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Effect of Palm Kernel Shell (PKS) as Aggregate in Concrete with Varying Water Cement Ratio

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Abstract – This research examines the effect of palm kernel shell (PKS) as aggregate in concrete with varying water cement ratio. Palm Kernel Shells (PKS) concrete cubes (144 cubes) of sizes 150mm x 150mm x 150mm were cast and cured in water for 7, 14, 21 and 28 days respectively. A mix ratio of 1:2:4 was adopted with water-cement ratio of 0.45, 0.5, and 0.6 respectively while the batching was done by weight. The replacement levels of coarse aggregate with Palm Kernel Shells (PKS) were 0%, 25%, 50%, and 100% respectively. Slump test was conducted on fresh concrete while compressive strength tests were carried out on the hardened concrete cubes using a compression testing machine at the end of each curing ages. The results show that slump height increases with an increase in water-cement ratio and PKS% i.e the more the water-cement ratio and PKS%, the more the slump height increases. However, compressive strength of concrete cube increases with increase in curing age and decreases with increase in water-cement and PKS%. Concrete with 0.45 water-cement ratio comprising of 25% palm kernel shells as course aggregate replacement can be use for lightweight construction work like grout (weak concrete).

Keywords: Aggregate, Compressive Strength, Concrete, Palm Kernel Shell, Water-Cement Ratio.

1. Introduction

Concrete is the most widely used material on earth after water. Many aspects of our daily life depend directly or indirectly on concrete. Concrete is prepared by mixing various constituents like cement, aggregates, water, etc. which are economically available (Saravanan *et al.* 2015). The aggregates typically account about 75% of the concrete volume and play a substantial role in different concrete properties such as workability, strength, dimensional stability and durability, Conventional concrete consists of sand as fine aggregate and gravel, limestone or granite in various sizes and shapes as coarse aggregate. There is a growing interest in using waste materials as alternative aggregate materials and significant research is made on the use of many different materials as aggregate substitutes (Ravikumar *et al.* 2015). Industrial waste materials such as coal ash, blast furnace slag and steel slag and agricultural waste materials such as coconut shell, palm kernel shells etc. have been use by many researchers in replacement of aggregate in concrete for the purpose of recycling industrial and agricultural waste materials. However, palm kernel shells (agricultural waste) were used in this research to produce concrete in a quest for reducing environmental pollution.

Palm kernel shells (PKS) or oil palm shells (OPS) are organic waste materials obtained from crude palm oil producing factories in Asia and Africa (Alengaram et al., 2010). The oil palm industry is important in many countries such as Malaysia, Indonesia and Nigeria. Malaysia is one of the world leaders in the production and export of palm oil and contributes about 57.6% of the total supply of palm oil in the world. Oil palm shells are produced in large quantities by the oil mills. For instance, in Malaysia and Nigeria it was estimated that over 4 and 1.5 million tonnes respectively of oil palm shell (OPS) solid waste is produced annually and only a fraction is used for fuel (traditionally used as solid fuels for steam boilers at palm oil mills) and other applications (Shafigh et al., 2010). The main palm oil producing states include Ogun, Osun, Ondo, Oyo, Edo, Cross River, Anambra, Enugu, Imo, Abia, Ekiti, Akwa-Ibom, Delta and Rivers.

Alengaram et al., (2010) examine the effect of aggregate size and proportion on strength properties of palm kernel shell concrete. Their research presents information on the physical and mechanical properties of different sizes of palm kernel shells (PKS) used here as lightweight aggregates (LWA) and their influence on mechanical properties of palm kernel shell concrete (PKSC). Silica fume and fly ash were used as cementitious materials and all mixes had 1% superplasticizer on cement weight. They reported that it has been found that PKS consists of about 65 to 70% of medium size particles in the range of 5 to 10 mm. The other two sizes, namely, small (0-5 mm) and large (10-15 mm) sizes were found to influence the mechanical properties of PKSC. The 28-day compressive strengths were found in the range of 21 to 26 MPa. The concrete mix that was made with medium size PKS only produced lower compressive strength of about 11% compared to the mix that contained all sizes of PKS. However, the exclusion of medium size particles didn't cause any segregation in the gap-graded aggregate concrete. The strength of PKS and bond governed the failure of PKSC. The flexural and splitting tensile strengths were found respectively 12 and 7% of the compressive strength. PKSC with about 70% of PKS of large size produced the highest modulus of elasticity of about 11 GPa.

