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Effect of Palm Kernel Shell on the Compressive Strength and Saturated Surface Dry Density of Stabilized Soilcrete

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ABSTRACT:
This research studies the effects of palm kernel shell on the compressive strength and saturated surface dry density of stabilized soilcrete (SC). Preliminary tests were carried out for identification and classification of laterite and palm kernel shell (PKS). Compressive strength (CS) test on different percentage of PKS, and effect of cement aggregate ratio (CAR) on the saturated surface dry density (SSDD) of the stabilized palm kernel shell soilcrete were also carried out. A uniformly graded clayey SAND (SCl) laterite with low plasticity and uniformly graded palm kernel shell (PKS) with maximum grain size of 13.2 mm was used. The stabilized PKS soilcrete blocks were produced using CAR of 1:9, 1:12.33 and 1:19 at 10%, 20%, 30%, 40% and 50% replacement of laterite with PKS, with varying w/c ratios of 0.75, 0.77, and 0.80. Compaction pressure of 4.14 MPa was gradually applied to produce 150 × 150 × 150 mm SC cubes. A total of 162 cubes were produced from 54 mix ratios and 3 cubes for each mix ratio; the average compressive strength (CS) and saturated surface dry density (SSDD) were determine after 28^{th} day curing using. The results from the compressive strength at different replacement levels shows that, the optimal CS value occurred at 20% replacement of laterite with PKS with the numerical value of 1.68 MPa at 1:9 CAR and 0.80 w/c for compaction effort of 4.14 MPa. The SSDD value for CAR of 1:9, 1:12.33 and 1:19, at 0.75 w/c, 0.77 w/c and 0.80 w/c decreased as the %PKS content increases. Similarly, the SSDD decreases as the CAR increases and the maximum SSDD values was obtained at 1:9 CAR for 0.75, 0.77 and 0.80 w/c. The following conclusions drawn shows that the CS of soilcrete block (SCB) increased as %PKS increased from 0 to 20% and reduced with further increase in PKS content while the SSDD decreased as %PKS increased from 0 to 50%. Likewise, it was observed that increase in CAR reduced the saturated surface dry density (SSDD) at the same w/c and compaction effort. The optimal percentage replacement of laterite with PKS in SCB was 20%, which implies that the PKS possesses the potential for use in the production of compressed stabilized SC and hence recommended for use.
Keywords: Laterite, Palm Kernel Shell, Compressive Strength, Saturated Surface Dry Density

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NOMENCLATURE

CAR	Cement Aggregate Ratio
CEB	Compressed Earth Block
CS	Compressive Strength
CSEB	Compressed Stabilized Earth Blocks
Cu	Coefficient of Uniformity
F	Crushing Load
PKS	Palm Kernel Shell
SC	Soilcrete
SCB	Soilcrete Block
SCI	Very Clayey Sand
SSDD	Saturated Surface Dry Density

I. INTRODUCTION

Due to the high cost of conventional building material, the provision of adequate housing is one major problem facing most developing countries and mankind. The utilization of earth in building construction is one of the oldest and most common methods used by a larger percentage of the developing countries population (Joseph &Tarig, 2007). Maini (2010) as cited in Qu et al. (2012) documented the use of earth as a building material as far back as 2500 BC, and can take various forms, including adobe, rammed earth, compressed earth blocks, and baked bricks (Guillaud et al., 1995). The recent progression towards the compressed earth block is a logical extension of the benefits of the industrial revolution which brought the significant development of the fired brick. According to Joseph &Tarig, (2007), compressed stabilised earth blocks (CSEBs) are made with soils mixed with stabilizers and subjected to high compressive pressure, in order to stabilize and compressed the block to yield high compressive strengths. Alagbe, (2010) added that, the addition of a stabilizer differentiates it particularly from compressed earth bricks (CEBs) and from other traditional earth building technology whether moulded into a brick or compressed in a machines. Nigeria is one of the world major producers and exporters of palm oil but one significant problem in the processing of palm oil is the large amount of palm kernel shell wastes produced which is one of the contributors to the nation's pollution and disposal challenges (Yusuf &Jimoh, 2013). And because of the growing environmental concerns there is the need for adequate management of the large volumes of waste materials generated from the crushed palm kernel shell being investigated as an alternative material/source after the extraction of the oil. The thought of using natural fibres is not new in the construction industry, as the utilization of fibres in materials and construction can be traced back to many centuries ago. During the Egyptian times, straws or horsehairs were added to mud bricks, while straw mats were used as reinforcements in early Chinese and Japanese housing construction (Ugwuishiwu et al., 2013). Recently, because of growing environmental concerns, waste materials are being used as aggregates for construction (Johnson et al., 2013). Hence Ugwuishiwu et al., (2013) studied the influence of palm kernel fibre reinforcement on water absorption of compressed stabilized earth blocks for its suitability in block production, while the usefulness of crushed palm kernel shell as a partial replacement of fine aggregate in asphaltic concrete was carried out by (Mohammed et al., 2014). Previous literatures cited in Olanipekun et al., (2006) have shown that, PKS is suitable as granular filter for water treatment, as a suitable aggregate in plain, light and dense concretes and as a road building material. This research work is aimed at the determination of the effect of palm kernel shell on the compressive strength and saturated surface dry density of stabilized soilcrete. To achieve this aim, the following specific objectives are set aside;

