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Compressive Strength of Laterized Concrete Using Palm Kernel as Partial Replacement of Coarse Aggregate

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***Abstract*— This research work investigates the structural characteristic of concrete using palm kernel shells as partial replacement of crushed rock aggregate in laterized concrete of mix ratio 1:2:4 with water/cement ratio of 0.6 and 0.75. Samples of laterized concrete were made by partially replacing the content of crushed rock aggregate with palm kernel shell. The quantity of palm kernel shell was varied at 0%, 15%, and 25% by weight of crushed rock aggregate, the samples were cured for specified period of 3,7,14,21, and 28 days respectively and tested in the laboratory to determine their compressive strength. Workability test were carried out on fresh laterized concrete via slump test. It was observed that specimen of 0.6 water/cement ratio at 0% palm kernel replacement produced a higher 28 days compressive strength value of, 24.72N/mm^2, while that of 0.75 water/cement ratio at 0% palm kernel replacement exhibited better workability. Compressive strength of the specimens crushed at age 28days ranged between 10.67N/mm^2 to 24.72N/mm^2 for the laterized mixes considered. This result compared favourably with those of conventional concrete. 0% replacement by palm kernel shell at 0.6 water/cement ratio was found to be suitable for use as concrete for structural members in buildings.**

Keywords*— *Laterized Concrete, Palm Kernel Shell(PKS), Compressive Strength And Water/Cement Ratio.

I. INTRODUCTION

Concrete is the world's most consumed man made material. It's great versatility and relative economy in meeting wide range of needs has made it a competitive building material. The use of cheaper building materials without loss of performance is very crucial to the growth of developing countries. As a result of the continuous increase in the cost of conventional building items, various possible alternatives are being explored by researchers as a form of providing a cheaper alternative in the overall cost of construction without compromising safety, which has led to an increase in the use of lateritic sand as an alternative to sharp sand in concrete works and block molding. The practice is carried out by Local Masons, who mix lateritic sand with cement or combine this lateritic sand with certain amount of crushed aggregate and palm kernel shell in concrete works, this practices have continued without any reliable data on the structural adherent to relevant British Standard Codes of practice for design and construction, which as of now is a major cause for concern, given the rate of collapsed buildings in the country. This research work investigates the variation in compressive strength of laterized concrete incorporating palm kernel shell as partial replacement of coarse aggregate to obtain it`s effective utilization and proper documentation.

II. LITERATURE REVIEW

This study on the compressive strength of Laterized concrete using palm kernel shells as partial replacement of coarse aggregate in which the crushed rock component of Laterized concrete is replaced partially by palm kernel shells considered contributions made by other researchers regarding the introduction of lateritic sand and palm kernel shells in concrete works. Osei and Jackson [1] conducted an experimental study on palm kernel shells as coarse aggregates in concrete of two control mixes of ratio 1:2:4, batched by volume and weight respectively, where palm shells were use to replace crushed granite of concrete. Base on the results obtained from the compaction factor test, it was seen that workability of concrete reduces as palm kernel shell content increases due to the increase of the specific surface as a result of increase in quantity of palm kernel shell, thus requiring more water to make the mix workable. The data obtained from the crushing test on the concrete indicated that the compressive strength decreases with the increment of palm kernel shell content. The compressive strength is maximum at 0% replacement by palm kernel shell and minimum at 100% replacement, with compressive strength of 24.02 N/mm^2 and 1.84 N/mm^2 respectively at 28 days of age.

Olutoge [2] investigated the suitability of sawdust and palm kernel as replacement of fine and coarse aggregate in the production of reinforced concrete slabs. He concluded that 25% sawdust and palm kernel shell substitution reduced the cost of concrete production by 7.45% also indicating the possibility of partially replacing sand and granite with sawdust and palm kernel shell in production of light weight concrete slabs.

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Kankam [3] investigated the potential for using palm kernel shell as aggregates in Portland cement concrete. From the result obtained, it was observed that the high water absorption of palm kernel shells resulted in a lower workability of the constituent concrete since the percentage water absorption of palm kernel shell and crushed rock was found to be 20.5% and 1.04% respectively. Therefore concrete with palm kernel shell aggregate would be expected to require more water during mixing compared with natural rock aggregate while for the compressive strength, it was evident that for both types of aggregate the compressive strength of palm kernel shell concrete shows an approximate uniform reduction in compressive strength for all mixes considered.

Emiero and Oyedepo [4] investigated on the strength and workability of concrete using palm kernel shell and palm kernel fibre as concrete coarse aggregate. A water cement ratio of 0.75 was used, for mix ratio of 1:1.5:3 and 1:2:4, the maximum compressive strength of palm kernel shell and palm kernel fibre was reported as 12.29 N/mm^2 and 10.83N/mm^2respectively ,which confirmed light weight concrete strength of 10$N/mm^2$to 15 N/mm^2 and 10.35 N/mm^2 was achieved when granite plus palm fibre was used for mix ratio 1:2:4 having the higher strength against 1:1.5:3 at 28 days. This also confirms light weight concrete strength although it didn't correspond to the conventional strength attainment.

