Economical Structural Lightweight Concrete made with Natural Palm Kernel Shell Aggregates.

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Abstract

Palm kernel shell (PKS) is a solid waste and a by- product from processing palm nuts to produce palm oils. Palm kernel shell is non toxic, inert, bio -renewable, abundantly available, strong, stiff, lightweight and corrosion resistant

Most coarse aggregates are from quarries which are expensive to produce. The quarry operations also affect the environment negatively.

The major objective of this study was to evaluate the suitability of palm kernel shells as a light weight aggregate in concrete.

The study assessed the workability, strength and production cost of light weight concrete using palm kernel shell as a partial replacement for coarse aggregate.

Batching was done by volume with a mix ratio of cement: fine aggregate: coarse aggregate of 1:2:4 Laboratory tests were conducted on concrete made with 30 percent and 50 percent of palm kernel shell aggregate replacement of normal granite coarse aggregate. The density of the normal weight concrete using granite aggregate was 2655 kg- m^3 while the densities of the 30 percent and 50 percent of the palm kernel shell aggregate replacement were 2000 kg- mm^3 and 1779 kg-mm^3 respectively. The 28 day compressive strength values for the normal granite coarse aggregate concrete was 20.1 N- mm^2 while the 30 percent and 50 percent palm kernel shell partial replacement of the granite coarse aggregate were 12.6 N- mm^2 and 11.2 N- mm^2 respectively. The reduction in density and the compressive strength of the palm kernel shell aggregate concrete met the criteria for structural lightweight concrete. There was a cost savings of 10.69 cedis and 17.81 cedis per cubic meter of concrete with 30 percent and 50 percent palm kernel shells replacement of granite aggregates respectively.

In conclusion, the major advantage for palm kernel shell aggregate utilization in concrete is cost and waste reduction leading to the production of a cheaper structural lightweight concrete and a cleaner environment.

Keywords

Palm kernel shell; lightweight concrete; bio-renewable; inexpensive; absorption.

1. Introduction

1.1 statement of the problem

Palm kernel shell (PKS) is a solid waste and a by- product from processing palm nuts to produce palm oils and also palm nut soup, a local delicacy, in Ghanaian household dishes. Palm kernel shells which come in different shapes and sizes are hard endocarps that surround the kernel. The shells which are flaky and irregular shape depend on the breaking pattern of the nut (Olutoge, 1995). The color ranges from dark grey to black. The surfaces of the shells are fairly smooth for both the concave and convex faces except the broken edges which are rough and spiky.(Shafigh et. Al, 2010).Palm kernel shell cane an ideal construction material for lightweight concrete since it is non toxic, inert, bio -renewable, abundantly available, strong, stiff, lightweight, and corrosion resistant. (Atteh, 2012)

Despite the above attributes, palm kernel shells are stockpiled at open spaces in Ghana which have negative impact on the environment such as breeding spots for mosquitoes. During major rainstorms, some of the palm kernel shells are also carried away by surface water thereby clogging local drains.

Currently, there is inadequate supply of fresh high quality aggregates from quarries near metropolitan areas in Ghana. The cost of production of crushed aggregates is high due to importation of dynamites with hard currencies..Moreover, the quarrying operations adversely affect the environment in various ways such as:

- Pollution of water bodies with sediments and industrial oils
- Excessive dusts causing air pollution which trigger asthma attack in children
- Noise pollution from blasting and crushing
- Increased erosion at the quarry site.
- Vibration damage (cracks) to nearby buildings.

The high cost of production of aggregates and the environmental concerns have necessitated the partial replacement of coarse aggregates with palm kernel shells to produce lightweight concrete which can mitigate potential ecological disaster.

Lightweight concrete has numerous advantages such as savings on reinforcement, formwork, scaffolding, foundation work, better fire resistance, heat insulation, and sound absorption. Moreover, the use of concrete with a lower density permits construction on grounds with a low load –bearing capacity (Neville, 2005).

