PERFORMANCE OF CONCRETE MADE USING PALM KERNEL SHELLS AS A PARTIAL REPLACEMENT FOR COARSE AGGREGATE

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ABSTRACT: *The high cost of conventional construction material is a dominating factor affecting housing system around the world. This has necessitated work into alternative materials in the construction industry. This study presents results of an investigation into the potentials of using Palm Kernel Shells (PKS) in concrete production as partial replacement for coarse aggregate. Concretes cubes were cast using two concrete mixtures (0.5 and 0.7 w/c ratio) with PKS used to replace the coarse aggregate content in the mixtures at a percentage of 0%, 10%, 20% and 30%. The compressive strength and porosity of the cast concrete cubes were evaluated at 7, 14 and 28 days. It was observed that the compressive strength decreases at a rate of 3.3 Nmm^{-2}, 3.6 Nmm^{-2} and 4.0 Nmm^{-2} at 28 days for 0.5 w/c mix and 3.1Nmm^{-2}, 2.9Nmm^{-2}, and 3.3Nmm^{-2}at 28days for 0.7w/c mix per unit percentage increase in PKS content. The following results were obtained for the porosity test at 28 days; 0.24, 0.28 and 0.39 for 0.5 w/c ratio and 0.15, 0.17 and 0.21 for 0.7 w/c ratio. It was observed that, while strength decreases, porosity increases per unit percentage increase in PKS content. The density of concrete cubes decreases as the curing age and PKS addition increases. It was concluded that PKS can be used to replace coarse aggregate up to 20% before drastic reduction in property become noticeable.*

Keywords: Palm kernel shell; Compressive strength; Coarse aggregate; Construction cost; Lightweight concrete.
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INTRODUCTION

Concrete is one of the building materials that can be delivered to the job site in the plastic state and can be moulded in-situ or precast to virtually any form or shape. Its basic constituents are cement, fine aggregate (sand), coarse aggregate (granite) and water [1, and 12]. Thus, the overall cost of concrete depends largely on the availability of the constituents materials [12, 10]. Alternative materials are however adopted for non-load bearing walls, non-structural and structural floors in buildings in a bid to reduce construction cost [4]. For some years now, Nigeria government has been clamouring for the use of local materials in the construction industry to reduce costs of construction. Additionally, the global recession coupled with the market inflationary trends, the constituent materials used for concrete production led to a very high cost of construction [1,2 and 3]. With the aforementioned issues, researchers in the materials science and engineering are committed to investigating local materials to partially or fully replace conventional concrete materials. Palm kernel shells (PKS) are available in large quantities in palm oil producing areas of South Western Nigeria [8]. These materials are underutilized and are usually abandoned as waste materials or used in small scale as fuel in furnaces and filling materials for potholes on roads. Furthermore, in most communities in Nigeria the aftermath of palm oil production leaves the environment littered with wastes such as palm kernel shells which causes development of slums.Thus, its large supply can be harnessed to reduce construction cost without undermining the strength and integrity of concrete structures. The cost of producing concrete using coarse aggregate is expensive but with percentage replacement of coarse aggregate with palm kernel shells, the cost of concrete production will drastically reduce and consequently the cost of construction works.For the purpose of this research, PKS are used as partial replacement for coarse aggregate in concrete mixture with the aim of producing concrete that has light weight but also with the objectives of reducing concrete construction cost.

MATERIALS AND METHODS

MATERIALS

Binders: Ordinary Portland cement (OPC) of the Dangote Brand was used. The cement is CEM I, 42.5N conforming to EN 197-1. It exhibited all the qualities of good cement by visual means, touch and hydration. Table 1 shows the chemical analysis on the cement.

TABLE 1: CHEMICAL COMPOSITION OF PORTLAND CEMENT

Constituent	Percentage by weight
Lime (CaO)	64.3
Silica (SiO_2)	22.1
Alumina (Al_2O_3)	5.9
Iron Oxide (Fe_2O_3)	3.6

Magnesia (MgO)	2.1
Sulphur Trioxide (SO_3)	2.4
N_2O	0.2
Loss of ignition	0.7
Lime saturation factor	0.9

Palm Kernel Shell: PKS were obtained from Idah in Kogi state, Nigeria. The PKS was thoroughly washed and sieved to remove debris before use. Table 2 gives the physical property of the PKS.

