# EFFECT OF REPLACEMENT OF SAND WITH GRANITE FINES ON THE COMPRESSIVE AND TENSILE STRENGTHS OF PALM KERNEL SHELL CONCRETE (PKSC)

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Lately, research works are being focussed on using renewable agricultural waste resources as construction materials. This is to ensure sustainability and to reduce cost of construction. Palm kernel shell concrete (PKSC) is concrete containing cement, sand and palm kernel shells wholly or partially as a coarse aggregate. This paper therefore presents results of an experimental laboratory investigation carried on PKSC by incorporating varying percentages of granite fines to replace sand in steps of 20% to study its effect on the compressive and tensile strength of PKSC. A mix proportion of 1:1.77:0.77 was used with a w/c = 0.50. Calcium Chloride ($CaCl_2$) was added as an accelerator. Results of 28-day strength test using 100 mm cubes and 150 × 300 mm cylinders revealed that the compressive and tensile splitting strengths increased with curing age and with increase in the percent granite fines content. Maximum compressive and tensile splitting strengths were obtained for PKSC containing 100% granite fines. Tensile strength obtained fall within the range of values (1.24-1.90 $N/mm^2$) given for grade 30 concrete.

Keywords: Renewable Resources; Palm Kernel Shell; Compressive Strength; Water Absorption; Palm Kernel Shell Concrete.

## INTRODUCTION

One of the major challenges facing the construction industry is the growing concern over resource depletion, hence, the need to source and utilize renewable materials. A renewable resource like the palm kernel shell (PKS) is usually not used in the construction industry but dumped as an agricultural waste. However, researches have shown that it could be used as a replacement (total or partial) for coarse aggregate in concrete (Okafor, 1988; Okpala, 1990; Mannan and Ganapathy, 2002; Mannan and Ganapathy, 2004; Teo *et al.* 2005; Teo *et al.* 2006a, b, c, d; Ramasamy *et al.* 2008).

These researches were necessitated as a result of the growing increase in the cost of building materials, the need to utilize materials seemingly regarded as agricultural waste and most importantly, the need for sustainable construction.

PKS is available in Nigeria in large quantity as waste from agricultural industries, particularly in Southern Nigeria. Exploiting this waste material not only maximises the use of the oil palm, but also helps preserve the natural resources and maintain ecological balance (Teo *et al.* 2006a).

Concrete made with PKS is a lightweight concrete. Past researches on PKSC have shown that its compressive strength is in the range of 15-25 $N/mm^2$ (Abdullah, 1984; Okafor, 1996, Basri *et al.* 1999; Ata *et al.* 2006). The strength of PKSC has been reported to be influenced by the aggregate-cement matrix bond (FIP Manual, 1983). The aggregate-cement bond is also generally reported to

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be influenced by the cement, water, sand and aggregate contents, shape, roughness and stiffness of the aggregate. Alengaram *et al.* (2008) reported that the failure of PKSC is also governed by the strength of the PKS. However, PKS usually have smooth concave and convex surfaces which produce a poorly compacted concrete and this will ultimately result in bond failure between PKS and cement matrix. To achieve PKSC of improved strength, the bond between the mortar and PKS has to be improved. Alengaram *et al.* (2008) had considered improvement of the bond of concrete by considering the influence of sand content on the mechanical properties of concrete. With all mixes super-plasticized and the addition of 10% Silica fume and 5% fly ash, Alengaram *et al.* (2008) reported that the increase in sand content has positive influence on the mechanical properties of PKSC by an increase in the density and compressive strength. Osunade (2002) had reported an increase in the compressive strength and a decrease in the tensile strength of laterized concrete with the replacement of sand with granite fines. Since sand content is a factor that influences the compressive and tensile strengths and also the bond properties of concrete, this study therefore studied and reported the influence of replacement of sand with granite fines on the workability, compressive and tensile strengths of PKSC. In this study, 2.0 % Calcium Chloride ($CaCl_2$) by weight of cement was used as an accelerator.