II. MATERIALS AND METHOD

2.1. Materials

The materials used in the research study are water, laterite, cement and palm kernel shells. Lateritic soil sample was collected at a depth of 1.5m to 2m from an existing burrow pit along the Otamiri River close to the Federal University of Technology Owerri campus, Imo State Nigeria and tested for their suitability for compressed stabilized earth block (CSEB) production. The Palm kernel shells were obtained from a palm kernel shell dump at Ebehi water side in Imo state, Nigeria. The crushed palm kernel shell were obtained, washed, dried and then graded in Plates D3 and D4. Ordinary Portland cement grade 42.5R manufactured by Dangote cement factory, Nigeria was used in the stabilization. It conforms to the requirement of BS 12 (1980) and it was bought from a building material market in Owerri, Imo State. Potable tap water used for the mixing was properly examined to ensure that it is clean, free from particles and good for drinking as specified in BS 3148 (1980)

2.2 Methods:

The methods used in this research work to achieve the set aim and objectives are preliminary tests for the identification and classification of laterite and palm kernel shell (PKS), compressive strength (CS) test on different percentage of PKS, and effect of cement aggregate ratio on the saturated surface dry density (SSDD) test.

2.2.1 Preliminary Laboratory Tests on Laterite and PKS

The following preliminary tests were carried out for the identification and classification of materials (laterite and PKS) for the preparation of the soilcrete.

i. Sieve analysis was performed on samples of palm kernel shells and laterite to determine their grading.The aggregates (lateritic soil and palm kernel shell) used in this research were prepared as specified in BS 1377-1:1990. The samples were shaken through a set of sieves of successively smaller openings and the mass of sample retained by each sieve was recorded. Percentages of mass passing each sieve calculated. Figures 3.1 - 3.2 show the sieve/particle size distribution curve of the both samples. The coefficient of uniformity is calculated from the sieve analysis graph using Equation 3.1;

The Uniformity coefficient; $C_u = \frac{D_{60}}{D_{10}}$ 3.1

ii. Percentages of sand and clay in the laterite sample is determined in order to have a good knowledge of the soil composition being used achieved by washing off clay proportions in laterite, leaving the sand which its weight is recorded and results compared with that of laterite. The detail procedure for preparation of samples and testing are as specified in BS 1377-1:1990 and BS 1377-2:1990. The percentages of sand and clay in laterite can be determined using Equations 3.2 and Equation 3.3 respectively.

$$\text{Percentage Sand} = \frac{W_{SD}}{W_{LD}} \times 100 \qquad 3.2$$

$$\text{Percentage Clay} = \frac{[W_{LD} - W_{SD}]}{W_{LD}} \times 100$$
3.3

Weight of Dry Laterite (Kg) =(W_{LD}),
Weight of Dry Sand (Kg) = (W_{SD})

iii. Specific gravity test was carried out on samples of palm kernel shells and lateritic soil. Specific gravity is the ratio of mass of sample (or weight in air) to that of an equal volume of water at a stated temperature. The detail procedure for preparation of samples and testing are as specified in BS 1377-1:1990 and BS 1377-2:1990. The stoppered bottle is then wiped dry and weighed to the nearest 0.01g (m_4) the particle specific density ρ_s (in Mg/m^3), from equation 3.4

$$\rho_s = \frac{m_2 - m_1}{(m_4 - m_1) - (m_3 - m_2)} \qquad 3.4$$

Where m_1 is the mass of density bottle (in g), m_2 is the mass of density bottle and dry soil (in g), m_3 is the mass of density bottle and water (in g), m_4 is the mass of bottle when full of water only (in g)

iv. Moisture content of the Samples of palm kernel shells and laterite soils were determined by oven dry method. The detail procedure for preparation of samples and testing are as specified in BS 1377-1:1990 and BS 1377-2:1990.