Daneshmand et al., (2011) investigated the influence of oil palm shell on workability and compressive strength of high strength concrete. In their experiment, set of laboratory tests including Slump, Compaction Factor, Density, Compressive Strength and Schmidt Hammer test was conducted on concrete made by natural aggregate as control sample and concrete produced by different percentage of OPS i.e. 10%,20%,30%,40% and 50% of dry weight of coarse aggregate. All samples were submerged for 3, 7, 14 and 28 days as curing age. The results demonstrate that the rate of workability for OPS samples shows a relatively medium to high workability ranging from 28 to 50mm for slump height and 0.93 to 0.95 for compaction factor. They concluded that the results of the study can be contributed to produce high strength concrete as well as lightweight concrete particularly in construction of high rise buildings.

Shafigh et al., (2010) carried out a study on Mix design and mechanical properties of oil palm shell lightweight aggregate concrete. They reported that research over the last two decades shows that OPS can be used as a lightweight aggregate for producing structural lightweight aggregate concrete. However, they concluded that significant achievements can be attained in OPS concrete and comparing it with other lightweight aggregate concrete.

2. Materials and Methods

2.1 Materials

The materials consist of Ordinary Portland cement (OPC) – Dangote cement brands 42.5R which conformed to NIS 444 – 1:2003, water, fine aggregate (natural sand) which passes through sieve 4.75mm and conformed to IS 383-1970, coarse aggregate (crushed stone) of maximum size 19.0mm and conformed to IS 383-1970 and palm kernel shells (obtained from a local palm oil producing in Konta-Ijabe, Osun State Nigeria).

2.2 Preparation of Palm Kernel Shells (PKS)

The palm kernel shells were washed and properly rinsed to remove residual and dirt which can doubtlessly affect the performance of the concrete produced. After rinsing, the palm kernel shells were air dried and sieved mechanically with sieve shaker. The palm kernel shells pass through the sieve of 19mm diameter.

2.3 Methods

Palm Kernel Shells (PKS) concrete cubes (144 cubes) of sizes 150mm x 150mm x 150mm were cast and cured in water for 7, 14, 21 and 28 days respectively. A mix ratio of 1:2:4 was adopted with water-cement ratio of 0.45, 0.5, and 0.6 respectively while the batching was done by weight. The replacement levels of coarse aggregate with Palm Kernel Shells (PKS) were 0%, 25%, 50%, and 100%. Slump test was conducted on fresh concrete while compressive strength tests were carried out on the hardened concrete cubes using a compression testing machine at the end of each curing ages.

3. Results and Discussion

3.1 Particle Size Distribution

The result of particle size distribution **(**sieve analysis test) conducted on the Palm Kernel Shells (PKS) is shown in Table 1 and the test conform to ASTM C136 (2001).

Table 1: Particle Size Distribution of Palm Kernel Shells

S/N	Sieve size (mm)	Weight of empty sieve(g)	Weight of sieve + sample (g)	Weight of sample retained (g)	Cumulative weight retained (g)	% cumulative weight retained(g)	% weight passing (g)
1.	19.0	450	500	50	50	5.88	94.12
2.	14.0	450	580	130	180	21.17	78.83
3.	10.0	580	700	120	300	35.29	64.71
4.	9.5	600	840	240	540	63.52	36.48
5.	6.3	450	560	110	650	76.47	23.53
6.	Pan	410	610	200	850	100	0
Total				850			

The result of particle size analysis reveals that the particles of the PKS used in this research are poorly graded, this particle falls under gravel (medium) from the particle size distribution graph as shown in Figure 1.

