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# An Investigation on The Strength and Workability of Concrete Using Palm Kernel Shell and Palm Kernel Fibre As A Coarse Aggregate

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Abstract— The study examined the compressive strength and workability of concrete using palm kernel shell and palm kernel fibre as a partial replacement for coarse aggregate. Lightweight aggregate obtained using, Palm Kernel Shell (PKS) and Palm kernel Fibre (PKF) respectively as partial replacement for coarse aggregate. Batching was done by volume using a water cement ratio of $1.1^{1}/_{2}$ :3 and 1:2:4. The concrete obtained of size 150 x 150 x 150mm$^3$ was crushed using manual compression testing machine at 7, 14, 21, and 28 days respectively. The result of the specific gravity test using water displacement method and the sieve analysis for palm kernel shell are 2.59 and it has an S-shape curve; while 4.70 and 0.265 obtained for the coefficient of uniformity ($C_u$) and coefficient of curvature ($C_c$) respectively indicate that the aggregate is uniformly graded and can be used for the production of light weight concrete. Also the values of the slump obtained for mix 1:1½:3 and Mix 1:2:4 for concrete produced with (PKS) and (PKF) are 30mm and 38mm which indicate true slump. The concrete mix ratio PKS:PKF of 50:50 for 1:1½:3 and 1:2:4 has compressive strength of 12.29N/mm$^2$ and 10.38N/mm$^2$ after 28 days, which confirms light weight concrete.

Thus, from the result obtained from this research, both palm kernel shell and palm kernel fiber could be used as a replacement for coarse aggregate in light weight concrete.

**Index Terms—** Light Weight Concrete, Compressive Strength, Workability, Palm Kernel Shell, and Palm Kernel Fibre

## 1.0 INTRODUCTION

The high demand for concrete in construction using normal weight aggregates such as; gravel and granite drastically reduces the natural stone deposits and this has damage the environment thereby ecological imbalance (Short and Kinniburgh, 1978), (Alengaram, Jumaat, Mahmud, 2008). Therefore, there is need to explore and to find out suitable replacement material to substitute the coarse aggregate which could be used in the production of light weight concrete.

Palm kernel shell which is found cheep in large quantities as a by-product in the production of palm oil in some parts of the country Nigeria is investigated. This is the reason why the engineering properties of cracked palm kernel shell and fibre was chosen to be analyzed so as to ascertain it suitability as a substitute for gravel/granite in production of concrete for construction.

Palm kernel shell and fibre shown in plate 1.0 are not common materials in Nigeria Construction Industry but it has found it usefulness in country such as Malaysia which is the second largest palm oil producing Country in the World and it produces more than half of World's Palm Oil (Alangaram, Jumaat, Mahmud, 2008). The requirement of vegetable oil is constantly increasing and more cultivation of palm oil is forecast in the near future (Ramli, 2003). At the same time, the production of palm oil result on by-products such as Empty Fruits Bunches (EFB), Palm Kernel Shells, (PKS) or Oil Palm Shells (OPS), pericap, Palm Oil Mill Effluent (POME) and Palm Kernel Fibre (PKF). These are waste materials and stockpiling such wastes have caused storage problem in the vicinity of the factories as large quantities of these waste are produced everyday.

Also, these waste are stockpile in open fields, thus it has negative impact on the environment. One of the ways of disposing waste materials would be, by using them as replacement for coarse aggregate in Building and Civil Engineering Construction Works. This will help to reduce cost of natural gravel/granite and also help to prevent the depletion of natural resources and to maintain ecological balance.

Palm kennel fibres are derived from oil palm tree (Elaeis guneensis), (Akpe 1997, Ayanbadeto 1990) and economically valuable tree, and native to West African and widespread through out the tropics.

In Nigeria, the oil palm tree, and palm fibre are used mostly as a source of fuel for domestic cooking in most areas where they occur.

Palm kernel shell PKS is the hard endocarp of palm kernel fruit that surrounds the palm seed. It is obtained as crushed pieces after threshing or crushing to remove the seed which is used in the production of palm kernel oil (Olutoge, 1995). PKS is light and therefore ideal for substitution as aggregate in the production of light weight concrete.

