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Waste Management and Application of Waste Micro-Sized Palm Kernel Shell Ash (MSPKSA) in the Stabilization of Engineering Soil

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Abstract

The management of solid waste and the application of Palm Kernel Shell Ash in the stabilization of Umuntu Olokoro lateritic soil for construction purposes were studied. The waste PKSA was mixed with the stabilized soil in the proportions of 3%, 6%, 9%, 12% and 15% and the behavior of the soil observed for its Geotechnical properties. The results of the study showed that the strength properties of the A-2-7 soil improved with the addition of waste PKSA. The indication is such that further addition of the waste would increase the strength properties further. Waste management and disposal which has posed a big problem for the southeastern states of Nigeria has, by the results of the work received a boost in that disposal of waste; palm kernel shell would now be beneficial to the works ministry for use as admixture in the stabilization and improvement of soil for road construction purposes. So, we call on the works and environment Ministries to collaborate in the task of Geowaste management of the area to save our environment from the hazards of dumping palm kernel shell and the pavement facilities.

Keywords: Waste management; Palm kernel shell ash; Micro-sized; Stabilization; Application; Umuntu olokoro

Introduction

Palm Kernel Shell is a solid waste common in the southeastern part of Nigeria, where palm oil is a major agro industrial product and the hazard the dumping of this waste exposes the people of this region cannot be overemphasized. It is found after the processing of palm fruits in the agro industrial production of palm oil and palm kernel. This ash is a by-product of the incineration of palm kernel shells under a controlled temperature of between 600°C and 800°C and in most cases uncontrolled open air burning. In the developing the countries like Nigeria, solid waste management has been a major environmental problem [1]. This is because these third world countries are yet to embrace the technologies of the developed world in the management of solid waste. But the introduction of what may be termed Geo-waste engineering in the field of Geotechnical Engineering; wastes have been used in the stabilization and improvement of soil for different construction purposes. In this process, Palm Kernel Shell, which is a huge waste and pollution in both rural and urban cities in the southeastern Nigeria is processed and used as aggregate in the production of concrete and as ash in the stabilization of soil for pavement construction [2-4]. Consequently, Concrete and Geotechnical Engineering serve as a platform for the management and displacement of this solid waste. Similarly, the management procedures made possible by the Geotechnical Engineering open another window for this waste energy to be renewed and reused in a different form that benefits the society. There is serious environmental decay in terms of road pavements in the southeastern Nigeria and this research work has as its main aim to create an atmosphere where the management of solid waste; palm kernel shell is used to save the cost of pavement construction and other civil engineering works. This will be achieved by ensuring that subgrade soils are improved in strength capacity by mixing a percentage of this solid waste either as ash or aggregate with the soil or concrete. However, the specific objectives of this research work were; (i) to create a technological approach to the disposal and management of solid waste; Palm Kernel Shell in southeastern Nigeria where it is prominent, (ii) to reduce the cost of flexible and rigid pavement construction and revamping materials by making use of palm kernel ash as an admixture, (iii) to study the effect of this solid waste on the Geotechnical Engineering properties of Umuntu Olokoro lateritic soil used as subgrade within the southeastern states of Nigeria and (iv) to make suggestions to the solid waste management and works ministries of the states within the studied region.

Materials and Methods

In recent times, the demand for better flexible pavement materials accentuated by design guidelines that are based on the assumptions that aggregates are important ingredients of pavement structures, has increased due to increased constructional activities in the road sector and paucity of available construction materials in the developing countries. To overcome this problem, the use of solid waste materials, including reclaimed asphalt pavements (RAP) scarified from failed highway pavements, deposited in large quantities along reconstructed roads, Palm Kernel Shell Ash (PKSA), etc. is evaluated. The Palm Kernel Shell was collected from different dump sites along major roads and close to agro industrial sites as wastes occupying a large land mass. Most times, this solid waste is dumped where it obstructs vehicular movement. As a result of poor technologies in the management of these solid wastes, the dumping of these materials has been a source of worry to the Ministry of Environment. But the results of this research work will reposition the relationship between the Ministry of Environment and that of the Works on the management and disposal of Palm Kernel Shell as solid waste. The collected shells were sun dried to remove moisture, completely burnt and stored, for the laboratory evaluation. This was used in the proportions of 3%, 6%, 9%, 12% and 15% to mix with the studied soil sample and studied. Ordinary Portland cement was used as a binder at a fixed percentage of 5. Lateritic soil sample

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used for this study was collected from a borrow pit located at Olokoro, between latitude of 05°28 '36.700" north and longitude 07°32'23.170" east from a depth of 2 meters, a distance of 5 km along Ubakala road from Ishi Court, Umuahia the Abia state capital in Nigeria (www.google.com, 2017). The sample collected was in solid state and reddish brown in color. The soil obtained from this location was air dried in trays for six days, after which the soil was crushed.

