Investigation on Palm Kernel Ash as Partial Cement Replacement in High Strength Concrete

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ABSTRACT:

This study investigated the effect of palm kernel shell ash (PKSA) as a partial replacement for ordinary Portland cement in high strength palm kernel shell ash concrete. The mix design targeted a compressive strength of 50MPa at 28days. The properties studied include workability of fresh concrete, compressive strength, flexural tensile strength and splitting tensile strength hardened concrete. PKSA contents in mixes ranged between 0% and 50% by weight of cement The use of palm kernel shell ash (PKSA) has advantages like; reduction in cost of concrete, solving environmental pollution problems as well as reduced the number of landfill areas required for disposing the PKSA. PKSA partial replacement for cement not only reduced the strength properties but also the workability of steel fibre reinforced concrete. Also it was observed that increase in percentage of PKSA led to a corresponding reduction in both flexural and compressive strength when compared with control concrete. Since the strength reduced with further addition of PKSA from 25%, it is recommended that optimum replacement level of ordinary Portland cement by Palm kernel shell ash is 25% for good compressive and tensile properties.

Keywords - *Palm kernel shell ash, Cement, Flexural strength, Compressive strength.*

1. INTRODUCTION

There has been so much demand on construction materials in many countries around the world. Concurrently with the rapid expansion of construction activities, housing and other building, at the same time the rising cost of production with very serious shortage on construction material that will play a critical role in our long term future. The discovery of the alternative of conventional building materials that is cheaper and accessible became highly critical issue.

Due to the limited utilization of waste materials, the rate at which they disposed as landfill materials is expected to increase consequently leading to potential future environmental problem. Accumulation, burning and landfill of solid waste disposal could be expensive and undesirable. Reuse these materials in workable areas such as in the construction industry which is considered as very active area over the entire world is a current practice.

The introduction of new materials in today's construction market is the result of resource constraints, advances in engineering techniques and cost-serving measures. Attempts have equally been made by various researchers to reduce the cost of concrete and hence total construction cost by investigating and ascertaining the usefulness of materials which could be classified as agricultural or industrial waste. Some of these wastes include sawdust, pulverized fuel ash palm kernel shells, slag, fly ash etc which are produced from milling stations, thermal power station, waste treatment plants etc. The utility of fly ash as partial replacement in concrete mixes is on the rise.

The quantity of fly ash produced from power plants in India is approximately 105 million tonnes each year (Fernandez, 2007). The production of cement is increasing annually by about 3% (Mccafrey, 2002). The production of one tone of cement liberates about one tone of CO_2 to the atmosphere, as the result of de-carbonation of the limestone in the kiln during manufacture of cement and the combustion of fossil fuel (Mccafrey, 2002).The contribution of Portland cement production worldwide to the green house gas emission is estimated to be about 1.35 billion tonne annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere (Malhorta, 2002). Cement is also among the most energy intensive construction materials. To reduce the greenhouse effect, some mineral admixtures have been studied as partial replacements for cement in plain and reinforced concrete. Some of the material that have been used to replace cement partially in concrete include fly ash, rice husk ash, palm oil fibre ash, palm kernel shell ash, ground granulated blast furnace slag and silica fume.

Palm kernel shell ash (PKSA) has the potential to be used as a construction material.PKSA is the ash produced from husk fibre and shell of palm oil burning by generation plant boiler which generates energy to be used in palm oil mill in order to extract palm oil.PKSA is found to have high pozzolans material and it can not only be used as partial cement replacement but also can increase the compressive strength and durability of concrete.

2. AIM AND OBJECTIVES

The aim of this study is to investigate the potential of producing high strength concrete by partial replacement of cement with palm kernel shell ash concrete. The Specific Objectives include:

- To design a concrete mix with a targeted 28-day strength of 50MPa which will have the properties of high Strength Concrete;
- To study the compressive strength, flexural strength, split tensile strength and workability test of high strength palm kernel shell ash concrete from the cast sample;
- To compare the tests result from Concrete containing palm kernel ash as a partial replacement for cement, with that of conventional concrete with ordinary Portland cement (OPC).

3. METHODOLOGY

3.1 MATERIAL USED

The materials used for this experimental work are Cement, Palm kernel shell ash, Sand, Water, and Superplasticizer.

A. Cement

In the investigation, Ordinary Portland Cement obtained from Lafarge Company of 53 grade was used in the laboratory experiment carried out. It conforms to BS 12, (1996) and BS 4550 parts, (1978).

