FACULTY OF ENGINEERING
AHMADU BELLO UNIVERSITY, ZARIA
National Engineering Conference 2018

ABUNEC2018216

# EFFECT OF PALM KERNEL SHELL (PKS) AS COARSE AGGREGATE ON THE COMPRESSIVE STRENGTH OF REVIBRATED CONCRETE

**[1]S. M. Auta, [2]M. A. Arogundade and [3]N. S. Rimintsiwa**

*[1,2]Department of Civil Engineering, School of Infrastructure, Process Engineering and Technology, Minna*
*[3]Department of Civil Engineering, Baze University, Abuja*
*[1,2]samuel.auta@futminna.edu.ng*
*[3]nasir.sani@bazeuniversity.edu.ng*

**Abstract:** The effect of palm kernel shell (PKS) as coarse aggregate on the compressive strength of re-vibrated concrete is presented. Preliminary tests were carried out on the aggregates and the Palm Kernel Shell (PKS) to determine their physical properties. A water-cement ratio of 0.60 and a concrete mix design ratio 1:2:4 were used to cast a total of 56 concrete cubes: a set of eight (8) concrete cubes with partial replacement of PKS (0, 5, 10, 15, 20, 25, 30%) for granite (100, 95, 90, 85, 80, 75, 70%) respectively. A total of 26 cubes were non-revibrated and remaining 26 cubes revibrated. The revibration was done for 60 seconds at time interval of 10minutes for 1hour (60 minutes) within setting time. 26 cubes were place on 7days curing, and the remaining 26 cubes, on 28days. The result of both fresh and hardened concrete after curing for 7 and 28 days, showed that increase in the percentage replacement of crushed granite with palm kernel shell reduced workability and compressive strength of the concrete. However, the maximum compressive strength of the concrete cubes was 20.63N/mm$^2$ at 95% crushed granite and 5% PKS and the minimum is 6.08N/mm$^2$ when Palm kernel Shell is added at 30% replacement respectively. The compressive strength of concrte at 5% PKS replacement for granite satisfied the class of lightweight concrete grade C15.

## 1. INTRODUCTION

As developing nations strive for economic sustainability so also the cost of conventional building materials has increased and this increase has consequently placed a burden on effective performance of the construction industry. This has also led to the use of substandard materials by some builders and increased rate of building collapse in most recent times (Auta, *et al.,* 2016). Subsequently, researchers have gone into exploring local content construction materials such that could alternate conventional materials.

Large amount of waste burned in residential areas or specific location(dumping sites) such as waste agricultural biomass, create emissions and pollutants spreading into the atmosphere, causing environmental and health hazards for humanity. if some of the waste materials are found suitable in concrete making, not only cost of construction can be cut down, but also safe disposal of waste materials can be achieved. this is why this research work is geared towards exploring such biomass materials that could have alternative uses to their conventional low valued uses. it has become imperative to introduce and develop locally available materials. Local sourcing of building materials are deposited into the environment without any method of recycling them. Some of those deposits are not really decomposed and their accumulation is not environmentally friendly. Agro-wastes and industrial waste constitute environmental pollutants if not properly controlled and converted into construction materials, these waste includes PKS, Sawdust ash, Rice husk, Plantain fibre, Yam fibre, Slag and Locust Bean pods etc (Auta *et al.*, 2015a). The profitable use of these agro waste materials in an environmental friendly manner will be a great solution to what would in otherwise be a pollutant (James, 2013; Uwasomba, 2015) The use of Agricultural wastes as aggregates or cement replacement material in concrete (Alengarant *et al*., 2013)also has both Engineering and Economic advantage (Mannan and Ganapathy, 2002). Earlier investigations showed that PKS can be used as coarse aggregates in concrete, however, it was reported that PKS could be mixed with mud and formed into blocks for the construction of traditional houses (Alengarant *et al*., 2010). In a separate study, Alengaram *et al*. (2013) reported on the effect of cement materials, fine and coarse aggregates content on the workability and compressive strength of PKS concrete.

In Nigeria, Oil Palm is an important tree and the PKS as residue has been regarded as 'waste' from palm oil processing. The palm oil industry produces wastes such as palm kernel shells, palm oil fibres which are usually dumped in the open thereby impacting the environment negatively without any economic benefits. PKS are hard, carbonaceous, and organic by-products of the processing of the palm oil fruit. PKS consists of small size particles, medium size particles and large size particles in the range 0.5 mm, 5-10 mm and 10-15 mm (Alengaram *et al.*, 2013).

