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DOI: https//doi.org/10.64388/IREV9I3-1710503-479

Structural Characterization of Palm Kernel Shell-Sawdust Concrete Composite

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Abstract- ***This work investigates the structural characteristics of Palm Kernel Shell-Sawdust concrete composite. The materials used in the laboratory experiments include, Ordinary Portland Cement, Sawdust, Palm Kernel shells and water. The physical and mechanical characterization tests were performed on the aggregates: sawdust and Palm kernel shells, where sawdust was used as fine aggregate and Palm kernel shell as coarse aggregate. The results obtained for the Sawdust were 734kg/m3, 0.35, 14%, 1.0, 2.8 for average bulk density, average specific gravity, water absorption, coefficient of curvature (Cc) and uniformity (Cu) respectively. For Palm kernel shell, the results obtained were 740kg/m3 and 2.74 for average bulk density and specific gravity respectively. Eighteen (18) cubes of size 150 x 150 x 150mm and nine (9) cylinders of size 150 x 300mm were produced from mix ratios 0.75:1:1:1, 0.75:1:2:2, and 0.75:1:3:3. The following tests were carried out to ascertain structural characteristics of the concrete composite: compressive strength, split tensile strength, density and Poisson ratio tests. The results showed that the average compressive strength for the three (3) mix ratios as 10.25MPa, 9.08MPa and 4.36MPa respectively. The average split tensile strength for the three (3) mix ratios were found as 1.950MPa, 1.666MPa and 1.558MPa respectively. The average static modulus of elasticity for the three mixes were found as 8.90GPa, 8.56GPa and 6.77GPa respectively. The average Poisson's ratio ranges from 0.19-0.36, while the shear modulus of the composite ranges from 3.86MPa – 2.64MPa. The results obtained in this research showed that Palm Kernel-Sawdust concrete composite could be classified as a lightweight concrete***

Indexed Terms- ***Palm Kernel Shell, Sawdust, Compressive Strength, Poisson Ratio, Structural Characteristics.***

I. INTRODUCTION

Construction industry relies heavily on conventional materials such as cement, gravel and sand for the production of concrete. The high cost of these materials has unprecedently hinder the development of shelter and other infrastructural facilities in developing countries. There arises the need for engineering consideration of the use of cheaper and locally available materials to meet desired needs, enhance self-efficiency, and lead to an overall reduction in construction cost for sustainable development (Anyaogu et al., 2013). Aggregates contribute to 70 – 80% volume of concrete. Thus, cost of production of concrete is predominantly affected by the cost of procurement of aggregates. In recent times, increasing cost of building materials and subsequently construction coupled with re-energized eco-sensitive propaganda on waste management has sparked up interest in research and development of alternative low cost materials while sustaining satisfactory strength and safety levels (Aguwa, 1999). With the global economic recession and increasing inflation in the market, the constituent materials used for these structures had led to a very high cost of construction (Ndoke, 2006). Attempts have equally been made by various researchers to reduce the cost of its constituents and hence total construction cost by investigating and ascertaining the usefulness of materials, which could be classified as agricultural or industrial waste (Chandra, 1997). To this effect many researchers and engineers have resulted to the development of new materials and renewable resources, which include the use of by-products/ waste products from agriculture and industries in building construction. Many of these by-products are used as aggregate for the production of lightweight concrete, while many are used as cement supplement. (Akeju, 2007)

Therefore, researchers in material science and engineering are committed to having local materials to partially or fully replace these conventional materials (Ndoke, 2006). The use of supplementary pozzolanic materials therefore has gained a very strong position in the concrete industry. 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. (Anyaogu et al, 2013; Ibearugbulem et al, 2019). In this research, structural characterization of Palm kernel shell-Sawdust concrete composite was investigated.

