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EFFECT OF PALM KERNEL SHELL COATED WITH POLYSTYRENE PASTE POLYMER AS COARSE AGGREGATE REPLACEMENT IN CONCRETE PRODUCTION

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Abstract: One of the major problems facing the delivery of large number of development projects is the never-ending increases in prices of building materials including cement and aggregates. Palm kernel is an agro – waste generated in the processing of palm oil. The disposal of this waste is one of the key contributors to the environmental problem. This study explores and compares the properties of concrete produced with coated palm kernel shell using polystyrene paste polymer (CPKS) and uncoated palm kernel shell (PKS) as replacement for coarse aggregate in concrete production. The palm kernel shells used were gotten from a local farm. The coarse aggregate replacement varies from 0%, 25%, 50%, 75%, and 100% using 1:2:4 mix ratio and water cement ratio of 0.5. Laboratory tests were carried out to determine density, workability, compressive strength and flexural strength of concrete. The results showed that the density of concrete decreased as the percentage replacement of coarse aggregate with Palm kernel shell (coated and uncoated) increased. However, the density at 25% replacement was still much appreciable. For workability, there was no slump when producing concrete with both CPKS and PKS. This was because the granite and the palm kernel shells were able to compact together and better. However at 0% replacement, slump of 30mm and 35mm were recorded for CPKS and PKS concrete respectively. Results for compressive and flexural strength of both CPKS and PKS showed a decrease as the percentage replacement increases. 25% replacement gave the highest compressive strength of 12.44 N/mm^2 and 11.32 N/mm^2 at 28 days curing age for CPKS and PKS respectively.
Keywords: polystyrene paste polymer, palm kernel shell, aggregate, compressive strength and flexural strength

1. INTRODUCTION

As a quest for implementing affordable housing system for both the rural and urban population of Nigeria and other developing countries, various proposals focusing on cutting down conventional building material costs have been put forward. Over the years, the development and use of substitute, unconventional local materials have been a proposition from many researchers all over the world. Some of these materials include the possibility of using some agricultural and industrial wastes and deposits (e.g. palm kernel shells) as construction materials (Tukiman and Mohd, 2000). The cost value and quality of construction materials employed in housing developments are part of the major factors that determines the optimal delivery of housing projects (Akutu, 1983). Therefore, materials to be used for building construction must provide objective evidence of quality and cost effectiveness in terms of functional requirements and low income economy respectively. In the assessment of this, the need for low-cost material that is generally acceptable and economically obtainable becomes a subject of unceasing interest. The belief that the African region is full of raw materials suitable for local uses encourages this, yet the construction sectors are not making optimal use of them (Ramachandran 1983).

The Production of concrete depends largely on the availability of cement, sand and coarse aggregates, the costs of which have been extremely escalated over the years. Despite the rising cost of production of concrete, the demand for it is increasing. The adverse effect of the increasing demand for concrete has resulted in the depletion of aggregate deposits causing environmental degradation and imbalance (Alengaram *et al.,* 2010). The Nigerian government has been clamouring for the use of local materials in the construction industry to reduce costs of construction. There has therefore been a greater call for the development and use of substitute, unconventional local materials in construction works. Palm kernel shells used mostly as a source of fuel for domestic cooking in most areas are obtained from the oil palm tree (*Elaeis Guineensis*) which is native to western Africa and widespread throughout the tropics. It is an economically valuable tree. In Nigeria, oil palm trees generally grow in the rain forest region near the coastal areas and adjacent to some inland waterways. (Ndoke, 2006). Palm kernel shells (PKS) as shown in Plate 1 are hard, carbonaceous, and organic by products of the processing of the palm oil fruit. PKS consists of small size particles (0-5mm), medium size particles (5-10mm) and large size particles (10-15mm). Aggregates occupy between 70 to 80 per cent out of the total volume of concrete. It is therefore expected that aggregate will have intense impact on the concrete properties and its general performance (Alengaram *et al.,* 2010). Aggregates give concrete its volumetric stability and also have undisputed influence in reducing moistures related to shrinkage of concrete (Basri *et al.,* 1999). In the investigation of the suitability of sawdust and palm kernel shells as replacement for fine and coarse aggregate in reinforced concrete slabs production, it

Figure 1: Palm kernel shell

was concluded that 25% sawdust and palm kernel substitution reduced the cost of concrete production by 7.45%. This outcome indicated the prospect of partially replacing sand and granite with sawdust and palm kernel shell in the production of lightweight concrete slabs (Olutoge, 1995).

