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INVESTIGATION OF PALM KERNEL SHELL AS PARTIAL REPLACEMENT FOR AGGREGATE IN ASPHALTIC CONCRETE

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Abstract: Palm kernel shell (PKS) is used as a partial replacement for fine and coarse aggregates in asphalt. Crushed palm kernel shell (CPKS) and PKS were added at 20, 40, 50, 60 and 80% by weight of total aggregates to partially replace the fine and coarse aggregates in asphaltic concrete. Properties such as aggregate impact value, aggregate crushing value, bitumen penetration test and Marshall Stability test were performed in accordance with ASTM D 6927 – 06. From the analysis, CPKS has a stability value of 1,033kg at 20% replacement, 660kg, 646kg, 566kg and 528kg at 40%, 50%, 60% and 80% replacements respectively; while, PKS has a stability value of 2,860kg at 20% replacement, 2,398kg, 2,343kg, 2,156kg and 2,123kg at 40%, 50%, 60% and 80% replacements respectively. Comparing with ASTM D448-12, PKS can be used as alternative material for coarse aggregate for light, medium and heavy traffic roads while, 20% of CPKS can be used as fine aggregates in heavy traffic road and 60% in medium traffic roads. It is therefore recommended that this agro-based product can be used as partial alternate material in asphaltic concrete to reduce the cost of construction.

Keywords: *Palm kernel, asphalt, aggregate, penetration, traffic*

1.0 Introduction

The increasing volume of axle loads on our roads is currently a challenge on the design of road pavement. Factors such as durability, strength and economic needs have to be considered in the design and construction of road pavement. Safiuddin *et al.* (2010) investigates the potential use of various solid wastes in the production of construction materials; while Li *et al.*, (1998) used the processed rubber tires to replace fine and coarse aggregates depending on the fineness of particles; the study shows that the rubberized concrete shows excellent flexibility, ductility and energy absorbency as compared with conventional concrete. However, the road paving industry is interested in utilizing alternative and sustainable materials that satisfy aforementioned aid in the production, placement, and performance of road pavements. Diversification of material resources is important in the construction and maintenance of sustainable asphalt pavements. The materials must be sustainable, blend properly with bitumen and have a comparatively low cost when used in pavement construction. For the alternative materials to be considered sustainable, they must be technically economically and environmentally viable.

Palm kernel shells (PKS) are derived from the oil palm tree (*elaeisguineensis*), an economically valuable tree, and native to western Africa and widespread throughout the tropics (Omange, 2001). They are used in commercial agriculture in the production of palm oil. The African oil palm *elaeisguineensis*is native to West Africa, occurring between Angola and Gambia. The generic name is derived from the Greek word for oil, *elaion*, while the species name has referred to its country of origin (Sulyman and Junaid, 1990). In Nigeria, about 1.5 million tons of PKS are produced annually; most of which are often dumped as waste products (Nuhu-Koko, 1990). The waste could be converted to wealth by using it in the production of asphaltic concrete. Since few years ago, the use of local materials in the construction industry has been campaigned by the Nigerian government to limit costs of construction (Mohammed, 2014). There has been a greater call for the sourcing and development of alternative, agro-based and, non-conventional local construction materials in view to harness the maximum potential of agricultural waste in agricultural sector.

2.0 Problem Statement

The demand for more roads, increasing cost of production of asphaltic mixture and scarcity due to depletion of the naturally occurring materials been used had necessitated the search for alternative and sustainable materials, that will satisfy the aforementioned needs and aid in the production, placement and performance of pavements. Also, growth of population, increasing urbanization, and rising standards of living due to technological innovations have contributed to increase in the quantity of a variety of solid wastes generated by industrial, mining, domestic and agricultural activities. According to Nwaobakata and Agunwamba (2014); the use of biomaterials in general and agro-waste in particular is a subject of great interest nowadays not only from the technological and scientific points of view, but also socially, and economically, in terms of employment, cost and environmental issues. Hence the primary aim of this research is to determine the suitability of crushed palm kernel shell (CPKS) and palm kernel shell (PKS) as a partial replacement for fine and coarse aggregates in asphalt.