Olutoge (1995) in his investigations into the physical properties of palm kernel shell found tat it

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density to be 740kg/m3. He concluded that these materials has properties which resembled those of light weight concrete materials.

Olanipekun (2006) investigated the properties of palm kernel shells (PKS) as coarse aggregate to concrete. The CCS were crushed and substituted for conventional coarse aggregates in gradation of 0%, 25%, 50%, 75% and 100%. Two mix ratio (1:1:2) and (1:2:4) were used respectively. He noted that the compressive strength of concrete decreased as the percentage of the shells increased in the two proportions. His results also indicated a 30% and 42% cost reduction for concrete produced from coconut shells and palm kernel shells when used as substitute for the coconut shell were more suitable than palm kernel shells when used as substitute for conventional aggregates in concrete production. Also attempts by Abdullah (2003), Okafor (1988), and Okpala (1990) to use PKS as coarse aggregates replacing normal granite aggregate traditionally used for concrete production.

Ata et al, (2006) compared to the mechanical properties of palm kernel shell concrete with that of coconut shell concrete and reported the economy of using PKS as light weight aggregate. Generally, PKS consists of 60 – 90% particles in the range of 5 – 12.7mm (Okafor, 1988, Okala, 1990). The specific gravity of PKS between 1.17 and 1.37, while the maximum thickness of the shell was found to be about 4mm. The density of PKSC various in the range of 1,700 to 2050kg/m3 that depends on factors such as type of sand and PKS contents. Generally when the density of concrete is lower than 2000kg/dm3, it is categorized as LWC. The 28 day days cube compressive strength of about 15 – 25Mpa has been reported by them.

The present study aims to investigate the suitability of palm kernel shell PKS and palm kernel fibre PKS as replacement for coarse aggregates in the production reinforced concrete. Having carried out a brief examination of the background to this study it will be re-stated that this investigation will adopt a "waste to wealth" policy as the study materials presently have little or no economic value with disposal problem but will also ascertain their suitability as replacement for coarse aggregate in production of concrete and hence enhance their economic value.

PLATE SHOWING PALM KERNEL FIBERS

Plate 1. Palm Kernel Fibers

PLATE SHOWING PALM KERNEL SHELLS

Plate 2. Palm Kernel Shells

## 2.0 MATERIALS AND METHODS

The materials used include the following

**Sharp Sand:** The sharp was source from market where they are supply in Auchi Edo State, Nigeria. The Sharp sand was sun dried to control the moisture content during usage to conform to the requirements of BS 882 (1982).

**Palm Kernel Shells and Palm Kernel Fibre:** These were obtained from South Ibie community in Etsako West Local Government Edo State, Nigeria. The shell and fibre were put in a basket in batches and thoroughly flushed with water to remove impurities that could be a contaminant in concrete. They were sun dried and kept in waterproof sacks.

**Granite:** The granite (coarse aggregate) used for the study was of range 2mm to 19mm graded, it was source from a quarry on Iyuku Auchi suburb community Nigeria, Edo State.

**Cement:** The cement used was ordinary Portland Cement (Dangote) it was sourced from Auchi, Edo State Nigeria and conformed to the requirements of British Standard Code (BS 12 of 1996).

### 2.1 DETAILS OF MIXES

The water used conformed to BS 3148 (1980), however, the water – cement ratio of 0.75 was used, while the batching was done by volume using ratio 1:1½:3 and 1:2:4.

Calculation for the volume of constituents was carried out for a target concrete strength of 15N/mm2 using water cement ratio of 0.75. Volume of constituents for palm kernel shell and palm fibre replacement for batch one, as shown in table 2.0 below. Standard cone rubber bucket sizes (Depth 35cm) Diameter 30cm. (20 litres) was used as a measuring can (volumes 0.0235m2).