B. Palm Kernel Shell Ash

The palm kernel shell burnt to ash in this research work was obtained from a black smith workshop in Igbara – Odo Ekiti, Ekiti State, Nigeria. The ash was sieve using sieve number 0.425mm and only ash particles that pass through sieve was used in the concrete preparation.

C. Fine aggregates

The Fine Aggregate used (i.e. Sharp sand) was sourced from Ajibode borrow pit in Ibadan, Nigeria. It was thoroughly washed with water to reduce the level of impurities and organic matter, and later sun dried. The fine aggregates (sand) particle sizes ranges from 0.10mm-6.0mm in diameter which conformed to the requirements of BS 882 (1982).

D. Coarse Aggregates

The coarse aggregate used for the investigation was sourced from PW Construction quarry and crusher site located at Km 13+000 (Akinyele area) along the Ibadan – Ilorin dual carriageway, in Ibadan, Nigeria. Coarse aggregates of size 20mm were used in the preparation of the concrete.

E. Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Potable water was used in preparing the soil cement and concrete specimens. The water used for the study was obtained from a borehole at PW Laboratory, Ibadan. The water was clean and free from any visible impurities. It conformed to BS3148 (1980) requirements.

F. Chemical admixture

In concrete, the water-binder ratio is generally kept as low as possible and hence to obtain the given degree of workability, chemical admixtures, such as, super plasticizers were used. CONPLAST SP 430 was used throughout the investigation. The principal effect of this Superplasticizer admixture is its high range water reducing at equal consistency. It is a dark brown coloured liquid complying with BS 5075 part III and ASTM-C 494 Type F (as provided by the manufacturer). The specific gravity is 1.19±0.01 kg /l at 20°C and solid content is 43% by mass.

G. Mix Proportioning of concrete

In this study, control mix was designed to achieve a target compressive strength of 50MPa. Palm kernel shell ash was used to replace ordinary Portland cement at various levels of 0%, 25% and 50% by mass of binder content. The mix proportions of different mixes are shown in TABLE 3.4.Two types of investigations were carried out. The first investigation was the preliminary investigation in which the DOE method was used to design trial mixes for grade 50 concrete. After the preliminary investigations, a specific design mix was then adjusted for final experimental investigations in which the study materials were used as partial replacement for cement in plain concrete.

Table 3.1: Summarized Concrete Design for all Mixes

MIX No.	MIX ID.		WATER (Kg)	CEMENT (kg)	PKSA (Kg)	CA (kg)	FA (kg)	SP (L)	W/C
1	**G**	**Per m^3**	170	425	-	1083	722	88.54	0.4
2	**GA**	**Per m^3**	170	425	-	1083	722	88.54	0.4
3	**K**	**Per m^3**	170	318.75	106.25	1083	722	88.54	0.4
4	**Y**	**Per m^3**	170	212.50	212.50	1083	722	88.54	0.4

Table 3.2: Designation for Each Mix Proportion

MIX NO.	MIX ID.	MIX Proportion.
1	G	Control concrete
2	GA	Concrete with 0% PKSA
3	K	Concrete with 25% PKSA
4	Y	Concrete with 50% PKSA

3.2 Experimental Methodology

3.2.1 Compressive Test Strength

Eleven cubic specimens of 100mm x 100mm x 100mm each were cast. Three each were to be tested to determine the compressive strength at 7, 28 and 56 days of curing; this was done in accordance with to BS EN 12390-3 (BSI, 2002). As earlier mentioned, eleven cubic specimens of dimensions 100mm×100mm×100mm were cast for each concrete mix of varying PKSA content. The specimen were demoulded after 24 hours and cured under water in a curing tank. Three each of the cubes were tested to determine the compressive strength at 7, 28 and 56 days. It was done in accordance with BS EN 12390-3 (BSI, 2002).After the specimen have been soaked and removed from the curing tank, the specimens were taken to the electronic testing machine where load was applied and increased until failure. The machine automatically stops when failure occurs, and then displays the load and the compressive strength was evaluated. The compressive strength of each sample was determined as follows;

$$\textit{Compressive strength} = \frac{\textit{Crushing load (N)}}{\textit{Effective Area (mm}^2\textit{)}}$$

Figure 3.1: Compressive test

Figure 3.2: Weighing of Hardened Concrete Cube

3.2.2 Flexural Strength Test

The specimens used for flexural tests were 100 x 100 x 500 mm. The flexural test was performed according to BS EN12390-5 (BSI, 2000). The test was carried out with the automatic techno test flexural machine at The Polytechnic Ibadan, Oyo state, Nigeria. Three cylindrical concrete specimens of 100mm x 150mm each were cast.