Revibration of concrete is the process of again vibrating the placed concrete systematically, sometimes after its consolidation is completed (Krishna Rao *et al*., 2008). When proper re-vibration of concrete has taken place, it increases the quality of the concrete in terms of strengthand bond, low permeability, reduction in creep and shrinkage, reduction in surface and other voids as well as cracks in freshly cast concrete cube. In the research work of Auta, *et al.* (2015), it was affirmed that the strength of concrete is enhanced when it is re-vibrated within the plastic state of concrete. Auta (2011) also investigated on the dynamic effect of re-vibration on the compressive strength of concrete; it was observed that at the successive time lag of 5 minutes each from 60 minutes, there was an appreciable rise in the compressive strength of the concrete.

It will be important that this paper focuses on investigating the effect of Palm Kernel Shell (PKS) as coarse aggregate on the compressive strength of concrete that has been revibrated over a period of time to gain strength.

## 2. MATERIALS AND METHOD

### *2.1 Materials*

The materials used for this experiment include the following: The coarse aggregate used for this work was obtained from a cement deport in Minna, Niger State. The size of the granite was within 18mm and 20mm.Fine Aggregates (sand) used for the purpose of this research work was obtained from the Civil Engineering Laboratory of the Federal University of Technology Minna, Niger State. Water was obtained from a borehole close to the Civil Engineering Laboratory of the Federal University of Technology Minna. The materials meet the specifications in BS EN 12620 (2008).

### *2.2 Palm kernel shell (PKS)*

The dried PKS were obtained from Ile Ife and brought to Minna, where they were oven dried (Plates I).

Plate **1**: Oven dried PKS

### *2.3 Physical properties of aggregates*

Physical properties and strength of the aggregates were determined by carrying out the following test: Moisture Content, Specific Gravity, Bulk density, Void ratio, Particle Size Test (sieve analysis), Slump Test,Mix Design, and Compressive Strength Test at the ages of 7 days and 28daysin accordance to requirements of codes of practice as specified for each tests.

### *2.4 Fresh concrete and slump test*

The slump test determines the workability of the concrete. Workability as a property of freshly mixed concrete refers to the ease at which the concrete can be mixed, compacted and finished(BS EN 12350-2, 2000).

### *2.3 Experimental procedure*

TABLE 1:Experimental concrete cubes specimens

| S/No. | Total no. of cubes | PKS percentage replacement (%) | Number of concrete cubes | | | |
|---|---|---|---|---|---|---|
| | | | concrete 7 days curing | | concrete 28 days curing | |
| | | | Non-revibrated | Revibrated | Non-revibrated | Revibrated |
| 1 | 8 | 0 | 2 | 2 | 2 | 2 |
| 2 | 8 | 5 | 2 | 2 | 2 | 2 |
| 3 | 8 | 10 | 2 | 2 | 2 | 2 |
| 4 | 8 | 15 | 2 | 2 | 2 | 2 |
| 5 | 8 | 20 | 2 | 2 | 2 | 2 |
| 6 | 8 | 25 | 2 | 2 | 2 | 2 |
| 7 | 8 | 30 | 2 | 2 | 2 | 2 |
| Total | 56 | - | 14 | 14 | 14 | 14 |

Preliminary tests were carried out on the materials, physical properties of aggregates and Palm kernel shell (PKS) such as moisture content(BS 812 Part 109, 1990), specific gravity (SG), sieve analysis (BS 812 Part 103, 1985), bulk density, void ratio calculation and slump test.

Fifty-six (56) concrete cubes specimen of metal mould size 150mm × 150mm × 150mm was produced for the study according to the arrangement in Table 1. Batching and casting of the concrete cubes were carried out in accordance with BS 1881: part 108 (1983) with mix design ratio of 1:2:4 and constant water cement ratio of 0.60 for target strength of 20MPa. The mix design ratio was used to select the required proportion of the constituent materials which include cement, PKS, water, fine aggregate (sand) and coarse aggregate (granite) to produce concrete that will satisfy the requirements of strength, durability and workability. The concrete cubes were prepare for two categories, re-vibrated and non-re-vibrated. And both categories were for 7 and 28 days curing.