II. MATERIALS

The materials used for this work were (i) Ordinary Portland cement; (ii) sawdust; (iii) Palm kernel shell and (iv) water

i. Cement: Ordinary Portland cement which conforms to the requirements of BS EN 197-1: (2000) was used for all the work.
ii. Palm kernel shell: Palm kernel shell was obtained from Palm kernel processing mill Umuagwo in Ohaji-Egbeme L.G.A, Imo State, Nigeria. The Palm kernel shells were washed to remove any oil contaminant from mills. The fibres were also removed. The Palm kernel shells were classified according to their granulometry, in sieves of different sizes. It was used for complete replacement of coarse aggregate. It had a moisture content of approximately less than 12.
iii. Sawdust: Sawdust was obtained from timber sawmill in Ogbosisi in Naze timber market along Owerri-Aba road. The sawdust was sun dried for 7 days before use. Sawdust was used for complete replacement of fine aggregate. an average specific gravity of 0.35 and a percentage of water absorption of 14%. Also, this sample has a coefficient of uniformity Cu of 2.8 and a Coefficient of curvature Cc of 1.0. The maximum aggregate size of Sawdust used was 4mm.
iv. Water: Water was obtained from a borehole within the premises of Federal University of Technology, Owerri, Imo State. The water is potable and conformed to the standard of BS EN 1008: (2002).

III. METHODS

Laboratory Investigation on Materials

The properties of materials investigated include the physical properties of palm kernel shell, sawdust, wood, reinforcement and chemical properties of cement.

i. Physical Property tests of Palm Kernel shell and Sawdust

The palm kernel shell and sawdust were tested to determine their specific gravities, bulk densities and gradation (sieve analysis). The water absorption of sawdust was specifically obtained to know the water/cement ratio to be used. Collection of samples was in accordance to BS EN 932-1(1997) while the sieve analysis was in accordance to BS 812-103.1(2000). The results of sieve analysis of the sawdust are as shown in Table 1 and Figure 1 respectively. While the results of other Physical properties determined are as shown in Tables 2, 3,4,5,6 and 7 respectively.

ii. Chemical Property Test of Cement used in the Research

Chemical analysis was conducted on the cement to determine the chemical composition. The test was carried out in accordance to the requirements specified by USEPA 6200 (2007). Loss on ignition was determined in accordance to the specification by BS EN 196-2(1995). The chemical analysis result of the cement is as shown in Table 8.

Test for Structural Characteristics of Palm Kernel Shell - Sawdust Composite Concrete

The following test were carried out to determine the structural characteristic of palm kernel shell - sawdust composite concrete.

i. Compressive Strength Test for palm kernel shell - sawdust composite concrete.

The Palm kernel shell-sawdust composite concrete cubes were produced using manual mixing method in a mould measuring 150 x 150 x 150 mm in size. The moulds were first oiled for easy removal of the samples after setting. The palm kernel shell-sawdust composite sample was introduced into the mould in three layers with proper vibration. 18 cubes were produced from the three mix ratios used and the mix ratios were 0.75: 1:1:1, 0.75: 1:2:2, 0.75: 1:3:3, three cubes from each mix. The first set of 9 cubes made from the mix ratios, were used to obtain the seventh

(7^{th}) day compressive strength, while the second set of 9 cubes, were used to obtain the 28-day compressive strength. The palm kernel shell-sawdust composite concrete cubes were cured by spraying water on it for both 7days and 28 days. Thereafter, they were tested in Okhard Machine Tool's WA-1000B digital display Universal Testing Machine (UTM). The machine conforms to the requirement of BS EN 12390-4 (2000) and has a testing range of 0-1000kN. The compression load at failure was recorded and Equation (1) was used to determine the compressive strength of the palm kernel shell-sawdust composite concrete.

$$f_c = \frac{P\ (N)}{A\ (mm^2)} \quad (1)$$

Where f_c = compressive strength, P = compressive load of cube at failure and A = cross sectional area of the mould.