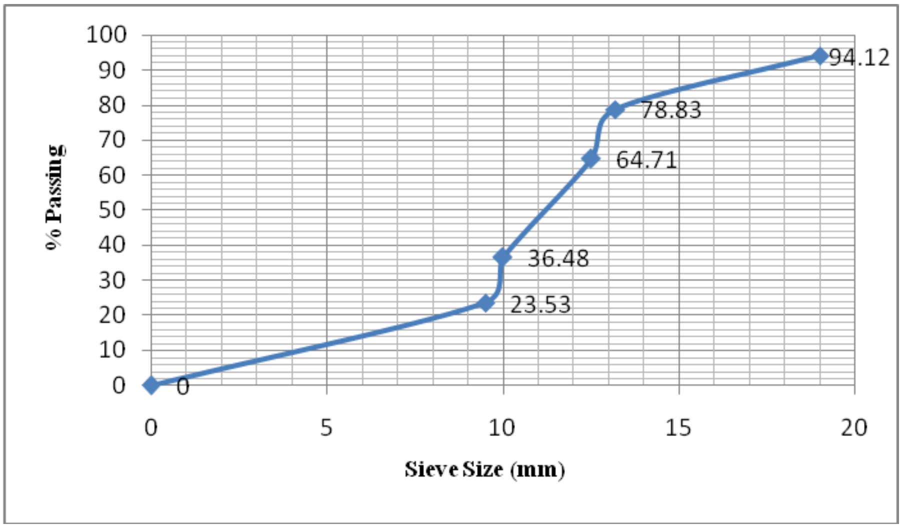

Figure 1: Sieve Size against Percentage Passing

3.2 Specific Gravity

The result obtained from specific gravity of fine aggregate, coarse aggregate and palm kernel shell (PKS) are shown in Table 2.

Table 2: Specific gravity of Fine, Coarse Aggregate and Palm Kernel Shell

S/No.	Test Samples	Specific Gravity
1.	Fine Aggregate	2.53
2.	Palm Kernel Shell	1.36
3.	Coarse Aggregate	2.64

Specific gravity of aggregates as specified by ACI Education Bulletin E1 (2007) ranges from 2.30 to 2.90. The results of specific gravity of fine and coarse aggregate shown in Table 2 are within the acceptable limits while that of Palm Kernel Shell is below the limit and it implies that PKS is a lightweight aggregate.

3.3 Concrete Slump Test

This test was conducted to determine the workability of concrete. The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The test was conducted in accordance with ASTM C192/C192M (2006) and the result is shown in Table 3.

Table 3: Slump Test Result

% Replacement	w/c	Slump Height(mm)
0% PKS	0.45	50
	0.5	60
	0.6	65
25% PKS	0.45	76
	0.5	80
	0.6	85
50% PKS	0.45	87
	0.5	100
	0.6	108
100% PKS	0.45	154
	0.5	160
	0.6	163

The slump height increases with an increase in water-cement ratio and PKS% i.e. the more the water-cement ratio, the more the slump height increases. The result is represented in Figure 2.

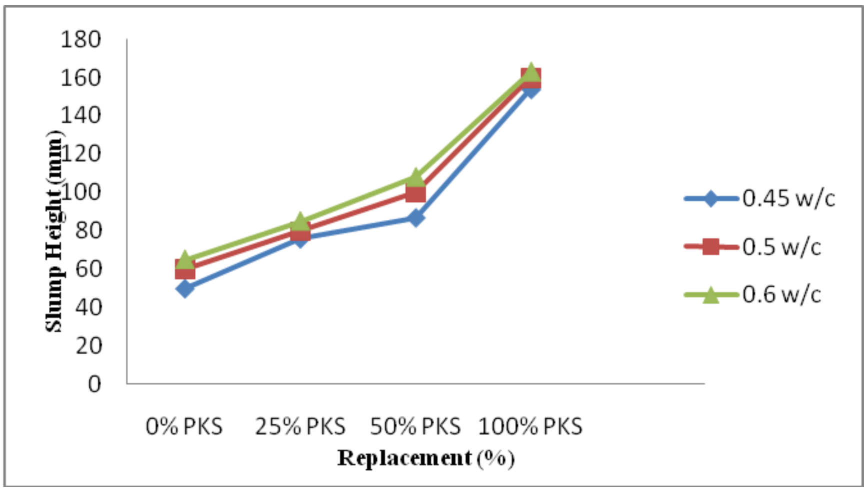

Figure 2: Percentage Replacement with Various Water-Cement Ratios against Slump Height

3.4 Compressive Strength Test

The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications, concrete is used primarily to resist compressive stresses. The compressive strength was calculated from the failure load divided by the cross sectional area resisting the load.

The Compressive Strength Test conformed to BS 1881: Part-116 (1983) and the average compressive strength test is shown in Table 4.

Table 4: Average Compressive Strength Test

		Average Compressive Strength			
		7 days	14 days	21 days	28 days
0% PKS	**w/c**	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)	Strength (N/mm^2)
	0.45	16.963	20.740	23.703	25.185
	0.5	14.800	18.370	21.185	22.222
	0.6	12.592	16.148	18.029	21.622
25% PKS	0.45	12.703	13.778	15.896	17.800
	0.5	11.851	13.481	15.174	16.074
	0.6	9.629	11.777	13.556	14.814
50% PKS	0.45	7.614	11.925	13.037	15.000
	0.5	7.50	9.481	13.000	14.800
	0.6	4.592	7.674	9.111	10.037
100% PKS	0.45	6.629	8.785	10.370	11.592
	0.5	5.925	7.111	8.711	10.296
	0.6	3.407	5.629	6.666	7.556

The compressive strength result shows that the concrete cube gain strength with an increase in the curing age but the strength decreases with an increase in the water cement ratio. However, the strength of concrete cubes decreases with an increase in PKS percentage.

