

Oil Palm Fiber as Partial Replacement Aggregates for Normal Concrete

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Abstract: *This study is focused on assessing the effectiveness of palm kernel shell (PKS) as partial replacement aggregates for normal concrete. The tests carried out on PKS concrete at a constant water cement ratio of 0.5 with mix ratios 1:2:4 and 1:1 $\frac{1}{2}$: 3 with PKS varied from 0%-30%. The results of the slump and compaction factor test showed that all mixes were workable for all replacement levels considered. The compressive strength values obtained ranges between 32.2N/mm²- 13.4N/mm² with implies that, the addition of PKS in the production of light weight concrete is suitable for both mix ratios. The cost analysis also revealed reduction in cost by 6.5%, 13% and 19.5% for PKS replacement at 10%, 20% and 30% respectively. It is concluded that PKS is effective, less expensive as partial replacement aggregates and also reduces environmental pollution.*

Keywords: Concrete, Compressive strength, aggregates, cement, slump and PKS

I. Introduction

Concrete is a construction material manufactured by mixing aggregates (i.e. sand, gravel, crushed stones), cement and water in the designed proportion. Concrete is strong in compression and has good resisting properties. The production of concrete using normal weight aggregates such as; gravel and granite has resulted in reduction of natural stone deposits and a continuous exploration this deposit could lead to environmental damage and ecological imbalance, the need to explore and suitable replacement material to substitute the coarse aggregates in producing concrete cannot be overemphasized. Concrete produced by using palm kernel shell could be used characterized as light weight concrete.

Palm kernel shells are not common materials in the construction industry. Palm kernel shell which is found cheap in large quantities as a by-product in the production of palm oil in some parts of Nigeria is investigated. This is the reason why the engineering properties of cracked palm kernel shell were chosen to be analyzed so as to ascertain its suitability as a substitute for gravel/granite in production of concrete for construction. Palm kernel shell are not common materials in Nigeria Construction Industry but it has found its 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. One of the ways of disposing these waste materials would be, by using them as replacement for coarse aggregate in Building and Civil Engineering Construction Works, by this it would help to reduce cost of natural gravel/granite and also help

to prevent the depletion of natural resources and to maintain ecological balance. Palm kernel shells are derived from oil palm tree and economically valuable tree found in West African and widespread throughout 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 are grown. 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 as reported by Olutoge, 1995. PKS is light and therefore ideal for substitution as aggregate in the production of light weight concrete researchers like Abdullah, 1996; Okpala, 1990; Olanipekun, 2006; Mannan and Ganapathy, 2002; Alengaram, 2008; Jumaat, 2008 investigated the physical, mechanical and structural properties of Palm kernel shell and have shown its behavior as similar to that of normal weight concrete.

1.1 Physical properties and uses of palm kernel shells

PKS have smooth and concave surfaces which are likely to affect the bond matrix with cement. Shells are one of the wastes produced during processing of palm oil. Their colour ranges from dark grey to black. However, the broken edge is rough and spiky. The thickness varies and depends on the species of palm tree from which the palm nut is obtained its ranges from 0.15 - 8 mm as reported by Basri et al., 1999 and Okpala, 1990. They are usually hard and porous in nature Palm kernel shells are used for the following:

- i. As a good source of fuel for domestic cooking in most area where they occur.
- ii. They are used as aggregates in light and dense concretes for structural and non-structural purposes.
- iii. Palm kernel shells can be used as fuel for boilers in extraction mills.
- iv. They are used as fill materials for filling pot holes in muddy areas in some areas.

II. Material and Methodology

The materials used for the Lightweight concrete experiment include;

- i. Palm kernel shells as coarse aggregate.
- ii. Fine aggregate
- iii. Cement
- iv. Water

The materials for the Normal concrete experiment are;

- i. Granites as coarse aggregate
- ii. Fine aggregate
- iii. Cement
- iv. Water

Procurement

Ordinary Portland Cement (OPC) available in the local market of Ado-Ekiti was used. The fine aggregate used was sharp sand obtained locally and having a specific gravity of 2.56. Granite of nominal size 20mm with a specific gravity of 2.65 is one of the coarse aggregate used and was obtained from a local quarry. Palm kernel shells (PKS) the second coarse aggregate having a specific gravity of 1.57 was obtained from a local market in Ikere Ekiti.

Methods

Shell Treatment: The shells were washed to remove the possibility of oil and clay particles. The shells were oven dried at a temperature of 45⁰C in order to determine the dried weight of the shells. The heaped palm kernel shell is shown in Fig 1.