3.0 Literature Review

Asphaltic concrete is derived from a mixture of coarse and fine aggregates, stone dust, mineral fillers and binder, usually bitumen. The mix is done such that the finished product does not have too much bitumen which will eventually lead to bleeding and frictionless surface, or too much coarse aggregate that lead to removal of the surface. The bitumen and aggregates are usually mixed and heated at a central location. Asphaltic concrete surfaces are fairly easy to construct and repair (Neville, 1995). Several researchers in material science and engineering have used locally available materials to partially or fully replace these costly conventional materials in both concrete mixture and asphaltic mixture. Oyedepo and Oluwajana (2014) investigated the properties of bitumen modified with used tyre. Basic tests such as penetration, softening point, viscosity, flash and fire point and ductility test were carried out by using shredded waste tyre which varied from 0% to 20% by weight of 60/70 penetration grade bitumen at 160^{0}C using dry mix method. Penetration value decreased with addition of 20% tyre while increase in softening point, viscosity, flash and fire point were obtained with the corresponding values of 80.9^{o}C, 250.96 sec and 189/280.12^{0}C respectively.

Dahunsi *et al.* (2013) investigated the properties of pure water sachet modified bitumen and found that the waste pure water sachet showed potential for enhancing the properties of bitumen, particularly between 2.5% and 7.5%. Emmanuel *et al.* (2012) introduced alternative binder from microalgae; this thermo-fusible viscoelastic material shows rheological properties similar to those of asphalt. Moreover, a tuning of those properties can be achieved by adjusting the percentage of algaenans in the oil. Yinusa and Stephen (2011) used Dissolved Pure Water Sachet (DPWS) as an optimum binder content modifier in bitumen, they established that Dissolved Pure Water Sachet (DPWS) can be combined with bitumen to exhibit the desired flow and stability of a Hot Mixed Asphalt wearing or bearing course for a flexible pavement at 15 % replacement of the optimum binder content and 25% additions by weight of total mix in emulsified condition.

Ndoke (2006) examine the performance of palm kernel shells as coarse aggregates in road binder courses with emphasis on strength of the asphalt concrete as given by the Marshal Stability and flow values. It was observed that palm kernel shells can be used to replace coarse aggregate up to 30% before drastic reductions become noticeable. He recommended that for heavily trafficked roads, palm kernel shells up to 10% can be used for the replacement while even 100% replacement is possible for lightly trafficked roads in the rural settings.

In another study by Joseph and John (2012) on the properties of Soy Fatty Acids (SFA) as sustainable modifier for asphalt binders, they came to the conclusions that SFAs are a plausible, sustainable modifier for asphalt binders and that they decrease the viscosity and stiffness of asphalt binders thereby making them more workable. Liu *et al.* (2012) studied Organo Montmorillonite Nano clay as alternative modifier to sustain durability of asphalt pavement. They came to the conclusion that Organo Montmorillonite Nano clay improves the short-term aging resistance of base bitumen. Joana *et al.* (2012) worked on development of Rubber-Modified Fractionated Bio-Oil for use as non-crude petroleum binder in flexible pavements, they arrived at a conclusion that a bio-binder consisting of fractionated bio-oil reacted with crumb rubber can produce a binder that is comparable to asphalt binders derived from crude petroleum and also that the bio-oil can successfully react with crumb rubber at 125°C, which is a substantially lower temperature than that used in normal asphalt binders, typically around 185°C. In the research carried out by Adewuyi and Adegoke (2008) on exploratory study of periwinkle shells as coarse aggregates in concrete, they established that 35.4% and 42.5% of the periwinkle shells in replacement for granite was quite satisfactory for the concrete mix ratios 1:2:4 and 1;3:6 respectively.

The palm oil plant (*Elais Guinensis*), considering its three different varieties Dura, Peripheral and Tenera, produces an edible fruit similar to an apricot which has inside a nut. During the crude palm oil process that fruit's flesh is melted through a steaming treatment. The residual nuts are further mechanically crashed shells are called palm kernel shell (PKS), a virgin biomass with high calorific value (NCVAR typical about 3,800 kcal/kg- ASTM D5865-02) (ASTM, 1999). Foraminifera in their market survey said palm kernel shell has a very low ash and Sulphur contents; ash content (typical about 3% weight - ASTM D3174-02) and Sulphur content (typical about 0.09% weight as stipulated in ASTM D4239-02) (ASTM, 2002 & 2012a). In the international trading of palm kernel shell (PKS), the specification is listed below:

- Moisture: 1.7% max
- Impurity: 2% max
- Fiber: 5% max
- Hard Shell: 90% minimum.

