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Comparative analysis of the strength of periwinkle shell ash concrete and periwinkle shell dust concrete

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Abstract
The constant demand for building material such as concrete as increase significantly due to the increasing global population. However, to meet up with this demand several innovations in terms of different materials have been researched upon. One of such is the use of agro-waste as partially replacement for cement in concrete. The research compares two variations of such agro-waste material: Periwinkle shell. The Periwinkle shell ash (PSA) was obtained from the burning of the periwinkle shell at 600^0c in a closed system while the Periwinkle shell dust(PSD) was obtained from the process of grounding dried periwinkle shell to powdery form. The percentage replacement used were 5%, 10% and 20% for strength grade of $20N/mm^2$, $25N/mm^2$, $30N/mm^2$ and $40N/mm^2$. It is observed that when cement was replacement with 10% PSA, the maximum strength was achieved, while 5% replacement gave PSD its maximum compressive concrete strength. The test for physical properties, it was realized that at 20% PSD replacement the consistency of the paste failed and was attributed to the presence of organic matter and high free-lime CaO content. The pore of the concrete increased with increase in percentage replacement for both materials which lead to weakness in the adhesive strength of the composite materials and reduce compressive strength for both sets of concrete.

Keywords: Periwinkle shell ash (PSA), periwinkle shell dust (PSD), compressive strength, scanning electron microscopic (SEM)

Introduction

Concrete as a composite material combines different constituents, such as cement, coarse aggregate, fine aggregate etc. the addition of other material in order to alter or improve it properties has been a subject of immense research. These properties include strength, durability, resilience to certain chemical attacks, weathering and for special purposes. To achieve the stated properties both natural and artificial pozzolana has been used. However, for sustainability and reusability, agricultural wastes products like rice husk, groundnut shell, sawdust, palm kernel nut, periwinkle shell etc is being used than ever before.

In heterogeneous materials like concrete, the structure, quality of the constituent and proportions in which they are mixed determine the strength and properties of the resulting products. A good knowledge of the properties of cement, aggregates and water is required in understanding the behaviour of concrete.

Periwinkle a marine mollusks (gastropods) with thick shells is the source of periwinkle shell. As they grow, gastropod shells follow a mathematically regular pattern and when it increases in size still retains its original form. The resulting shell becomes a strong compact home for the mollusk inside (Amaziah *et al*, 2013) [3]. They are common in North America and European shores and are widely distributed in their littoral drifts and sand banks. The major species available in the lagoon and mudflats of Nigeria's Niger Delta, between Calabar in the east and Badagry in the west, are Tympanostomus species and Pachmellania species (Dahunsi, 2002) [7].

Periwinkle shell was used by (Olarunge and Olabisi, 2003) [12] as partial alternative to coarse aggregate in light weight concrete, (Koffi, 2008) [11] determined compressive strength of concrete incorporating periwinkle shell ash, to assess the suitability of periwinkle shell ash as partial replacement for ordinary Portland cement in concrete and (Ibearugbulem, et.al 2014) [9] analyzed the stress of stick reinforced granite-periwinkle concrete slab under uniformly distributed load.

Materials and Methods

The main materials used for the experiment were sourced from different locations and each of them were tested to conform to the required code of practice. Below are the lists of materials namely:

Ordinary Portland cement (OPC), Periwinkle Shell (ash and dust), Fine Aggregate, Coarse Aggregate and Water.

Cement

The Dangote brand of Ordinary Portland cement with strength class of 42.5R was used as the binder and obtained from a local dealer in Samaru Zaria. Both physical and chemical properties test were carried out on the Cement in accordance with BS 4550: Part1

Periwinkle Shell

The periwinkle shell was obtained from mammy market Ikeja Military cantonment in Lagos state. The shells were dried first and transported to zaria where some part of it was subjected to close burning (calcinations) at 600^0C to obtain the Periwinkle shell ash (PSA) and the other part was grounded in a local rice mill to obtain the Periwinkle shell dust

Plate 1: Periwinkle Shell

Periwinkle Shell Dust (PSD)

To obtain periwinkle shell dust the dry shells of the periwinkle was grinded using the automatic poultry feed grinding machine. The following tests were conducted on the ash and dust: particle size distribution, specific gravity and X-ray Diffraction Analysis (XRD). The particle size distribution of the periwinkle shell dust was determined using sieve analysis

Periwinkle Shell Ash (PSA)

Periwinkle shell ash was obtained from the calcination of the dry periwinkle shell to a temperature of 600^0C and then grinded to obtain smooth surface texture.

