INFLUENCE OF CURING MEDIA ON THE COMPRESSIVE STRENGTH OF PALM KERNEL SHELL (PKS) CONCRETE

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ABSTRACT
The influence of curing media on the compressive strength of palm kernel shell concrete with varying coarse aggregate sizes (5-10 mm, 5-14 mm and 5-20 mm) and replacement level of granite with palm kernel shell (0-100 % in steps of 25 %) were investigated in this study. The results showed that the compressive strength was significantly influenced by the curing media. Compressive strength of palm kernel shell concrete decreased from curing media CM-1 to CM-3 (CM-1: complete immersion; CM-2: partial immersion; CM-3: no immersion) with increase in percentage replacement of granite with palm kernel shell from 0 % (control) to 100 % in steps of 25 %. However, compressive strength increased from curing media CM-1 to CM-3 with increase in coarse aggregate sizes. The ANOVA showed that the curing medium had significant effect on the compressive strength. The Duncan's multiple range tests revealed that the mean compressive strengths at different aggregate sizes, replacement levels and curing media were significantly different.

Keywords: *Palm kernel shell, palm kernel shell concrete, compressive strength, curing media, replacement level*

1. INTRODUCTION

The use of palm kernel shell (PKS), an agricultural waste material, in concrete production has been investigated by numerous researches [1-6]. It is well known that among the factors influencing the strength development of concrete is the curing environment where the specimens are put after been de- moulded. Curing is usually done in a fully saturated environment to ensure proper hydration of the cement over time thereby leading to significant strength development. It is acknowledged that for concrete to achieve best performance, the temperature and humidity under which it is cast and cured are part of the major considerations. It has been reported that at higher temperatures, the rate of cement hydration is negatively affected and lower ones retard the hydration process leading to poor strength development [7].

The goal of curing is to ensure that air-filled void is filled with the products of hydration of cement as time progresses. Mannan *et al.* [7] and Çakir and Aköz [8] have shown that the method of curing concrete also has significant effect on its mechanical properties.

This study therefore investigates the effect of three curing media on the compressive strength of palm kernel shell (PKS) concrete. The concrete was tested at different aggregate sizes and replacement levels of granite with PKS.

2. EXPERIMENTAL WORKS

2.1 Materials and Methods

The basic components of palm kernel shell concrete are cement, sand, granite and/or palm kernel shell. The fine aggregate, sharp sand had a specific gravity and fineness modulus of 2.55 and 3.12 respectively. The palm kernel shells obtained from a local mill along Ede road in Ile-Ife, Nigeria, was already in the cracked form, the fibrous outer parts of the nut already removed. The shells were kept outdoors under a shed for three months. This enabled the oil coating to be removed by natural weathering which is one of the methods recommended for pre-treatment among others [9-11]. The PKS were later washed and sun-dried before use. The granite used was purchased in Ile–Ife, Nigeria. The coarse aggregates, that is, PKS and granite, were divided into three groups, namely 5-10 mm, 5-14 mm and 5-20 mm sizes. The diverse sizes of the PKS can be obtained depending on the method of cracking. The cement used was obtained from the open market in Ile-Ife and was that produced by the West African Portland Cement Company (WAPCO) that conforms to the requirements of BS EN 197-1 [12] for Ordinary Portland Cement. A mix proportion of 1:1½:2 was used for this work with a water/cement ratio of 0.50 arrived at after preliminary mix design. PKS was used to replace granite in steps of 25 % from 0-100 % in the mix to study the effect of proportions while the three coarse aggregate sizes were used to study its influence on PKS concrete. Steel moulds were used for casting test samples. The inner parts of the moulds were coated with used engine oil to ensure easy de-moulding and smooth surface finish. Immediately after the mixing, the wet mixture was cast into the moulds using hand trowel. 100 mm cube moulds were used for the compression strength test. They were filled in two layers and compacted using the compaction rod (25 mm diameter steel rod). Each layer was compacted manually by uniformly distributing 25 strokes of the steel rod across the cross-section of the mould. The top of each mould was smoothened and levelled and the outside surfaces cleaned. The mould and their contents were kept in the curing room at temperature of 21°C and relative humidity not less than 70 %. After 24 hours, the specimens were de-moulded and taken to the different curing media.