Since some structural characteristic of concrete depends on its density, the density of the 28-day concrete was determined using Equation (2).

$$p = \frac{m}{v} \quad (2)$$

Where p = density, m = mass of the concrete cube, v = volume of the concrete cube

The compressive strength results of the composite concrete are as shown in Tables 9a and 9b respectively, while the result on their densities is as shown in Table 10.

ii. Split tensile Strength Test for Palm kernel shell - Sawdust composite concrete

The palm kernel shell - sawdust composite concrete sample, were cylinder measuring 150 x 3000mm in size. The test was done in accordance to the requirements of BS EN 12390-1 (2000) and BS EN 12390 – 6 (2009). A total of nine (9) cylinder were produced from the three mix ratios used and the mix ratio are 0.75: 1:1:1, 0.75: 1:2:2 and 0.75: 1:3:3 respectively with three cylinders from each mix. The palm kernel shell - sawdust cylinders were cured by spraying water on it for 28 days, and were thereafter tested in Okhard Machine Tool's WA-1000B digital display Universal Testing Machine (UTM) compression machine. The cylinder specimens were placed with its horizontal axis between the platens of the machine and the load gradually applied until failure by splitting along the centre line occurred. The compression load at failure were recorded and Equation (3) was used to determine the split tensile strength of the palm kernel shell sawdust

$$\text{Splitting strength tensile strength, } \sigma_c = \frac{2F\ (N)}{\pi L d\ (mm^2)} \quad (3)$$

F is the maximum load (in Newton); L is the length of the specimen; d is the cross-sectional dimension of the specimen. The test will be in according to BS 1881-117(1983), BS EN 12390-1 (2000), BS EN 12390-6, (2009). The split tensile strength test result of the composite concrete is as shown in Table 11

iii. Static Modulus of Elasticity of palm kernel shell - sawdust composite concrete

The static modulus of elasticity of the palm kernel shell - sawdust composite concrete was determined as a function of the compressive strength and density as shown in Equation (4)

$$E_S = 1.7p^2 {f_c}^{0.33} \text{x } 10^{-6} \quad (4)$$

Where E_S =Static modulus of Elasticity

p = density; f_c = compressive strengths

The Static modulus of elasticity result of the composite concrete is as shown in Table 12

iv. Poisson Ratio of Palm Kernel Shell-Sawdust Composite Concrete

The Poisson ratio of Palm kernel shell - sawdust composite concrete was determined as a function of the tensile stress at cracking in flexure and compressive stress at cracking for compression members. The value of Poisson ratio, μ is determined using Equation (5).

$$\mu = \frac{\delta_f}{\delta_c} \quad (5)$$

The Poisson ratio result of the composite concrete is as shown in Table 13

v. Shear Modulus of palm kernel shell - sawdust composite concrete

The shear modulus of the palm kernel shell - sawdust composite concrete was determined as a function of the modulus of elasticity over the linear range of the deformation and Poisson's ratio it is obtained by using Equation (6).

$$G = \frac{E_c}{2(\mu+1)} \quad (6)$$

μ = Static Poisson's ratio

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DOI: https//doi.org/10.64388/IREV9I3-1710503-479

E_c = modulus of elasticity of concrete over the linear range of the deformation.

IV. RESULTS

Properties of sawdust used for the research

Table 1: Sieve Analysis of Sawdust

Sieve size (mm)	Mass retained (g)	% mass retained	Cumulative mass retained (g)	% cumulative mass retained	% passing
5.6	0.00	0.00	0.00	0.000	100.00
3.35	1.34	0.54	1.34	0.54	99.46
2	3.45	1.38	4.79	1.92	98.08
1.18	20.22	8.09	25.01	10.01	89.99
0.6	30.46	12.19	55.47	22.20	77.80
0.425	69.10	27.66	124.57	49.86	50.14
0.3	50.32	20.14	174.89	70.00	30.00
0.212	33.01	13.21	207.90	83.21	16.79
0.15	22.14	8.86	230.04	92.07	7.93
0.075	12.46	4.99	242.50	97.06	2.94
Receiver	7.35	2.94	249.85	100.00	0.00
Total	249.85	100.00			