4.0 Materials and Method

4.1 Materials

Palm kernel shell in Figure 1 used for this research was obtained locally from Engr. Akinjo’s farm in Akure, Ondo State, Nigeria, while filler and coarse aggregate were obtained from F.M. quarry site in Irese, Ondo State, Nigeria. River sand free from deleterious materials was obtained from a riverine area in Igbokoda town, Ondo state. Impurities such as soils and other dirt were removed and the shells were sun dried and oven dry at a temperature of 400^{o}C, crushed and sieved with sieve No 200. However, bitumen with penetration grade of 70/80 was obtained from Sapelle, Delta State, Nigeria.

Figure 1: Palm Kernel Shell. .

4.2 Method

Specified proportions of each material such as 4% filler of size 0.075mm, 6% quarry dust of maximum size 5mm, 66% river sand of maximum size 5mm also and 28% crushed stone of size 5-16mm with 6% bitumen of penetration grade 70/80 was mixed together at 163˚C. The mixture was compacted with 50 blows both at the top and bottom to obtain cylindrical samples for the Marshall Stability tests. Palm kernel shells were partially replaced at 20, 40, 50, 60 and 80% by weight of total coarse aggregate in the mixture. Three samples were as shown in Figure 2 were prepared for each percentage replacement of coarse aggregate with Palm Kernel Shell. Same procedure was repeated for Crushed Palm Kernel Shell to replace fine aggregate.

Several tests were performed in accordance to the standard specifications as follows:

i. Sieve Analysis (ASTM C136-06) (ASTM, 2014).

ii. Aggregate Impact Value (AIV) Test (BS 812-112:1990) (BS, 1990).

iii. Aggregate Crushing Value (ACV) Test (BS 810-112:1990) (BS, 1990).

iv. Specific Gravity Test (ASTM C127 - 12 and ASTM C128 - 12) for coarse and fine aggregates respectively (ASTM, 2012b).

v. Bitumen Penetration Test (BS 2000-487:2009) (BS, 2000).

vi. Marshall Stability Test (ASTM D 6927 – 06) (ASTM, 2006).

Figure 2: Prepared samples

5.0 Results

5.1 Sieve Analysis

The results of sieve analysis carried out on the materials showed that Palm Kernel Shell (PKS) is fairly graded, Crushed Palm Kernel Shell (CPKS) is fairly graded, Fine Aggregates (FA) is well graded and Coarse Aggregates (CA) is fairly graded. The results are given graphically in Figure 3.

