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Strength Comparison of Palm Kernel Shell (PKS) and Corn Cob as Aggregates in Lightweight Concrete

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Abstract - **Continuous increase in the cost of construction is one of the major problems that hindered shelter in many countries; this is the reason why many researches have been focused on how to make use of agricultural wastes which are abundantly available and in cheap supply. In this study, a concrete mix of 25 grade (1:2:4) used with 0.5 water/cement ratio, while Palm Kernel Shell (PKS) shell and corn cob were used to replace coarse aggregate by volume. A total number 80 cubes were produced and allowed for curing, workability (slump), density and compressive were evaluated at 7 days, 14 days, 21 days and 28 days. The density and compressive strength of concrete reduced as the percentage replacement increases. Concrete produced by 0%, 25%, 50%, 75% and 100% replacement of Palm Kernel Shell (PKS) shell attained 28-days compressive strength of 29.34N/mm^2, 19.23N/mm^2 16 56N/mm^2, 4.11Nmm^2 and 3.89Nmm^{2}respectively, while with corresponding concrete produced with 25%, 50%, 75% and 100% replacement of Corn Cob attained 28 days compressive strength of 8.45N/mm^2, 4.45N/mm^2, 3.67N/mm^2 and 3.00Nmm^2. A potential exists for the use of Palm Kernel Shell (PKS) shell as replacement of conventional aggregate in both conventional concrete and lightweight concrete construction. It was concluded that Palm Kernel Shell (PKS) shell can partially be used to replace coarse aggregate (granite) in production of lightweight concrete where it is abundantly available and can be recommended as an alternative material (partial replacement) to coarse aggregate.**

Keywords: concrete, Palm Kernel Shell (PKS) shell, corn cob, density, compressive strength, lightweight concrete.

I. Introduction

The construction industry relies heavily on conventional materials such as cement, granite and sand for the production of concrete. The high and increasing cost of these materials has greatly hindered the development of shelter and other infrastructural facilities in developing counties. There arises the need for engineering consideration of the use of cheaper and locally available materials to meet desired need and enhance self-efficiency, and lead to an overall reduction in construction cost for sustainable development.[9], defined Structural lightweight concrete as concrete made with low-density aggregate having an air-dry density of not more than115 lb/ft3 (1850 kg/m³) and a 28-day compressive strength of more than 2500 psi (17.2 MPa.

Attempts have equally been made by various researchers to reduce the cost of its constituents and hence total construction cost by investigation and ascertaining the usefulness of materials which could be classified as agricultural or industrial waste. Some of these wastes include sawdust, pulverized fuel ash, Palm Kernel Shell (PKS) shells, Rice Husk Ash (RHA), Cassava Peel Ash (CPA), Periwinkle Shell Ash (PSA), slag, fly ash etc. which are produced from milling stations, thermal power station, waste treatment plants etc. The utility of fly ash as partial replacement in concrete mixes is on the increase. [12], concluded in their investigation on utilization of agro-wastes on conventional concrete, that, (RHA, CPA and PSA) investigated possessed adequate pozzolanic properties to be used in place of cement and their engineering properties in terms of workability and compressive strength is suitable for light weight concrete production. The percentage of its utilization is currently less than 13%.

According to [14], Palm Kernel Shell (PKS) shells (PKS) are gotten from threshing or crushing mill to remove the palm seed after the Palm Kernel Shell (PKS) oil has been extracted. He added that during the process of extracting the oil at the mill industry, the solid residues that serve as protective covering for the Palm Kernel Shell (PKS) which are usually in diver's sizes and shapes. They are naturally sized. Light in weight and are appropriate for replacing coarse aggregate in lightweight construction, since they are known to be hard and of organic origin, once used to produce concrete, they hardly contaminate or leach to form toxic substances, since they are attracted together in matrix form. He therefore asserted that the PKS used for lightweight concrete has an advantage over aerated concrete, since permeability is low and the chance for carbonation is reduced.