## MATERIALS AND EXPERIMENTAL PROCEDURE

### Material Procurement and Preparation

The basic components of palm kernel shell concrete are cement, sand, gravel or granite and palm kernel shell as total or partial replacement of the coarse aggregate. In this study, total replacement of the coarse aggregate was adopted while granite fines (GF) replaced sand at steps of 20% up to 100%. The sand and PKS used were purchased in Ile–Ife, Nigeria. The palm kernel shells (14 mm maximum aggregate size) obtained from a local mill along Ede road, 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 (Salam, 1982; Mohd Noor *et al.* 1990; Okafor *et al.* 1996 and Mindess *et al.*2003) among others. It was washed and dried again before use. Thereafter, it was graded in accordance with the British Standard methods of sampling, testing and sieve test of lightweight aggregates for concrete. The cement was obtained from the open market in Ile-Ife and was that produced by the West African Portland Cement Company (WAPCO) since their products are believed to conform to the requirements of BS EN 197-1 (2000) for Ordinary Portland Cement. The range of sizes of the fine aggregate used were those that passed through the 5 mm BS Sieve. The granite fine was obtained from a quarry along Ondo Road, Ile-Ife. Table1 presents some physical properties of the constituent materials. Water used for the mixing was clean water obtained from the tap.

### Concrete Mixture and Testing

It has been reported by Mannan and Ganapathy (2001) that the mix design of lightweight concrete using palm kernel shell as aggregate differs widely from the procedure of mix proportioning for conventional concrete with crushed stone aggregate. This study therefore adopted the acceptable trial mix design for palm kernel shell concrete reported in the work of Mannan and Ganapathy (2001). A mix proportion of 1:1.77:0.77 (cement: sand/GF: PKS) with 2.0% $CaCl_2$ by weight of cement was used. The sand content in the mix was replaced with granite fines in gradation of 0%, 20% 40%, 60%, 80% and 100%. A water/cement ratio of 0.50 was used throughout the research.

Due to the high water absorbing nature of palm kernel shells, they were immersed in water for 1 hour (pre-soaking) before use. The absorption capacity of the shells was found to be in the range of 10-15%. Cubical specimen of 100 mm and cylindrical specimen of 150 × 300 mm were used to determine the compressive and the splitting tensile strengths of the PKSC. A total of 108 PKSC specimens, 54 apiece, were cast and tested for compressive and splitting tensile strengths respectively. Each specimen was made by filling each mould in three layers and then compacted manually by evenly distributing 25 strokes of a steel rod of 25 mm diameter across the cross-section of the mould as stipulated by the requirements of BS EN 12390–2:2000. The cast specimens were covered with polythene bags to prevent evaporation until demoulding after 24 hours of casting, thereafter the specimens were transferred into a water bath maintained at $27 \pm 5^{0}$C in the curing room. The compressive and tensile strengths were determined after 7, 21 and 28 days of curing.

Strength characteristics of the cube and cylindrical specimens were tested using the ELE 2000KN Compression Testing Machine. Three replicates of each specimen at the requisite curing age of 7, 21 and 28 days were brought out of the curing tank and allowed to rest for 2 hours and then crushed. The average values of the maximum loads at which each group of three specimens failed was found and then the compressive and tensile strengths were determined. This was in accordance with BS EN 12390-3 (2002). The cylindrical specimens were compressed along two diametrically opposed generators lying horizontal. To prevent multiple cracking and crushing at the point of loading, two thin plywood strips (25 mm thick) were placed between the loading platen and the specimen to distribute the load while a special appliance fabricated was used to hold the cylindrical prisms in place to avoid tilting or rolling under load. The induced stress caused the specimen to fail by splitting into two halves across the loading plane. These tests were carried out in accordance to the provision of BS EN 12390 – 6:2000.

## DISCUSSION OF RESULTS

### Workability

The result of the slump tests are shown in Figure 1.