Plate 2: Periwinkle shell dust (PSD)

Plate 3: Periwinkle shell ash (PSA) Aggregate

The fine aggregate (sand) and the coarse aggregate were obtained from a block industry in Zaria. The tests carried out includes, particle size distribution analysis, specific gravity and bulk density.

Methods

All the experiments conducted on the materials, the test specimens (Concrete cubes) and also the analysis on the concrete cubes are presented in this chapter. The test involves the preliminary and major tests on the constituent materials (cement, Periwinkle shell ash, Periwinkle shell dust and aggregates) and the test specimens. All the tests were carried out in the department of Civil Engineering, Ahmadu Bello University, Zaria with the exception of X-ray fluorescence analysis carried out in Chemistry Department and Scan Electron Microscopy (SEM) test conducted in Chemical Engineering Department all in ABU Zaria.

Cement Specific Gravity

This is one of the fundamental characteristics of the material and is defined by the mass of a unit volume of material substance, expressed as grams per cubic centimeter (g/cm^3). The test is in accordance with BS 4550: Part 3 (1978) using the density bottle (Pycnometer method).

Consistency Test for cement

The basic aim of this test is to find out the water content required to produce a cement paste mix with different percentages of PSD and PSA. The tests were carried out in accordance with BS 4550: Part 3(1978) using a vicat apparatus with plunger. Standard consistence of cement is specified by resistance to penetration by standard plunger defined as that consistency which will permit the vicat plunger to penetrate to a point 5 to 7mm from the bottom of vicat mould.

Setting Time of OPC

This test is used to characterize the cementing material. The test comprises of the initial setting time which is important for (transportation, placing and compaction) and final setting time determines the hardening of the cement paste. The test was conducted in accordance with BS 4450: Part 3(1978) using Vicat apparatus with steel needle.

Soundness Test

The test is use to determine the expansion of cement paste and it reveals the ability of hardened concrete to retain its volume after setting. The test was conducted in accordance with BS 4550: Part 3 (1978).

Table 1: Summary of Physical Properties of Cement

Physical Property	Results Obtained
Normal Consistency (%)	31.5
Initial Setting time (min)	108
Final Setting time (min)	168
Specific gravity	3.34
Soundness (mm)	0

Chemical Properties of PSD

The X-Ray Diffraction Analysis was conducted at the Department of Chemistry using 1g of periwinkle shell dust to determine the oxide composition of the samples and they were labelled sample X and Y respectively. The rationale behind conducting XRD analysis was to determine if calcination temperature will have any effect on the elemental composition of the Periwinkle shell as dust or ash especially its silica content.

Table 2: Chemical Analysis of PSD

Element	Na_2O	MgO	Al_2O_3	SiO_2	P2O5	K_2O	CaO	TiO_2	Fe_2O_3	Others	
PSD (Wt%)	1.31	2.78	20.08	16.50	0.58	1.02	50.20	0.02	6.79	-	
PSA (Wt%)	2.45		2.48	18.93	49.98	2.58	1.33	14.99	0.68	6.34	19.17

Table 3: Physical Properties of PSD and PSA

S/No	Physical Properties	PSD	PSA
1	Colour	Light gray	White
2	Specific gravity	1.21	2.46
3	Fine Modulus	2.82	2.62

Results and Analysis

Table 4: Consistency of OPC partially replaced with PSD and PSA

Percentage Replacement	PSD Consistency (%)	PSA Consistency (%)
5%	33.5	37
10%	35.5	42.5
20%	38.5	48.5

Table 5: Setting time of OPC replaced with PSD and PSA

Sample	Final setting time(mins)	Initial setting time(mins)
PSD (5%)	238	414
PSD(10%)	244	422
PSD(20%)	255	439
PSA (5%)	162	304
PSA (10%)	190	346
PSA (20%)	203	362

Table 6: Soundness of OPC Partially Replaced with PSD and PSA

Sample	Initial Measurement (mm)	Final Measurement (mm)	Expansion (mm)
PSD 5%	5	5	0
PSD 10%	5	7	2
PSD 20%	5	8	3
PSA 5%	5	5	0
PSA 10%	5	6	1
PSA 20%	5	8	3