2.2 Curing Media

The effect of three curing conditions on the 28th day compressive strength of PKSC at three levels of coarse aggregate sizes and five replacement levels of granite with PKS was investigated in this study. The curing media (CM) investigated were complete immersion in water for 28 days strength test (CM-1), complete immersion in water for an initial 7 days before open air-curing in the laboratory under room temperature for the remaining 21 days (CM-2); and open air-curing for 28 days in the laboratory (CM-3).

2.3 Physical and Mechanical Test Performed

The physical properties – Dry sieve analysis of aggregates used, moisture content, workability, water absorption capacity and de-moulded density were determined following standard laboratory procedures. All specimens were cured for 28 days in the different curing media. The average values of the maximum loads at which each group of three specimens failed was found and the compressive strength determined. This is in accordance with BS EN 12390-3 [13].

3. RESULTS AND DISCUSSION

3.1 Dry Sieve Analysis of Aggregates Used

The results of the dry sieve analysis revealed that sand, granite and PKS have coefficients of uniformity of 7.2, 1.77 and 2.00 respectively. A coefficient of uniformity of 7.2 for sand showed that it was well graded while granite and PKS are uniformly graded [14]. These showed that the aggregates were suitable for making concrete unlike a gap-graded or poorly graded aggregate having coefficient of uniformity less than 1.0.

3.2 Moisture Content

The measured moisture contents of granite, palm kernel shell and sand were 0.22 %, 1.20 % and 8.88 % respectively. Neville [15] posited that coarse aggregates rarely contain more than 1.0% of surface moisture but fine aggregate can contain in excess of 10 %. Since the moisture content of coarse aggregate is not significant on concrete mix Neville [15], only the moisture content of sand was allowed for in the calculation of batched quantities.

3.3 Workability

The results of the slump test indicating the workability of the concrete for different percentage replacement of palm kernel shell with granite is shown in Table 1. Tests were done according to BS EN 12350-2 [16]. The Table indicates that the concrete slump decreases as the percentage of the palm kernel shell increased in the mixes. In the three different aggregate-size mixes, the slump test values showed concrete of workabilities ranging from very low (5-10 mm) to medium (35-75 mm) [15]. At 0 % PKS replacement level (normal concrete), results show collapsed slump for the three aggregate size mixes. This could be traced to the high water-cement ratio of 0.5 for a mix proportion of 1:1½:2 used throughout the experimentation so as to establish a basis of strength comparison between the PKS concrete and normal concrete. It should however be noted that the mix did not segregate. With 25 % and 50 % PKS in the 5-10 mm and 25 % PKS in the 5-20 mm aggregate sizes, medium workabilities were achieved while low workabilities were obtained for the remaining 25 % and 50 % PKS mixes. However, for 75 % and 100 % PKS in the three mixes workabilities were almost zero showing a stiff consistency. This revealed that to obtain high workability from PKS concrete, a water-reducing agent such as a ‘super plasticizer’ may have to be used as attested to by earlier researchers [4, 5].

Table 1. Slump values in (mm)

Quantity of PKS (%)	5-10 mm	5-14 mm	5-20 mm
0	collapsed	collapsed	collapsed
25	30	22	40
50	40	18	12
75	2	4	1
100	0.5	3	0

3.4 Water Absorption Capacity

The water absorption capacity of the PKS was 9.03 %. This result is within the range of absorption capacity of lightweight aggregates which has been put at 5-20 % [17]. Table 2 shows the details of some of the physical properties of the aggregates used.

Table 2. Properties of PKS, granite and sand

Properties	PKS	Granite	Sand
Maximum size (mm)	5-20	5-20	0-5
Specific gravity	1.58	2.60	2.55
Water absorption for 24 h (%)	9.03	3.85	3.75

3.5 De-moulded Density

The results of the de-moulded density of the cubes, 100 mm of the different aggregate-size mixes are shown in Table 3. The results show that at 0 % and 25 % PKS replacement levels, the de-moulded density of PKS concrete ranges between 2000 and 2400 kg/m^3, classifying them as dense concrete [15]. At 50 %, 75 % and 100 % PKS replacement levels, the de-moulded density of PKS concrete ranges between 1340 and 1900 kg/m^3; this makes them lightweight [5]. It can however be seen from Table 3 that the density is a function of the level of replacement of granite with palm kernel shell. The density decreases as the percentage of PKS increases in the mix. This could be attributed to the fact that PKS has a lower relative density when compared with granite. It also increases with aggregate size. Determination of masses and volumes of specimens were as received [18].