v. Consistency limits of laterite soil such as liquid limit, plastic limit, and the plasticity index were also determined. The detail procedure for preparation of samples and testing are as specified in BS 1377-1:1990 and BS 1377-2:1990. Plasticity index and liquidity index of the lateritic soil was obtained from the moisture content, w_a of the fraction passing a 425 µm test sieve of the sample of soil in its natural condition, the liquid limit, w_L and the plastic limit,w_p using Equation 3.5 and Equation 3.6

The plasticity index I_p; $\quad I_p = w_L - w_p \qquad 3.5$

The liquidity indexI_L: $\quad I_L = \frac{w_a - w_p}{I_p} \qquad 3.6$

vi. Compaction testwas conducted to determine the maximum dry density and the optimum moisture content of the soil that would give the best compaction when moulded into blocks and hence the maximum strength when tested on drying. The soil test was conducted as specified in BS 1377- 4:1990 using the standard 2.5Kg hammer, known as the Standard Proctor Test.

2.2.2 Compressive Strength Test on Soilcrete Cube

High level of accuracy, reliability and consistency was maintained throughout the experiment. Specimen preparation describes the raw materials used, the mix proportions, addition of moisture, the compression method used, the curing regime, and the dimensions of the samples. The respective quantities of laterite, PKS, cement as well as water required for the mixes proportion were batched by volume.

i.Mix Proportion

The Batching method employed in this work was carried out by equivalent volume-mass. The equivalent volume-mass of the constituent materials (laterite, PKS, water and cement) were obtained by weighing the mass of equal volume of each component constituent materials. The mixes were conducted to study the variation in compressive strength values, rate of strength development of the block produced using cement to aggregate (soil and PKS) stabilization ratio of 1:9, 1:12.33 and 1:19. The soil contents in each aggregate mix were partially replaced with PKS at 10%, 20%, 30%, 40% and 50% of the soil (laterite) volume which resulted to eighteen (18) mix ratios, and stabilized with ordinary Portland cement. Each of the eighteen (18) mix ratios were mixed with varying water-cement ratio of 0.75, 0.77, and 0.80 which produced a total of fifty four (54) proposed design mix ratios. The mix proportions are given in Table A.1 to Table A.3 (see Appendix).

ii. Sample Preparation

The laterite and washed crushed PKS were properly air dried before use. The mix proportions were measured by volume, and a total of 162 cubes of 150mm × 150mm × 150mm were produced. Trial mixes were done to determine the ideal water content for the experiment and water contents of 75%, 77% and 80% of the equivalent volume-mass of cement gave satisfactory results and hence adopted. Laterite and PKS were mixed together and cement was added to the mixture. Thereafter water was added based on the water-cement ratio and mixing continued until a homogeneous mix was obtained. The damp mix was poured into the detachable steel mould, after measurement of the required quantity of mix required for a cube. A detachable steel plate mould was used for easy removal and placement of the freshly compacted blocks. Three cubes were produced for each of the mix ratio by applying a compacting pressure of 4.14 MPa using 10 tones Enerpac compressing equipment shown on Plate B.1 (see Appendix). The blocks were de-moulded immediately after and placed on a clean surface in the laboratory for curing. Curing was done by wetting the cubes twice daily for 27 days under laboratory conditions thereafter they were immersed in water for the remaining day. Compressive strength test was done on the 28th day using a 10 tones Enerpac compression testing machine and compression load/pressure at failure was recorded.

ii. Compressive Strength (CS)

The Enerpac compression testing machine shown on Plate B2 (see Appendix) with a loading capacity of 10,000 psi which is certified and calibrated for the test duration was used to determine the failure load/pressure of the soilcrete cubes. The test was carried out in accordance with BS 1881-116:1983 (Method for determination of compressive strength of concrete cubes). The average crushing force (F) can be calculated using Equation 3.7 while the compressive strength of the cube is calculated using Equation 3.8.

$$\text{load}\ (F) = \text{applied pressure} \times \text{hydraulic jack Area} \quad 3.7$$

$$\text{compressive cube strength} = \frac{\text{Average Crushing/Failure Load (Mpa)}}{\text{Cross Section Area of Cube } (mm^2)}$$