In an independent research carried out by [17], he concluded that The compressive strength of the concrete for

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the 100% and 25% replacement are 4.78 N/mm2 and 4.44 N/mm^2 respectively, at an age of 28 days, which did not satisfies the requirement for structural light weight concrete Palm Kernel Shell (PKS) shell (PKS) is the hard endocarp of Palm Kernel Shell (PKS) fruit that surround the palm seed. It is obtained as crushed pieces after threshing or crushing to remove the seed which is used in the production of Palm Kernel Shell (PKS) oil [14]. PKS is light and therefore ideal for substitution as aggregate in the production of lightweight concrete. [13], investigated properties of coconut shells (CCS) and Palm Kernel Shell (PKS) shells (PKS) as coarse aggregates in concrete the CCS were crushed and substituted for conventional coarse aggregate in gradations of 0%,25%,50% 75% and 100%. Two mix ratios (1:1:2) and (1:2:4) were used respectively. He noted that the compressive strength of the concrete decreased as the percentage of the shells increased in the two mix ratios. However, concrete obtained from CCS exhibited a higher compressive strength PKS concrete in the two proportions. His result also indicated a 30% and 42% cost reduction for concrete produced from coconut shell sand Palm Kernel Shell (PKS) shells respectively he concluded that coconut shells were more suitable than Palm Kernel Shell (PKS) shells when used as substitute for conventional aggregate in concrete production.

Palm Kernel Shell (PKS) shell is characterized for use as a sorbent in water treatment technology, as a filler material in the construction industry. PKS has utility for a wide range of applications as alternative to direct combustion. As a source of energy, PKS has an appreciable heating value but suffers from smoke production during combustion. X-ray photoelectron spectroscopy reveals a higher carbon-to-oxygen ratio on the surface than in the bulk solid, implying that PKS may serve as suitable coarse aggregate.

Corn cob (CC) is a biomass feedstock with direct potential as an energy resource that can be used in gasification systems for energy production. It has a number of advantages over other biomass feed stocks including its dense and uniform nature as well as its increased energy content and its low sulphur and nitrogen concentrations. [9][11], compared concrete made with coconut shells and Palm Kernel Shell (PKS) shells as replacement for coarse aggregates and concluded that coconut shells performed better than Palm Kernel Shell (PKS) shells as replacement for conventional aggregates in the concrete.

II. Materials and methods

2.1 Materials

The materials used for this research were Portland cement conforming to [4], Sand(Fine aggregate), Granite (Coarse aggregate),Palm Kernel Shell (PKS) shell ash (PKS), Corn cob Ash (CC), clean and deleterious-free water. The PKS used were obtained from Esure Ekiti in Ekiti-State, Nigeria. The shells were thoroughly washed with water to remove impurities. They were sun dried and kept in cool place to allow air drying process. The Corn Cob was sourced from ministry of Agric., Ekiti State. It was sun dry and kept in waterproof bags.

The Corn cob and Palm Kernel Shell (PKS) Shell were independently used to replace coarse aggregate at a replacement level of 0%, 25%, 50%, 75% and 100%. This was done to determine the proportion that would give the most favorable result. The 0% replacement was to serve as control for other samples.

2.2 Methods

The methods adopted in this research are primarily to establish the compressive strengths, workability (slump) and density of the concrete produced.