Table 3. De-moulded densities of PKS concrete (kg/m^3).

Quantity of PKS (%)	5-10 mm	5-14 mm	5-20 mm
0	2325	2350	2400
25	2025	2040	2060
50	1840	1860	1900
75	1435	1460	1500
100	1350	1380	1400

3.6 Effect of Curing Media on the 28th Day Compressive Strength

The results obtained from these experimental tests are represented in graphical forms as shown in Figures 1-3. The Figures show the variation of the 28th day compressive strength of the three groups of aggregate sizes with percent replacement of granite with PKS at the various curing media.

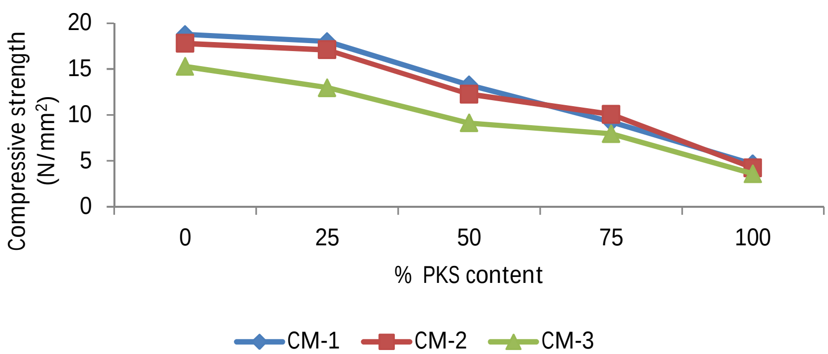

Figure 1. Compressive strength vs. % PKS content under different curing media for aggregate size of 5-10 mm.

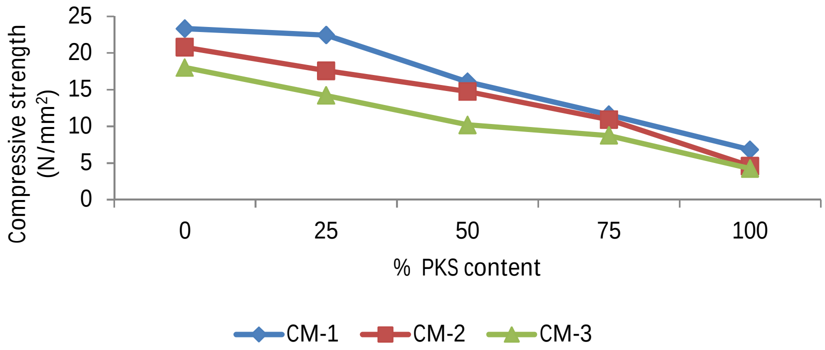

Figure 2. Compressive strength vs. % PKS content under different curing media for aggregate size of 5-14 mm.

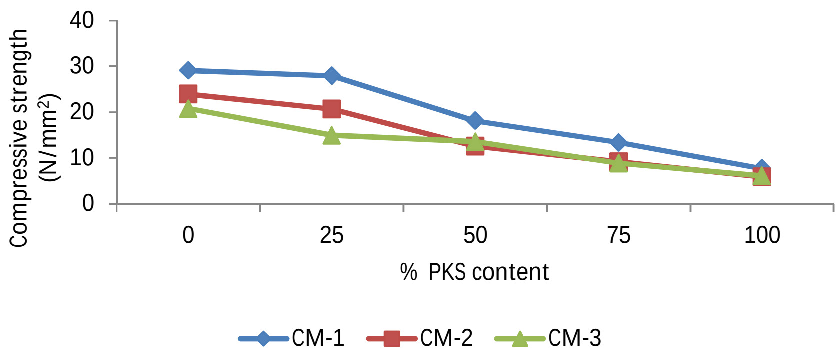

Figure 3. Compressive strength vs. % PKS content under different curing media for aggregate size of 5-20 mm.

In Figures 1-3, the results show that the compressive strength of PKS concrete decreased with increase in the replacement of granite with PKS for the three aggregate sizes and in the three curing media. Figures 1 and 2 showed that the strength development between curing media 1 and 2 was not significantly different for aggregate sizes 5-10 mm and 5-14 mm except at 25% PKS content in 5-14 mm aggregate size. However, for 5-20 mm aggregate size, result showed significant strength increase between curing media 1 and 2.