3.8

III. RESULT AND DISCUSSION

3.1. Results Presentation

3.1.1 Preliminary Tests Results Presentation

The preliminary test results of the physical properties of the soil and PKS are given in the Tables 3.1 and 3.2

Table 3.1: Physical Properties of the Laterite

Table 3.1: Physical Properties of the Laterite

S/N	PHYSICAL PROPERTIES	VALUES
1	Specific gravity	2.38
2	Natural moisture content	6.63%
3	Optimum moisture content	9.67%
4	Maximum dry density	1.89 Mg/m^3
5	Bulk density	2052.46 Kg/m^3
6	Coefficient of uniformity C_u	2.95
7	Clay content	23.84%
8	Sand content	76.16%
9	Liquid limit	28.36%
10	Plastic limit	19.50%
11	Plasticity index	8.86%

Table 3.2; Physical Property of Crushed Palm Kernel Shell (PKS)

S/N	PHYSICAL PROPERTIES	VALUE
1.	Specific gravity	1.25
2.	Natural moisture content	15.1%
3.	Coefficient of uniformity C_u	1.5
4.	Maximum grain size	13.2

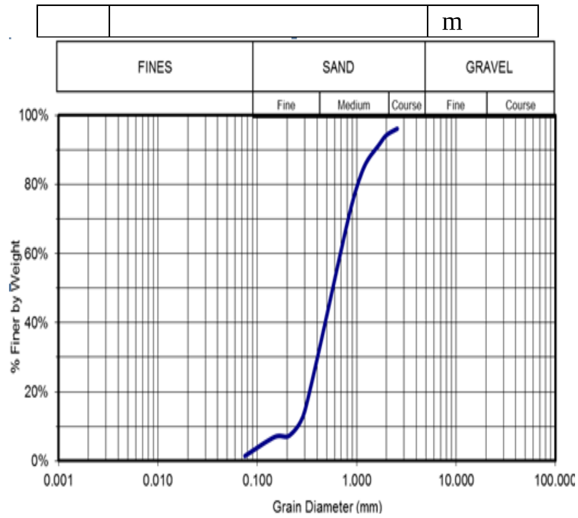

Figure 3.1: Grain size analysis of lateritic soil

From Figure 3.1: D_{10} = 0.27 and D_{60} = 0.7 for lateritic soil

$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.7}{0.27} = 2.95$$

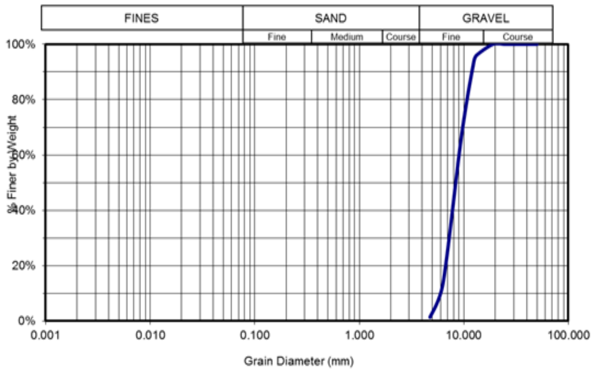

Figure 3.2: Grain size analysis of Palm Kernel Shell

From Figure 3.2, D_{10} = 6 and D_{60} = 9 for palm kenel shell

$$C_u = \frac{D_{60}}{D_{10}} = \frac{9}{6} = 1.5$$

3.1.2 Results for Compressive Strength Test

The result of the average compressive strength test at different %PKS was summarized in Table 3.3 for 4.14 MPa compacting pressure.

Table 3.3: 28-Day Average Compressive Strength Results

Mix mark	Cube Strength (MPa)	Mix mark	Cube Strength (MPa)	Mix mark	Cube Strength (MPa)
A_1	0.73	B_1	1.08	C_1	1.16
A_2	0.81	B_2	1.25	C_2	1.42
A_3	0.96	B_3	1.44	C_3	1.68
A_4	0.91	B_4	1.3	C_4	1.61
A_5	0.91	B_5	1.24	C_5	1.55
A_6	0.92	B_6	1.06	C_6	1.43
A_7	0.52	B_7	0.75	C_7	0.9
A_8	0.56	B_8	0.85	C_8	0.94
A_9	0.66	B_9	1.01	C_9	1.09
A_{10}	0.59	B_{10}	0.83	C_{10}	0.98
A_{11}	0.59	B_{11}	0.69	C_{11}	0.8
A_{12}	0.56	B_{12}	0.67	C_{12}	0.78
A_{13}	0.26	B_{13}	0.43	C_{13}	0.55
A_{14}	0.27	B_{14}	0.51	C_{14}	0.6
A_{15}	0.31	B_{15}	0.57	C_{15}	0.61
A_{16}	0.24	B_{16}	0.42	C_{16}	0.46
A_{17}	0.22	B_{17}	0.28	C_{17}	0.4
A_{18}	0.15	B_{18}	0.22	C_{18}	0.3