Alawode and Idowu [5] investigated the effects of water-cement ratio on the compressive strength and workability of concrete and Laterized concrete mixes to evaluate the compressive strength and workability. Cube and slump tests were carried out for mix proportion 1:2:4. Comparison between Laterized concrete and concrete were made in variation of weight, density and compressive strength of mixes, it was reported that for a 28 day cured cube of mix proportion 1:2:4, for concrete of water/cement ratio of 0.55, density of cube was 2.488 g/cm^3 and Compressive strength of 20.00 N/mm^2 while for Laterized concrete of water cement ratio 0.55, density of cube 8.600 g/cm^3, compressive strength 38.13 N/mm^2. Concrete of water cement ratio 0.60, 0.65, 0.70, .80 had compressive strength of 17.33 N/mm^2, 17.11N/mm^2, 16.31 N/mm^2 and 16.00 N/mm^2 respectively while Laterized concrete of water cement ratio 0.6, 0.65, 0.70, 0.8 had compressive strength of 37.47 N/mm^2, 37.02N/mm^2, 6.13 N/mm^2 and 5.64N/mm^2 respectively, from the results above it can be observed that from water cement ratio 0.65-0.70 there is a significant reduction in compressive strength by 83.44% in the Laterized concrete which is not applicable to concrete. It was observed that the highest compressive strength of Laterized concrete, 38.13 N/mm^2 was obtained for 1:2:4 mixes at 0.55 water cement ratio. The effect of water cement ratio on the workability of concrete and Laterized concrete, from the slump test performed the slump of water cement ratio of 0.55 to 0. 70 were classified true slumps in concrete mixes, while for 0.80 water cement ratio; the water content was such that the fluidity of the mixture was large enough to cause collapse of the concrete cone. However, in Laterized concrete the slumps of 0.55 to 0.80 water cement ratio were all classified true.

III. MATERIALS

The materials used in this research work include:

- Water
- Palm kernel shell
- Crushed aggregate
- Lateritic sand

A. *Water*

Portable tap water from the Cross River State water Board was used throughout the duration of the research.

B. *Palm Kernel Shell(PKS)*

The palm kernel shells obtained from Akamkpa Local Government Area in Cross River State with Bulk density of 569.23kg/m^3, Specific gravity of 1.32 and Water absorption value of 12.0% was used. Fig. 1 shows the particle size distribution curve of crushed aggregate and PKS.

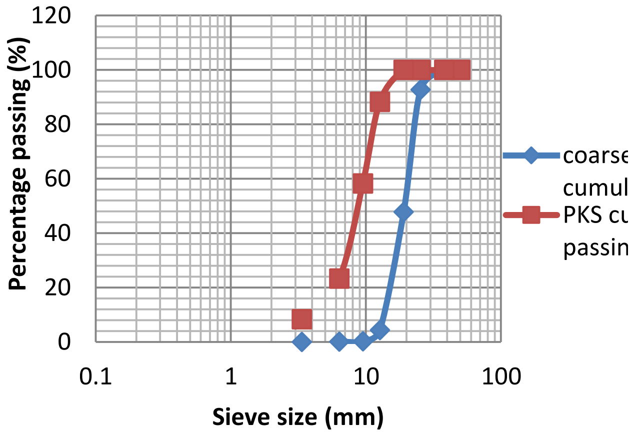

Fig. 1 particle size distribution curve of crushed gravel and pks

C. *Lateritic Sand*

The lateritic sand was obtained from the airport by pass borrow pit with Bulk density of 1465.93kg/m^3, Specific gravity of 2.39 and Water absorption value of 10.71%. , the laterite falls under the class of **A-2-4(0)** sandy GRAVELLY, coefficient of uniformity, Cu = 19 while the coefficient of curvature, Cc = 1.89 which falls within the range where Cu > 4 and 1<Cc>3 with little amount of fine which satisfy the requirement of subgrade rating. According to Rajput [6], the proportion of the soil sample passing 75µm sieve representing silt particles in the soil sample is 3.4% (same as percentage retained in the pan). This added to the proportion of Alumina (Al_2O_3) also known as clay in the soil sample (=27.60%) gives a total of 30.78% < 50% by weight indicating the soil sample fits well into specifications for a good brick making earth. See Fig 2 for the particle size curve of laterite used.