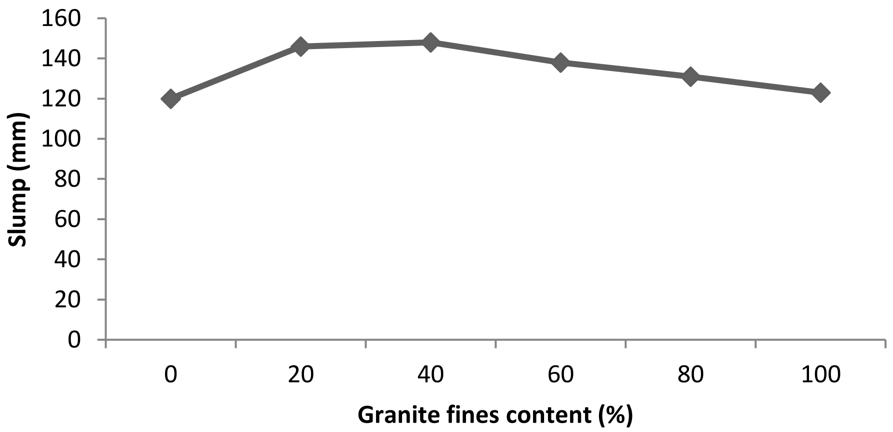


**Figure 1**: Variation of slump with granite fines content

From Figure 1, it was observed that the slump values for each replacement level of sand with granite fines (20-100%) increased at a decreasing rate above the slump value with the mix without granite fines (control). The peak slump value, 148 mm, was obtained at 40% granite fines content.

The results obtained showed that the slump increased when percentage of granite fines in the mix increased up to 40% and thereafter (60-100%), the slump value decreased. However, the result showed concretes of high workability, that is, above 50 mm. Neville (1995) stated that concrete having slump between 25 and 50 mm can be used for mass concrete foundations without vibration or lightly reinforced concrete sections with vibration. Accordingly, concrete having slump between 50 and 100 mm can be used for manually compacted flat slabs using crushed granite and also for normal reinforced concrete manually compacted and heavily reinforced sections with vibration. It can therefore be implied that, PKSC of mix proportion 1:1.77:0.77, containing 2.0% $CaCl_2$ as accelerator, with the shells at saturated surface dry (SSD) condition and a water-cement ratio of 0.5 with or without granite fines can be used for mass concrete foundations without vibration or lightly reinforced sections with vibration.

## Water Absorption Capacity

The water absorption capacity of the PKS was 9.03% (see Table1). This result is within the range of absorption capacity of lightweight aggregates which has been put at 5-20% (PCA, 1979).

**Table 1**: Physical and mechanical properties of PKS, Granite fines and Sand

| Properties | PKS | Granite fines | Sand |
|---|---|---|---|
| Maximum size | 14 | 4.75 | 5.00 |
| Specific gravity | 1.58 | 2.4 | 2.55 |
| Water absorption | 9.03 | 3.85 | 3.75 |
| Coefficient of uniformity | 1.77 | 2.60 | 2.50 |
| Coefficient of curvature | 1.00 | 0.82 | 0.75 |
| Density (g/cm$^2$) | 1.22 | 2.63 | 2.57 |

## Density of Concrete

The demoulded density of concrete produced in all cases of replacement (Table 2) ranges within 1900-1950 Kg/m$^3$. It was observed that the replacement level of the sand with GF did not impact greatly upon the density of concrete produced, though the higher the GF content, the higher the density and the higher the density, the higher the strength characteristics of PKSC. This density range falls within that of lightweight aggregate concrete (Newman, 1993; Shetty, 2002; Teo *et al.* 2006b).

## Compressive Strength of PKS Concrete

The results showed that the compressive strength of PKSC increased with increase in the granite fines content (see Fig.2). Maximum compressive strength of 14.73 N/mm$^2$ was obtained at 28 days when the sand was completely replaced with granite fines. This indicated that palm kernel shell concrete performs better in compressive strength when sand is completely replaced by granite fines. The compressive strength also increased with increase in curing age from 7 to 28 days like normal concrete. However, compressive strength at 28-day test was only slightly higher than for

21 days at the various replacement levels of sand with granite fines. Neville (1995) posited that the knowledge of the strength-time relation is of importance when a structure is to be put into use, which is, subjected to full loading, at a later age. This is similar with the results obtained when granite dust was partially substituted for sand in laterized concrete (Osunade, 2002). It could be deduced that granite fines enhanced better bond between the mortar and palm kernel shell than when sand is used.