3.1.3 Result of Effect of Cement Aggregate Ratio (CAR) on Saturated Surface Dry Density (SSDD) Test.

The results of the effect of CAR on the SSDD were presented in Figures 3.1 – 3.3 using a compacting pressure of 4.14 MPa. There are three different total cement-aggregate ratios 1:9, 1:12.33 and 1:19. These three graphs were plotted on the same graph sheet for the same w/c ratio for easy comparison.

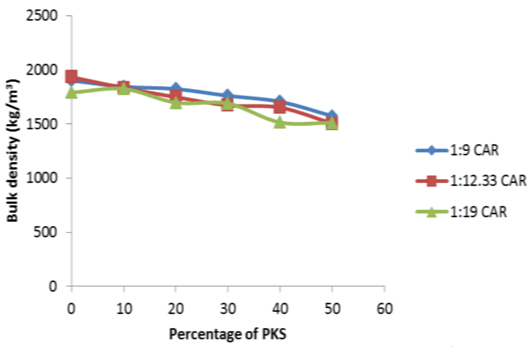

Figure 3.1; Graph of CAR on SSDD (kg/m^3) against % PKS for 0.75 w/c ratio

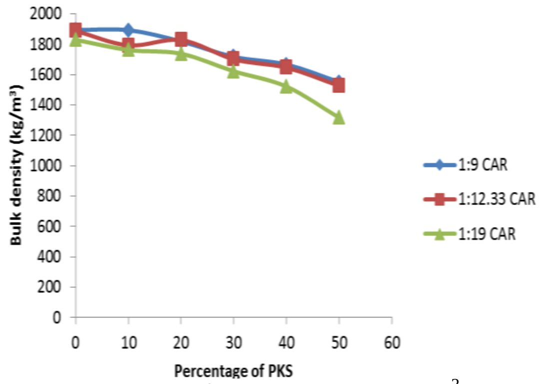

Figure 3.2; Graph of CAR on SSDD (kg/m^3) against %PKS for 0.77 w/c ratio

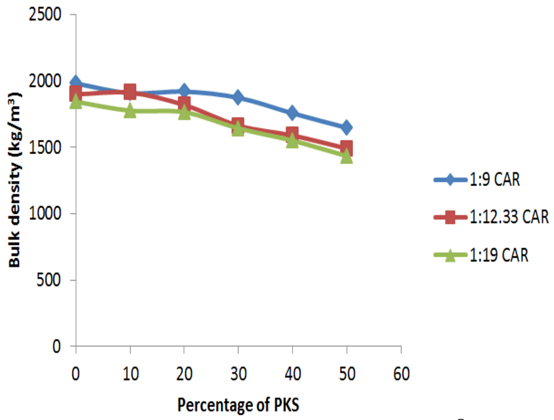

Figure 3.3; Graph of CAR on SSDD (kg/m^3) against % PKS for 0.80 w/c ratio

3.2Discussions

3.2.1 Preliminary Test Results on Laterite Soil and PKS

i. Laterite Soil

Table 3.1 shows the preliminary results for the lateritic soil which indicates that, the bulk density obtained was 2052.46 Kg/m^3, while the proctor compaction test carried out recorded a maximum dry density of 1.89 Mg/m^3 and an optimum moisture content of 9.67%. The results from of the test on the proportions of sand and clay in laterite conducted reveals that, the sand and clay contents in the lateritic soil were 76.16% and 23.84% respectively. The particle distribution test conducted reveals that the coefficient of uniformity (C_u) was 2.95 which is less than 4.0 indicates that, laterite was uniformly graded (Emesiobi, 2000). The soil name was based on particle size distribution and plasticity properties. From Table 3.1 and Figure 3.1, less than 35% of the soil material is finer than 0.06 mm and up to 5% is coarse which describes it as slightly gravelly sand. With more than 50% of coarse material of the soil size finer than 2 mm shows and fines within 15% to 35% less than 0.06 mm, the soil was classified as very clayey SAND (SCl) and it was poorly graded. With a plasticity of 19.50% which is less than 35% describe the soil as clay of low plasticity. The specific gravity of 2.38 compared closely with the specific gravity of 2.28 for laterite soil used by Aguwa (2012) for production of laterite block.