TABLE 2: PHYSICAL PROPERTIES OF PALM KERNEL SHELL

Property	**Value**
Bulk density (Mg/m^3)	0.8
Dry density (Mg/m^3)	0.6
Void ratio	0.5
Porosity (%)	34
Water content (%)	11
Water absorption (%)	17
Specific gravity	1.7
Impact value (%)	4.6

Aggregates: The fine aggregates used was sharp sand obtained from the river bank in Idah, Kogi state, Nigeria. The sharp sand was sun dried to control the moisture content during usage to conform to the requirement of BS882 (1982). The coarse aggregate used for this study are crushed aggregate of maximum size 19 mm, obtained from Ajaokuta in Kogi State, Nigeria.

METHODS

Preparation of Concrete Samples

Design mix for this study is based on trial and error method to produce concrete grade 20 for the control mixtures. The research has been conducted to replace the quantity of the coarse aggregate with PKS by volume as stated in Table 3.

TABLE 3: PROPORTION OF AGGREGATE IN MIX

Mix	Description	Number of sample			
A	Control mix (plain concrete) 100% coarse +100% fine + 0% PKS	3	3	3	2
B	90% coarse +100% fine + 10% PKS	3	3	3	2
C	80% coarse +100% fine + 20% PKS	3	3	3	2
D	70% coarse +100% fine + 30% PKS	3	3	3	2

Mixing of the concrete was carried out in a rotating drum mixer. All dry materials were added into the mixer in the following sequence of stone, cement, sand and PKS to get a homogenousmix while the drum mixer still rotates. The mixing water was added continuously over 1 minute. Afterwards, the concrete was allowed to mix for another 2 minutes to get a homogenous mix. Subsequently workability test were performed on the mix. The concrete mix was then cast into 150x150x150 mm cubes. After 24 hours in the laboratory under a plastic sheet, the samples were cured in water tank for up to 28 days. Compressive strength test was determined according to BS 1881: Part 116: 1983. Results were obtained on samples at 7, 14 and 28 days.

RESULTS AND DISCUSSION

Compressive Strength Results

Table 4 shows the average compressive strength in MPa obtained for the concrete cubes at 7, 14 and 28 days after casting for the 0.5 and 07 w/c concrete mixtures. Each value shown in this table represents the average of three individual concrete cube compression tests. The variability of the mass and strength results for individual concrete set for all the concrete types tested are suitably low. This signifies that the concrete samples were generally well prepared

TABLE 4: AVERAGE COMPRESSIVE STRENGTH TEST RESULTS OF THE CONCRETE

Percentage of PKS (%)	Average compressive strength (MPa)					
	0.5 w/c			0.7 w/c		
	7 days	14 days	28 days	7 days	14 days	28 days
0	20.7	22.7	25.3	19.3	20.7	22.3
10	13.3	15.3	17.3	12.9	13.3	16.7
20	12.8	14.5	16.6	11.3	12.7	13.3
30	10.7	12.9	13.3	10.1	11.3	12.6

The results in Table 4 are presented graphically in Figure 1, which show the relationship between compressive strength and curing age for each concrete type for the different percentage replacement considered. The figure also shows comparison of the strength gain for the concrete tested across mixture type as well as age.