**Table 2:** Summary of Demoulded Density, Compressive and Splitting Tensile Strengths of PKSC containing Granite Fines (GF)

| % GF content | Demoulded Density ($Kg/m^3$) | Compressive Strength ($N/mm^2$) | | | Tensile Strength ($N/mm^2$) | | |
|---|---|---|---|---|---|---|---|
| | | 7 Days | 14 Days | 28 Days | 7 Days | 14 Days | 28 Days |
| 0 | 1900 | 10.90 | 12.47 | 12.63 | 1.24 | 1.42 | 1.63 |
| 20 | 1912 | 11.17 | 13.13 | 13.33 | 1.26 | 1.48 | 1.74 |
| 40 | 1925 | 11.47 | 13.43 | 13.60 | 1.37 | 1.62 | 1.78 |
| 60 | 1932 | 11.77 | 13.70 | 13.83 | 1.49 | 1.69 | 1.81 |
| 80 | 1942 | 12.03 | 14.07 | 14.33 | 1.54 | 1.77 | 1.86 |
| 100 | 1950 | 12.33 | 14.33 | 14.73 | 1.56 | 1.82 | 1.90 |

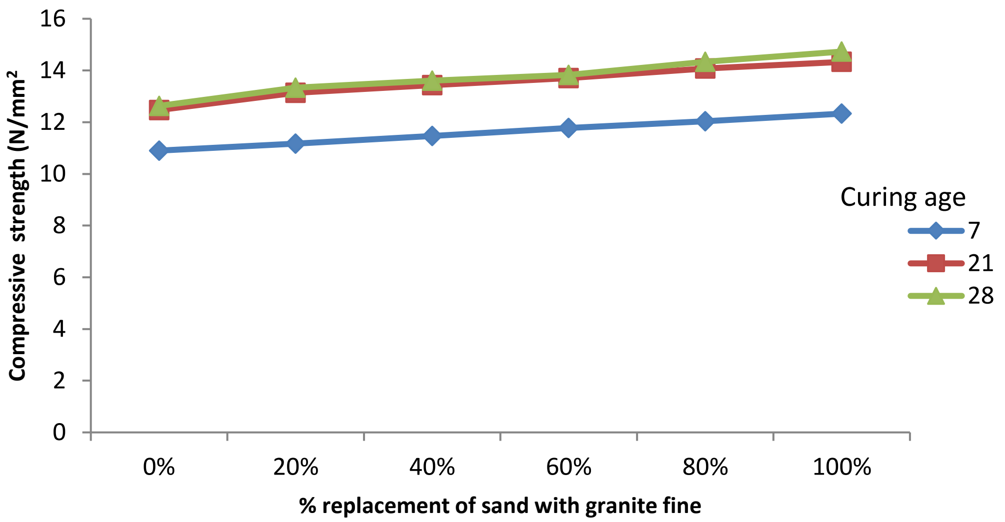


**Figure 2:** Variation of compressive strength with % granite fines

From the statistical analysis of the compressive strength results, Table 3, the analysis of variance (ANOVA) output showed that the independent factors; GF content and curing age and their interaction had significant effect on the compressive strength of PKS concrete at $p \leq 0.05$.

**Table 3:** ANOVA Output

| Source | Dependent Variab | Type III Sum Squares | df | Mean Squa | F | Sig. |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Model | Compressive Str. | 9137.800[a] | 18 | 507.656 | 4.154E4 | .000 |
| | Tensile Str. | 142.115[b] | 18 | 7.895 | 1.254E4 | .000 |
| GF | Compressive Str. | 18.933 | 5 | 3.787 | 309.806 | .000 |
| | Tensile Str. | .753 | 5 | .151 | 239.145 | .000 |
| Curing age | Compressive Str. | 49.517 | 2 | 24.759 | 2.026E3 | .000 |
| | Tensile Str. | 1.290 | 2 | .645 | 1.024E3 | .000 |
| GF * Curing age | Compressive Str. | .461 | 10 | .046 | 3.770 | .002 |
| | Tensile Str. | .049 | 10 | .005 | 7.827 | .000 |
| Error | Compressive Str. | .440 | 36 | .012 | | |
| | Tensile Str. | .023 | 36 | .001 | | |
| Total | Compressive Str. | 9138.240 | 54 | | | |
| | Tensile Str. | 142.138 | 54 | | | |
| a. R Squared = 1.000 (Adjusted R Squared = 1.000) | | | | | | |
| b. R Squared = 1.000 (Adjusted R Squared = 1.000) | | | | | | |