2.2.1 Density and Compressive strength

After the concrete constituents have been thoroughly mixed, it was poured out for casting. The distance between the place of mixing and the place of casting was ensured to be close in other to avoid segregation of the materials. The cube-mould adopted for the test was 150mm x 150mm x150mm size, it was cleaned and lubricated with suitable lubricant, as it does not enhance the strength of the cube. The cube moulds were then filled in three layers and properly tamped until all trapped air bubbles is been driven out with 35 blows of the tapping rod on each layer and when the mould was full the top of the cube was smoothly leveled off. The difference mixes are; 1:2:4 conventional concrete (granite), 1:2:4 lightweight Palm Kernel Shell (PKS) shells and 1:2:4 lightweight (Corn Cobs). The samples were weighed and measured to determine their individual density. Thus, in conformity with BS 1881 requirement, immediately after stripping the cubes were submerged in curing tank of clean water maintaining at an ambient temperature until they are ready for laboratory testing. The testing was carried out for each sample at 7days, 14days, 21days, and 28days which is the maximum strength. The quality strength of a concrete is determined by the manner in which curing, is accomplishes. Curing of test sample begins as soon it is manufacture and continues until it is crushed in the testing machine.

2.2.2 Slump test

Once the concrete sample has been mixed, then the slump test was carried out within five minutes by filling the slump

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mould in three equal layers by volume. Each layer is been tapped 35times with a tapping rod to compact each layer. After filling and tapping, the cone was raised to allow the concrete to subside. The difference in level between the height of the mould and that of the highest point of the subsided concrete was measured. This difference measured in height in mm was taken as slump of concrete, and the check test was typically performed to confirm test results. The test was carried out as specified in [1].

III. Results and Discussion

The summary of results of test carried on samples of concrete are presented in tables 3.1 (a) and (b) respectively for Palm Kernel Shell (PKS) and Corn cob (CC).

The results in table 1 reveal that the mean weights are different at varying percentages of Palm Kernel Shell (PKS) and granite. It is discovered that the highest weight (7.91) is recorded when Palm Kernel Shell (PKS) is 0% and granite is 100% (control), the next one closer to the control weight is when 25% of Palm Kernel Shell (PKS) is used with 75% granite, this gives us a mean weight of 7.51kg. The lowest mean weight is 4.25, which is obtained when 100% Palm Kernel Shell (PKS) is used for concrete. It can then be summarized that the mean weights drop as the percentage of Palm Kernel Shell (PKS) increases. It is observed that 7.91kg is the highest weight recorded when Corn Cob is 0% and granite is 100% (control), the next one closer to the control weight is when 25% of Corn Cob is used with 75% granite, this gives us a mean weight of 7.16kg. The lowest mean weight is 5.69kg, which is obtained when 100% Corn Cob (CC) is used for concrete. It can then be summarized that the mean weights drop as the percentage of Corn Cob (CC) is increased. It can be summarily stated that Palm Kernel Shell (PKS) performs better than Corn Cob (CC) with respect to weight, density, maximum load, and compressive strength. As shown in fig. 3.1and fig 3.2, it is observed that Corn Cob (CC) will be considered best when it does not exceed 7 and 14 days respectively.

TABLE 3.1 (a)

Summary table of Density and Compressive strength of Palm Kernel Shell (PKS) Shell (PKS)

Properties	0%PKS/100%Granite				25%PKS/75%Granite				50%PKS/50%Granite				75%PKS/25%Granite				0%PKS/100%Granite			
	Curing age (days)				Curing age (days)				Curing age (days)				Curing age (days)				Curing age (days)			
	7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28
Weight (kg)	7.9	7.9	7.9	7.9	7.15	7.15	7.15	7.15	6.0	6.0	5.9	6.0	4.75	4.85	4.85	4.85	4.2	4.2	4.25	4.35
Density (kg/m³)	2326	2326	2326	2326	2189	2189	2189	2189	1778	1778	1734	1763	1408	1408	1408	1408	1245	1245	1259	1289
Max. Load (kN)	348	348	348	348	300	380	385	432.5	257.5	350	355	373	77.5	67.5	85	92.5	50	57.5	72.5	87.5
Comp. Strength (N/mm²)	15.45	15.45	15.45	15.45	13..34	16.89	17.11	19.23	11.45	15.56	15.78	16.56	3.45	3.00	4.00	4.11	2.22	2.56	3.23	3.9