This paper aims at investigating the effect of palm kernel shell coated with polystyrene paste polymer and uncoated palm kernel shell as coarse aggregate replacement in concrete production. The specific objectives are to determine the physical and mechanical properties of Palm kernel shell coated with polystyrene paste polymer concrete and uncoated palm kernel shell concrete.

2. MATERIALS AND METHODS

— Palm kernel shell

The palm kernel shell used was collected from a local palm kernel oil factory at Sango Ota, Iyana-Iyesi, Ogun state, Nigeria. Palm kernel shells are hard, flaky and are of irregular shapes. In using palm kernel shell as aggregate replacement, care must be taken in its preparation. Pre-treatment of the palm kernel shell was carried out by putting the shells in a basket in batches and thoroughly flushed with water to remove impurities that could contaminant or affect the concrete properties. The shells were then sun dried as shown in figure 2. The palm kernel shells particle used as coarse aggregate ranges between 2.5mm to 14mm.


Figure 2: Sun drying of palm kernel shells


Figure 3: Polystyrene waste

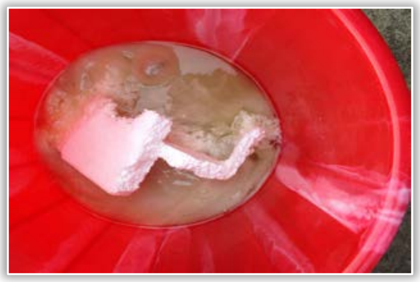
Figure 4: Polystyrene dissolved in petrol and kept for four days

— Fine Aggregate

The fine aggregate (Sharp sand) used throughout this study was from Ogun river bed located at ibafo town in Ogun state, Nigeria. The sand was free from clay, loam, dirt and organic or chemical matter of any description. The particles passed through BS sieve No 4 (aperture 2.36mm) but retained on sieve No 220 (aperture 0.06mm). This was in accordance with BS EN 933-4.

— Coarse Aggregate

The coarse aggregates used in this research were crushed granite and palm kernel shell. The size of the granite used as coarse aggregate for this study ranges between 2.36mm to 19mm as obtained from the gradation test result. Coarse aggregate helps to improve the strength of the concrete.

— Portland cement

Dangote 3x supaset ordinary Portland cement produced by Dangote Cement Limited, Nigeria was used for all the mixes required for this study.

— Expanded Polystyrene

Expanded polystyrene (EPS) shown in figure 3, is a waste product from different electronic appliances retailers around Lagos. It is rigid and tough, closed-cell foam. It is usually white and made of pre-expanded polystyrene beads. The polystyrene paste polymer (PPP) used was prepared from expanded polystyrene dissolved in Petrol (Premium motor spirit) for 4 days to obtain the polystyrene paste as shown in figure 4.

— Mix Design, Sample preparation and testing

The palm kernel shells were mixed by hand with the polystyrene paste polymer (PPP) at mix ratio of 1:14 (a bowl of PPP to 14 bowls of palm kernel shell) and then sun dried.