Workability: The workability of the various levels of granite replacement PKS (0%, 10%, 20% and 30%) for the different mix ratios of 1:2:4 and 1:1 $\frac{1}{2}$:3 was tested using slump and compacting factor test.

Determination of the thickness of PKS: The thickness of the PKS is the dimension between the inner and the outer surfaces of the shells and was determined to have an average thickness of 4mm.

Determination of densities of the shells: The mass of the shells was determined as 6355g and the volume is 7389.98cm³.The volume of the shells was determined by the volume of the tray used for batching. The tray is round in shape with diameter of 28cm and 12cm high.

Setting up the moulds: The type of moulds used for the experiment was standardized steel mould with dimensions 150mmx150mmx150mm.

The inner surfaces of the cube moulds were oiled. After the oiling, they were assembled and made ready to be filled with concrete.

Batching of aggregate: The batching of the aggregates was done by volume with a measuring tray of known dimension this was done because the palm kernel shells are lighter in weight than the granite it is replacing, The replacement levels considered were 0%, 10%, 20% and 30%, the water cement ratio is kept constant at 0.5 and the mix ratios considered are 1:2:4 and 1:1 $\frac{1}{2}$:3.

Casting of cubes: The filling of moulds was done in three layers of approximately 50mm with each layer receiving 25 strokes of the tampering rod. After filling the moulds, the cubes were covered with polythene to control the rate of evaporation of water from the cubes

Curing of cubes: The cubes were de-moulded after twenty four hours and placed in water curing tab as shown on Fig. 2 until the required test ages of 3, 7, 14, 21 and 28 days were attained.

Crushing of the cube: At the required test age the cubes were removed from the curing tab, wiped off from the grit and weighed to determine their individual masses in grams, the cubes were centrally aligned on the base plate of the machine with the upper movable portion of the machine rotated gently by electrical means so that it touches the top surface of the cube as shown on Fig 3. Load is applied at the rate of 15N/mm² per minutes as specified in BS1881 until the cube fails.

This load is known as ‘Failure Load’ or ‘maximum crushing load’. The compressive strength of the specimen was expressed as equal to the maximum crushing load in Newton (N) divided by the cross sectional area in millimeter (mm).

$$\text{Strength} = \frac{\text{LOAD}}{\text{AREA}}$$



Fig -1: Heaped palm kernel shell



Fig - 2: Curing of concrete cubes



Fig -3: Crushing of cubes

III. Results and Tables

Workability

The results of the slump test for the different level of granite replaced with PKS for all mix ratios is shown in Tables 1 and 2. Test was done in accordance with BS EN 12350-2. The Tables indicates that the addition of PKS to the concrete is quite workable since the slump value increased for 0% - 20% percentage replacement with a slightly reduction at 30% replacement. The compacting factor ranges from 0.87-0.94 for mix ratio $1:1\frac{1}{2}:3$ and 0.83-0.91 for mix ratio 1:2:4 as presented in Table 3 and 4 which is close to the range 0.82-0.95 specified in BS 1881, part 102 of 1993. Although mix ratio $1:1\frac{1}{2}:3$ produced higher workability than 1:2:4 mix there are both workable mixes for the production of concrete using PKS as partial replacement for granite.

Compressive Strength Test

The results of the compressive strength test at 28 days for the various level of granite replacement with palm kernel shell (0%, 10%, 20% and 30%) for both mix ratios ($1:1\frac{1}{2}:3$ and 1:2:4) are 29.2N/mm², 24.3N/mm², 25.9N/mm², 13.4N/mm² and 32.2N/mm², 24.3.2N/mm², 25.9 N/mm² and 25.9 N/mm² respectively as shown in Fig 4. From the results it was observed that all the strength values were above 20N/mm² with the exception 13.4N/mm², this implied that PKS can substitute granite up to 30%, since a minimum strength of 17 N/mm² has being specified by the American Standard for Testing Material: 1978 for structural light weight concrete while British code CP 110: 1972 has specified strength values between 15 N/mm² and N/mm².

Cost Analysis

The cost analysis as presented in Tables 5-8 has shown that there is economic benefit in PKS being used as partial replacement for granite in the production of light weight concrete.

