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PALM KERNEL SHELL AS PARTIAL REPLACEMENT FOR FINE AGGREGATE IN ASPHALT

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Abstract: The Nigerian government has been clamouring for the use of local agro-based wastes in the construction industry so as to reduce cost of construction. Asphalt concrete (commonly called asphalt, blacktop, or pavement in North America, and tarmac or bitumen macadam in Great Britain and Ireland) is a composite material commonly used to surface roads, parking lots, and airports. One of the materials (quarry dust) used in conventional asphalt was replaced with crushed palm kernel shell in varying percentages; 0, 50, & 100%. Laboratory tests were carried out on the materials and asphalt. The research was done in two phases; test experiment (50 and 100% shell replacement and the referenced (0% shell). The results obtained show that marshal stability decreased by 22.97% and 103.84% for 50 &100% shell replacement. The fineness modulus is 1.0 which could also result into strength reduction. The moisture content absorption increased as palm kernel shell increases. The specific gravity of granite was found to be 2.67 greater than 1.6. However, Crushed Palm Kernel Shell (CPKS) can be used as a suitable material as partial replacement for fine aggregate (Quarry dust) in asphaltic concrete up to 50% for rural roads of low traffic.
Keywords: palm kernel shell, fineness modulus, water absorption, Marshal stability, specific gravity

1. INTRODUCTION

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 a bleeding and frictionless surface, or too much coarse aggregate leading to ravelling 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 (Mohammed *et al.,* 2014). In the course of design and construction of road pavements, factors such as materials, durability, strength and economic needs have to be considered. The demand for conventional flexible pavement materials has increased due to increase in constructional activities in the road sector and at the same time, paucity of construction materials. 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 (Oyedepo *et al.,* 2015). In order to overcome the aforementioned problems, different alternatively generated waste materials like Palm Kernel Shell (PKS) deposited in large quantities can be crushed and used as partial replacement for fine aggregate in the production of asphaltic concrete. 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; after the extraction of oil, part of the waste is the shell which could add more to problem of solid waste management. 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 idea of burning in waste management is contributing greatly to environmental pollution and emission of greenhouse gases which could add more to the depletion of the ozone layer; global warming. 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 *et al.,* 2014).

In addition, the 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 (Nwaobata & Agunwaba, 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. There has been a greater call for 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. Palm kernel shells are not common materials in the construction industry. This is either because they are not available in very large quantities as sand or gravel, or because their use for such, has not been encouraged.

Safiudeen *et al.,* (2010) investigated the potential use of various solid wastes in the production of construction materials.

Mohammed *et al.,* (2014) discovered the specific gravities of the fine sand and crushed palm kernel shells were found to be 4.34 and 2.25 respectively. The characteristic curves are typical of those of uniform sands and are corroborated by their uniformity coefficients (C_u) of 2.08 and 2.0 for sand and crushed palm kernel shells respectively. Grading of aggregates is aimed at determining the mean size of the particle in a given batch of aggregates. This is commonly found by the method of Fineness Modulus (FM). The recommended value of FM for fine aggregates is between a minimum of 2.0 and maximum of 3.50 (Singh, 2004). Also, the Marshall stability against the mix proportions indicates that as the percentage of crushed palm kernel shells, the stability value decreases. The results of properties of asphaltic concrete with 10 and 50% palm kernel shell as replacement of fine aggregate were within the specification for asphaltic concrete roads (Mohammed *et al.,* 2014). According to (Oglesby & Hicks, 1982) Marshall Stability range for road surfaces carrying between 1 and 6000 commercial vehicles per day should be between 2 and 10kN. The implication is that with the proper stress calculation and appropriate thicknesses of underlying layers, even the asphalt concrete with 100% palm kernel shells is suitable for lightly trafficked roads. Since the same amount of bitumen was used, the flow values are almost similar. The increase would have been caused by the weaker bonds created by the palm kernel shells and their high water retention capacity which can mix the bitumen to increase its water content, hence viscosity. The marshal stability obtained for 0%, 50% and 100% is 14.44KN, 11.10KN and 7.70KN respectively. The percentage decrease in strength from 0-100% shell replacement is 87.53% (Peter, 2006).

It was observed that palm kernel shells can be used to replace coarse aggregate up to 30% before drastic reductions become noticeable. It is therefore 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 (Peter, 2006). The physical properties of palm kernel shell obtained by Peter (2006) are shown in Table 1.