The following preliminary tests were conducted in accordance with [5-21] Sieve Analysis Test, Compaction Test (Standard Proctor Test), California Bearing Ratio Test (CBR), Atterberg Limit Test (cassagrande apparatus), Unconfined Compressive Strength (UCS) Test, Specific Gravity Test, and Chemical Composition Test on the natural soil sample and results were obtained.

Results and Discussion

After a series of preliminary laboratory exercises and laboratory study on the behavior of the Umuntu Olokoro lateritic soil with the Palm Kernel Shell Ash, the results were collated and tabulated. Observations were also made to enable the right judgement and decisions on the use of Palm Kernel Shell Ash in Geotechnical Engineering and at the same time rid the environment of such a disturbing solid waste. Electrical conductivity, pH and cation exchange capacity.

From Table 1, we can deduce that the studied Umuntu Olokoro soil sample has the following properties in its natural state;

- Has a plasticity index of 21.85% > 17% and that condition satisfies that Umuntu Olokoro lateritic soil is a highly plastic soil. Also the plasticity index falls between 20% and 35%, a condition for high swelling potential and between 25% and 41%, a condition for a high degree of expansion [22].
- Has, from the consistency limits tests that the soil relative consistency and liquidity index, which are 1.69% > 1 and 0.91% < 1 respectively show that the soil is in a semi-solid or solid state, very stiff and plastic [22].
- Is classified as A-2-7 soil on AASHTO soil classification, well graded, GW on USCS, the group index of 0 and of silty, clayey gravel and sand material [22].
- Has optimum moisture content (OMC) of 13% and maximum dry density (MDD) of 1.84 g/cm^3.
- Has Unconfined Compressive Strength (UCS) of 230.77 kN/m^2 at 28 days curing time, which falls between 200 and 400 kN/m^2, a condition for soils of very stiff consistency with respect to UCS, which satisfies the material condition for use as sub-grade material [22,23].
- Has California bearing ratio of 14 which makes it good for the sub-grade material [23].

Property/Unit		Quantity
% Passing BS No. 200 sieve		25.40
Natural Moisture Content, (%)		10
Liquid Limit, (%)		47.00
Plastic Limit, (%)t		25.15
Plasticity Index, (%)		21.85
Coefficient of Curvature, $C_c = \frac{D_{30}^2}{D_{10} \times D_{60}}$		0.09
Coefficient of Uniformity, $C_u = \frac{D_{60}}{D_{10}}$		10
Specific Gravity		2.67
AASHTO classification		A-2-7
USCS		GW
Group Index		0
Material		Silty or Clayey Gravel, Sand
Condition/General Subgrade Rating		Good
Optimum Moisture Content, (%)		13
Maximum Dry Density (g/cm^3)		1.84
California bearing ratio, (%)		14
Unconfined Compressive Strength, (KN/m^2)	28 days	230.77
	14 days	219.11
	7 days	194.26
Color		Reddish Brown

Table 1: Geotechnical properties of umuntu olokoro lateritic soil collected sample.

From Figure 1 and Table 1, we can deduce that the soil is a well graded with Cc equals 0.09 and Cu equals 10.

Effect of variable proportions of PKSA on the consistency limits of stabilized umuntu olokoro lateritic soil

Table 2 shows the behavior of the stabilized Umuntu Olokoro lateritic soil as regards its consistency limits. The natural soil had a high plastic consistency of PI greater than 17%. But the behavior reduced, drastically to plastic consistency at 9% addition of PKSA and non-plastic at 12% and 15% addition of PKSA. This trend showed that further addition of PKSA will equally reduce the PI further.