At 7 days, the compressive strength results of 0% PKS with water-cement ratio of 0.6, 25% PKS (with water-cement ratio of 0.45, 0.5 and 0.6), 50% PKS (with water-cement ratio of 0.45, 0.5 and 0.6) and 100% PKS (with water-cement ratio of 0.45, 0.5 and 0.6) is lower than the minimum required compressive strength of 13.5 N/mm^2 for concrete grade 20 as specified by BS 8110 Part 2 (1985) while the strength of 0%PKS with water-cement ratio of 0.45 and 0.5 met the minimum required compressive strength of 13.5 N/mm^2 for grade 20 concrete specified by BS 8110 Part 2 (1985). At 28 days, the strength of 0% PKS (with water-cement ratio of 0.45, 0.5 and 0.6) was above the specified value of 20 N/mm^2 for grade 20 concrete (BS 8110:1985) while the strength of 25% PKS (with water-cement ratio of 0.45, 0.5 and 0.6), 50% PKS (with water-cement ratio of 0.45, 0.5 and 0.6) and 100% PKS (with water-cement ratio of 0.45, 0.5 and 0.6) is lower than the specified value of 20 N/mm^2 for grade 20 concrete (BS 8110: Part 2, 1985) as shown in Table 5. The results are represented in Figure 3, 4 and 5 respectively.

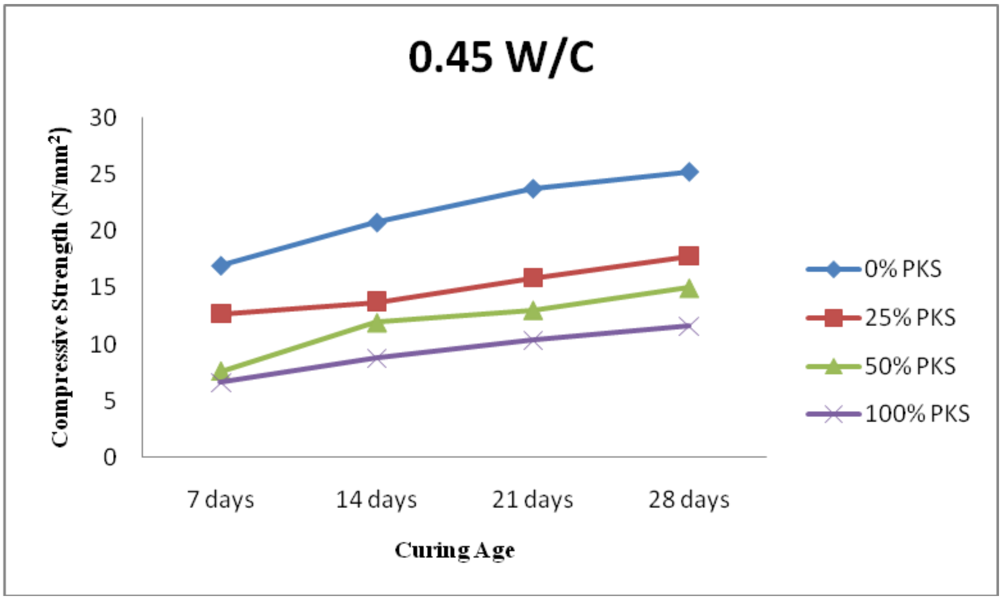

Figure 3: Effect of Percentage (%) Replacement of PKS with Water-Cement Ratio of 0.45