Coarse aggregate were partially replaced with PKS at 5%, 10%, 15%, 20%, 25% and 30% replacement and each placement has a total of 8 concrete cubes specimen as presented in Table 1. A total of twenty-eight (28) cubes were re-vibrated for 60 seconds at 10 minutes interval for duration of 1 hour. The process of curing was carried out after the de-moulding of the concrete cubes by placing them in water curing tank and left for ages 7 and 28 days. The curing of the concrete cubes was carried out in accordance to BS 1881 part 111: (1983).

### *2.6 Compressive strength of hardened concrete cubes specimen*

After the curing process in the curing tank for the number of days, the cubes were removed from the curing tank and crushed using the compressive strength apparatus. The readings were recorded as the compressive strength of the cubes in accordance to BS 1881: part 116: (1983) using a compression machine (Plates 2 and 3).

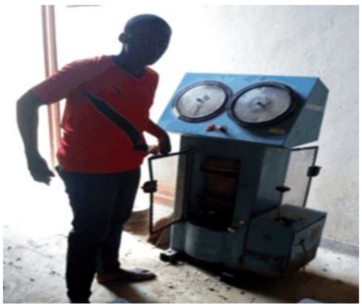
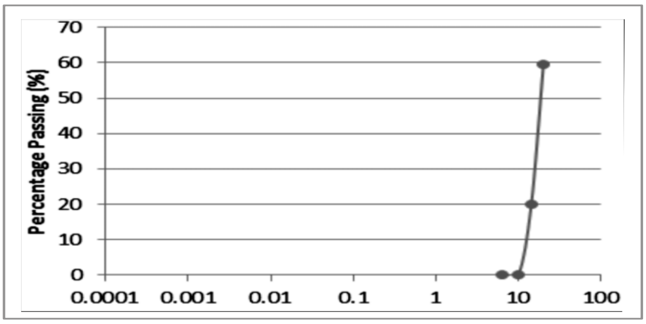


Plate 2: Crushing Test Plate 3: Failed PKS concrete cube

## 3. RESULTS AND DISCUSSION

### 3.1 Results

The result of sieve analysis for both coarse and fine aggregates are presented figures 1 and 2. While the remaining physical properties of the aggregates are summarized and presented on Tables 2 and 3, while the compressive strengths of cured concrete cubes are also presented in Table 4.




Sieve Sizes (mm)

Figure 1: Particle size distribution of coarse aggregate

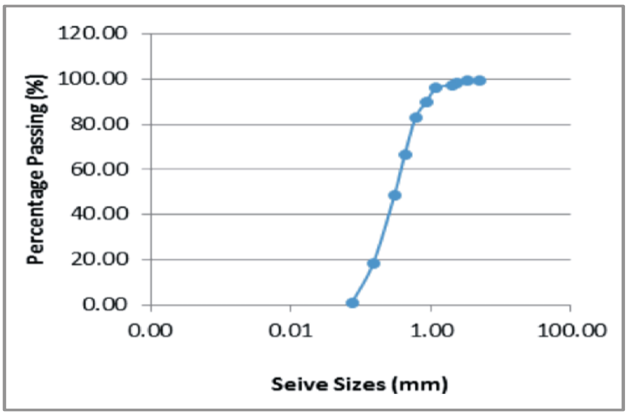



Figure 2: Particle size distribution of fine aggregate.

The result shown in figure 2 depicts that the sand is well-graded fine sand with a standard specific gravity value (BS EN 12620, 2008).The summary of the physical properties of aggregates presented in Table 1 meets specifications stipulated in BS EN 12620 (2008), while slump test satisfies BS EN 12350-2 (2000).

Table 2: Physical Properties of Aggregates

| S/N | Properties | Fine Aggregate | Coarse Aggregate | |
|---|---|---|---|---|
| | | | Granite | PKS |
| 1 | Moisture Content (%) | 5.39 | 0.158 | 4.81 |
| 2 | Specific Gravity | 2.6 | 2.9 | 1.26 |
| 3 | Uncompact Bulk Density (Kg/m$^3$) | 1547.06 | 1458.82 | - |
| 4 | Compacted Bulk Density (Kg/m$^3$) | 1617.65 | 1594.12 | - |
| S/N | Properties | Fine Aggregate | Coarse Aggregate | |
| | | | Granite | PKS |

Table 3: Slump

| S/N | Replacement level (%) | Slump Value (mm) |
|---|---|---|
| 1 | 0 | 30 |
| 2 | 5 | 29 |
| 3 | 10 | 26 |
| 4 | 15 | 22 |
| 5 | 20 | 20 |
| 6 | 25 | 19 |
| 7 | 30 | 17 |