3.2.3 Splitting Tensile Test

This test is sometimes referred to as, "Brazilian Test". The splitting tensile test of cylinder was conducted in general accordance with BS EN 12390-6 (BSI, 2000). Three prism concrete specimens of 100mm x 100mm x 500mm each were cast. These were to be tested to determine the flexural strength; this was done according to BS EN 12390-6 (BSI, 2000).

3.3. EXPERIMENTAL RESULTS

3.3.1 Workability

The workability of concrete was carried out throughout all the concrete series mixes and measured by Slump test. The result gotten is presented in TABLE 3.3

Table 3.3: Results of the Slump test carried out on fresh concrete

MIX NO.	MIX ID	SLUM(mm)	Difference (%)
1	G	120	0
2	GA	125	+4
3	K	110	-8
4	Y	94	-22

All the measure slumps were true slumps. According to the slump values G (Control concrete) produced good workability and the value of slump depends on the PKSA replacement in the concrete mix. From TABLE 3.3 it can be seen that the workability decreases with increment of palm kernel shell ash (PKSA) as partial replacement of cement. It was observed that the slump values of concrete contained PKSA when compare with control concrete decreases as the percentage of ash increases. This is mostly because of a lesser amount of available free water in the presence of PKSA. The PKSA particles were more porous and possessed a greater specific surface than cement. These results show that the higher the PKSA rate, the lower the workability of concrete.

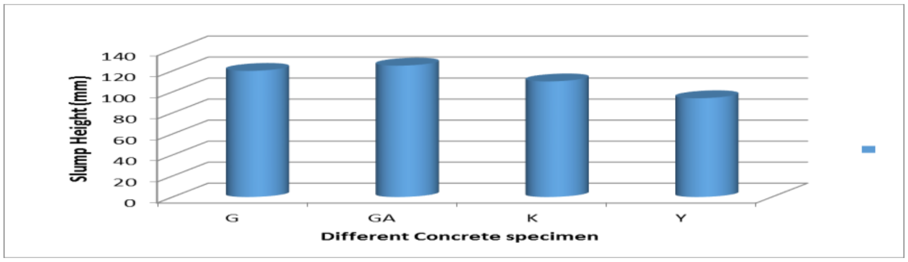

Figure 3.3: Results of the Slump test carried out on fresh concrete

3.3.2 Compressive Strength Test

Compressive strength was tested using direct compression testing on 100mm cubes. The maximum load for failure was obtained and the average of the compressive strength of three samples was reported in this study at each age of test. TABLE 3.4 shows the values of compressive strength at 7, 28 and 56 days respectively.

Table 3.4: Summary of Compressive Strength of Cubes

Mix No	Mix ID	7 days	28 days	56 days
1	G	35.97	42.06	47.14
2	GA	37.20	43.38	47.98
3	K	31.42	45.38	49.28
4	Y	19.08	34.83	39.25

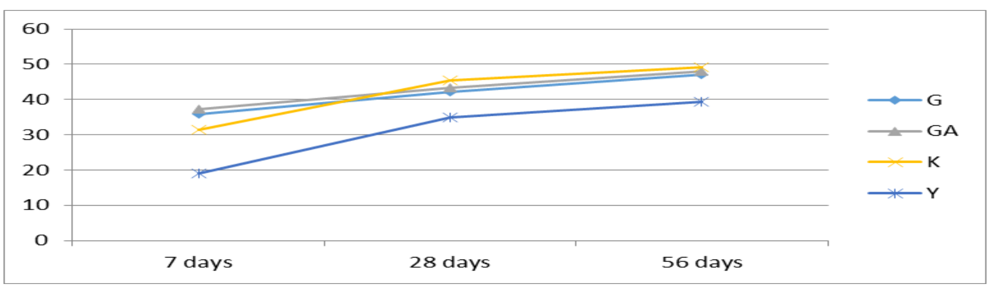

Figure 3.5: Compressive strength development with respect to age of different concrete Mix

The following discussions can be made from the results shown above;

The summary of compressive strengths of the concrete mixes measured at 7, 28 and 56 days are presented in Table 3.4. It was observed that, under compressive loading for the specimens, extensive cracks were produced in the concrete during the pre-peak stage and then suddenly failed at peak load (brittle failure). The PKSA mix had a reduced compressive strength at 7 days. This was particularly true for the 50% PKSA mix. Its early strength was reduced by about 47% when compare with compressive strength value of control concrete. However, significant recovery of the compressive strength occurred after 28 days and the recovery was more pronounced after 56 days.