A research work conducted by Shafigh et, al. (2010) on palm kernel shells concluded that the density of the palm kernel shell aggregate concrete is lower than normal weight concrete by 20 -25 percent. They also stated that the mechanical properties of palm kernel shells (pks) aggregate concrete are slightly lower than the normal weight concrete.

Okpala, (1990), also reported that the mechanical properties of the palm kernel shell aggregate lightweight concrete range from 20 -25 MPa due to the smooth surface of the palm kernel shell which weakened the bond between the aggregate and the cement matrix.

1.2 *Objectives of the Study*

The major goal of this study was to evaluate the suitability of palm kernel shells as a light weight aggregate. The specific objectives covered the following:

- To produce lightweight concrete using palm kernel shell as a partial replacement for granite coarse aggregate
- To compare the compressive strength of palm kernel shell lightweight concrete versus normal Portland cement concrete using granite coarse aggregates.
- To examine the consistency characteristics of fresh palm kernel shell lightweight concrete.
- To evaluate the cost of producing one cubic meter of concrete made with palm kernel shell partial replacement aggregate to that of normal Portland granite concrete.

2. Methodology

2.1 *Materials and sample preparation*

2.1.1 Palm kernel shells

The palm kernel shells were collected from an abandoned palm kernel shell pile from a local palm kernel grinding machine shop at Bolgatanga, capital city of Upper East region of Ghana, West Africa. The palm kernel shells which came in different shapes and sizes represented the three types of palm nuts in Ghana namely pacifera, dura and pennera palm fruits. The dura has the large nuts followed by pacifera (local wild variety) and then pennera (small nuts). (Asare Bediako, 2012, personal communication) The palm kernel shells were mostly black in color, organic, lightweight, inert, and hard and had micro grooves on their external convex surfacegiving them rough textures.The palm kernel shells were cleaned and air dried for 72 hours at a temperature of 40 degrees Celsius

2.1.2 Coarse aggregates

The coarse aggregate wasgranite which was collected from theUpper Quarry site in Bolgatanga municipality. The area is underlain by a large granite body, designated as granite series, a Proterozoic Precambrian rocks, on Ghana Geological Map. The mineralogy of the granite comprised quartz, mica, plagioclase feldspar and hornblende,

2.1.3 Cement

The cement used was ordinary Portland cement which conformed to the requirements of BS 12 (1996) . The manufacturer was GHACEM, the main producer of cement in Ghana.

2.1.4 Water

Water for this research was portable, i.e., clean and free from any visible impurities. It was obtained from a borehole but complied with BS 3148 (1980) requirements

2.2materials testing

Various tests such as grading, flakiness/elongation, loose density, specific gravity and absorption were conducted on the coarse aggregates (granite and palm kernel shells).Similar tests were performed on the fine aggregates except for the flakiness/elongation tests.

2.3 *Design of Concrete Mix*

The goal of the concrete mix design was to achieve a consistent workable fresh concrete and the desired compressive strength at a specified age and at a reasonable cost.

2.4 Batching and mixing of materials

Batching was done in volume using a trial mix of cement/fine aggregate/coarse aggregate ratio of 1:2:4. The percentage partial replacements of granite coarse aggregate by palm kernel shells were 30 percent and 50 percent respectively. A mix using 100 percent granite coarse aggregate was prepared as a control mix; the water/cement used was 0.45. A summary of the trial mixes is tabulated in Table 1.

A standard size 100mm x100mm x100 mm concrete cubes wasmolded with different mixes.

Table 1: Summary of the Trial Mixes Proportions

GROUP	% PKS	MIX RATIO	WATER	CEMENT	SAND	GRANITE	PKS
1	0	1:2:4	3200ml	1.0	2.0	4.0	0.0
2	30	1:2:2.8:1.2	3200ml	1.0	2.0	2.8	1.2
3	50	1:2:2:2	3200ml	1.0	2.0	2.0	2.0

2.5 Curing

The cubes were placed under shade immediately after casting. They were removed after 24 hours and soaked in large water bath until the specified test days of 7 and 28 days.