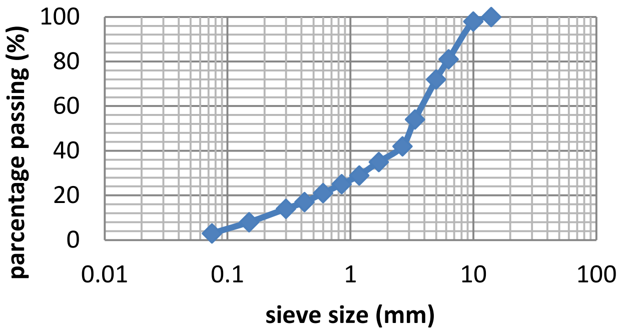

Fig. 2: Particle size distribution curve of laterite

D. Coarse aggregate (Crushed Gravel))

The crushed aggregate was obtained from the Akamkpa quarry site in Akamkpa Local Government Area having a Bulk density of 1407.72kg/m^3, Specific gravity of 2.76 and Water absorption value of 1.25%

E. Portland Cement

Ordinary Portland cement was used in this work obtained from a distributive outlet in Calabar with a Specific Gravity of 3.15. The physical and chemical properties are summarized and compared with the code specification in Table 1 and Table 2

TABLE 1 COMPARISON OF CEMENT PARAMETERS WITH CODE SPECIFICATION

S/No.	Parameter	Value	Code Specifications BS EN 197-1 (2000)
01	Fineness	0.035	0.01 – 0.06
02	Consistency	30%	26 – 30%
03	Initial Setting time	201	≥ 45 minutes
04	Final Setting time	429 minutes	≤ 600 minutes
05	Soundness	3.5 mm	≤ 10 mm

TABLE 2 CHEMICAL COMPOSITION OF OPC COMPARED WITH BS EN 197[7]

Chemical composition	% Concentration	BS EN 197-1:2000 (% concentration)
AL_2O_3	2.10	2.6 – 8.0
SiO_2	10.50	18 – 24
CaO	76.57	61 – 69
Fe_2O_3	4.9	1.5 – 7.0
K_2O	0.33	0.2 – 1.0
MgO	1.4	0.5 – 4.0
SO_3	2.84	0.2 – 4.0

IV. METHODS

A. Design Mix

This is the process of determining required and specifiable characteristics of concrete mixture. Mixture proportioning to determine the quantities of concrete ingredients using Local materials to achieve the specific characteristics of concrete, adequate mixture proportioning was used in other to obtain a characteristic concrete strength of 20N/mm^2. The mix ratio used for the research work was 1:2:4 with water cement ratio of 0.6 and 0.75 respectively.

B. Fabrication of Concrete Cubes

150mmx150mm wooden cube moulds were used throughout for fabricating the concrete cube. Samples were mixed with the aid of spade. The molds used were cleaned and greased to avoid the sticking of the concrete paste on moulds, resulting in difficulty when the cubes would have to be separated from the moulds. The batching was done by weight using mix ratio 1: 2: 4, with partial replacement of coarse aggregate with palm kernel shell at 0%, 15% and 25% respectively with gradual spray of water, to avoid coagulation and formation of lumps.

The mixture was transferred to each mould in three layers; each layer tamped with 35 blows each with a rammer. The specimens were cured for 3, 7, 14, 21 and 28 days respectively with compressive strength obtained after each cube was cured for its specified number of days. [8]

C. Slump Test

To determine the consistency of concrete mix of given proportions, the slump is a measure indicating the consistency or workability of fresh concrete, a concrete is said to be workable if it can be easily mixed, placed, compacted and finished without segregation or bleeding. The test was carried out by mixing the dry constituent thoroughly with gradual addition of water. The mixed concrete was placed in a cleaned slump cone mould in 4 layers each appropriately ¼ the height of the mould tamped 25 blows each layer with a tamping rod. The top of the cone is struck off with a trowel so that the mould is exactly filled; the cone is slowly removed carefully in the vertical direction. Once the concrete settlement comes to a stop, the subsidence of the concrete in "mm" is measured. With the obtained results we can determine the slump class of the concrete. Each class determines its application in effective usage. The slump was done in accordance to [9]

D. Curing of Concrete Cube

The cubes were carefully removed from the moulds and then submerged in water for 3,7,14,21 and 28 days respectively in other for the hydration process to continue as long as necessary since it's influenced greatly by temperature. The longer the favorable condition is maintained the longer the concrete will cure, resulting in a better product.