Table 1: Properties of the Palm kernel shells

Property	Value
Bulk density Mg/m^3	0.74
Dry density Mg/m^3	0.65
Void ratio	0.40
Porosity (%)	28
Water content (%)	9
Water absorption (%)	14
Specific gravity	1.62
Impact Value (%)	4.5

Source: (Peter, 2006)

Crushed Palm Kernel Shell (CPKS) and Palm Kernel Shell (PKS) can be used as a suitable 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 (Oyedepo *et al.,* 2015).

In the course of this research, the following objectives were considered; the properties (physical and chemical) of palm kernel shell; the effect of varying percentage of palm kernel shell as a partial replacement of fine aggregate in asphaltic concrete on the marshal stability; the optimal level at which crushed palm kernel shell can replace fine aggregate in asphaltic concrete.

2. MATERIALS AND METHODS

— Material Sourcing

The materials used in this study are Palm kernel shell, filler, coarse aggregate, river sand free from deleterious materials and bitumen. The Palm Kernel Shell used was obtained locally from Ila Orangunon coordinates 8^{0}1^{1}N and 4^{0}54^{1}E, Osun State, Nigeria. The river sand free from deleterious materials was obtained from a riverine area around Coca-Cola road, Ilorin, and conventional filler and coarse aggregate were obtained from Mount Olive quarry site in Eiyenkorin, both in Ilorin Metropolis, Nigeria. However, bitumen with penetration grade of 70/80 was obtained from Sapelle, Delta State, Nigeria. The Crushed Palm Kernel Shell (CPKS) used is shown in Figure 1.

Figure 1: Crushed Palm Kernel Shell

— Methods

Impurities such as soils and other dirt were removed from the PKS; sun dried and later oven dried at a temperature of 400^{0}C. Thereafter, crushing and particle distribution analysis was carried out on the crushed shell. The research methodology is as outlined below:

The material (Palm Kernel shell) was thoroughly cleaned for removal of impurities, after which it was crushed and grinded to quarry dust size (as shown in Figure 1).

Particle size distribution analysis was carried out on all the aggregate (crushed PKS and granites (3/8", 1/2, & 3/4)

The specific gravity and water absorption tests were carried out on the aggregates.

The physical and chemical properties of the bitumen were determined.

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; control test.

The mixture produced item 4; was compacted with 50 blows both at the top and bottom to obtain cylindrical samples for the Marshall Stability tests.

Palm kernel shells was partially replaced at different percentages of 50% and 100% by weight of total fine aggregate and Marshal stability test was carried out; test experiment.

The test sample specimen produced at a temperature of 315°F and laying temperature of not less than about 2500, was used to patch some potholes in Share Local Government Area of Kwara State.

3. RESULTS AND DISCUSSION

— Particle Size Distribution

The particle size distribution (Table 2) of PKS was conducted in accordance with BS 812-103.1:1985. And the distribution curve is shown in Figure 2.

Table 2: Results of Particle Size Distribution of palm kernel shell

Sieve size (mm)	Wt of sieve (g)	Weigh of sieve + sample (g)	Weight retained (g)	% retained	% passing
1	340.11	730.08	389.97	77.94	22.06
0.85	333.29	360.85	27.56	5.51	16.55
0.6	313.52	352.25	38.73	7.74	8.81
0.5	299.5	313.80	14.30	2.86	5.95
0.3	278.79	296.45	17.66	3.53	2.42
0.25	271.84	274.45	2.61	0.52	1.90
0.18	269.78	272.93	3.15	0.63	1.27
Pan	371.65	378.01	6.36	1.27	0