Moisture content of the fine sand is 5.39 and 0.158 for coarse aggregate. The standard specific gravity values ranges from 2.5 and 3.0 and the values gotten for fine and coarse aggregate are 2.6 and 2.9 respectively. The Bulk density values for fine aggregate is found to be 1617.65kg/m$^3$ and 1547.06 kg/m$^3$ for compacted and uncompacted, for coarse aggregate is 1594.12kg/m$^3$ and 1458.82 kg/m$^3$ respectively. The void ratio values gotten using compacted bulk densities for the calculation are **0.0016 and 0.0018**for fine and coarse aggregate respectively. Palm Kernel Shell (PKS) relatively has a low specific gravity and generally hard in its physical structure to a certain degree depending on the size and if air-dried, the specific gravity value gotten for PKS is 1.26 and the average moisture content value is 4.81. The summary of slump of fresh concrete is presented in Table 4 at each percentage replacements indicating that the slump reduces with increase of PKS

### *3.2 Effect of partial replacement of granite with PKS on the strength of concrete*

The summary of compressive strength test results for each of the non-re-vibrated and re-vibrated concrete cubes for both 7 and 28days curing ages is presented on table 4.

Table 4: Average compressive strength of concrete at 7 and 28 days curing

| S/No. | No. of cubes | Percentage replacement (%) | Average compressive strength (N/mm$^2$) | | | |
|---|---|---|---|---|---|---|
| | | | concrete 7 days curing | | concrete 28 days curing | |
| | | | Non-revibrated | Revibrated | Non-revibrated | Revibrated |
| 1 | 8 | 0 | 15.38 | 18.00 | 21.73 | 24.40 |
| 2 | 8 | 5 | 17.78 | 18.45 | 20.11 | 20.16 |
| 3 | 8 | 10 | 14.11 | 16.40 | 14.89 | 16.22 |
| 4 | 8 | 15 | 11.07 | 10.89 | 12.89 | 13.87 |
| 5 | 8 | 20 | 7.47 | 9.74 | 8.49 | 9.24 |
| 6 | 8 | 25 | 6.89 | 7.25 | 6.09 | 6.56 |
| 7 | 8 | 30 | 5.22 | 6.00 | 6.20 | 5.96 |

Compressive strength of concrete is the most universally used measure for concrete quality, because it influences other properties of hardened concrete.

The results shown in Table 4 depicts that there is an appreciable increase in compressive strength at the curing age of 28days compared with 7days curing age. There is a noticeable increase in the strength of the concrete cubes of certain percentage replacement and as the PKS content in the mix increases there is a general decrease in the compressive strength attaining a strength peak of 20.16 N/mm2 and 20.11N/mm2 for revibrated and non-revibrated concrete cubes respectively at 5% PKS in under the age of 28days. In this manner, not all the percentage replacement level meets the strength requirement of grade C20 concrete (BS 8110, 1997; Celik, 2011). Only 5% replacement of granite with PKS at

28days curing age attained the strength class of grade C15 and C20, which is the minimum strength of this type of concrete grade. Except for 25% and 30% replacement level, all other remaining replacement levels meet the minimum strength of 10N/mm2 - 15N/mm2 after 28days of curing and can be used for plain concrete where strength is of less important as specified by BS 8110 (1997).

Therefore, this means that the effect of replacing granite with PKS on the compressive strength of concrete is positive for up to 5% replacement level equivalent to grade C15 and C20 of normal strength concrete and it is negative above 5% replacement level because the compressive strength are of lesser strength.

**4. CONCLUSION AND RECOMMENDATIONS**

Experimental study on Palm Kernel Shell (PKS) as coarse aggregate replacing granite and its effect on the compressive strength of the concrete is presented. The following conclusions can be deduced:

a. Considering PKS, it has a low specific gravity and the value is 1.26, hence it requires more granite to maintain a consistent lightweight concrete strength, its average moisture content value gotten is 4.81%, the specific gravity of both fine sand aggregate and granite are within the Standard specific gravity value, and the values are 2.6 and 2.9 respectively, also the moisture content value gotten for fine sand and granite are 5.39% and 0.158%.

b. The maximum compressive strength that the 60th minute of there-vibration time at 28 days curing age for 5% PKS, suggesting that PKS can be used to replace pure granite up to 5% if the concrete is also re-vibrated up to 60 minutes.

c. The effect of Palm Kernel Shell (PKS) as coarse aggregate on the compressive strength of re-vibrated concrete is positive up to 5% replacement and meets the strength requirement of grade C20 concrete (BS 8110, 1997), but negative above 5%. Hence it can be concluded that Palm Kernel shell could be used as a constituent material of Lightweight Concrete within the class of C15 and C20.