Table 1: Mix proportion for the control concrete and blended concrete mix

Mix ID	%Replacement	Cement (Kg/m^3)	Fine Aggr. (Kg/m^3)	Coarse Aggr. (Kg/m^3)	CPKS/PKS	w/c
A1(Control)	0	480	960	1920	-	0.5
B2*	25	480	960	1440	480	0.5
B2		480	960	1440	480	0.5
C3*	50	480	960	960	960	0.5
C3		480	960	960	960	0.5
D4*	75	480	960	480	1440	0.5
D4		480	960	480	1440	0.5
E5*	100	480	960	-	1920	0.5
E5		480	960	-	1920	0.5

Note: * (Coated palm kernel shell, CPKS)

Prescribed mix ratio of 1:2:4 and water-cement ratio of 0.5 were adopted throughout this work. Replacement of coarse aggregate with CPKS and PKS were carried out from 0% to 100% at an interval of 25%. A total number of Eighty-one (81) Concrete cubes of 150x150x150mm and Fifty-four (54) beams of 150x150x750mm were produced under laboratory condition to test for the compressive and flexural strength respectively. The palm kernel shells retained by 14mm sieve were used for the preparation of the palm kernel shell coated with polystyrene paste. The cubes for compressive strength determination were cured for a period of 7, 14 and 28 days, while the beams for flexural strength determination were cured for 28 and 56 days. For all mix compositions, the test specimens were prepared in accordance with BS EN 206-1 and BS EN 12350-1 respectively. Results obtained were from the average of three specimens per mix. The mix proportion is shown in Table 1.

3. RESULTS AND DISCUSSIONS

— Physical test on study aggregates

The results of some physical properties of the aggregates used in the study are given in Table 2. The specific gravity values for the fine, coarse and PKS aggregates were 2.59, 2.63 and 2.30 respectively which is acceptable for soils according to ASTM D854 (2018). Generally, soils with specific gravity lesser than 2.0 have organic and porous particles while those with specific gravities above 3.0 are considered to have heavy substances. For the moisture content, it was observed that the moisture content of coated palm kernel shell was less than the uncoated palm kernel shell which made the coated palm kernel shell absorbs less water than the uncoated palm kernel shell. This attribute positioned the coated palm kernel shell as a more suitable replacement for the coarse aggregate than the uncoated palm kernel shell. Results obtained from the dry density test showed that the concrete produced with PKS had less air voids compared to the concrete produced with granite. Aggregate impact value for granite portrayed it to be extremely strong, while that of palm kernel shell showed that it is weak and therefore can be used in lightly trafficked roads in the rural settings. Some of these geometrical and physical properties of Fine and coarse aggregates and Palm kernel shell are in accordance with BS EN 933-3, BS 812-112 and BS EN 1097-6.

Table 2. Physical properties of Fine and coarse aggregate (granite) and Palm kernel shell (PKS).

Physical properties	Fine	Coarse	PKS
Sp.gravity	2.59	2.63	2.30
Moisture content (%)	5.78	0.38	5.06[(a)] / 9.51[(b)]
Bulk density ($\mathbf{Mg/m^3}$)	2.78	2.56	1.45
Dry density($\mathbf{Mg/m^3}$)	2.57	2.36	1.35
Aggregate Crushing value (%)	-	25.60	-
Aggregate Impact value (%)	-	15.6	55.0

[(a)]coated PKS; [(b)]uncoated PKS

— Workability

The workability of the fresh concrete, as determined by the slump test in accordance with section 7.2 of BS 5328 (2009) for the mix proportions used in the concrete is presented in the Figure 5. All mixes with CPKS and PKS showed higher slump values than the control mix. This may be due to the difference in the mix compositions and the interlock effect. The slump value increases as the replacement percentage increases. However, concrete with PKS showed slightly higher slump than concrete with CPKS.