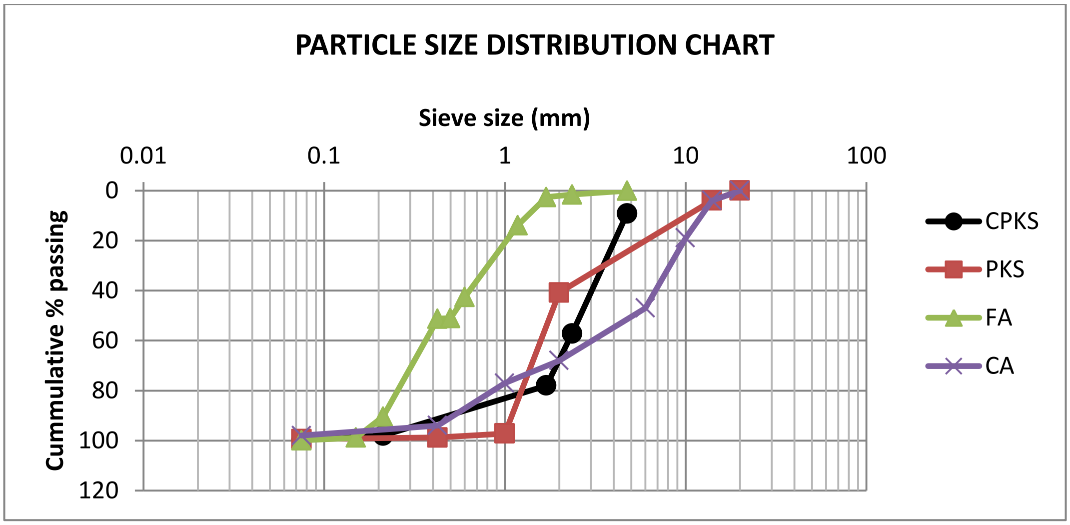

Figure 3: Particle Distribution Curves for Crushed Palm Kernel Shell, Palm Kernel Shell, Fine Aggregate and Coarse Aggregate.

Comparison was made between the results of CPKS and fine aggregate (Figure 4) and it was shown that there is no significant different in the particle grading properties between these materials.

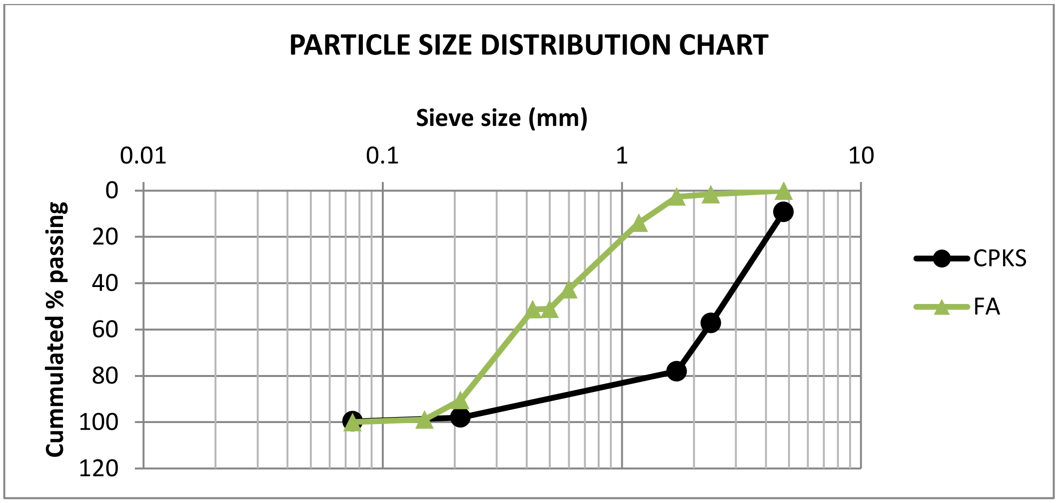

Figure 4: Particle Distribution Curves for Crushed Palm Kernel Shell and Fine Aggregate.

The results of PKS and CA were compared (Figure 5) and it was found out that the materials exhibited similar properties which made it suitable for replacement of each other.

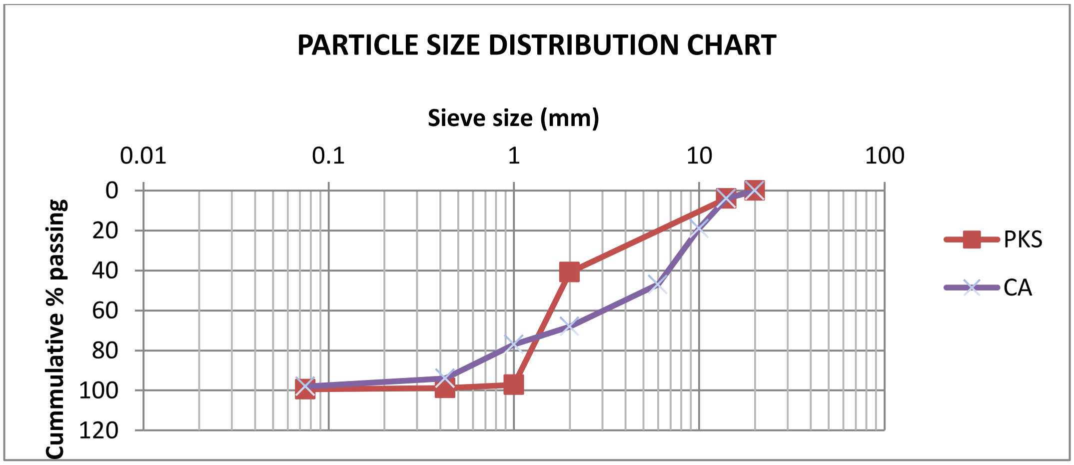

Figure 5: Palm Kernel Shell and Coarse Aggregate

Table 1 shows the result of Specific Gravity test, Moisture Content test, AIV test, ACV test and bitumen penetration test carried out on the materials and asphalt mix using PKS and CPKS as partial replacement for Coarse and Fine aggregates respectively.