Table 7: Mix Ratio of Concrete Cubes for Different grades of Concrete

Grade N/mm^2	Water/cement	Cement	Fine Aggregate	Coarse Aggregate
20	0.56	1	2	4
25	0.49	1	1.5	2.7
30	0.44	1	1.3	2.5
40	0.36	1	1	2

Compressive Strength Test (N/mm^2)

The compressive strength test of the hardened concrete was determined after the required curing days of 7, 14, 21 and 28days using the Compressive testing machine (Denison) at the concrete laboratory of Ahmadu Bello University Zaria in accordance with BS 1881: Part 116 (1983).

Table 8: Compressive Strength of OPC Concrete

Sample	Grade	%	Strength (N/mm^2)			
			7 Days	14 Days	21 Days	28 Days
Control	20	0	18.3	21.8	25.9	29.03
	25	0	19.4	22.8	27.1	29.2
	30	0	22.8	26.7	30.9	36.3
	40	0	28.7	34.5	40.6	44.4

Table 8 shows the compressive strength of OPC at different grades and different curing days. For grade 20, the 7days strength gained is 91.5% of the compressive strength and 64.2% of the mean target strength while the 28days strength is 145% of the compressive strength and 101.9% of the mean target strength indicating a high rate of hydration, these are compatible with (Dahunsi and Bamisaye 2012) but lower than (Koffi 2008) [11]. For grade 25, the 7 days attained up to 77% of the compressive strength and 57.9% of the target mean strength indicating that the higher the grade of concrete the lesser the rate of strength gained. This is attributed to the high cement content required to achieve higher grade concrete, which tends to slow down the rate of hydration.

Table 9: Compressive Strength of Concrete PSD Replacement

Sample	Grade	Percentage Replacement	Compressive Strength N/mm^2 (Days)			
			7	14	21	28
PSD	20	5	14.7	19.4	22.5	23.7
		10	13.9	16.7	18.1	20.1
		20	10.7	12	12.7	15.4
	25	5	15.9	21.3	23.3	25.3
		10	13.5	14.9	18.9	21.9
		20	12.2	14.4	16.4	18.9
	30	5	17.7	21.6	25.5	28.3
		10	14.2	17.0	19.6	23.7
		20	12.3	13.9	18.1	21.3
	40	5	18.1	22.8	29.0	33.6
		10	18.1	20.1	24	30.1
		20	12.9	18.4	24.6	27.3

Table 10: Compressive strength of concrete with PSA replacement

Sample	Grade	Percentage Replacement	Compressive Strength N/mm^2 (Days)			
			7	14	21	28
PSA	20	5	15.4	21.3	23.3	25.2
		10	15.1	16.3	18.8	20.6
		20	14.2	15.7	17.3	19.0
	25	5	16.1	21.8	23.9	26.5
		10	15.9	18.4	22.1	24
		20	14.4	17.8	20.9	22.4
	30	5	20.7	26.7	30.1	32.6
		10	16.3	18.5	22.8	27.7
		20	15.7	17.2	21.9	23.9
	40	5	28.4	32.1	34.7	39.4
		10	25.3	26.8	32.4	36.7
		20	22.2	23.9	28	31.4

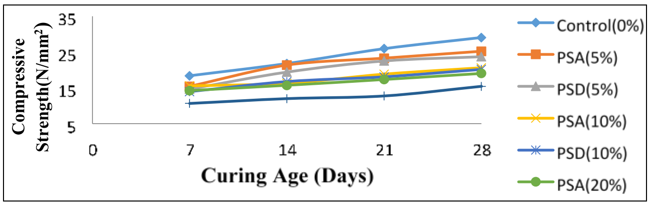

Fig 1: Compressive Strength of Concrete partially replaced with PSA and PSD Grade 20

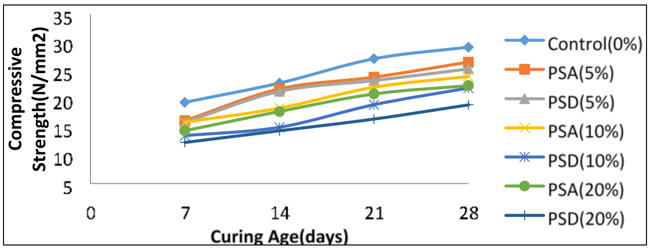

Fig 2: Compressive Strength of Concrete partially replaced with PSA and PSD OPC grade 25