TABLE 3.1 (b)

Summary table of Density and Compressive strength of Corn Cob (CC)

Properties	0%MC/100%Granite				25% MC /75%Granite				50% MC /50%Granite				75% MC /25%Granite				0% MC /100%Granite			
	Curing age (days)				Curing age (days)				Curing age (days)				Curing age (days)				Curing age (days)			
	7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28	7	14	21	28
Weight (kg)	7.85	7.8	8.0	7.9	7.35	7.25	7.05	7.00	6.0	6.0	5.9	6.0	6.2	6.15	6.0	5.95	5.85	5.75	5.5	5.65
Density (kg/m³)	2386	2341	2370	2521	2178	2148	2089	2074	2089	2059	1985	2030	1835	1822	1778	1763	1734	1704	1629.5	1674.5
Max. Load (kN)	348	505	595	660	218	203	195	185	160	145	155	100	62.5	57.5	72.5	82.5	47.5	37.5	62.5	67.5
Comp. Strength (N/mm²)	15.45	22.45	26.45	29.34	9.67	9.00	8.78	8.45	7.11	6.44	6.89	4.45	2.79	2.56	3.23	3.67	2.11	1.67	2.78	3.00

TABLE 3.2

Results of Slump test

Specimen (concrete) ID	Slump value (mm)	Consistency	Degree of Workability BS EN 12350-2:2000
0%(control)	38	Plastic stiff	Low
Pks (25%)	37	Plastic stiff	Low
Pks (50%)	35	Plastic stiff	Low

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Pks (75%)	35	Plastic stiff	Low
Psk (100%)	34	Plastic stiff	Low
m.c (25%)	35	Plastic stiff	Low
m.c (50%)	33	Plastic stiff	Low
m.c (75%)	33	Plastic stiff	Low
m.c (100%)	34	Plastic stiff	Low