Table 1: Result of other tests.

S/N	Material Type	Specific Gravity %	Moisture Content %	AIV %	ACV %	Penetration
1.	Palm Kernell Shell	1.36	13	5.08	5.07	
2.	Filler	2.76	11			
3.	Fine Aggregate	2.74	14			
4.	Coarse Aggregate	2.7		22.40	27.0	
5.	Bitumen		4			75

The specific gravity values of fine and coarse aggregates are 2.74% and 2.70% respectively which conform to section 4085 of the general specification for roads and bridges (1997). The specific gravity of CPKS is 1.36%, fine aggregates has the highest moisture content of 14%, followed by filler and CPKS with 11%, and 13% moisture content respectively. The moisture content of bitumen is 4% which is less than 5% which is the highest value permitted for bitumen. General specification for roads and bridges (1997) in section 6251 (1) specified that coarse aggregate shall be free from clay or silty materials, and when subjected to 10% fine test or aggregate crushing value, the value of the results shall range from 7.5% to12.5% for 10% fine and not more than 35% for aggregate crushing value. The ACV values of coarse aggregates which is 22.40% showed that the aggregates are strong and good for use in asphalt. Penetration test on bitumen shows that 70/80 grade bitumen was used.

5.2 Marshall Stability Test

The stability values obtained using 20%, 40%, 50%, 60%, and 80% of PKSC as partial replacement were 1,033kg, 660kg, 646kg, 566kg and 528kg respectively; while the stability values obtained using 20%, 40%, 50%, 60%, and 80% of PKS as partial replacement were 2,860kg, 2,398kg, 2,343kg, 2,156kg and 2,123kg respectively (Figure 6).

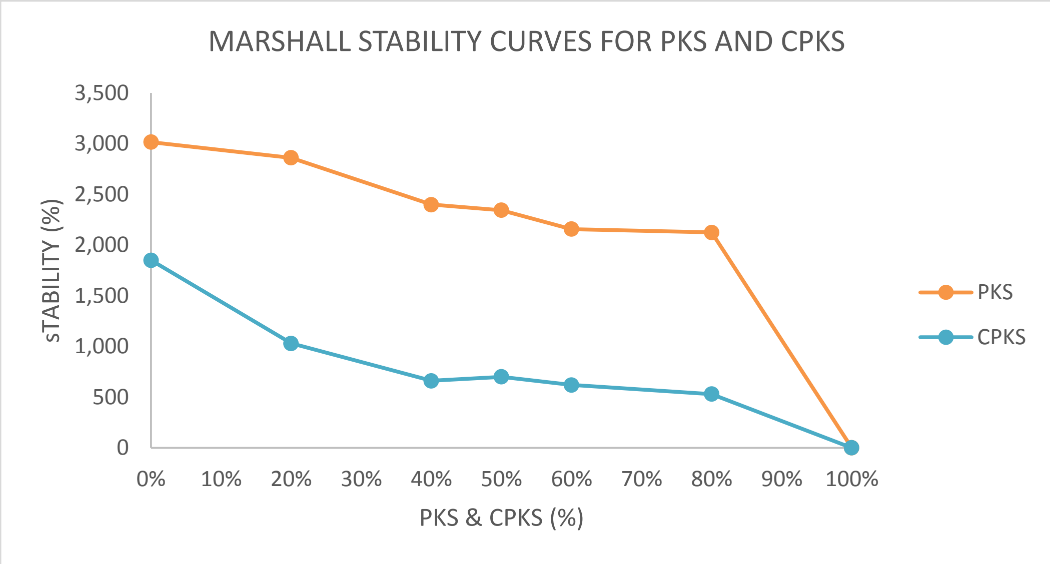

Figure 6: Marshall Stability curve for Crushed Palm kernel Shell and Palm Kernel Shell

The Marshall Design Criteria for Stability provided by the Asphalt Institute requires minimum values for different traffic classifications starting at:

- 750 pounds or 340kg for Light Traffic.
- 1200 pounds or 544kg for Medium Traffic.
- 1800 pounds or 815kg for Heavy Traffic.