In all the curing media for all range of aggregate sizes, CM-3 gave the lowest strength at 28^{th} day. This can be attributed to incomplete hydration of the cement particles. These results established that same as for normal concrete, hydration of cement in PKS concrete also performs best when cured by complete immersion in water, CM-1. This is followed by CM-2.

4. STATISTICAL ANALYSIS AND INTERPRETATION

The ANOVA (Table 4) shows that the curing medium as an independent variable has significant effect on the compressive strength at the 28^{th} day.

Table 4. ANOVA for 28th day Compressive Strength Test

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Aggregate size	2	341.838815	170.919407	689.40	<.000
Replacement (%)	4	4263.935852	1065.983963	4299.61	<.000
Agg. size*Replment (%)	8	106.019704	13.252463	53.45	<.000
Curing medium	2	520.419704	260.209852	1049.55	<.000
Agg. size*Curing medium	4	79.549185	19.887296	80.21	<.000
Replment*Curing medium	8	132.894370	16.611796	67.00	<.000
Agg.size*Replment*Curing	16	52.823407	3.301463	13.32	<.000
Error	90	22.313333	0.247926		

Table 4 revealed that the independent variables; aggregate sizes, replacement level of granite with PKS and curing media have significant effect on the compressive strength of PKS concrete when considered individually and also with two or three factors interaction.
The Duncan's multiple range tests revealed that the mean compressive strengths at different aggregate sizes, replacement levels and curing media are significantly different (Tables 5-7).

Table 5. Multiple range tests for compressive strength with varying aggregate sizes

Duncan Grouping	Mean	N	Aggregate size
A	15.5200	45	5-20mm
B	13.5822	45	5-14mm
C	11.6222	45	5-10mm

Table 5 shows that when the other two independent variables were kept constant, that is, curing media and PKS content, the compressive strength of PKS concrete are different one from the other. The maximum strength was obtained for coarse aggregate size 5-20 mm with a mean value of 15.52 N/mm^2. The strength are significantly different, hence the difference Duncan's groupings into A, B and C.

Table 6. Multiple range tests for compressive strength with varying percent replacement

Duncan Grouping	Mean	N	PKS (%)
A	20.8556	27	0
B	18.4259	27	25
C	13.3259	27	50
D	9.9481	27	75
E	5.3185	27	100

Table 6 reveals that when the aggregate sizes and curing media are kept constant with quantity of PKS as the independent variable, the compressive strength of PKS concrete are significantly different with maximum mean strength of 20.86 N/mm^2 (control). It should be observed that for replacement of granite with PKS, optimum strength of 18.43 N/mm^2 was obtained at 25 % replacement level.

Table 7. Multiple range tests for compressive strength with varying curing medium

Duncan Grouping	Mean	N	Curing medium
A	16.0244	45	CM-1
B	13.4822	45	CM-2
C	11.2178	45	CM-3

When aggregate sizes and quantity of PKS was kept constant, compressive strength was greatest when specimens were cured by CM-1 and the mean strength is 16.02 N/mm^2 (Table 7).

5. CONCLUSION

The effect of curing media on the 28th-day compressive strength of PKS concrete at different replacement levels of granite with PKS and coarse aggregate sizes have been investigated. Curing media investigated were complete immersion in water for 28 days; complete immersion in water for an initial 7 days period before exposing to laboratory open-air condition for the remaining 21 days; and then exposure to open-air in the laboratory for 28 days. Coarse aggregate sizes and replacement levels of granite with PKS are 5-10 mm, 5-14 mm, 5-20 mm and 0-100 % in steps of 25 % respectively.

The following conclusions have been drawn from this research;

1) The slump values for mixes with PKS were highest at 25 % PKS contents (22-40 mm) but reduced to zero at 100 % PKS content.

2) Aggregate size of 5-20 mm had the highest de-moulded density. At 25 % PKS content in the mix, densities of specimens were dense weight for all aggregate sizes. However, at 50-100 % PKS contents, densities of specimens were lightweight.
3) Compressive strength of PKS concrete increased with increase in aggregate sizes at all curing media. Optimum strength at 28 days was obtained for 5-20 mm aggregate size specimen at 25 % PKS content. However, at 50 % PKS content, which is lightweight, compressive strength was 18.43 N/mm^2 for 5-20 mm aggregate specimen which is above the minimum value of 17 N/mm^2 for lightweight concrete.
4) As in normal concrete, specimens cured by complete immersion in water for the test period gave the highest compressive strength at all aggregate sizes and PKS contents.

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