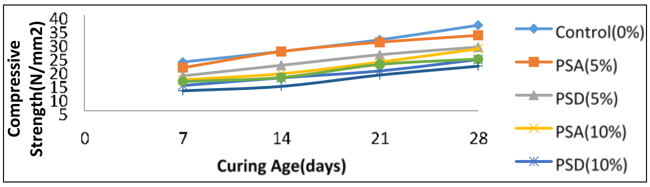

Fig 3: Compressive Strength of Concrete partially replaced with PSA and PSD grade 30

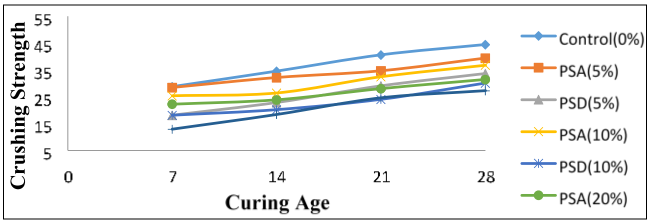

Fig 4: Compressive Strength of Concrete partially replaced with PSA and PSD grade 40

The table 9 represents the compressive strength of OPC partially replaced with PSD. For grade 20, PSD concrete at 5% replacement has strength of 23.7N/mm^2 at 28days curing. When this strength was compared to strength of OPC concrete at 28days, the strength of 5%PSD concrete was 81.64% of OPC concrete, at 10% PSD concrete the strength was 69.23% of OPC concrete and at 20% PSD replacement gave 53.05% of OPC concrete strength. Thus PSD concrete at 5% satisfied the 75% recommended by ASTM C618.

At grade 25, PSD concrete at 5% replacement had strength of 25.3N/mm^2 at 28days curing, when compared to OPC concrete it represent 86.34% of the concrete strength. At 10% replacement PSD strength when compared to OPC concrete gave 74.74% while 20% replacement of PSD represents 64.51%, OPC strength at grade 25 after 28days was 29.3N/mm^2. From the analysis it shows that 5% and 10% replacement conforms to ASTM C618 recommendation.

Grade 30 PSD concrete followed similar trends as grade 20 with only 5% PSD concrete reaching the ASTM C618 recommendation at 77.96% of the OPC concrete strength. 10% and 20% PSD concrete had strength of 65.29% and 58.68% of the OPC concrete respectively.

There was a reduction in strength also in grade 40 as the percentage replacement increases. In comparism with the OPC concrete, the 5% PSD replacement had strength of 33.6N/mm^2 for 28days curing which represents 75.68% of OPC strength grade 40. While 10% and 20% PSD replacement represents 67.79% and 61.49% respectively when compared with OPC concrete, thus only 5% replacement of PSD conforms with ASTM C618.

Table 10 represent the compressive strength of OPC partially replaced with PSA which shows a higher value of strength when compared with the strength of OPC partially replaced with PSD and is due to the presence of silica and alumina high surface area of PSA thus leading to more and quicker hydration of the concrete sample.

PSA at grade 20 the strength gained by 5%PSA replacement represented 86.81% strength of the OPC concrete at 28days curing, while 10%PSA and 20%PSA concrete represent 70.96% and 65.45% of OPC concrete strength respectively. From the observation, only 5%PSA replacement conforms to the 75% recommended by ASTM C618.

At grade 25 the strength of 5%PSA concrete represented 90.75% of the OPC concrete without replacement. At

10%PSA concrete the strength gain is 82.19% of the OPC concrete while 20% PSA concrete had strength 76.71% of OPC concrete at grade 25. The partial replacement of periwinkle shell ash at grade 25 satisfied the recommendation by ASTM C618

PSA concrete at grade 30 was also used to replace OPC and from the strengths obtained 5%PSA replacement gave 89.81% strength compared with OPC concrete, 10% PSA replacement was 76.31% and finally 20%PSA replacement was 65.84% strength of OPC concrete. 5% and 10% satisfied the 75% recommendation in ASTM C618, while 20% replacement was less than the recommended value.