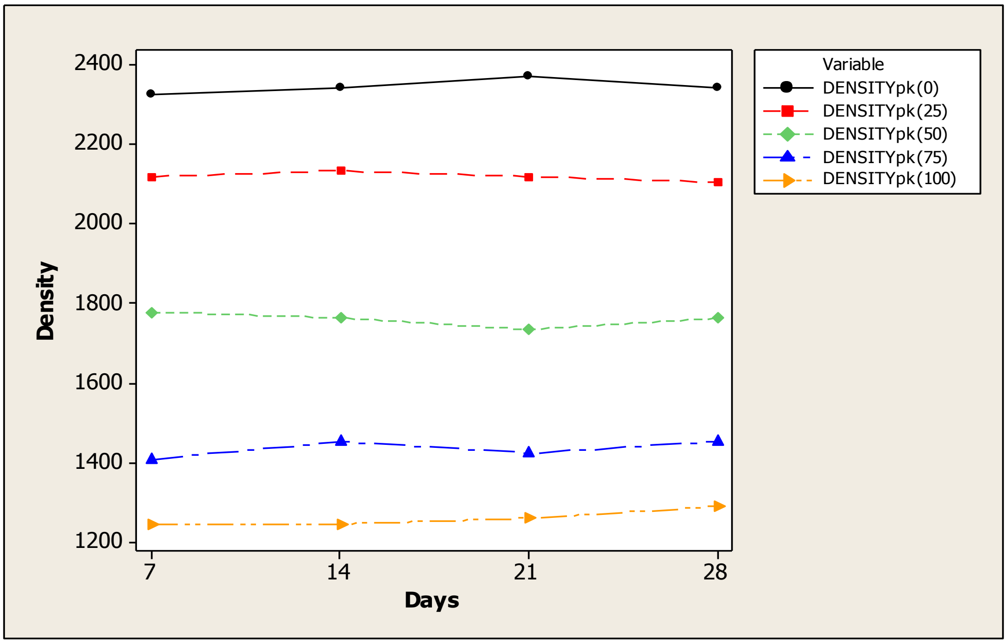

Figure 3.1: Density at varying % of palm kernel and granite

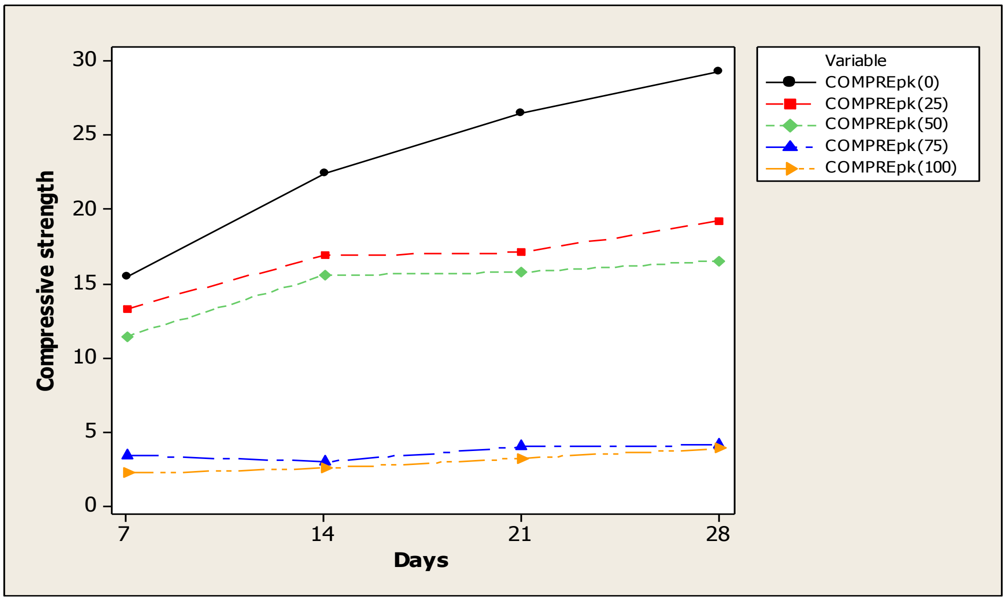

Figure 3.2: Compressive strength at varying % of Palm Kernel Shell (PKS) and granite

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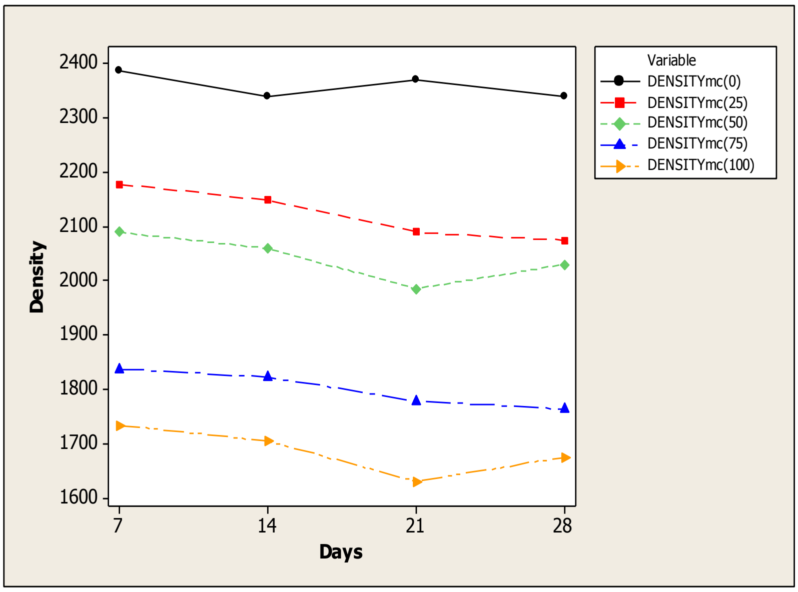

