 98.90% respectively. Meanwhile it is noteworthy that the design strengths attained at 0% and 10% replacement levels for both test ages were very close with a difference of 0.75% and 0.4% respectively. The strength development at 14 days satisfied the 60-75% of the design strength stipulated by Illston [14]. At 28 days, none of the cubes met the design strength of 20 N/mm.^{2} However a strength of 19.78N/mm^2 was obtained at 0% replacement level. This may be attributed to inadequate compaction resulting from the number of blows received (30 blows per layer). This is however contrary to the finding of Olutoge *et al.* [9] who reported compressive strength of 24.11N/mm^{2}at 0% replacement with 36 blows per layer.

The statistical analysis using ANOVA at 5% significant level shows that PSA had no significant effects on the compressive strength of the concrete, while curing age had significant effects on the compressive strength of the concrete. When considered collectively i.e. PSA content and curing age, they both had no significant effects on the strength of the concrete judging by the p-values obtained from ANOVA. Tables 4a-4c show the statistical analysis.

TABLE 4A. ANOVA 1

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Sample 1,2,3	143.5779	8	17.94723	0.418249	0.898603	2.355081
%PSA	97.5573	3	32.5191	0.757838	0.52874	3.008787
Error	1029.848	24	42.91035			
Total	1270.984	35				

TABLE 4B. ANOVA 2

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Sample 1,2,3	517.9334	8	64.74168	4.026044	0.003745	2.355081
Days 7,14,28	8.428411	3	2.80947	0.174711	0.912456	3.008787
Error	385.9372	24	16.08072			
Total	912.2991	35				

TABLE 4c. ANOVA 3

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample1,2,3	381.1423	8	47.64278	1.03131	0.433573	2.244396
%PSA and ages	110.9725	4	27.74313	0.600548	0.664951	2.668437
Error	1478.284	32	46.19637			
Total	1970.399	44				

From Table 5, it was observed that at 28 days the compressive strength for 0% and 20% PSA content reduced with increase in the concentration of magnesium sulphate (1000ppm-2000ppm) and for 10% PSA content a slight increase in strength was noticed. At 56 days the compressive strength for 0% and 10% PSA content reduced with increase in the concentration of magnesium sulphate (1000ppm-2000ppm) and for 20% PSA content a slight increase in strength was observed.

The statistical analysis of compressive strength using analysis of variance (ANOVA) (P<0.05) presented in Table 5a indicated that the independent factors (i.e. PSA content, concentration of sulphate and curing age), when collectively considered had no significant effects on the strength of the concrete judging by the p-values obtained. From Table 6, the results showed that at 28 days the compressive strength for 0% and 10% PSA content reduced with increase in the concentration of hydrochloric acid (1000ppm-2000ppm) and for 20% PSA content a slight increase in strength was noticed. At 56 days, the compressive strength for 0% PSA content reduced with increase in the concentration of hydrochloric acid (1000ppm-2000ppm) while for 10% and 20% PSA content an increase in strength was observed.
The results at 28 and 56 days have shown that concrete containing pozzolanic materials have better resistance to acid attack when compared with the conventional concrete. This could be attributed to the presence of the pozzolanic materials (PSA) which contains mainly silicious aggregates. They provide better resistances to acid attack than calcareous aggregate [10]. However, the ANOVA results in Table 6a showed that PSA content, concentration of acid and curing age, when collectively considered had no significant effects on the strength of the concrete judging by the p-values obtained.

TABLE 5. COMPRESSIVE STRENGTH FOR CUBES IMMERSED IN MAGNESIUM SULPHATE

Days	Sulphate concentration in parts per million (ppm)	%PSA	Sample 1	Sample 2	Sample 3	Mean
28	1000	0	11.16	8.55	6.84	8.85±1.78
		10	9.52	8.54	7.40	8.49±1.73
		20	12.12	9.00	7.02	9.38±2.10
	2000	0	4.28	5.11	3.27	4.22±0.75
		10	7.91	7.62	10.44	8.66±1,27
		20	8.12	8.6	6.32	7.01±1.19
56	1000	0	9.55	14.56	12.9	12.34±2.08
		10	8.76	11.8	7.24	9.27±1.90
		20	8.16	8.84	7.72	8.24±0.46
	2000	0	2.64	2.12	4.33	3.03±0.94
		10	6.6	4.03	4.86	5.16±1.07
		20	8.04	10.26	8.09	8.80±1.03

TABLE 5a. ANOVA 4

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample 1,2,3	491176	11	44652.36	0.977562	0.477478	1.967547
Age, %PSA, Concentration	22060021	5	4412004	96.59079	5.77E-26	2.382823
Error	2512250	55	45677.28			
Total	25063447	71				