Effect of variable proportions of PKSA on the compaction of stabilized umuntu olokoro lateritic soil

The compaction behavior of the studied soil with the addition of PKSA was observed to improve in terms of density and optimum moisture content as shown in Table 3. There was an increase in the maximum dry density with a corresponding decrease in the OMC with the addition of variable proportions of PKSA. The maximum value of the density was achieved by the addition of 15% PKSA. This is as a

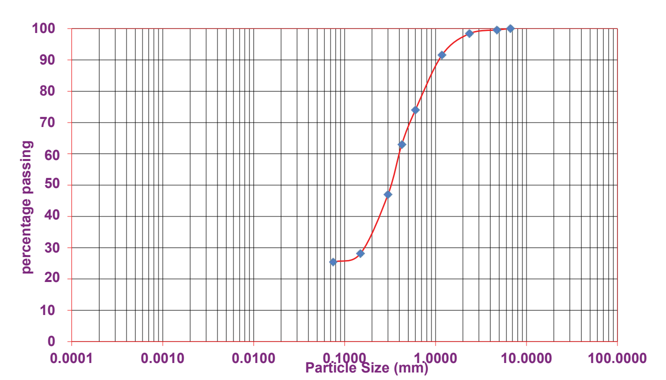

Figure 1: Particle size distribution curve of umuntu olokoro lateritic soil sample.

PKSA Proportion, (%)	0	3	6	9	12	15
Liquid limit, (%)	47.00	53.81	52.41	32.80	24.76	24.56
Plastic limit, (%)	25.15	22.92	23.01	25.00	20.90	21.50
Plasticity index, (%)	21.85	30.89	29.40	7.80	3.86	3.06

Table 2: Effect of PKSA additive on the consistency limits test result of umuntu olokoro stabilized soil.

Palm Kernel Shell Ash (%)	M.D.D (gm/cm³)	O.M.C (%)
0	1.84	13.00
3	1.75	13.77
6	1.76	12.55
9	1.85	10.71
12	1.88	10.19
15	1.96	10.19

Table 3: Effect of PKSA additive on the compaction test result of umuntu olokoro stabilized soil.

result of the loss of the air voids by the addition of the ash.

Effect of variable proportions of pksa on the cbr of stabilized umuntu olokoro lateritic soil

This strength property improved as well from 3% addition of PKSA considerably till 15% addition of PKSA. A maximum CBR of 76% was achieved at 15% addition of PKSA. The results as shown in Table 4 showed that the CBR showed an exponential increase, which also shows that further addition of the higher percentage of PKSA will further increase the CBR behavior. With the above results, the stabilized soil sample has met the material requirement to be used as sub-base material in flexible pavement construction purposes in southeastern Nigeria.

Effect of variable proportions of pksa on the ucs of stabilized umuntu olokoro lateritic soil

From the study of the effect of the addition of PKSA to the unconfined compressive strength (UCS) of the stabilized Umuntu Olokoro lateritic soil shown in Table 5, we can deduce the following;

1. The addition of PKSA as admixture to the stabilized Olokoro soil improved the strength of the sample at different curing periods.

2. The soil with PKSA maintained a consistent improvement, which showed that further addition of PKSA will bring advantageous results and improvements to the stabilized soil [24].

Conclusion

From the foregoing, it can be concluded as follows:

1. That Palm Kernel disposal as a solid waste in southeastern Nigeria is no longer a problem with the breakthrough made in this research work.

2. That with the use of huge proportions of PKSA, the sub-grade and sub-base materials needed for the construction of flexible pavements will be replaced partly by this admixture that has proven through the results to be a good soil strength optimizer.

3. That PKSA has proven to be a good admixture in the stabilization of Umuntu Olokoro lateritic soil for the improvement of the strength properties of the soil for use as base material in pavement construction.

4. That the Ministries of Environment and Works should collaborate in the management and disposal of this solid waste to save the environmental from the hazards of dumping palm kernel shell indiscriminately.

PKSA (%)	0	3	6	9	12	15
CBR (%)	14	22	23	28	45	76

Table 4: Effect of PKSA additive on the california bearing ratio (ucs) test result of umuntu olokoro stabilized soil.

PKSA Proportion, (%)	0	3	6	9	12	15
UCS @ 7 days, (KN/m²)	194.26	202.85	273.12	286.51	350.47	381.62
UCS @ 14 days, (KN/m²)	219.11	313.87	333.15	356.49	372.55	397.08
UCS @ 28 days, (KN/m²)	230.77	357.22	365.96	379.98	390.45	400.11

Table 5: Effect of PKSA additive on the unconfined compressive strength (ucs) test result of umuntu olokoro stabilized soil.

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