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TABLE 1
Proportion of Constituent Materials in the Concrete Mixture

| PKS : PKF | CEMENT | SAND | PKS | PKF |
|---|---|---|---|---|
| 50:50% (Mix 1:1½:3) | 0.025m³ | 0.0375m³ | 0.0375m³ | 0.0375m³ |
| 50:50% (Mix 1:2:4) | 0.025m³ | 0.05 | 0.05 | 0.05m³ |
| **GN : PKF** | **CEMENT** | **SAND** | **GN** | **PKF** |
| 50:50% (Mix 1:1½:3) | 0.025m³ | 0.0375m³ | 0.0375m³ | 0.0375m³ |
| 50:50% (Mix 1:2:4) | 0.025m³ | 0.05m³ | 0.05m³ | 0.05m³ |

## 2.2 CASTING OF SAMPLE

The size of from work adopted for concrete cub was 150×150×150mm. The concrete was mixed with various constituent in their respective percentage, placed and compacted in three layers after proper mixing by hand. The samples were remolded after 24 hours and kept in a curing tank for 7, 14, 21 and 28 days as required.

All tests were carried out at strength/ materials laboratory of civil engineering department Auchi Polytechnic, Auchi Edo States; table 2.1, 2.2 and 2.3 below shows the particles size distribution of the fine aggregate, coarse aggregate and palm kernel shell respectively, Figure 2.0, 2.1 and 2.2 shows their grain size distribution on the logarithmic scale. In all the mix, the crushing strength of the concrete cubes was determined using the compression testing machine. The result of workability was noted and also the crushing strength of the concrete cubes was noted 7, 14, 21 and 28 days respectively as shown in table 2.4 and 2.5 below. Each sample was weighed before putting into the crushing machine to ascertain it density. The compression strength of each sample was determined as follows

$$\text{Compressive strength} = \frac{Crushing\ \ Load\ (N)}{Effective\ Area\ (mm^2)} = N/mm^2$$

TABLE 2
Particles Size Distribution of the Fine Aggregate Sharp Sand.

| Sieve (mm) | Mass retained (g) | %retained | % passing |
|---|---|---|---|
| 6.30 | 0 | 0 | 100 |
| 3.35 | 500 | 16.7 | 83.3 |
| 2.36 | 300 | 10.0 | 73.3 |
| 2.00 | 250 | 8.30 | 65 |
| 1.40 | 580 | 19.3 | 45.7 |
| 1.20 | 400 | 13.3 | 32.4 |
| 0.60 | 650 | 21.7 | 10.7 |
| **Receiver** | 320 | 10.7 | 0 |

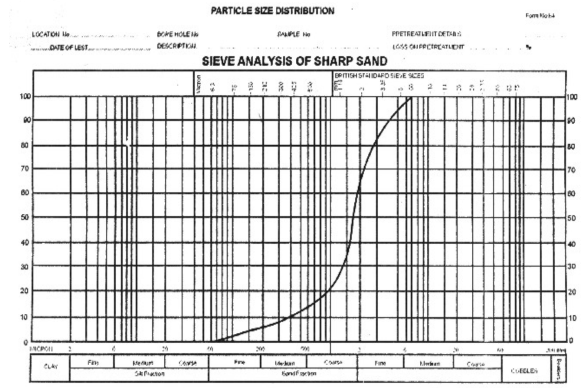


Fig. 1. The Particle Distribution Of Sharp Sand

From the graph, the uniformity coefficient cu is 4.0 and coefficient of curvature or concavity cc is 1.06 and the fineness modulus of sharp sand is 2.9. This means the fine aggregate is medium sand and it's good for concrete production. The specific gravity was found to 2.09. This make the fine aggregate satisfactory for production light weight concrete (M.S Shetty, 2005).

TABLE 3
Particle Size Distribution of Coarse Aggregate (Granite).

| SIEVE (MM) | MASS RETAINED (G) | %RETAINED | % PASSING |
|---|---|---|---|
| 24 | 0 | 0 | 0 |
| 19 | 150 | 6 | 94 |
| 13.2 | 350 | 14 | 80 |
| 9.53 | 400 | 16 | 64 |
| 6.35 | 600 | 24 | 40 |
| 3.35 | 650 | 26 | 14 |
| 2.00 | 300 | 12 | 2 |
| **Receiver** | 150 | 2 | 0 |