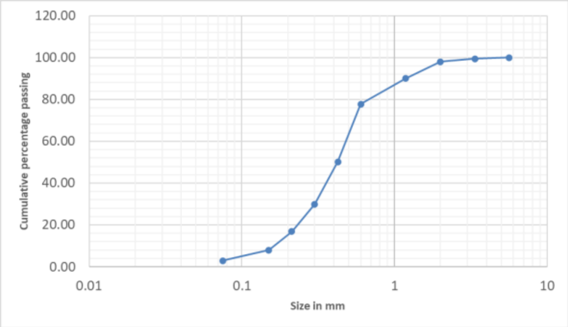

Figure 1: Grading Curve of Sawdust

From the grading curve shown in Figure 1, uniformity coefficient, Cu and curvature coefficients, Cc which are used as part of unified soil classification for sand was calculated using Equations(8)

$$C_u = \frac{D_{60}}{D_{10}} \quad \text{and} \quad C_C = \frac{{D_{30}}^2}{D_{10} x D_{60}} \qquad (8)$$

Where C_u = coefficient of uniformity
D_{60} = sieve size at 60% passing = 0.5
D_{10} = sieve size at 10% passing (effective size) = 0.18
D_{30} = sieve size at 30% passing = 0.3
Substituting D_{60}, D_{10} *and* D_{30} *into* Equation (8) gives C_u = 2.8 and C_c = 1.0.

Table 2: Bulk density of Sawdust

Sample number	1	2	3
Mass of container W_1	2.55	2.60	2.60
Mass of soil +container, W_2	2.625	2.630	2.6295
Mass of soil (M)	0.025	0.030	0.0295
Volume occupied, V(m^3)	0.000035	0.00004	0.000047
Bulk Density =M/V(kg/m^3)	714.28	750	737.5
Average Bulk density(kg/m^3)	733.92		

The bulk densities of the sawdust were found to be 733.92Kg/m^3.

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DOI: https//doi.org/10.64388/IREV9I3-1710503-479

Table 3:Specific Gravity of Sawdust

Trial Sample	1	2	3
Mass of empty pyncnometer bottle (A)g	443.00	443.00	443.00
Mass of bottle + dry sample (B)g	696.89	714.60	714.60
Mass of bottle + dry sample + water (C)g	953.39	969.84	977.00
Mass of bottle filled with water only (D)g	1471.00	1471.00	1471.00
Mass of dry sample (E)=(B)-(A)g	253.89	271.60	271.60
Mass of water occupying same volume as the sample (F) = (D)-(C-E)g	771.50	772.76	765.60
Specific Gravity = E/F	0.33	0.35	0.35
Average Specific Gravity =	0.35		

Properties of Palm kernel shell

Table 4: Bulk density of Palm Kernel Shell

Test run	1	2	3
Mass of soil,	0.025687	0.029378	0.040371
Volume occupied, v	0.0000	0.00004	0.0000.
Bulk density =	733.92	734.45	734.01
Average bulk density (kg/m	734.13		

The bulk densities of Palm kernel shell was found to be 734.13 kg/m^3

Table 5: Specific gravity of Palm kernel shell

Trial run	Trial 1	Trial 2	Trial 3
Mass of empty	443	443	443
Mass of bottle + dry	978	1006	986
Mass of bottle + dry	1820	1849	1834
Mass of bottle filled	1471	1471	1471
Mass of dry sample [	535	563	543
Mass of water occupying same	194	205	200
Specific gravity = E/F	2.76	2.75	2.72
Average Specific gravity = 2.74			

Table 6: Workability Test Result for palm kernel shell - sawdust composite

Mix ratios	Slump Value (mm)	Type of slump
1:1:1	110	Collapse
1:2:2	80	True
1:3:3	75	True

Table 7: Penetration Resistance test for Palm Kernel Shell-Sawdust Composite

Penetration Resistance in (N/mm^2)	Elapsed Time in (min)
0	50
0	100
95	200
130	350
160	400
234	550
304	600
480	750
600	850

Chemical Composition of the Ordinary Portland Cement used in the research

The chemical composition of the Ordinary Portland Cement used in the research is as shown in Table 8