Table 1: Slump test for mix ratio $1:1\frac{1}{2}:3$

% PKS /% granite	Slump (cm)
0/100	4.0cm
10/90	5.0cm
20/80	6.7cm
30/70	5.0cm

Table 2: Slump test for mix ratio 1:2:4

% of shell /% of granite	Slump (cm)
0/100	3.0cm
10/90	3.7cm
20/80	4.0cm
30/70	3.9cm

Table 3: Compacting factor test values for mix ratio $1:1\frac{1}{2}:3$

% PKS /% of granite	C.F			
	A	B	C	C.F
0/100	4.55kg	14.3kg	15.55kg	$\frac{14.3 - 4.55}{15.5 - 4.55} = 0.89$
10/90	4.55kg	15.5kg	16.5kg	$\frac{15.5 - 4.55}{16.5 - 4.55} = 0.92$
20/80	4.55kg	14.2kg	15.6kg	$\frac{14.2 - 4.55}{15.6 - 4.55} = 0.87$
30/70	4.55kg	15.7kg	16.4kg	$\frac{15.7 - 4.55}{16.4 - 4.55} = 0.94$

Table 4: Compacting factor test values for mix ratio 1:2:4

% PKS /% of granite	C.F			
	A	B	C	C.F
4.55kg	13.3kg	14.25kg	$\frac{13.3 - 4.55}{14.25 - 4.55} = 0.87$	
4.55kg	12.6kg	13.8kg	$\frac{12.6 - 4.55}{13.8 - 4.55} = 0.87$	
4.55kg	12.95kg	13.8kg	$\frac{12.95 - 4.55}{13.8 - 4.55} = 0.91$	
4.55kg	11.9kg	13.4kg	$\frac{11.9 - 4.55}{13.4 - 4.55} = 0.83$	

Parameters

- a = weight of empty mould
- b = weight of partially compacted
- c = weight of fully compacted

$$\text{Compacting factor (C.F)} = \frac{b-a}{c-a}$$

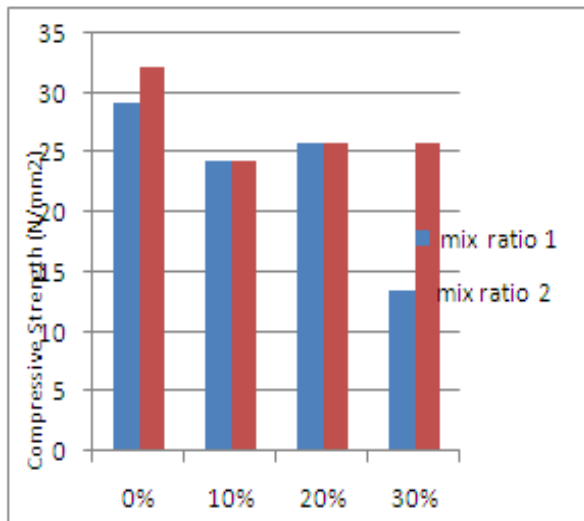


Fig-4: Compressive Strength at 28 days for both mix ratios

Table 5: Bill of Quantities

ITEM	QUANTITY	UNIT PRICE	COST
Cement	50kg(1bag)	□2,000	□2,000
Fine aggregate	10tonnes	□1,300	□13,000
Coarse aggregate	10tonnes	□2,800	□28,000
TOTAL			□43,000

Table 6: Cost Analysis for 10% PKS

ITEM	QUANTITY	UNIT PRICE	COST
Cement	50kg(1bag)	□2,000	□2,000
Fine aggregate	10tonnes	□1,300	□13,000
Coarse/PKS aggregate	9/1 tonnes	□2,800	□25,200
TOTAL			□40,200

Table 7: Cost Analysis for 20% PKS

ITEM	QUANTITY	UNIT PRICE	COST
Cement	50kg(bag)	□2,000	□2,000
Fine aggregate	10 tonnes	□1,300	□13,000
Coarse/PKS aggregate	8/2 tonnes	□2,800	□22,400
TOTAL			□37,400

Table 8: Cost Analysis for 30% PKS

ITEM	QUANTITY	UNIT PRICE	COST
Cement	250kg (5bags)	□2,000	□2,000
Fine aggregate	10 tonnes	□1,300	□13,000
Coarse/PKS aggregate	7/3 tonnes	□2,800	□19,600
TOTAL			□34,600

Economical Percentage of PKS

At 10% PKS

$$\frac{43000 - 40200}{43000} \times 100 = 6.5\%$$

At 20% PKS

$$\frac{43000 - 37400}{43000} \times 100 = 13\%$$

At 30% PKS

$$\frac{43000 - 34600}{43000} \times 100 = 19.5\%$$

IV. Conclusion

- The 28-day compressive strength of Palm kernel shell (PKS) concrete at both ratios is in the range of the typical compressive strength for structural lightweight concrete which indicates that PKS concrete is workable, consistent and easily placed.
- Cost benefit analysis revealed that PKS economical in use as partial replacement aggregates.
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