E. Compressive Strength Test

This test was performed to determine the maximum compressive load each cube can withstand before failure in accordance to [10]. The test specimens (cubes) are removed from water after the specified curing time, wiped, with the dimension of cube read and placed in a Universal compression machine in such a manner that the Load shall be applied to the opposite side of the cube cast with the cube aligned centrally to the base plate of the machine, the Load is gradually applied continuously till the specimen fails with the maximum Load recorded. The compression strength would be expressed as

$$f_{cu}\ (N/mm^2) = \frac{\text{Failure load (N)}}{\text{Cross sectional area of cube (mm2)}} \quad 1$$

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G. Water Absorption Test

Each sample of the produced blocks, whose weights had been taken in the dry state and noted, was then fully immersed in water. The time taken for full immersion was noted, and period of twenty-four (24) hours was allowed to elapse. After the 24hours, the wet block samples were removed and weighed. The difference between the dry and wet weights of each block was the calculated by subtracting the dry weight from the wet weight. From this the water absorption capacity can then be expressed as a percentage i.e.

$$\text{Water absorbed (\%)} = \frac{Wet\ weight - dry\ weight \times 100}{dry\ weight} \qquad 2$$

V. RESULTS AND DISCUSSION

A. Workability

Laterized concrete using W/C ratio of 0.6 and 0.75, with partial replacement of coarse aggregate 0%, 15% and 25% exhibited one basic form of slump (i.e True slump).

This can be seen in the slump result which range between 0 to 43.33mm. The tests for workability are represented in Table 3 (i.e slump test) it can be observed that workability decreases with increase of percentage replacement of crushed aggregate with Palm kernel Shell. For 15% replacement by PKS, at 0.6 w/c ratio, it proved to be impossible to have a non segregated laterized concrete mix. Due to the considerably higher water absorption capacity of PKS and increase in specific surface as the quality of PKS increases causing us to increase the water/cement ratio from 0.60 to 0.75 implying that at a water cement ratio of 0.6 with 15% partial replacement of coarse aggregate with PKS, the laterized concrete is not workable, and from the slump results you would observe that the slump value continually decreases with increase of quantity PKS in laterized concrete (i.e 0% PKS, 43.33mm. 15% PKS, 23.30mm and 25% PKS, 10.67mm).

TABLE 3 SLUMP RESULT

Combination	W/C Ratio	Slump (mm)			
PKS- Cagg %		*1*	*2*	*3*	*Mean*
0-100%	0.60	25.00	25.00	30.00	26.70
0-100%	0.75	40.00	50.00	50.00	43.33
15-85%	0.75	21.00	30.00	30.00	23.30
25-75 %	0.75	10.00	10.00	10.00	10.67

(Each is an average of 3 test results)

B. Compressive Strength

The result of the compressive strength test of laterized concrete with PKS partial replacement of coarse aggregate using mix ratio 1:2:4 are presented in Table 4. Showing results of crushing test done on Cubes aged 3, 7, 14, 21 and 28 days. The results obtained revealed that the compressive strength at 28 days for Lateritic concrete with 0% PKS replacement at 0.6 W/C ratio was 24.72 N/mm^2 which can be suitably deployed in reinforced concrete works while at 0.75 W/C there was a decrease in compressive strength to 17.56 N/mm^2 it can be observed that the change In W/C ratio not only affects the workability of Laterized concrete, but also its compressive strength. With partial replacement of crushed aggregate with PKS at 0.75 W/C for 15% and 25%, the compressive strength was gotten to 13.67 N/mm^2 and 10.67 N/mm^2 respectively. Highlighting a gradual decrease in compressive strength as PKS percentage replacement increases, which agrees with the findings made by [1] in experimental study on palm kernel as coarse aggregate in concrete.

C. Water Absorption

The result for water absorption is shown in Table 5. The percentage water absorbed increased with increase in the amount of PKS in the mix. High water absorption value of PKS lead to increase in percentage water absorbed by the mix with 25% pks used to replace coarse aggregate.

TABLE 5 WATER ABSORPTION TEST RESULTS

S/N	Specimen % Combination		w/c ratio	%Water Absorption
	%PKS-% C agg.			
1	0	100	0.60	1.43
2	0	100	0.75	0.96
3	15	85	0.75	1.65
4	25	75	0.75	1.85

(Each is an average of 3 test results)

VII. CONCLUSION

The following conclusions can be drawn based on the results of the study.

- The compressive strength of laterized concrete at 0.6 W/C ratios is 24.72 N/mm^2 at 28 days. The value compares favorably with conventional concrete.
- With the continuous increase in quantity of PKS replacement, workability decreases gradually (i.e at 0.75 W/C slump values for 0%, 15%, and 25%partial replacement were 43.33mm, 23.30mm and 10.67mm respectively).
- Compressive strength decreases gradually with continuous increase in quantity of PKS replacement (i.e. at 0.75 W/C ratio, compressive strength values for 0%, 15%, and 25% partial replacement were 17.56N/mm^2, 13.67 N/mm^2 and 10.67N/mm^{2}respectively at age of 28days).
- The cement used for the research satisfied the requirements of BS EN 197-1:2000, for Ordinary Portland Cement and thus is of good quality.

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