**Tensile strength of PKS concrete**

From Table 2 and Fig. 3, it was observed that the tensile splitting strength of the PKS concrete increased as the percentage of granite dust increased from 20% to 100%. A similar pattern of performance of compressive strength was observed for the tensile splitting strength. Total replacement of sand with granite fines (100%) at 28 days gave the optimum tensile splitting strength of 1.90 N/mm$^2$. Tensile strength obtained fall within the range of values (1.24-1.90 N/mm$^2$) given for grade 30 concrete. The tensile splitting strength also increased with curing ages from 7 to 28 days. Neville (1995) posited that although concrete is not usually designed to resist direct tension, the knowledge of tensile strength is of value to estimating the load under which cracking will develop. Table 1 showed that granite content and curing ages and their interactions also have significant effect on the tensile splitting strength of PKS concrete at 95% confidence level.

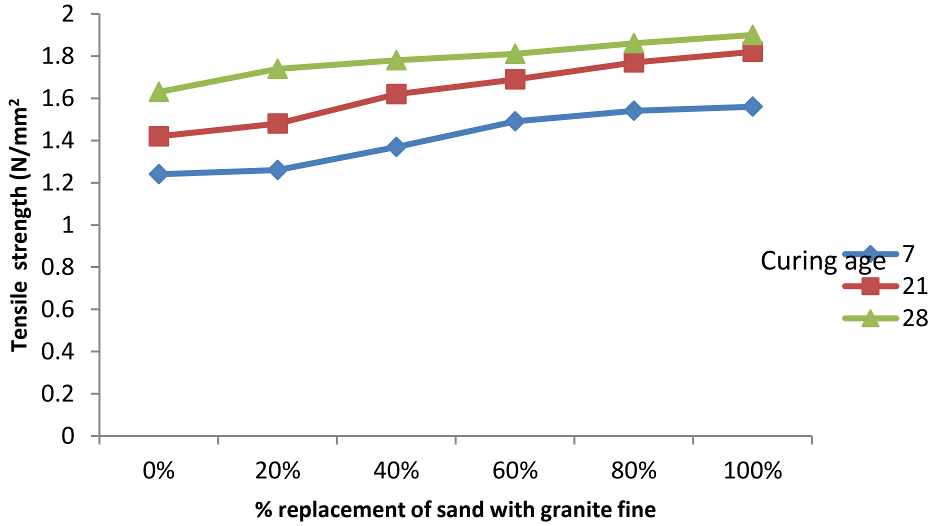


**Figure 3:** Variation of tensile strength with % granite fines

## CONCLUSIONS

Based on the results of this research, the following conclusions can be drawn;

1. Optimum slump of concrete with PKS was obtained at 40% replacement level of granite fines with sand.

2. PKSC of mix proportion 1:1.77:0.77, containing 2.0% $CaCl_2$ as accelerator, with the shells at saturated surface dry (SSD) condition and a water-cement ratio of 0.5 with or without granite fines can be used for mass concrete foundations without vibration or lightly reinforced sections with vibration.

3. The density of PKSC is not greatly influenced by the replacement of sand with granite dust at whatever percent replacement level. At all percent replacement level, PKSC was still found to be lightweight.

4. Compressive and tensile strengths of the concrete increased with increase in percentage of granite fines in the mix and with the curing age.

5. The 28-day compressive and tensile strengths of PKSC were 14.70 N/mm$^2$ and 1.90 N/mm$^2$ respectively at 100% granite fines contents.

6. The replacement of sand with granite fines (GF) in PKSC better enhanced the bond between the mortar and the coarse aggregate.

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