iiPalm Kernel Shell

Table 3.2 shows preliminary tests results of specific gravity test, natural moisture test and sieve analysis test carried out on palm kernel shell (PKS) for identification and grading. From the results obtained, the natural moisture content was 15.1% while the specific gravity was 1.25, which is less than 50% of the specific gravity values for natural rock aggregate whch ranges between 2.6 and 2.7 (Owolabi, 2012). From the sieving analysis, the maximum and minimum PKS grain sizes were 13.2 mm and 4.75 mm and the coefficient of uniformity (C_u) was 1.5 which indicates that the PKS was also uniformly graded. The allowable maximum size fraction for gravel used for compressed stabilized block production was not standardized but some literature sources recommend 15 mm to 20 mm, while others recommend 6mm (Kerali, 2001). This compared favourably with the maximum PKS gain size of 13.2 mm used in the production of the soilcretes. The PKSs can therefore be classified as lightweight aggregates, and the clear differences in specific gravities of the PKS (1.25), laterite soil (2.38) and cement (3.15) explained why it was necessary, as done in this investigation, for the material quantities to be batched by the method of equivalent volume mass.

3.2.2 Result of Compressive strength of Soilcrete at Different Replacement Level by Palm Kernel Shell (PKS).

Table 3.3, describes the effect of PKS on compressive strength for the different mix ratios at any given w/c, CAR using compacting effort of 4.14 MPa.

Table 3.3, shows that the compressive strength value for the A_1-A_6,B_1-B_6 andC_1-C_6 mix increased from 0.73 MPa to 0.96 MPa, 1.08 MPa to 1.44 MPa and 1.16 MPa to 1.68 MPa an increment of 31.5%, 33.33% and 44.83% respectively due to increase in PKS from 0 to 20% PKS replacement. Further increase in PKS content to 50% replacement resulted in the decrease of compressive strength for all three mix range. The optimum compressive strength for A_1-A_6, B_1-B_6, and C_1-C_6 mixes were recorded at 20% PKS replacement. Similar trend was observed for A_7-A_{12}, B_7-B_{12}, and C_7-C_{12} mix ranges, the compressive strength values increased by 26.92%, 34.67% and 21.11% with peak compressive strength values of 0.66 MPa, 1.01 MPa and 1.09 MPa respectively, and were recorded at 20% PKS replacement for all three mixes. Likewise, the compressive strength for soilcrete cube for mix of A_{13}-A_{18}, B_{13}-B_{18} and C_{13}-C_{18} increased by 19.23%, 32.56% and 10.91% with optimum compressive strength values of 0.31 MPa, 0.57 MPa, and 0.61 MPa respectively were recorded at 20% PKS replacement for each of the mix. The optimum replacement of laterite with palm kernel shell was observed at 20% PKS above which there was a reduction in compressive strength and this compared favourably with the findings of Owolabi (2012). The maximun compressive strength value of 1.68 MPa was recorded at 20% PKS for C_1-C_6 mix at 1:9 CAR at 0.80 w/c, and the result obtained revealed that, soilcrete cubes reinforced with palm kernel shells are about 44.83% stronger than plain soilcrete cubes. The maximuim compressive strength compared fairly with 1.65 N/mm^2, the minimum specification as requirement for compressive strength of laterite brick proposed by Nigerian Building and Road Research Institute (NBRRI) (Wilson et al., 2016). Hence soilcrete blocks could be substituted for sandcrete blocks as partitions in buildings and the use of kernel shells as aggregate in soilcrete blocks should be encouraged. The compressive strength of soilcretes produced were between (10.91% - 48.85%) stronger than plain soilcrete blocks and this compared closely to the observation of Owolabi (2012).

3.2.3 Result of Effect of Cement Aggregate Ratio (CAR) on Saturated Surface Dry Density (SSDD)

Table A.4 - Table A.6 (see Appendix), Shows the results of the effect of cement aggregate ratio (CAR) (1:9, 1:12.33 and 1:19) on the saturated surface dry density (SSDD) for w/c ratios of 0.75, 0.77 and 0.80 respectively using compacting efforts of 4.14 MPa. For each w/c, three graphs for 1:9, 1:12.33 and 1:19 CAR were plotted on a sheet. For each CAR, a graph of SSDD against %PKS replacement was plotted. The graph on Figures 3.1 – 3.3 describes the effect of CAR on SSDD for different w/c ratios using compacting effort of 4.14 MPa.