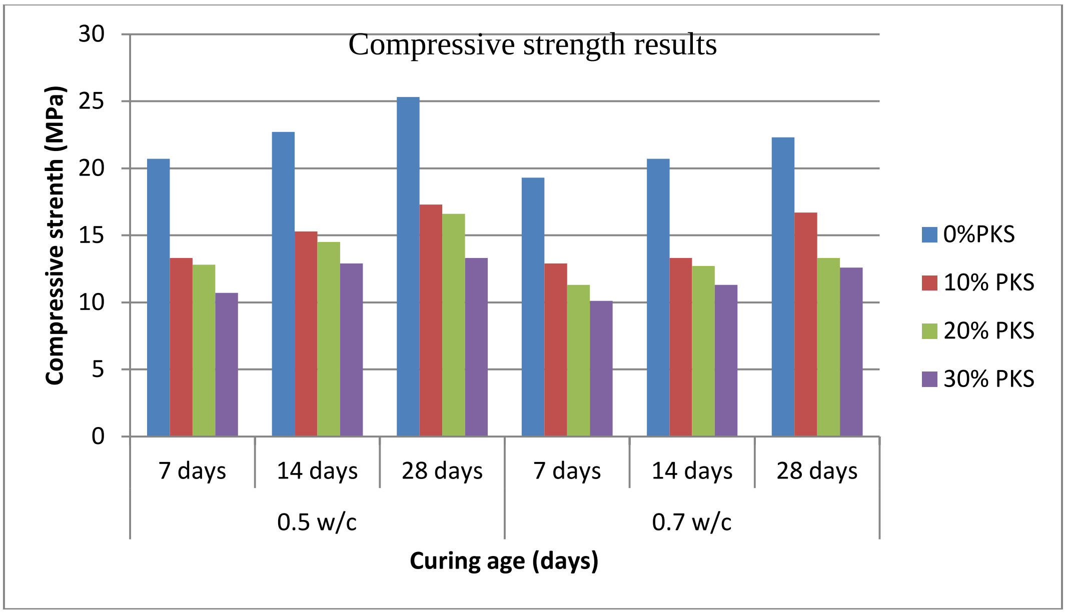

Figure 1: Compressive strength versus curing age

From the presented results, it is evident that quality control in terms of mixing, compaction and curing were carried out properly. However, the use of different percentage replacement of PKS in concrete, influenced strength developmentwithdecreasing w/b ratio and age resulting in improved strength. From the compressive strength plots shown above, it can be seen that compressive strengthdecreases with an increase in w/b ratio for all percentage replacement and for all moist curing ages investigated. From the figure also it can be seen that 0% replacement of PKS presented increased compressive strength in comparison to the other percentage replacement investigated. Similar influences have been found in results for concrete systems published elsewhere [11, 12]. Note that as the moist curing age of the concrete increase, thus the hydration of its binder components, the gain in compressive strength becomes more apparentat low w/b ratio especially for the 0% PKS.Due to the higher replacement level used and its inherent bonding, a slight reduction in compressive strength occurred as the percentage replacement increase for the different concrete mixtures especially at higher w/b ratio. Similar observations were also noted by other researcher [14, 15].

Porosity Test Results

Table 5 shows the average porosity results in percentage obtained for the concrete cubes at 28 days after casting and moist curing for the 0.5 and 0.7 w/c concrete mixtures. Each value shown in this table represents the average of 2 individual concrete cube porosity tests.

TABLE 5: POROSITY RESULTS FOR THE CONCRETE AFTER 28 DAYS CURING

Percentage of PKS (%)	Porosity (%)	
	0.5 w/c	0.7 w/c
0	0.16	0.09
10	0.24	0.15
20	0.28	0.17
30	0.39	0.21

The results in Tables 5 are presented graphically in Figure 2 which shows the relationship between porosity and w/c ratio for each concrete type and percentage replacement considered.