In strength comparism of PSA concrete with OPC for grade 40, followed similar trends has was noticed. Where the drop in strength progressed gradually with percentage increment in replacement. 5%PSA concrete gave a strength which is 88.74% that of OPC concrete, 10%PSA gave 82.66% and 20%PSA gave 70.72% strength to that of OPC. 5%PSA and 10%PSA satisfied the 75% recommendation in ASTM C618 for partial replacement of class F pozzolana, while 20%PSA was less than the recommended.

Scanning Electron Microscopy (SEM)

The cube considered were grade 25 at 0%, 5%, 10% and 20% of PSD and PSA for 28days curing period.

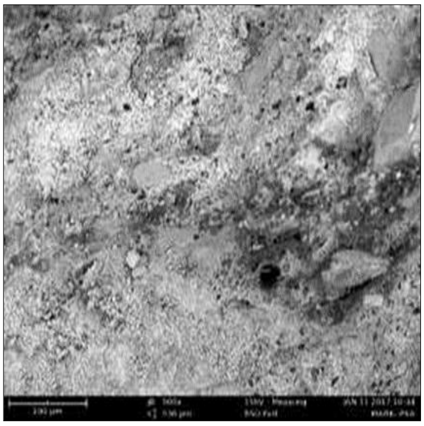

Plate 5: 5% PSA

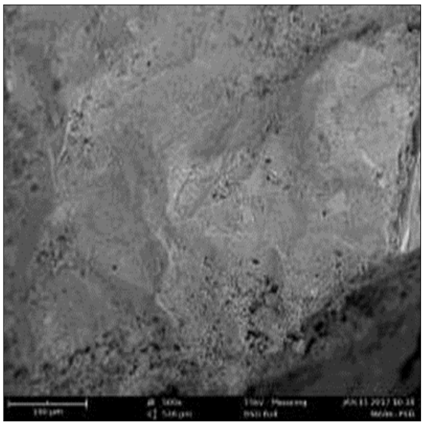

Plate 6: 5%PSD

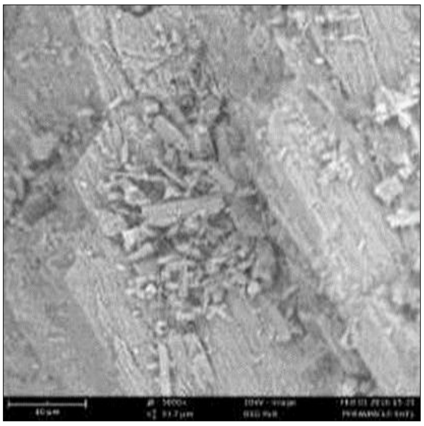

Plate 7: 10% PSA

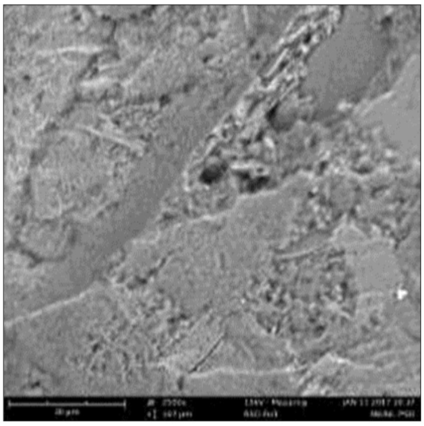

Plate 8: 10% PSD

Plate 4.6: SEM of 20% PSA Replacement

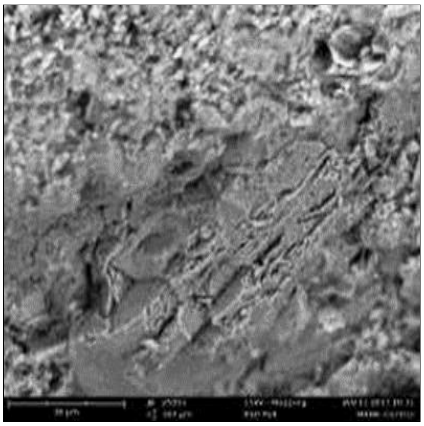

Plate 4.7: SEM of 20% PSD Replacement

From the observation of the transition zone in the above concretes, there are large crystals of Ettringite and CH with preferred orientation and porous structure. At 5% replacement the porosity of the PSA concrete was more than that of PSD. The SEM image in plate 5 which is for 10% PSD replacement show a gradual crack in the concrete with larger pores compared to plate 4 which is 10% PSA replacement. At

20% replacement of PSD, Calcium hydroxide was noticeable which agrees with Baker and Cory (1991). Very large pores was observed which is believed to reduce as calcinations temperature increases. In comparism the periwinkle shell ash (PSA) was subjected to high temperature generally exhibited smaller pore structure and better bonding than the periwinkle shell dust (PSD) which was not subjected to heat and contains high calcium oxide (lime).