At 28 days, control mixture G (control concrete) achieved compressive strength of 42.06 MPa, where as other mixtures GA, K, and Y achieved compressive strength of 43.38 and 34.83 MPa, respectively. The 25% and 50% replacement level of PKSA mixes (K and Y) the compressive strength is low at 28 days but improved at 56 days. Figure 3.5 further illustrates the compressive strength results.

3.3.3 Flexural Strength Test

Flexural strength was carried out at 28days.The specimens were loaded and tested in accordance with the BS EN12390-5 (BSI, 2000). The three-point loading method was adopted with the forces applied perpendicularly to the beam without eccentricity. Loading is done continuously without any shock. The reaction was parallel to the direction of the applied force at all times and the ration between the point of loading and the nearest reaction to the depth of the beam was not less than one.

Flexural strength of the concrete prisms is shown in TABLE 3.5, the flexural strength reported is the ultimate flexural strength.

Table 3.5: Summary of Flexural Strength of Prism

Mix No	Mix ID	28 days
1	G	3.94
2	GA	4.01
3	K	2.62
4	Y	2.44

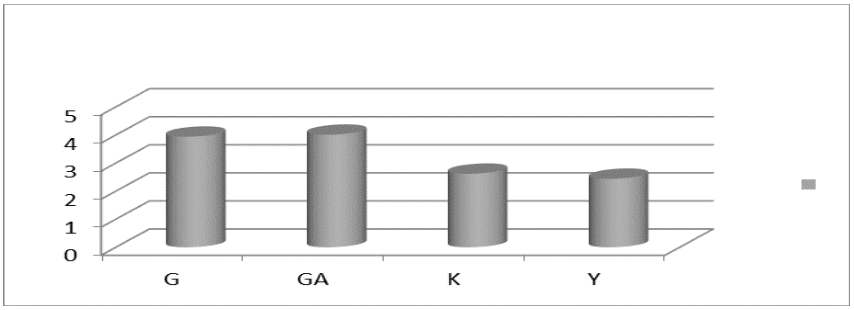

Figure 3.6: Graph showing variation of flexural strength for different concrete specimen

The following discussions can be made from the results shown above;

Flexural strength of all the specimens is very low. From Figure 3.6 flexural strength at 28 days of control mixture G was 3.94 MPa and the flexural strength of other mixes GA, K and Y achieved strength of 4.01, 2.63 and 2.44 MPa respectively. The flexural strength values of concrete with palm kernel shell ash (PKSA) when compare with the control concrete were reduced by 33.5% and 38%. Flexural tensile strength was increased with age. Flexural tensile strength was reduced with increase in palm kernel shell ash replacement.

3.3.4 Split Tensile Strength

Table 3.6 shows the split tensile strength values of cylinder after 56 days of curing.

Table 3.6: Summary of Split tensile Strength

Mix No	Mix ID	56 days
1	G	4.03
2	GA	4.04
3	K	5.31
4	Y	4.39

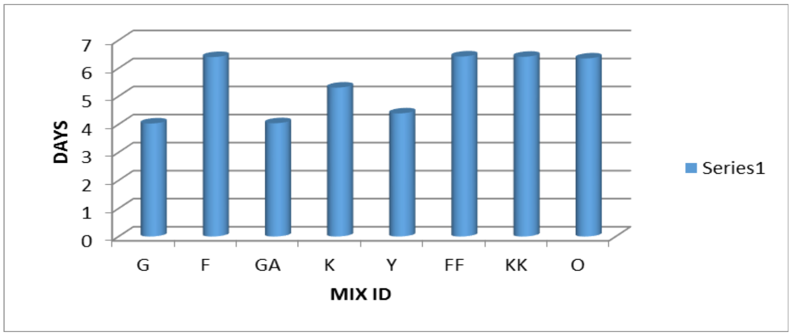

Figure 3.7: Graph showing variation of Split tensile strength for different concrete specimen

From TABLE 3.7 split tensile strength at 56 days of control mixture G (0 % PKSA) was 4.03 MPa. The other mixes K, and Y achieved a split strength of 5.31 and 4.39MPa respectively ; An increase of 31.8% and 8.9% were noticed respectively in Comparison with G (control concrete mix). Split tensile strength was reduced with increase in palm kernel shell ash replacement.