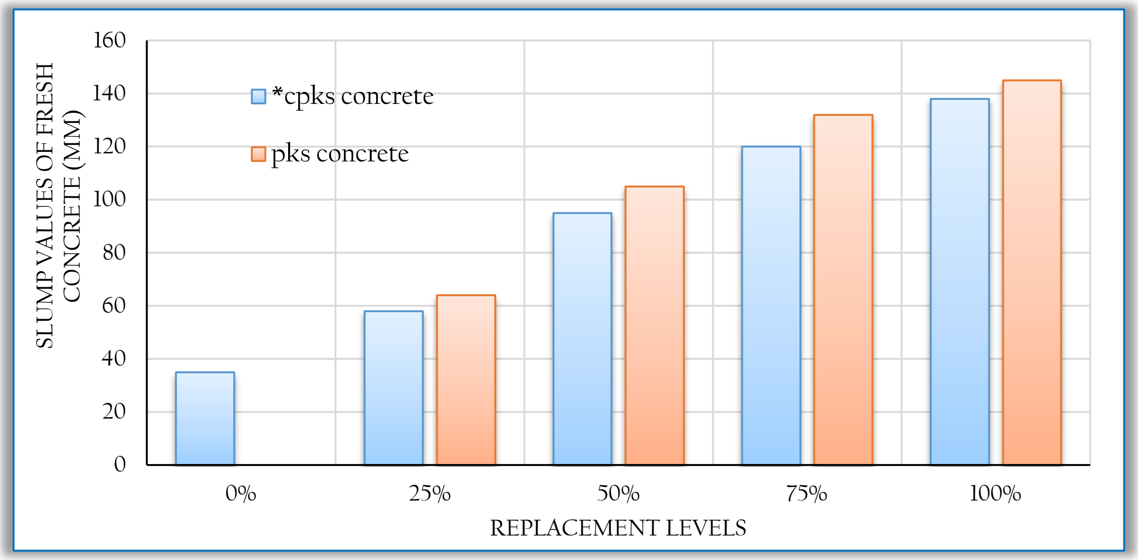

Figure 5: Workability of fresh concrete measured by slump test

— Density of Concrete

Figures 6 and 7 represent the densities of polystyrene paste coated Palm kernel shell (CPKS) concrete and uncoated PKS concrete respectively. It was observed that the density of concrete decreased as the percentage replacement of coarse aggregate with PKS (coated and uncoated) increased. However, the density at 25% replacement was still much appreciable.

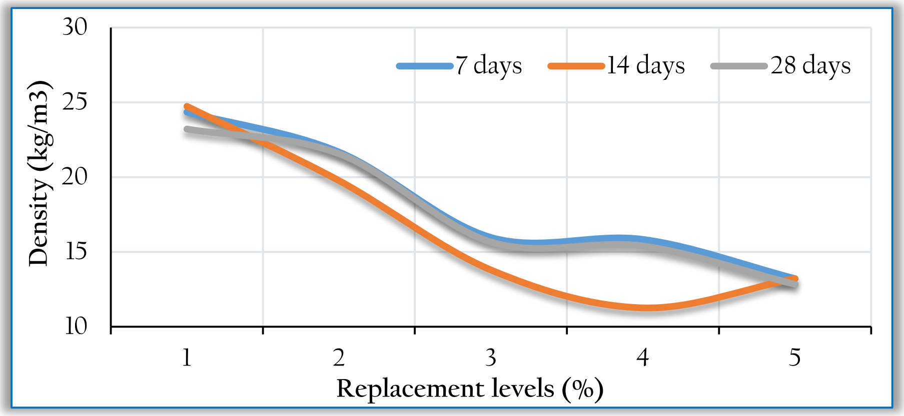

Figure 6: Relationship between the densities and curing age for CPKS concrete cube.

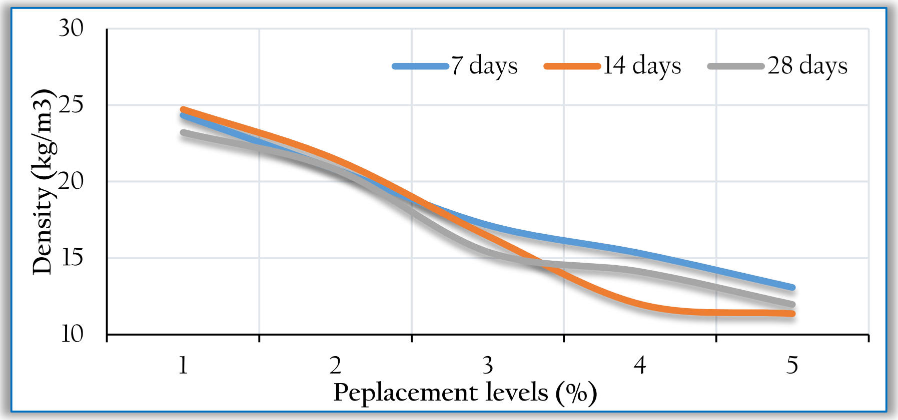

Figure 7: Relationship between the densities and curing age for uncoated PKS concrete cube.