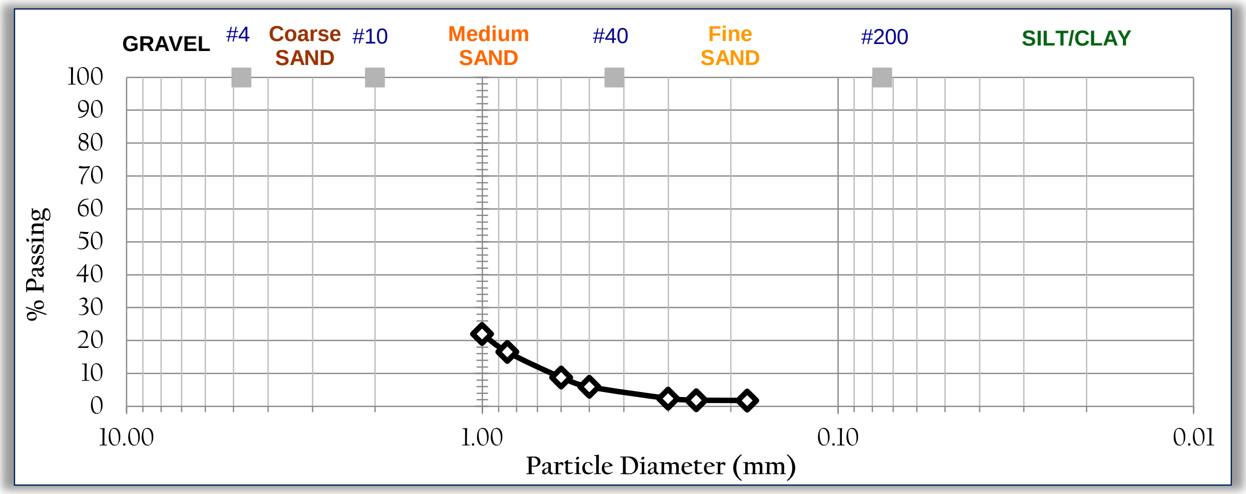

Figure 2: Particle size distribution curve for palm kernel shell

The fineness modulus of the PKS is 1.0 which is less than the value recommended by (Singh, 2004). It implies the crushed shell falls in the medium of very fine material. Hence, fineness modulus was determined using Equation 1

$$\text{Fineness modulus} = \sum \text{cumulative \% weight retained} \div 100 \qquad \text{Eqn. 1}$$

The fineness modulus of this research = 100/100 = 1.0

— Water Absorption of Granite

The water absorption test shown in Table 3 of PKS was done in accordance with BS 812:2 (1975).

Table 3: Water Absorption of Granite

Procedure	Sample 1	Sample 2
weight of aggregate before soaking (gms)	300	300
weight of aggregate after 24hrs soaking (gms)	300.8	300.7
Water absorption (%)	0.27	0.23
Average water absorption (%)	0.25	

Water absorption of PKS is higher than the value of granite; it means there is higher tendency for reduced strength of asphalt containing higher percentages of palm kernel shell in water logged area or environment.

— Specific Gravity of Granite

The specific gravity of coarse aggregate shown in Table 4 was conducted in accordance with BS 1377:2 (1990).

The specific gravity of 1.62 for palm kernel shell as obtained by (Peter, 2006) is less than 2.67 of granite; this implies granite is denser than palm kernel shell.

— Marshal Stability of Asphalt

This test was done in accordance with ASTM D6926 (2010). The result is shown in Table 5.

The percentage decrease in marshal stability test is 103.84% as against a value of 87.53% obtained by (Peter, 2006).

Table 4: Results for Determination of Specific Gravity of Granite by Pycnometer

Test Procedure	Sample A	Sample B
Wt. of Pycnometer (gm)	598.5	398.5
Wt. of Pycnomter+dry soil (gm)	898	898.1
Wt. of dry soil $W_2 – W_1$ (gm)	499.5	499.6
Wt. of Pycnomter+soil+water	1736.9	1737
Wt. of water $W_3 - W_2$ (gm)	838.9	839.6
Temp.of water^{0}C	29	29
Vol. of Pycnometer cm^3	1025.9	1025.9
Density of water - temp	0.9959	0.99597
Vol. of dry soil cm^3	187.8	187.1
Specific gravity	2.66	2.67
Average Specific gravity	2.67	

4. CONCLUSIONS

The specific gravity of crushed palm kernel shell was found to be less than that of granite. Also, crushed palm kernel shell absorbed more water than granite. In addition, the results of the tests showed that the marshal stability value decreased as the percentage of crushed palm kernel increases which implies the reduction in the strength of the asphaltic concrete. The marshal stability value at 50% palm kernel shell replacement was found to be within the limit of specification and hence, suitable for rural roads with light traffic.

Table 5: Results of Marshal Stability of Asphalt

Palm kernel (%)	Marshal Stability (kN)
0	12.74
50	10.36
100	6.25

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ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665