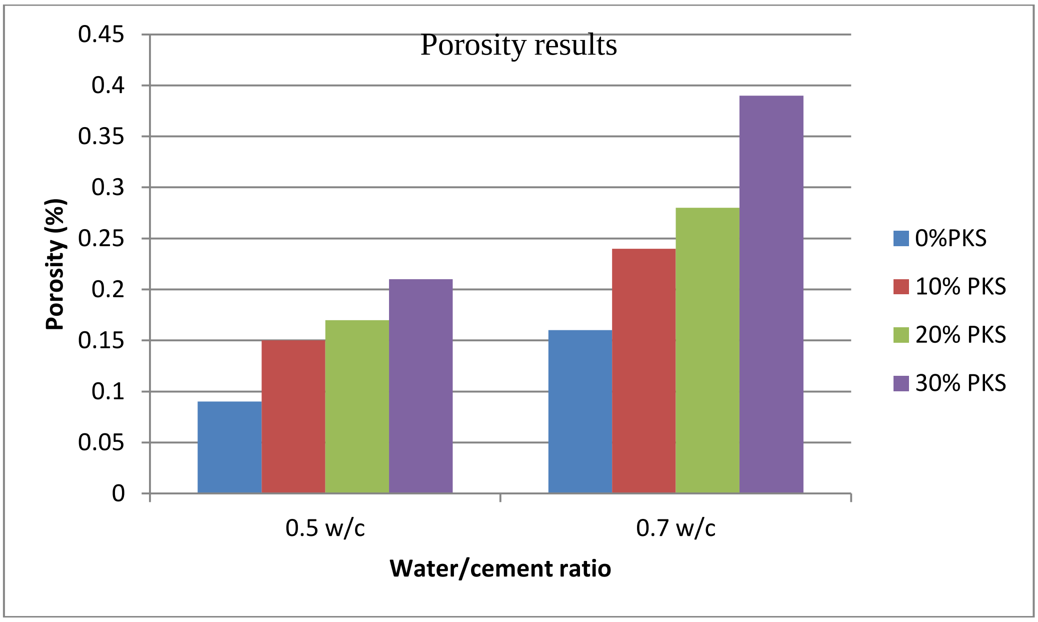

Figure 2: Porosity versus Water/Cement Ratio

From the presented results, it is evident that the use of different percentage replacement of PKS in concrete influenced the pore structure of the concrete. As the percentage replacement of PKS in concrete increases the pore spaces increases. The pore spaces in concrete depend on the hardened cement paste (hcp) and more on its interfacial transition zone (ITZ). The ITZ is the space between the bulk cement paste and aggregate and composed of the same elements as the hcp although it is weaker [5, 14]. Thus, as the PKS content increased, weaker bonding is developed giving raise to increased porosity and strength. Additionally, concrete pore spaces increases as the water content increases due to the eventual evaporation of the water leaving pore spaces.

CONCLUSIONS

From the results obtained from the strength and porosity testof the concrete, it can be concluded that:

- The quest by government in developing countries to use locally available materials in the production of low cost housing will be met with the use of PKS;
- The economic power of rural dwellers will be enhanced if they are encourage to plant palm trees from which these shells could beobtain;

- Environmental pollution caused by indiscriminate dumping of PKS as waste can be reduced when used as alternate coarse aggregate in concrete production;
- PKS can be used as partial replacement for coarse aggregate up to 20% for the production of medium strength concrete for use in lintel of bungalow;
- For strip foundation of bungalows and fences and in concreting of compounds, PKS replacement of up to 30% can be used. This will go a long way to reducing construction cost.

REFERENCES

1. Addis, B. (2001) Cementitious materials, and Strength of hardened concrete, Fulton's Concrete Technology, Edited by Brian Addis and Gill Owens, 8th edition, Cement and Concrete Institute Midrand, South Africa. ISBN 0-9584085-5-6, pp. 7-11, 85-92.

2. Ferrari, L, Kaufmann, J, Winnefeld, F, Plank, J (2011). "Multi-method Approach to Study influence of Superplasticizers on Cement Suspensions" Cement and Concrete Research vol.41 pp.10.

3. Kosmatka, S., Kerkhoff, B., Panarese, W. (2002) Design and control of concrete mixtures (14th edition). Portland Cement Assosiation, Skokie, Illinois.

4. Kumar, P.;Paulo, J.M.; Monteiro (1993) Concrete microstructure, properties and materials, Mcgraw-hall, 3rd edition, ISBN 0-07-146289-9, pp. 15,21-54.

5. Martys, N.S and Ferraris, C.F (1997) Capillary transport in mortars and concrete, Cement and Concrete Research, vol. 27, pp 747-760.

6. Mosely W.H. and Bungey J.H. (1999) Reinforced Concrete Design, New York; Tounmills.

7. Neville A.M. (1981) Properties of concrete, London; Pithman press.

8. Nigerian Institute for Oil palm Research (NIFOPR), Oil Palm Products and their Uses. Information Bulletin No 3, 1986.

9. Omange G.N., Palm kernel Shells as Road Building Materials, Technical Transactions of the Nigerian Society of Engineers, 2001, 36(1), pp. 17-25.

10. Siddique, R (2008) Utilization of Waste Materials and by-Products in Cement-based Materials Sci Topics.

11. British Standard Institution (BS 812, 1775), Methods of Determination of Mechanical Properties of Aggregate, Part 3, p. 4-8.

12. Khan, M. and Lynsdale, C. (2000). Porosity and Strength of PFA/SF/OPC ternery Blended Paste. Cement and Concrete Research, 30(8), 1225-1229.

13. Mehta, P.K. and Gjorv, O. E. (1982). Properties of Portland Cement Concrete containing Fly Ash and Condensed Silica Fume. Cem, Concr. Res, 12(5): 587-595.

14. Mehta, P. and Monteiro, P. (1993). Concrete: Structures, Properties, and Materials, Prentice-Hall, Englewood Cliffs, NJ.

15. Nuhu-Koko M.K. (1990). The use of palm kernel shells as aggregate for concrete, Paper presented at 21st Annual Conference of Materials Testing, control and research, FMW, Lagos, Nigeria, pp.20, 1990.

16. Okpe, Friday; Sule John and Onuh Celestine. (2014). Performance of palm kernel shells as a partial Replacement for coarse aggregate in concrete. Unpublished HND Final Year Report, Department of Civil Engineering, Federal Polytechnic Idah, Nigeria.

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