Tables A.4 – A6 (see Appendix), comprises of the results of the variation of SSDD of soilcrete blocks due to the effect of %PKS content at varying w/c and CAR using a compaction effort of 4.14 MPa. For 0.75 w/c at 0% PKS content, SSDD values of 1902.22kg/m^3, 1933.83 kg/m^3 and 1790.62 kg/m^3 were recorded for CAR's of 1:9, 1:12.33 and 1:19 respectively. As the % PKS content increased to 50%, the SSDDvalues decreased to 1573.33 kg/m^3, 1505.19 kg/m^{3}and 1512.10 kg/m^3, a drop of 17%, 22% and 16% respectively was observe. Therefore, the relationship between SSDD and %PKS content is linear for all three curves as seen in Figure 3.1. Similar trends was observed for 0.77 and 0.80 w/c, as the % PKS content increased to 50%, the SSDDvalues decreased with a maximum reduction of 28% and 22% respectively. Also a linear relationship between

SSDD and %PKS content was established for all three curves as shown in Figure 3.2 and Figure 3.3.
The SSDD of plain soilcrete blocks of 1:9, 1:12.33 and 1:19 cement aggregate ratio (CAR) produced with 0.75, 0.77 and 0.80 w/c using a compaction effort of 4.14 MPa ranges from 1790.62 – 1981.23 kg/m^3. And this SSDD range of soilcrete compares favourably with the density of light weight concrete in the range 300–1850 kg/m^3 (Neville, 1995 as cited in Olanipekun et al., 2006). The density range obtained when (10–20) % of PKS was used to replace laterite in the soilcrete blocks compared fairly with 1810 kg/m^3, the minimum specification as requirement for bulk density of laterite brick was proposed by Nigerian Building and Road Research Institute (NBRRI) (Wilson et al., 2016). From Figure 3.1 it was observed that the SSDD of soilcrete blocks at 0.75w/c for 1:9, 1:12.33 and 1:19 CAR, decreased as the % PKS content increased to 50%. Likewise Olanipekun et al. (2006) observed that, the density of the concrete produced decreased with increase in the percentage replacement of conventional coarse aggregate (gravel) with CSs and PKSs. Also it was observed that increase in CAR, results to a reduction of SSDD. Therefore, the relationship between SSDD and %PKS content is linear for all three curves as seen in Figure 4.25. The same trend was observed for the graphs of 1:9, 1:12.33 and 1:19 CAR for 077 w/c and 0.80 w/c shown on Figures 3.2 - 3.3 respectively. Increase in percentage of palm kernel shell content and cement aggregate ratio reduces the saturated surface dry density at the same cement aggregate ratio, w/c and compaction effort.

IV. CONCLUSION

The lateritic soil was uniformly graded very clayey SAND (SCl) with low plasticity while palm kernel shell was uniformly graded with a maximum grain sizes of 13.2 mm.
Increase in % palm kernel shell content increased the compressive strength at the same cement aggregate ratio, w/c and compaction effort. The maximum compressive strength of 1.68 MPa was recorded at 1:9 cement aggregate ratio and 0.80 w/c.
Increase in percentage of palm kernel shell content and cement aggregate ratio reduces the saturated surface dry density at the same cement aggregate ratio, w/c and compaction effort. The saturated surface dry density of soilcrete blocks at 0.75w/c, 0.77w/c and 0.80w/c for 1:9, 1:12.33 and 1:19 cement aggregate ratio, decreases as the % palm kernel shell content increases.

4.0 APPENDIX

Table A.1: Proposed mix proportions of constituent materials using w/c of 0.75

Mix Mark	w/c ratio	Cement	Soil	PKS	% PKS	total part of solid
A_1	0.75	1	9	0	0	9
A_2	0.75	1	8.1	0.9	10	9
A_3	0.75	1	7.2	1.8	20	9
A_4	0.75	1	6.3	2.7	30	9
A_5	0.75	1	5.4	3.6	40	9
A_6	0.75	1	4.5	4.5	50	9
A_7	0.75	1	12.33	0	0	12.33
A_8	0.75	1	11.097	1.233	10	12.33
A_9	0.75	1	9.864	2.466	20	12.33
A_{10}	0.75	1	8.631	3.699	30	12.33
A_{11}	0.75	1	7.398	4.932	40	12.33
A_{12}	0.75	1	6.165	6.165	50	12.33
A_{13}	0.75	1	19	0	0	19
A_{14}	0.75	1	17.1	1.9	10	19
A_{15}	0.75	1	15.2	3.8	20	19
A_{16}	0.75	1	13.3	5.7	30	19
A_{17}	0.75	1	11.4	7.6	40	19
A_{18}	0.75	1	9.5	9.5	50	19