From the conclusion made above, the use ofup to 5% Palm kernel shell (PKS) in Civil Engineering works is recommended. It can be used as a Light weight concrete especially when used in conjunction with re-vibration being adoptedasthe process of concrete placement; this will improve the concrete quality and characteristic strength of structural elements.

**ACKNOWLEDGMENT**

The authors are sincerely grateful to the Management and Department of Civil Engineering, Federal University of Technology, Minna, for the provision of the facilities for the research.

**REFERENCES**

Alengaram U., Abdullah A. l. and Muhammed Z. J. (2013). Utilization of Oil Palm Kernel Shell as Lightweight Aggregate in Concrete. Construction and Building Materials Journals,38(5): 161-172.

Auta S. M., Uthman A., Sadiku S., Tsado T. Y. and Shiwua A. J. (2016). Flexural Strength of Reinforced Revibrated Concrete Beam with Sawdust Ash as a Partial Replacement for Cement. Construction of Unique Buildings and Structures, 5(44): 31-45. Retrieved from http://www.unistroy.spb.ru August 29th 2018.

Auta S. M., Amanda U. and Sadiku S. (2015). Effect of Revibration on the Compressive Strength of 56-aged RHA - Cement Concrete.Nigeria Journal of Engineering and Applied Sciences (NJEAS).2(1), pp.115-121.

Auta S. M. (2011)..Dynamic Effect of Revibration on the Compressive Strength of Concrete. Nigerian Journal of Technological Research, 6(2): 13-17.

BS 1881 Part 108 (1983).Method for making test cubes from Fresh Concrete, British Standard Institution (BSI), 2Parks Street, London.

BS 1881 Part 111 (1983). Method for curing of Normal concrete specimens, British Standard Institution (BSI), 2 Parks Street, London.

BS 1881 Part 116 (1983).Method for determining compressive strength of concrete cube, British Standard Institution (BSI), 2 Parks Street, London.

BS 8110 Part 1 (1997).Structural use of concrete, British Standard Institution (BSI), 2 Parks Street, London.

BS 812 Part 103 (1985).Method for determination of Particle size distribution, British Standard Institution (BSI), 2 Parks Street, London.

BS 812 Part 109 (1990).Method for determination of Moisture Content of aggregates, British Standard Institute (BSI) 2 Parks Street, London.

B.S. E.N. 12620 (2008).Specifications for Aggregates from Natural Sources for Concrete. BSI, London. UK.

B.S. E.N. 12350-2 (2000).Testing fresh concrete: slump test. BSI, London. UK.

Celik H. Ozyildirim (2011). Laboratory Investigation of Lightweight Concrete Properties. Retrieved from http://www.virginiadot.org/vtrc/main/online_reports/pdf/11-r17.pdf March 25th 2018.

Krishna Rao, M.V., Rathish Kumar P. and N.V.R.C Bala Bhaskar (2008). Effect of Re-Vibration on Compressive Strength of Concrete. Asian Journal of Civil Engineering (Building And Housing) VOL. 9, NO. 3, pp. 291-301.

Kling R., Crawford H., Rosenbaum H., Sawyer S. and Weisbard S., (2000). Learning from social informatics: Information and communication technologies in human contexts. Available Online at http://www.slis.indiana.edu/SI.Retrieved May 15, 2010.

Musa, U. M. (2008) “Globalization and it effect on Nigeria. Daily triumph. Monday 7 January, p7 no 6,580, web site. www.triumphnewspapers.comOutreach in Family Life:

Principles and practices for effective family life outreach education (pp. 180-219). Thousand Oaks, CA: Sage. G.

Robertson R. and Scholte J. (2007). Encyclopedia of Globalization volume 4 U-Z MTM Publishing Inc New York.

Roodt. M. (2001). Land Restitution in South Africa; An overview in Coetzee, J.*et al* (eds) Development; Theory,Policy and Practice, OxfordUniversity Press; Oxford pp. 305-315.

Sadiq A. A. and Nwosu M. N. (2013). Evaluation of Inter – Area Available Transfer Capability of Nigeria 330KV Network, International Journal of Engineering and Technology , Vol.3 No. 2, pp.148 – 158.