Table 8: chemical composition of Dangote cement

S /No	Oxides	Mass Fraction(g)
1	Silicate (SiO_2)	20.39
2	Alumina (Al_2O_3)	6.03
3	Lime (CaO)	67.62
4	Magnisum Oxide (MgO)	1.31
5	Iron Oxide	2.29
6	Potassium Oxide (K_2O)	0.84
7	Sodium Oxides (Na_2O)	0.3
8	Titanium Oxide (TiO_2)	0.2

9	LOI	2.8
	Total	98.98

Note: LOI is Loss on Ignition

Table 9a: 7th day Compressive Strength Result for Palm Kernel Shell - Sawdust composite

Mix ratio	Sample No	Area of Sample in (mm^2)	Weight of Sample in (kg)	Crushing load in kN	Compressive Strength (N/mm^2)	Average Compressive strength (N/mm^2)
1:1:1	A	22500	5.3	115.4	5.13	
1:1:1	B	22500	5.23	120.2	5.34	5.35
1:1:1	C	22500	5.05	125.4	5.57	
1:2:2	A	22500	5.2	103.23	4.59	
1:2:2	B	22500	5.3	109.23	4.85	4.52
1:2:2	C	22500	5.14	92.4	4.11	
1:3:3	A	22500	5.2	52.12	2.32	
1:3:3	B	22500	5.3	53.45	2.38	2.34
1:3:3	C	22500	5.12	52.14	2.32	

Table 9b: 28th day Compressive Strength Result for palm kernel Shell - Sawdust Composite

Mix ratio	Sample No	Area of Sample in (mm^2)	Weight of Sample in (kg)	Crushing load in kN	Compressive Strength (N/mm^2)	Average Compressive strength (N/mm^2)
1:1:1	A	22500	5.35	225.56	10.02	
1:1:1	B	22500	5.31	234.2	10.41	10.25
1:1:1	C	22500	5.12	232.4	10.33	
1:2:2	A	22500	5.25	205.6	9.14	
1:2:2	B	22500	5.34	208.9	9.28	9.08
1:2:2	C	22500	5.2	198.45	8.82	
1:3:3	A	22500	5.41	98.67	4.39	
1:3:3	B	22500	5.23	98.46	4.38	4.36
1:3:3	C	22500	5.21	96.89	4.31	

Table 10: Density Result for Palm Kernel Shell - Sawdust Composite

Mix ratio	Sample No	Volume of Sample in (m^3)	Weight of Sample in (kg)	Density of the Palm kernel shell-Sawdust composite in kg/m^3
1:1:1	A	0.003375	5.35	1585.19
1:1:1	B	0.003375	5.31	1573.33
1:1:1	C	0.003375	5.12	1517.04
1:2:2	A	0.003375	5.25	1555.56
1:2:2	B	0.003375	5.34	1582.22
1:2:2	C	0.003375	5.2	1540.74

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DOI: https//doi.org/10.64388/IREV9I3-1710503-479

1:3:3	A	0.003375	5.41	1602.96
1:3:3	B	0.003375	5.23	1549.63
1:3:3	C	0.003375	5.21	1543.70

Table 11: 28th day Split- Tensile Strength result for Palm Kernel – Sawdust Composite

Mix ratio	Sample No	πdL (mm^2)	Weight of Sample in (kg)	Crushing load in kN	Split-Tensile Strength N/mm^2	Average split- Tensile strength (N/mm^2)
1:1:1	A	141371.67	10.7	278.3	1.969	1.951
1:1:1	B	141371.67	10.62	268.95	1.902	
1:1:1	C	141371.67	10.24	280.3	1.983	
1:2:2	A	141371.67	10.5	235.78	1.668	1.666
1:2:2	B	141371.67	10.68	240.56	1.702	
1:2:2	C	141371.67	10.4	230.34	1.629	
1:3:3	A	141371.67	10.82	216.78	1.533	1.558
1:3:3	B	141371.67	10.46	218.45	1.545	
1:3:3	C	141371.67	10.42	225.5	1.595	