3.4 Cost Analysis

This analysis is done under two sections for a unit of concrete ($1.0m^3$). Firstly, cost analysis for plain concrete was done, and then concrete containing 25% Palm kernel shell ash (PKSA) as partial replacement for cement was analyzed. TABLE 3.7-3.9 shows the analysis as follows;

Table 3.7: Cost Analysis for $1m^3$ of Plain Concrete

ITEM NO.	ITEM DESCRIPTION	QUANTITY REQUIRED	UNIT	RATE (N)	AMOUNT(N)
1.1	Cement	425	Kg	34	14,450.00
1.2	FA	722	Kg	2	1,444.00
1.3	CA	1083	Kg	3.50	3790.50
1.4	SP	1.28	Kg	75	95.63
1.5	Water	170	L	0.8	138.00
1.6	Workmanship	-	Sum	-	6,000
1.7	Overhead	-	Sum	-	4,000
TOTAL					**29,918.13**
CONTINGENCY (5% of Total Cost)					**1495.91**
OVERALL TOTAL FOR 1m3					**31,414.04**
COST FOR 0.038m3					**1,193.73**

NB: Cement is **N1, 700** per 50kg, 1kg=**N34**, CA is #3,500 per 1Ton, **1kg= N3.50**

FA is **N2, 000** per 1Ton, **1kg= N2.00**, Water is **N20** per **25L**, **1L= N0.8**

SP is N75 per kg.

Table 3.8: Cost Analysis for 1m^3 of Concrete Containing 25% PKSA

ITEM NO.	ITEM DESCRIPTION	QUANTITY REQUIRED	UNIT	RATE (₦)	AMOUNT(₦)
2.1	Cement	318.75	Kg	34	10,837.50
2.2	PKSA	106.25	kg	10	1062.50
2.3	FA	722	Kg	2	1,444.00
2.4	CA	1083	Kg	3.50	3790.50
2.5	SP	1.28	Kg	75	95.63
2.6	Water	170	L	0.8	138.00
2.7	Workmanship	-	Sum	-	6,000
2.8	Overhead	-	Sum	-	4,000
TOTAL					**27,368.13**
CONTINGENCY (5% of Total Cost)					**1365.41**
OVERALL TOTAL FOR 1m^3					**28,736.53**
COST FOR 0.038m^3					**1,091.99**

Savings per cubic meter of concrete = 1,193.73-1,091.99 =₦ 101.74

Percentage savings = (101.74/1,193.73)*100 = 8.52%

NB: The cost of PKSA is placed at #10 per kg. This cost is a variable cost because it depends on the location where the Palm kernel shell ash is gotten, the transportation and the workmanship to burn it to ash. The fibre is free of charge at present because, it is consider as a waste. This cost can be as low as #1 if a better approach is adapted to getting and burning the fibre. The quantity of fibre taken per time is also a factor. There were reductions in cost up to 8.52% for every cubic meter of concrete with 25% quantity of palm kernel shell ash as a partial replacement for cement during the concrete production in the study. The higher the quantity, the cheaper the cost per kg.

5.0 CONCLUSIONS AND RECOMMENDATIONS

Concrete with high volume of cement replacement by palm kernel shell ash (PKSA) is investigated for its mechanical and durability properties. The following conclusions were derived from the above studies.

- The incorporation of palm kernel shell ash (PKSA) as a partial replacement of cement in fresh concrete also decreases workability when compared to control concrete made without PKSA
- The addition of PKSA into concrete mixture did not improve its ultimate compressive strength of 7 days curing specimen, but after 28days and 56days only small increase in compressive strength with addition of PKSA content was observed.
- It is observed that the Flexural strength was reduced with increased in PKSA content.
- Split tensile strength is not affected much by the cement replacement. The higher the percentage of PKSA in the concrete the lower the split tensile strength
- Increase in cement replacement with palm kernel shell ash also reduced the water absorption of concrete.
- It is recommended that optimum replacement level of ordinary Portland cement by Palm kernel shell ash is 25% for good compressive and tensile properties, since the strength reduced with further addition of PKSA from 25%.
- It can also be recommended to carry on the investigation of this material for the rest of durability aspects of high strength concrete that not yet be investigated such as Rapid chloride penetration and Alkali silica resistance tests.
- Production of Palm kernel shell (PKSA) ash in terms of fineness of the particle should be taken under account in order to enable better performance of concrete consisting of PKSA.
- Study should also be carried out on mechanical properties of PKSA concrete such as modulus of elasticity.

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