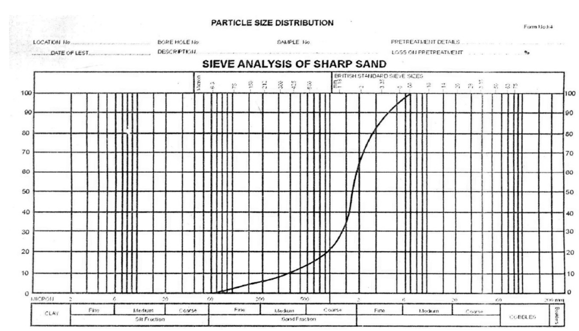


Fig. 2. Graph of particle distribution of granite

From the graph, the coefficient of curvature cc is = 0.75, uniformity coefficient cu is 2.4, the aggregate is well graded. The specific gravity was found to be 2.34 which make it suitable for a production of light weight concrete and construction of road pavement (Ahmedu, A.A., 2002, Shelty, M.S., 2005)

TABLE 4
Particle Size Distribution of Palm Kernel Shell
.

| SIEVE (MM) | MASS RETAINED (G) | %RETAINED | % PASSING |
|---|---|---|---|
| 19 | 0 | 0 | 100 |
| 13.2 | 300 | 10 | 90 |
| 9.63 | 750 | 24 | 65 |
| 9.50 | 400 | 16.4 | 52.6 |
| 6.35 | 900 | 30.0 | 22.6 |
| 3.35 | 430 | 14.3 | 8.3 |
| Receiver | 250 | 8.30 | 0 |

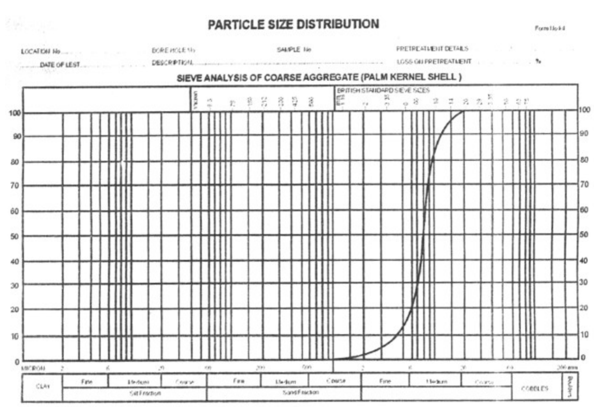

Fig. 3. Particle Size Distribution of Palm Kernel Shell

From the graph, the uniformity coefficient is 4.70 and coefficient of curvature cc = 0.265. It means the aggregate is well graded, can be used for production of light weight concrete. Also the specific gravity was found to be 2.29 which make it suitable for light weight concrete, (Ahmed, A. A. 2002, Shetty, M. S. 2005). The palm kernel shell impact value was found to be 50% which confirmed it suitability for light weight concrete production of grade C10 to C15 but weak for pavement construction (Ahmed, A. S. 2002).

### 2.3 TEST ON CONCRETE

TABLE 5
Summary of Workability Test on the Various Mix Ratios

| Mix Ratio | Slump (mm) | Compaction Factor Value | Remark |
|---|---|---|---|
| PKS : PKF 1:1½ : 3 | 30 | 0.90 | True slump |
| PKS : PKF 1: 2 : 4 | 38 | 0.70 | True slump |
| GN : PKF 1 : 1½ : 3 | 28 | 0.94 | True slump |
| GN : PKF 1 : 2 : 4 | 34 | 0.90 | True slump |

From the slump and compaction result of the various mixes the concrete made is of high degree of workability. (Shetty, M. S. 2005).