For light traffic, all the Marshall Stability values obtained are more than minimum values Figure 7 also shows the minimum specified value for Medium Traffic and it can be deduced from the graph that only CPKS 80% replacement falls below the minimum value of 544kg which invariably makes CPKS 80% replacement unsuitable for use in Medium Traffic pavement. It can also be seen from Figure 5 that minimum value for Heavy Traffic as specified by Asphalt Institute is 815kg which only CPKS 20% replacement is above this minimum value while others are below it. It is also crystal clear from Figures 5 that PKS from 20% to 80% has Marshall Stability value that is far above the specified values by the Asphalt Institute for Light, Medium and Heavy Traffic.

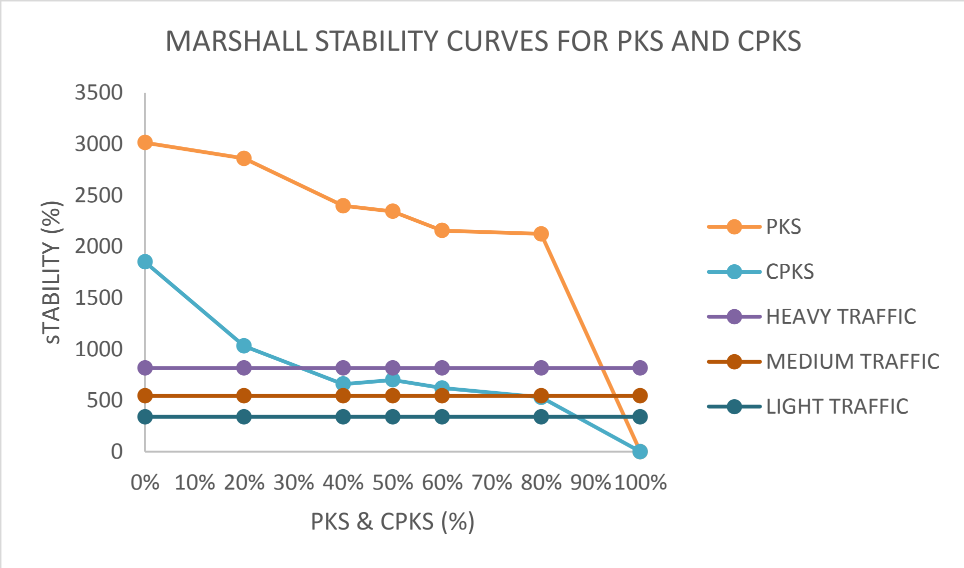

Figure 7: Marshall Stability curve for Crushed Palm kernel Shell and Palm Kernel Shell with specified value for Heavy, Medium and Light Traffic.

6.0 Conclusion

It can thus be concluded, based on the results of standard tests carried out on the materials, that both Crushed Palm Kernel Shell (CPKS) and Palm Kernel Shell (PKS) can be used as a suitable material as partial replacement for coarse and fine aggregates respectively in asphaltic concrete up to 80% in Light Traffic roads. CPKS can be used as a suitable material as partial replacement for coarse aggregates in asphaltic concrete up to 20% in Heavy Traffic roads. CPKS can be used as a suitable material as partial replacement for coarse aggregates in asphaltic concrete up to 60% in Medium Traffic roads. Meanwhile, PKS can be used as a suitable material as partial replacement for fine aggregate in in asphaltic concrete up to 80% in Light, Medium and Heavy Traffic roads. Palm kernel shell when used as a replacement in asphaltic concrete will reduce the littering of the environment by it and thus put it to a beneficial use. The use of palm kernel shell in asphaltic concrete is expected to provide a cheap source of construction material, does reducing the demand for naturally occurring coarse aggregates.

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