Table 12: Static Modulus of Elasticity of Palm kernel shell- Sawdust Composite

Mix ratio	Sample No	Density of Sample in (mm^2)	Weight of Sample in (kg)	Crushing load in kN	Compressive Strength N/mm^2	Static modulus of elasticity GPa	Average Static modulus of elasticity GPa
1:1:1	A	1585.19	5.35	225.56	10.02	9.14	8.90
1:1:1	B	1573.33	5.31	234.2	10.41	9.12	
1:1:1	C	1517.04	5.12	232.4	10.33	8.45	
1:2:2	A	1555.56	5.25	205.6	9.14	8.54	8.56
1:2:2	B	1582.22	5.34	208.9	9.28	8.88	
1:2:2	C	1540.74	5.2	198.45	8.82	8.28	
1:3:3	A	1602.96	5.41	98.67	4.39	7.12	6.77
1:3:3	B	1549.63	5.23	98.46	4.38	6.65	
1:3:3	C	1543.70	5.21	96.89	4.31	6.56	

Table 13: Poisson Ratio Result for Palm Kernel Shell-Sawdust Composite

Mix ratio	Sample No	Density of Sample in (kg/m^3)	Crushing load in kN	Compressive Strength N/mm^2	Tensile Stress N/mm^2	Poisson Ratio μ	Average Poisson ratio μ
1:1:1	A	1585.19	225.56	10.02	1.969	0.20	0.19
1:1:1	B	1573.33	234.2	10.41	1.902	0.18	
1:1:1	C	1517.04	232.4	10.33	1.983	0.19	

1:2:2	A	1555.56	205.6	9.14	1.668	0.18	0.18
1:2:2	B	1582.22	208.9	9.28	1.702	0.18	
1:2:2	C	1540.74	198.45	8.82	1.629	0.18	
1:3:3	A	1602.96	98.67	4.39	1.533	0.35	0.36
1:3:3	B	1549.63	98.46	4.38	1.545	0.35	
1:3:3	C	1543.70	96.89	4.31	1.595	0.37	

Table 14: Shear Modulus Result for Palm Kernel Shell - Sawdust Composite

Mix ratio	Sample No	Density of Sample in (mm^2)	Tensile stress (N/mm^2)	Compressive Stress (N/mm^2)	Static modulus of elasticity	Poisson Ratio μ	Shear Modulus GPa	Average Shear Modulus GPa
1:1:1	A	1585.19	1.969	10.02	9.14	0.20	3.81	3.74
1:1:1	B	1573.33	1.902	10.41	9.12	0.18	3.86	
1:1:1	C	1517.04	1.983	10.33	8.45	0.19	3.55	
1:2:2	A	1555.56	1.668	9.14	8.54	0.18	3.62	3.63
1:2:2	B	1582.22	1.702	9.28	8.88	0.18	3.76	
1:2:2	C	1540.74	1.629	8.82	8.28	0.18	3.51	
1:3:3	A	1602.96	1.533	4.39	7.12	0.35	2.64	2.50
1:3:3	B	1549.63	1.545	4.38	6.65	0.35	2.46	
1:3:3	C	1543.70	1.595	4.31	6.56	0.37	2.39	

Table 15: Average Values of Standard Properties of Palm Kernel Shells- Sawdust Concrete Composite

Mix ratio	Compressive strength (N/mm^2)	Split tensile strength (N/mm^2)	Shear Modulus (GPa)	Static modulus elasticity (GPa)	Poisson ratio
1:1:1	10.25	1.951	3.74	8.90	0.18
1:2:2	9.08	1.666	3.63	8.56	0.19
1:3:3	4.36	1.558	2.50	6.77	0.36

V. DISCUSSION

i. Physical Properties of Sawdust and Palm Kernel Shells:

The sieve analysis of Sawdust shows that it falls in Zone II of the grading of fine aggregates as given in NIS 87 zone 4 and BS 882 (1992) and are suitable for making concrete. The coefficient of uniformity, C_u and coefficient of gradation, Cc for sawdust is 1.0. The Sawdust is approximately well graded since C_c is equal to 1. The specific gravity of the Palm kernel shell and sawdust were 2.65 and 0.35 respectively. BS 812-107(1995) prescribed that the specific gravity of normal weight aggregates should in fall within 2.3-3.0, and any aggregate that fall below the prescribed range will be considered as a lightweight aggregate. Palm kernel shells used in this work fell with the range specified by the referred code, whereas sawdust fell below the recommended values. Hence, Palm kernel shells can be classified as normal weight aggregate, while sawdust can be considered as lightweight aggregate. The bulk densities of the Palm kernel shells and sawdust were found to be 740 kg/m^3 and 734kg/m^3 respectively. BS 812-2(1990) prescribed that bulk density of normal aggregate should be greater than 1500 kg/m^3, otherwise, the aggregate should be classified as

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DOI: https//doi.org/10.64388/IREV9I3-1710503-479

low weight aggregate. The results in Table 2 and 4 showed that both Sawdust and Palm kernel shells used in the research can be classified as low weight aggregates. Thus, they are suitable for construction of low weight structures.

ii. Chemical analysis of cement

The percentage concentration of the major compounds namely CaO, Al_2SO_3, SiO2 and Fe_2O_3 are 67.62, 6.03, 20.39, and 2.29% respectively. These values are within the ranges given in Table 2.5 for ordinary Portland Cement. The concentration of the other compounds – Na_2O, K_2O, TiO_2 and loss on ignition are 0.3, 0.84, 0.2 and 2.8% respectively. These are also within the limit given in BS EN 197-2 (2000). The cement is therefore suitable for general-purpose concrete work.

iii. Analysis of Results of structural characteristics of palm kernel shell – Sawdust composite

a. The slump results for 1:1:1, 1:2:2 and 1:3:3 for 0.75 water cement ratio are 110mm, 80mm and 75mm respectively. The mix ratio 1:2:2 and 1:3:3 have true slump while the mix ratio 1:3:3 has a collapse slump.

b. The average compressive strength of Palm Kernel-Sawdust concrete composite for mix ratios of 1:1:1, 1:2:2 and 1:3:3 are 10.25 MPa, 9.08MPa and 4.36MPa respectively. This implies that as the quantities of sawdust increases in the mix, the compressive strength of the concrete composite decreases. The values of compressive strength obtained are less than the minimum value of lightweight concrete for 28-day strength, which should not be less than 17.5MPa for structural purposes. The values obtained are less than the minimum value of lightweight concrete at 28-day strength which is mostly higher than 17.5MPa for structural concrete. However, the values obtained here are higher than the 1.2MPa to 3.0MPa obtained by Kakamare et.al (2017).

c. The average density of Palm Kernel-Sawdust concrete composite is 1561.15kg/m^3. Comparing with the provisions of BS 5328 (1997), this falls within the density of lightweight concrete which does not exceed 2000 kg/m^3. Therefore, Palm Kernel-Sawdust concrete composite is a lightweight concrete in terms of density.

d. The split tensile strength of Palm Kernel-Sawdust concrete composite ranges from 1.558MPa to 1.951MPa. The tensile strength of lightweight concrete according to literature ranges from 1.87 to 2.75MPa. From the results of the split tensile strength, it can be seen that the Palm kernel shell - sawdust concrete composite has results that is comparable to those of normal weight concrete.

e. The static modulus of elasticity of sawdust-palm kernel shell composite ranges from 6.77MPa to 8.90MPa; but the static modulus of elasticity of normal concrete ranges from 21.4GPa to 46.4GPa that means the values obtained from Palm kernel shell- Sawdust concrete composite is less than those of normal weight concrete.

f. The Poisson ratio of Palm kernel shell- sawdust concrete composite ranges from 0.19 to 0.36 while that of normal concrete ranges from 0.15 to 0.3. The Poisson ratio of the concrete composite is within the acceptable limit of normal weight concrete. The shear modulus of Palm kernel shell-sawdust concrete composite from 2.40 GPa to 3.74GPa while the shear

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