Figure 3.3: Density at varying % of maize cob and granite

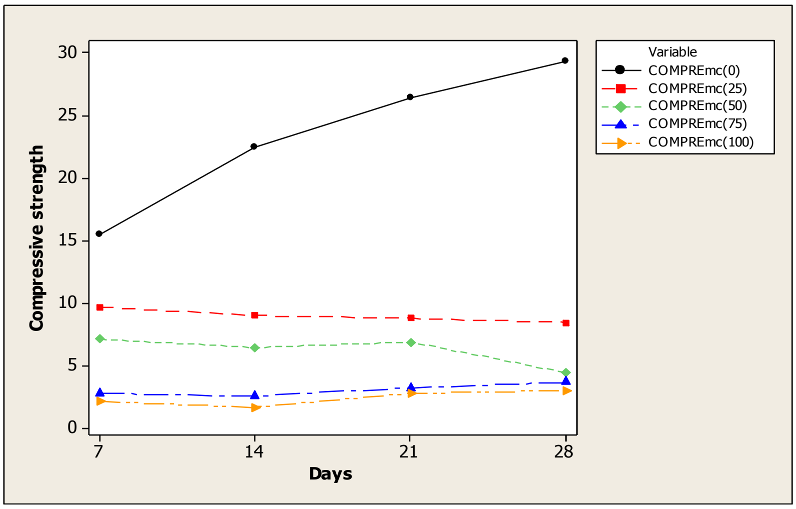

Figure 3.4: Compressive Strength at varying % of Corn cob and granite

Density is one of the properties used to quantitatively and qualitatively define light weight concrete. According to [11], light weight concrete are classified into three categories as follows; structural, structural/insulation and insulation which are otherwise classed as class I,II and III respectively with each having a minimum compressive strength and density range as following >15N/mm^2, >3.5N/mm^2 and 0.5N/mm^2, while densities are 1600-2000kg/m^3, <1600kg/m^3<<1450kg/m^3 respectively.

It is evidently clear that 50%PKS/50%Granite produced class II light weight aggregate based on its compressive strength, however in terms of density, it is categorized as class I. on the other hand, 50%CC/50%Granite behaved in opposite as the range of density was 1800kg/m^3-2089kg/m^3, but the compressive strength yielded a range of 4.45N/mm^2-7.11N/mm^2.Classification based on [3], showed that the samples are classed as LC8/9 of 9N/mm^2 and LC 12/13 13N/mm^2 which occurred majorly at 50%PKS/50%, while in terms of density it showed that 50%PKS/50% fell to D,16 and 50%CC/50%Granite fell to D, 20.

The results of the slump test indicate that all the samples tested have low degree of workability and stiff in plasticity in terms of consistency.

IV. Conclusion

As a result of investigation the following conclusion were drawn; the compressive strength of the concrete cube increases as the days of curing increases. The compressive strength of the concrete cubes decreases as the percentage by volume/mass of palm kernel shells or maize cob increases.

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The usage of palm kernel shells and maize cob as replacement for coarse aggregate in lightweight concrete, gave a better result on 50% palm kernel shell and 50% granite. The concrete cubes of palm kernel shells of 50% at 28% days gave a better result compare to the maize cob. As a result of this development, palm kernel shells can be used for the production of lightweight concrete structure. In addition the use of palm kernel shells for the production of this type of concrete structure allow a reduction in agriculture waste, a reduction in the costs of construction and an increase farmer profit.

V. Recommendations

Lightweight concrete containing palm-kernel shells can be used in construction involving non-load bearing structural elements due to its lower strength capability, durability and performance.

The use of maize cob as a coarse aggregate should be neglected simply because its strength and workability is not worthwhile.

Organic materials are subjected to deterioration over time hence maize cob and palm kernel shells concrete application should be regularly maintained and replaced when necessary. Further research work should be carried out on palm kernel shells to enhance it workability as alternative material to coarse aggregate (granite).

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