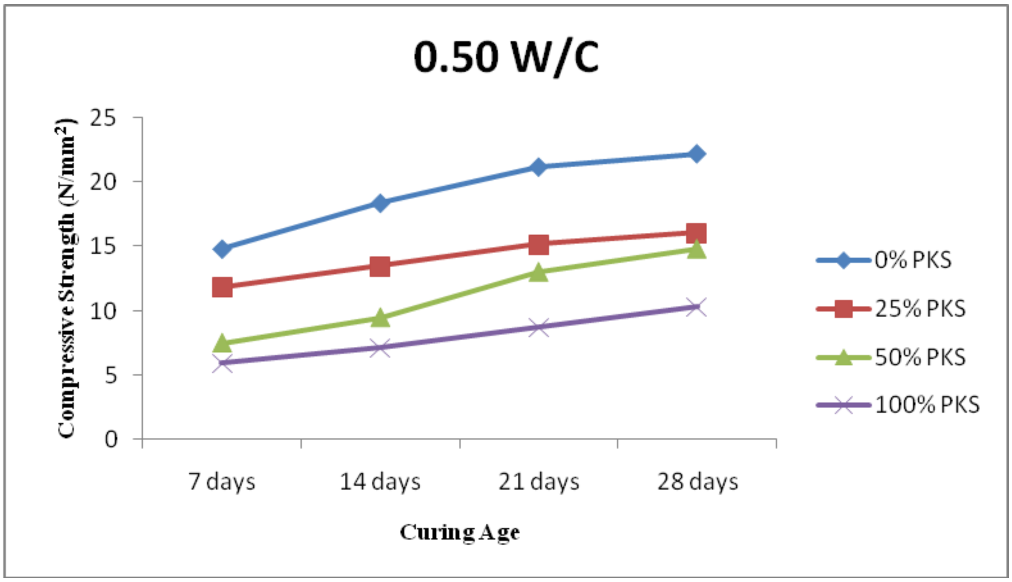

Figure 4: Effect of Percentage (%) Replacement of PKS with Water-Cement Ratio of 0.50

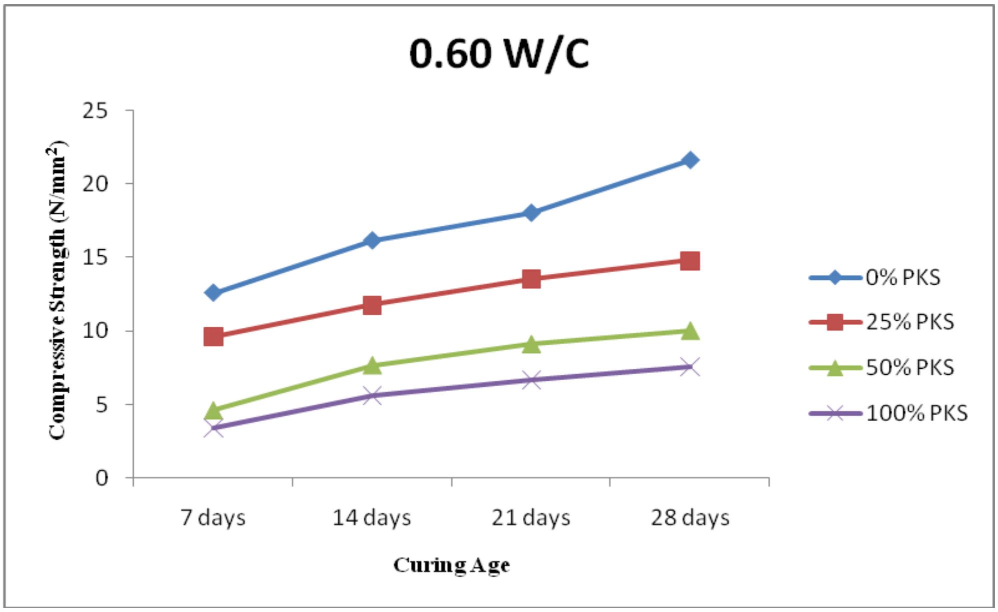

Figure 5: Effect of Percentage (%) Replacement of PKS with Water-Cement Ratio of 0.60

Table 5: Required/recommended strength of concrete (BS 8110 Part 2, 1985)

Grade	**Characteristic Strength, f_{cu} (N/mm^2)**	**Cube strength at an age of:**				
		7 days	2 months	3 months	6 months	1 year
20	20.0	13.5	22	23	24	25
25	25.0	16.5	27.5	29	30	31
30	30.0	20	33	35	36	37
40	40.0	28	44	45.5	47.5	50
50	50.0	36	54	55.5	57.5	60

4. Conclusion

The following conclusion can be drawn from the results of the study:

i. Palm kernel shell is a lightweight aggregate and can be used to produce lightweight concrete.
ii. The specific gravity of PKS aggregate is relatively low compared to specific gravity of coarse aggregate as a result of the high amount of voids within the particles.
iii. The slump value increases with an increase in water-cement ratio and PKS% i.e the more the water-cement ratio and PKS%, the more the slump height increases.
iv. The compressive strength of concrete cube increases with increase in curing age and decreases with increase in water-cement ratio and PKS%.
v. Concrete with 0.45 water-cement ratio comprising of 25% palm kernel shells (PKS) as course aggregate replacement can be use for lightweight construction work like grout (weak concrete).

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