TABLE 6
Crushing Strength Value of Concrete Work

| Cube Ref | | Weight | Days /Age | Fracture Load (KN) | Compressive Strength ($N/mm^2$) | Density ($Kg/m^3$) |
|---|---|---|---|---|---|---|
| PKS:PKF 50:50%<br>PKS:PKF 50:50% | 1:1½ :3<br>1:2:4 | 5.70 | 7 | 109.12<br>109.20 | 4.85<br>4.85 | 1688.90<br>174.10 |
| PKS:PKF | 1:1½ :3<br>1:2:4 | 6.10<br>6.30 | 14 | 160.00<br>151.12 | 7.04<br>6.27 | 1807.40<br>1866.70 |
| PKS:PKF | 1:1½ :3<br>1:2:4 | 6.30<br>6.50 | 21 | 181.83<br>161.28 | 8.08<br>7.44 | 186.70<br>1926.0 |
| PKS:PKF | 1:1½ :3<br>1:2:4 | 6.60<br>6.70 | 28 | 276.37<br>243.43 | 12.29<br>10.83 | 1958.6<br>2014.60 |
| GN:PKF | 1:1½ :3<br>1:2:4 | 6.70<br>6.90 | 7 | 72.72<br>87.12 | 3.23<br>3.87 | 1985.2<br>2044.40 |
| GN:PKF | 1:1½ :3<br>1:2:4 | 6.90<br>7.20 | 14 | 145.44<br>159.84 | 6.47<br>7.10 | 2044.40<br>213.30 |
| GN:PKF | 1:1½ :3<br>1:2:4 | 6.80<br>6.90 | 21 | 196.84<br>218.16 | 8.71<br>9.70 | 2014.80<br>2044.40 |
| GN:PKF | 1:1½ :3<br>1:2:4 | 7.0<br>7.4 | 28 | 232.93<br>261.73 | 10.35<br>11.63 | 2074.0<br>2192.60 |

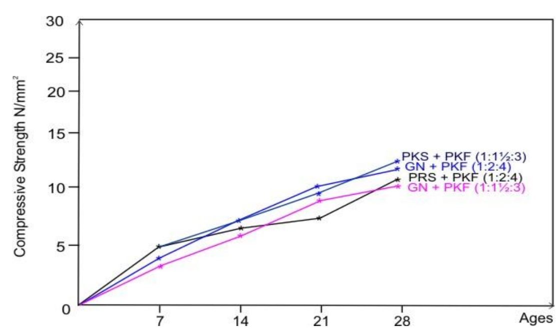

Fig. 4. Compressive Strength of Concrete Mixes

## 3.0 EFFECT OF REPLACEMENT OF COARSE AGGREGATE WITH PKS PLUS PKF IN CONCRETE

From the table, the maximum compressive strength of palm kernel shell plus palm kernel fibre is 12.29N/mm2 and 10.83N/mm2 which confirm light weight concrete strength of 10 to 15N/mm2 and 10.35N/mm2 was achieved when granite plus palm fibre was used for mix 1:2:4 having the highest strength against 1:1½:3. This also confirm light weight concrete strength although didn't follow the conventional strength attainment of the highest mix ratio having the highest strength. This could be as a result of reaction of fibre with concrete cementations materials.

It was observed that rate of absorption for water increase from 7 days to 28 days about 9.2% for PKS plus PKF for mix 1:1½:3 while mix 1:2:4 is 13.0%. It can be seen also that the percentage absorption of water for GN plus PKF of mix 1:1½:3 is 4.3% while mix 1:2:4 is 6.8%. This shows that PKF plus PKS concrete absorbed more water compared to concrete made with replacement of granite with PKF.

## 4.0 CONCLUSION/REMARK

From the result of the test carried out:

i. The possibility exists for the partial replacement of coarse aggregate with palm kernel shell plus palm kernel fibre to produce light weight concrete as recommended by BS; 8110, (1997).
ii. With 50:50 replacements of course aggregate with GN plus P.K.F. The strength attainments vary from mix 1:2:4 to 1:1½:3 with the later having the highest strength of 12.29N/mm2.
iii. With 50:50 replacement of coarse aggregate with GN plus P.K.F. The strength attainment varies from mix 1:1½:3 to mix 1:2:4 with the later having the highest strength of 11.63N/mm2. It indicates that granite is better compared to all other natural available aggregate.
iv. Organic materials are subject to deterioration over time hence concrete made with PKS + PKF and GN + PKF should be regularly maintained and replaced when necessary.
v. From it density which ranges between 1688kkg/m3 to 2014kg/m3 for concrete made with PKS plus PKF; it can be used only as light weight concrete, while partial replacement of granite with palm kernel fibre with a density running between 1985kg/m3 to 2192kg/m3 can be used as light weight concrete as well as dense concrete if the proportion of palm kernel fibre (PKF) is reduced to 10 to 25%.

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