Table A.2: Proposed mix proportions of constituent materials using w/c of 0.77

Mix Mark	w/c ratio	Cement	Soil	PKS	% PKS	total part of solid
B_1	0.77	1	9	0	0	9
B_2	0.77	1	8.1	0.9	10	9
B_3	0.77	1	7.2	1.8	20	9
B_4	0.77	1	6.3	2.7	30	9
B_5	0.77	1	5.4	3.6	40	9
B_6	0.77	1	4.5	4.5	50	9
B_7	0.77	1	12.33	0	0	12.33
B_8	0.77	1	11.097	1.233	10	12.33
B_9	0.77	1	9.864	2.466	20	12.33
B_{10}	0.77	1	8.631	3.699	30	12.33
B_{11}	0.77	1	7.398	4.932	40	12.33
B_{12}	0.77	1	6.165	6.165	50	12.33
B_{13}	0.77	1	19	0	0	19
B_{14}	0.77	1	17.1	1.9	10	19
B_{15}	0.77	1	15.2	3.8	20	19
B_{16}	0.77	1	13.3	5.7	30	19
B_{17}	0.77	1	11.4	7.6	40	19
B_{18}	0.77	1	9.5	9.5	50	19

Table A.3: Proposed mix proportions of constituent materials using w/c of 0.80

Mix Mark	w/c ratio	Cement	Soil	PKS	% PKS	total part of solid
C_1	0.8	1	9	0	0	9
C_2	0.8	1	8.1	0.9	10	9
C_3	0.8	1	7.2	1.8	20	9
C_4	0.8	1	6.3	2.7	30	9
C_5	0.8	1	5.4	3.6	40	9
C_6	0.8	1	4.5	4.5	50	9
C_7	0.8	1	12.33	0	0	12.33
C_8	0.8	1	11.097	1.233	10	12.33
C_9	0.8	1	9.864	2.466	20	12.33
C_{10}	0.8	1	8.631	3.699	30	12.33
C_{11}	0.8	1	7.398	4.932	40	12.33
C_{12}	0.8	1	6.165	6.165	50	12.33
C_{13}	0.8	1	19	0	0	19
C_{14}	0.8	1	17.1	1.9	10	19
C_{15}	0.8	1	15.2	3.8	20	19
C_{16}	0.8	1	13.3	5.7	30	19
C_{17}	0.8	1	11.4	7.6	40	19
C_{18}	0.8	1	9.5	9.5	50	19

Table A.4; Result of the effect of CAR on SSDD (kg/m^3) for 0.75 w/c using compacting pressure of 4.14 MPa

	W/C of 0.75		
	1:9	1:12.33	1:19
0%	1902.22	1933.83	1790.62
10%	1844.94	1834.07	1825.19
20%	1824.2	1749.14	1697.78
30%	1760.99	1672.1	1689.88
40%	1706.67	1652.35	1515.06
50%	1573.33	1505.19	1512.10

Table A.5; Result of the effect of CAR on SSDD (kg/m^3) for 0.77 w/c using compacting pressure of 4.14 MPa

	W/C of 0.77		
	1:9	1:12.33	1:19
0%	1893.33	1888.4	1829.14
10%	1892.35	1792.59	1761.98
20%	1818.27	1827.16	1737.28
30%	1716.54	1700.74	1621.73
40%	1666.17	1645.43	1520.99
50%	1550.62	1525.93	1313.56

Table A.6; Result of the effect of CAR on SSDD (kg/m^3) for 0.80 w/c using compacting pressure of 4.14 MPa

	W/C of 0.80		
	1:9	1:12.33	1:19
0%	1981.23	1899.26	1843.95
10%	1908.15	1912.10	1776.79
20%	1920.00	1819.26	1764.94
30%	1873.58	1663.21	1643.46
40%	1756.05	1589.14	1550.62
50%	1647.41	1491.36	1434.07

PLATE B1: Compaction Force Application Set Up

Plate B2: Enerpac Compressive Testing Machine

PLATE B3: Air Drying of Clean PKS after Washing

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