— Compressive Strength of Concrete

Figure 8 shows the results of the compressive strength testing for the 150mm× 150mm cube specimens for the control and the blended concretes (CPKS and PKS), cured in water for 7, 14 and 28 days.

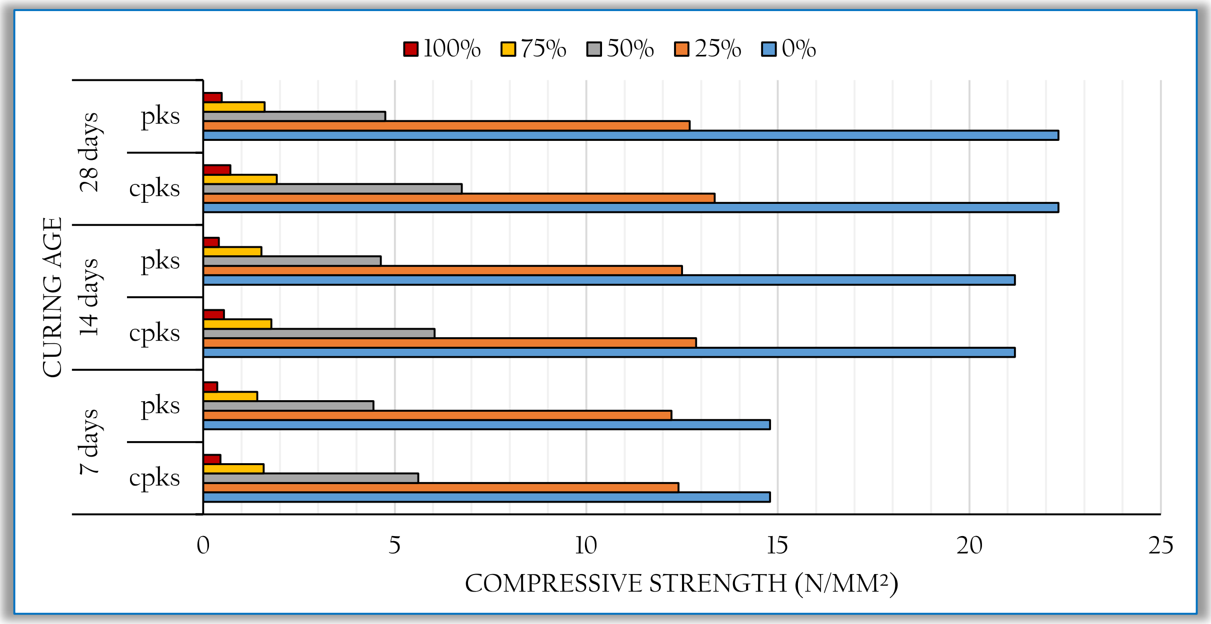

Figure 8: Variation of compressive strength with curing days for all concrete mixes

It can be seen that the control concrete had higher compressive strength than the blended concretes. However, concrete with palm kernel shell coated with polystyrene paste polymer (CPKS) had compressive strength higher than concrete with ordinary palm kernel shell (PKS) at all curing ages. Also, it was observed that compressive strength decreases as the replacement percentage increases for all blended concretes (CPKS and PKS). Replacement at 25% gave a better result when compared to other replacement levels. The variation in strength may be attributed to the differences in the aggregate compositions and aggregate impact values. For the control specimens, the higher strength development may be credited to the progressive C-S-H gel formation within the pore structure (Otis et al., 2010). Therefore, 25% replacement of granite with palm kernel shell coated with polystyrene paste polymer is suitable for lightweight concrete production. In previous research, palm kernel shell was used as coarse aggregate replacement in road binder and the suitable percentage replacement obtained was at 25% with a compressive strength of 11.61 N/mm^2 (Ndoke, 2006).