2.6 Workability and compressive strength Tests

The slump test which measures the workability of fresh concrete was performed in accordance with (BS EN 12350-2:2000).

The compressive strength test was carried out using BS 1881:116:1983 procedure.

The test results of specific gravity, absorption and flakiness index of the sand, granite coarse aggregate and the palm kernel shell are summarized in Table 2.

3. Results

Table 2; the test results for the specific gravity, water absorption and flakiness index.

Materials	specific gravity	absorption (%)	Flakiness index
Fine Aggregate	2.65	1.0	-
Coarse Aggregates	2.68	0.4	30.5
Palm Aggregates	1.81	8.0	69.7

Table 3 shows the results for consistency (slump), density of the fresh concrete and the effect of curing on the compressive strength of hardened concrete.

Table 3: Summary of test results for fresh and hardened concrete.

Mixed ratio	Slump (mm)	Density (kg/m^3)	Compressive strength (N/mm^2)	
			7 days	28 days
1:2:4 normal Concrete	55	2655	14.62	28.13
1:2:2.8:1.2 30% PKS concrete	53	2000	10.62	22.6
1:2:2:te2 50% PKS concrete	53	1779	7.78	21.63

4. Discussion

4.1 Absorption

The essential characteristic of light weight aggregate is its high porosity, which results in a low apparent specific gravity and high absorption rate. The absorption rate for the palm kernel shell aggregate of 8 percent was high for normal coarse aggregate, but was markedly lower than the 20 percent or greater absorption rate for both natural and synthetic light weight aggregates which have been reported in the literature.

These palm kernel shells if used as a lightweight coarse aggregate will reduce the drying shrinkage and desiccation of fresh concrete.

4.2 Density

The density of the fresh concrete with 100 percent granite coarse aggregate was 2655 kg/m^3. The density of the concrete was reduced by simply replacing some of the granite coarse aggregate with palm kernel shell aggregates while all the other constituents remained the same. The densities of the fresh concrete with 30 and 50 percent palm kernel shell aggregates were 2000 kg/m^3 and 1779 kg/m^3 respectively. The percentage reduction in density was 24.67 and 32.99 respectively. The results support the findings of Shafigh(et. Al. 2010) .These low densities qualified the mixture as lightweight concrete.

4.2 Curing and compressive strength development

Figure 1 shows the effect of curing on the compressive strengths of the various concrete mixes.. From the figure, the concrete mix with 50 percent replacement of palm kernel shell aggregate showed the greatest improvement in strength from the 7-day to 28-day of about 178 percent followed by the 30 percent palm kernel shell aggregate replacement which was 113 percent. The normal granite coarse aggregate concrete showed the least improvement of strength of 92 percent. This improvement in strength in the palm kernel shell aggregate concrete is attributable to the microgrooves on the palm kernel shells aggregates which provided a good mechanical interlock or bond with the surrounding hydrated cement paste. Atteh (2012) hypothesized that the water absorbed by the palm kernel shells aggregates at the time of mixing became available with time for the hydration of the hitherto unhydrated remnants of cement. As most of this additional hydration occurred in the aggregate-cement paste interface zone, the bond between the aggregate and the matrix becomes stronger.