Conclusion

The reduction in the compressive strength of PSD and PSA concrete samples can be attributed to the low percentage of Calcium Oxide in them. This oxide composition is one of the main constituent of cement and is mainly responsible for the strength development and conforms with Adeyemi *et al* (2013).

1. The temperature of burning of PSA has significant effect on the oxide composition of the periwinkle shell ash and this indicates the content of silica in the PSA constituent, while the periwinkle shell dust (PSD) that was not subjected to burning have less silica but more calcium oxide.
2. The presence of organic matter and high CaO (free-lime) in PSD contributed to its expansion and poor soundness in concrete at higher percentage replacement.
3. Strength gain by PSA concrete after 28days was much greater than PSD concrete within same period and condition.
4. The microstructure of PSA showed lesser pore space compared to PSD due to the PSA being subjected to high temperature to produce a more reactive substance.
5. As the concretes age with time, they gain significant strength that is higher than Ordinary Portland Cement concrete.

The replacement of Ordinary Portland Cement (OPC) with Periwinkle shell ash (PSA), is acceptable at a higher percentage replacement than replacement with Periwinkle shell dust (PSD) in concrete.

References

1. Agbede IO, Manaseh J. Suitability of Periwinkle Shell as Partial Replacement for River Gravel in Concrete, Leonardo Electronic Journal of Practices and Technologies, 2009, 5966.
2. Alabadan BA, Njoku CF, Yusuf MO. “The Potential of Groundnut shell Ash as concrete Admixture”. Agricultural Engineering International; The CIGR Ejournal,2006:111:1-8.
3. Amaziah Walter Otunyo, Idongesit Udo Friday, Theodore Alexander Israel. Exploratory Study of Crushed Periwinkle Shell as Partial Replacement for Fine Aggregates in Concrete. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS),2013:4(6):823-827. Scholarlink Research Institute Journals, (ISSN: 2141-7016)
4. Barker Alison P, Cory Howard P. “The Early Hydration of Limestone-Filled Cements,” Blended Cements in Construction, R. N. Swamy, Ed. Elsevier, 1991, 107-124.
5. British Standard Institution “Methods for Sampling and testing Mineral Aggregate”, BS 812
6. British Standard Institution, “Structural use of Concrete”, BS 8110, 1985.
7. Dahunsi BIO, Bamisaye JA. “Use of Periwinkle Shells Ash, (PSA) as a Partial, 2002.
8. Replacement for Cement in Concrete”. Paper presented at the annual conference of the Material Society of Nigeria, Akure, Nigeria.
9. Ibearugbulem OM, Ezeh JC, Inock EU, Obiekwe MC, Nwadike AN. “Stress Analysis of Stick Reinforced Granite- Periwinkle Concrete Slab under Uniformly Distributed Load” International Journal of Research in Engineering and Technology, 2014, 3.
10. Falade F. “An investigation on Periwinkle shells as Coarse Aggregates in Concrete.” Job F. O., Matawal, D. S. and Achuenu, E. (2009). The characteristics of periwinkle shell as an aggregate in concrete. Nigerian journal of construction technology and management,1995:10(1&2):96-101.
11. Koffi NE. Compressive Strength of Concrete Incorporating Periwinkle Shell Ash. Unpublised. BSc project, University of Uyo, Nigeria, 2008.
12. Olarunge GS, Olabisi OC. “Periwinkle \shell an alternative to coarse aggregate in Lightweight Concrete”, International Journal of Environmental,2003:1:231-236.
13. Olusola KO, Umoh AA. “Strength Characteristics of Periwinkle Shell Ash Blended Cement Concrete” International Journal of Architecture, Engineering and Construction, 2012, 1(4).
14. Olutoge FA, Okeyinka OO, Olaniyan OS. “Assessment of the suitability of periwinkle shell ash (PSA) as partial replacement for ordinary portland cement (OPC) in concrete”, 2012. www.arpapress.com/Volumes/Vol10Issue3/IJRRAS_10_3_08.