— Flexural strength test on beams

Figure 9 presents the results of the flexural strength of all concrete mixes at 28- day curing age and 56-day curing age. The control specimens gave the highest flexural strength at all ages. However when the blended concretes were compared, concrete with palm kernel shell coated with polystyrene paste polymer gave the highest strength of 0.65 N/mm^2 at 56 days curing age. The flexural strength of the unreinforced beams (coated and uncoated) reduced as the percentage replacement of coarse aggregate with both CPKS and PKS increased. The variation in flexural strength may be due to the aggregate-paste bond which has significant impact on flexural strength.

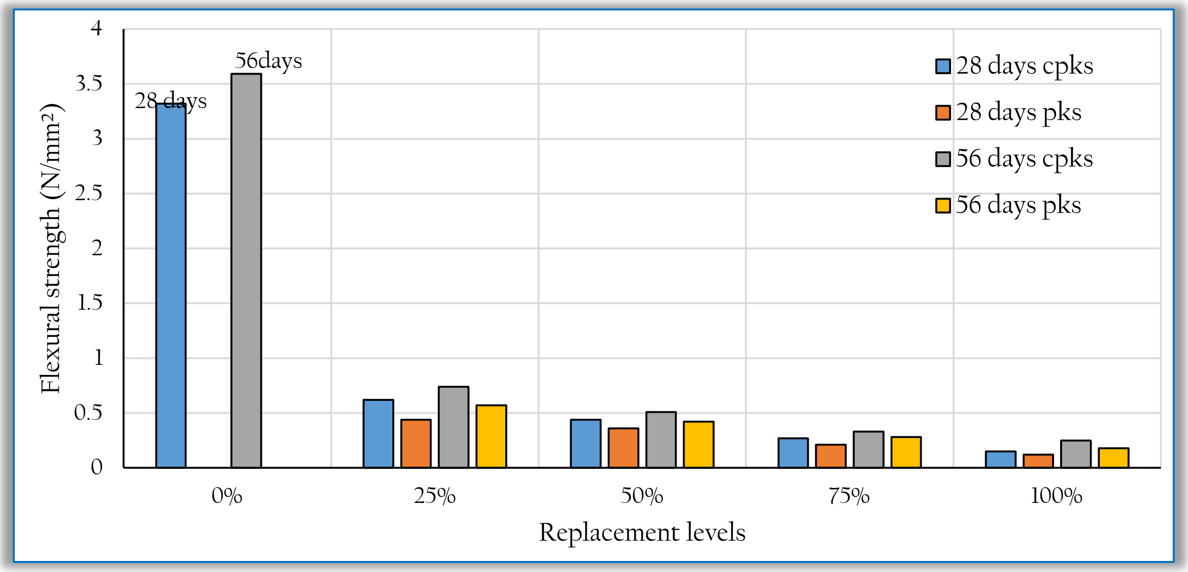

Figure 9: Variation of flexural strength for all concrete mixes

Also, there was no much difference in the average flexural strength of 56 days curing period compared to 28 days.

4. CONCLUSION

The use of polystyrene paste polymer in concrete production would no doubt reduce the environmental hazards caused by the carefree deposit of polystyrene waste. Uncoated palm kernel shell and coated palm kernel shell with polystyrene paste polymer concrete can be used for light weight construction works like non-load bearing partition walls. Results for compressive and flexural strength of both palm kernel shell coated with polystyrene paste polymer and ordinary palm kernel shell showed a decrease as the percentage replacement increases. 25% replacement gave the highest compressive strength of 13.35 N/mm^2 and 12.70 N/mm^2 at 28days curing age for palm kernel shell coated with polystyrene paste polymer concrete (CPKS) and ordinary palm kernel shell concrete (PKS) respectively.

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