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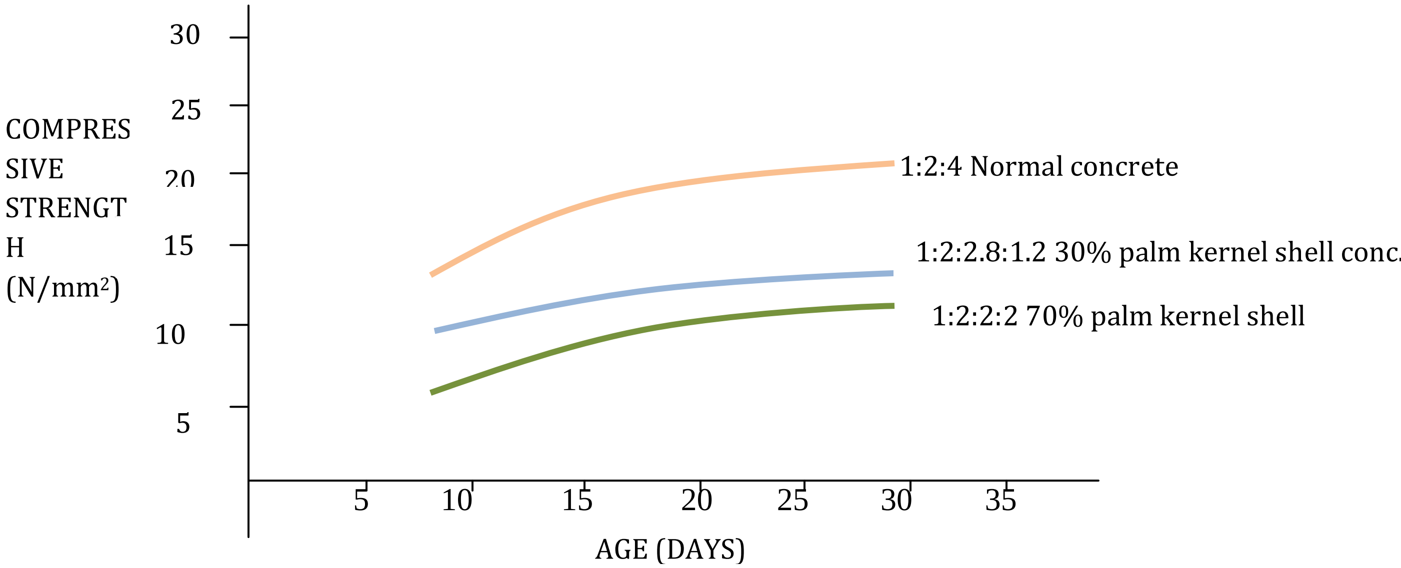
Figure 1:compressive strength development of palm kernel shell concrete comparing to normal concrete Cost analysis for one cubic meter of concrete using 30 percent and 50 percent replacement palm shell aggregate versus 100 percent granite aggregate



From Table 3, the 28 day compressive strength for the normal granite coarse aggregate concrete and the 30 and 50percent palm kernel shell aggregate concrete were 28.13 N/mm^2, 22.6 N/mm^2 and 21.63/mm^2 respectively.

The compressive strengths for the palm kernel shell aggregate concrete qualify them as a structural lightweight concrete. The greatest advantage of palm kernel shell aggregate compared to other aggregates is the cost. The production of the natural and synthetic lightweight aggregates is expensive while palm kernel shell aggregates, a solid waste, is 'virtually' free.

Table 4: Summary for the cost of one cubic meter of concrete

Mix ratio	Cost (cedis)
1:2:4 normal concrete (100 % granite aggregates.)	303.69
1:2:2.8:1.2 (30 % palm kernel shell aggregates.)	293.00
1:2:2:2: (50 % palm kernel shell aggregates,)	285.88

From Table 4, a considerable amount of cost saving is accrued from using palm kernel shell aggregate as a partial replacement for granite aggregate. The utilization of the palm kernel shell aggregate will reduce the cost of construction.

4.4 Environmental assessment for using palm kernel shell as partial replacement in concrete

The research has demonstrated that palm kernel shells can be used as a lightweight aggregate to produce structural lightweight concrete. Some of the environmental benefits are the reduction of pile of palm kernel shells waste which clog the drainage networks and aggravates flooding. .

The use of palm kernel shell or similar wastes materials will reduce the opening of new quarries for coarse aggregates and also the siting of new landfills to accommodate the palm kernel shell waste

5. Conclusion and Recommendations

The use of palm kernel shell as a coarse aggregate produced a cheaper structural lightweight concrete.

Environmental pollution caused by indiscriminate dumping of palm kernel shells waste will be eliminated when they are utilized as aggregates in concrete

Various governments in developing countries should promote the use of waste materials in construction because of its economic benefits and being environmental friendly.

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