TABLE 6. COMPRESSIVE STRENGTH FOR CUBES IMMERSED IN HYDROCHLORIC ACID

Days	Acid concentration in pack per million (ppm)	%PSA	Sample 1	Sample 2	Sample 3	Mean
28	1000	0	9.70	6.89	6.27	7.62±1.50
		10	10.58	9.63	9.08	9.76±0.62
		20	5.72	7.80	4.51	6.01±1.36
	2000	0	3.92	4.20	6.84	4.99±1.32
		10	9.33	8.38	6.86	8.19±1.02
		20	7.95	6.93	5.98	6.95±0.80
56	1000	0	4.64	11.84	10.35	8.94±3.10
		10	7.13	9.15	9.88	8.72±1.16
		20	7.31	8.94	7.52	7.92±0.72
	2000	0	4.41	3.69	3.10	3.73±0.54
		10	10.03	8.68	8.06	8.92±1.14
		20	10.26	8.11	10.09	9.49±0.98

TABLE 6a. ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample 1,2,3	497339.1	11	45212.65	0.992301	0.464902	1.967547
Age, %PSA, Concentration	22064377	5	4412875	96.8512	5.4E-26	2.382823
Error	2505990	55	45563.46			
Total	25067706	71				

IV CONCLUSIONS

From the results of the various tests performed, the following conclusions were drawn:

1. The values of slump decreased as the PSA content increased. This implies that concrete containing PSA will require more water for mixing.
2. The compressive strength of 10% PSA replacement compared well with 0% replacement at 28days for concrete cured in water.
3. Curing age is a significant factor that affects the compressive strengths of concrete containing PSA.
4. Concrete containing pozzolanic materials have better resistance to acid attack when compared with the conventional concrete.

REFERENCES

[1] Badmus, M. A. O., Audu, T. O. K., and Anyata, B. U. (2007). “Removal of lead ion from industrial wastewaters by activated carbon prepared from periwinkle shell (typanotonus fuscatus).” Turkish Journal of Engineering and Environmental Science, 31, 251–263.

[2] Powell, C. B., Hart, A. I., and Deekae, S. (1985). “Market survey of the periwinkle tympanotonus fascatus in rivers state: Sizes, prices, trade routes and exploitation levels.” Proceedings of the 4th Annual Conference of the Fisheries Society of Nigeria (FISON), Port-Harcourt, Nigeria.

[3] Job, O. F. (2008). The Durability Characteristics of Periwinkle Shell Concrete. Ph.D thesis, University of Jos, Nigeria University of Jos, Nigeria.

[4] Jamabo, N. and Chinda, A. (2010). “Aspects of the ecology of tympanotonous fuscatus var fuscatus (linnaeus,1758) in the mangrove swamps of the Upper Bonny River, Niger Delta, Nigeria.” Current Research Journal of Biological Sciences, 2(1), 42–47.

[5] Mmom, P. C. and Arokoya, S. B. (2010). “Mangrove forest depletion, biodiversity loss and traditional resources management practices in the Niger Delta, Nigeria.” Research Journal of Applied Sciences, Engineering and Technology, 2(1), 28–34.

[6] Sumaila, S. A. and Job, O. F. (1999). “Properties of SDA-OPC concrete: A preliminary assessment.” Journal of Environmental Sciences, 3(1-2), 155–159.

[7] Zhang, M. H. and Malhotra, M. H. (1996). “High performance concrete incorporating rice husk ash as a supplementary cementing material.” ACI Materials Journal, 93(6), 629–636.

[8] Adesanya, D. A. . (2001). “The effects of thermal conductivity and chemical attack on corn cob ash blended cement.” Professional Builder, 66(5), 3–10.

[9] Olutoge F. A., Okeyinka O. M.and Olatunji S. O. (2012) “Assessment of the Suitability of Periwinkle Shell Ash (PSA) as Partial Replacement For Ordinary Portland Cement (OPC) in Concrete” IJRRAS Journal, 10(3).

[10] Shetty M. S. (2004). “Concrete Technology” S. Chand and company Ltd, Ram Nagar, New Deihi

[11] Olusola K. O. and Umoh A. A. (2004).” Strength Characteristics of Periwinkle Shell Ash Blended Cement Concrete” International Journal of Architecture, Engineering and Construction 1(4), pp. 213-220.

[12] Habeeb, G. A. and Mahmud, H. B. (2010). ‘Study on Properties of Rice Husk Ash and Its Use as cement Replacement Material’. Materials Research, 13(2), 185-190

[13] British Standard Institution (1985). Structural Use of Concrete Part 2: Code of Practice for Special Circumstances.. British Standard Institution, London, United Kingdom.

[14] Illston, J. M. (1994). Construction Materials: Their Nature and Behaviour. Chapman and Hall, London, United Kingdom.