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Evaluation of Presence of Sawdust and Palm Kernel Shell Ashes on Geotechnical Properties of Ekiti State Soil

Adetoro A. Ezekiel, Adekanmi S. Jonathan
Dept. of Civil Engineering
The Federal Polytechnic
Ado - Ekiti, Nigeria.
yemmieadyt@yahoo.com

***Abstract* — this research was carried out in other to study the effects of Sawdust Ash (SDA) and Palm Kernel Shell Ash (PKSA) on the geotechnical properties of soil in Ido-Osi Local Government Area of Ekiti State. Soil samples were collected from eight locations within the study area and subjected to various laboratory tests (i.e. Grain Size Analysis, Atterberg Limits and Compaction tests). The tests were conducted on the samples both in untreated and treated state. The additives were added to the soil samples in proportions of 2%, 4%, 6% and 8%. The presence of the additives on the samples increased the Maximum Dry Density (MDD) of the specimen with PKSA having higher effects compared to the SDA. As the presence of the additives is well felt in the compaction test performed on the specimen used, it also display inconsistencies in the value of the plasticity indices and liquid limits of the samples. The increment in MDD values as the additives contents increase are likely to make the soil suitable for subgrade, subbase and base course. It can therefore be deduced that PKSA and SDA could be adopted as stabilizing agents in other to discourage the skyrocket rate of purchasing construction materials.**

Keywords—Compaction; Palm Kernel Shell Ash (PKSA); Plasticity Index (PI); Saw dust Ash (SDA); Liquid Limit (LL).

I. INTRODUCTION

The rate of development in Civil Engineering structures in developing nations like Nigeria is highly discouraging due to the daily geometrical increase in the cost of materials needed in the construction of these structures. This has caused the poor people in these nations to continue in their poorer state and only the rich could afford what pleases to them. Many in this part of the world lives in tents not houses as they were unable to see or make any advantages out of what encompasses them. As it is often said, “what is hardest to see is what you have in front of you”. The citizens of this community have what will make them to live as kings and queens but were blind to it. Waste Recycling is now becoming a business that gives great fame to any nation. In lieu of this fact, the available “Waste” and other resources in this community is now implored as a material to increase the product of living of the community in form of shelter materials and as a means of generating income to the families within the community and thereby increasing the GDP of the nations ([3], [4], [6], [12]).

Waste products are found in its large quantities everywhere all over the World and these had been resulting in environmental hazard and the suitable method of disposal has been causing headache to the governments. These wastes can be controlled by the governments through “Waste to Wealth policy” especially as in a country like Nigeria - properly treated and used for the improvement of soil with poor geotechnical properties especially expansive or problem soils. Some of these wastes were locally available materials from agriculture and industries e.g. Sawdust Ash (SDA), Palm Kernel Shell Ash (PKSA), Rice Husk Ash (RSA), Coconut Shell Ash (CSA), Maize Cobs, Cassava Peel Ash (CPA), Cocoa Pod Ash, Pulverized Fuel Ash, Locust Beans Ash, Fly Ash etc. They were usually products of milling stations, thermal power stations, waste treatment plants, breweries etc. ([3], [6], [12], [15]).

From the past research works carried out by [3], [4], [6], [7], [11], [12], [13], [14], [15], [16], [17], and others, it has been confirmed that locally available materials can be used as additives for improvement / stabilization of Geotechnical properties of different kinds of soil. The proper management of this waste will be of great help in slashing the cost of construction materials to the extent that the whole country will be crime free.

In this research work, the utilization of PKSA and SDA as additives on Geotechnical properties of Ekiti State soil will be checked. This will help in providing first hand technical information / data for Ekiti State soil, and also help in establishing the suitability of the additives for stabilization of soil purpose (s) instead of wasting huge amount of money on cement or lime since the additives are found in large quantities within the study area and its environment.

STUDY AREA - The study area is in Ido-Osi LGA which is one of the existing LGAs in Ekiti State with an average population of 107,000 people. It housed thirteen major towns and several numbers of farmsteads and is one of the LGAs in the state that was blessed with industries like printing press, bakery, saw mills and other Federal Government Parastatals. It is located on between Latitudes 7.30O and 7.64 O North; and Longitude 5.05O and 5.48 O East in the northern part of the state as shown in Fig. 1. The temperature ranges between 21ºC and 28ºC with high humidity. The state (where the study area is situated) is mainly an upland zone, rising over 250 metres above sea level and lies on an area underlain by metamorphic rock. The state is generally undulating with a characteristic landscape that consists of old plains broken by step-sided out-crops that may occur singularly or in groups or ridges. The study area has its LG Secretariat sited in between Ido town and Usi Ekiti, and shared boundaries with other LGAs like Moba by its North west, Ilejemeje by its North, Irepodun /Ifelodun by its South, Ijero by its West and Oye by its East ([1], [5]).

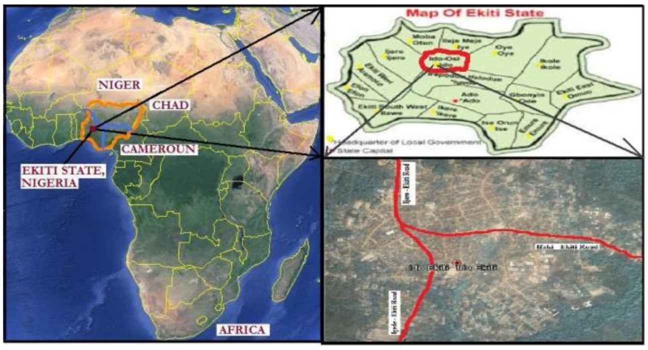

Fig. 1: Location of the Study area – Ido-Osi Local Government Area [10]

II. MATERIALS AND METHODS

Sawdust is a by-product of cutting, grinding, drilling, sanding, or otherwise pulverizing wood with a saw or other tool. It comprises of fine particles of wood and is also the byproducts of certain animals, birds and insects which live in wood, such as the woodpecker and carpenter ant. The dust is usually used as domestic fuel. The resulting ash which is a form of pozzolana is known as saw-dust ash (SDA). Clean Sawdust without a large amount of bark has proved to be satisfactory. This does not introduce a high content of organic material that may upset the reactions of hydration. The SDA used is produced by subjecting some cleaned quantities of sawdust obtained from Usi-Ekiti saw mill to laboratory furnace at the Federal University of Technology, Akure, Nigeria. The SDA was sieved with 75μmm diameter sieve and the content passing through this sieve was adopted for the study [6].

Palm kernel shell is an industrial waste which is readily available in its large quantities in palm oil producing area especially the southern part of Nigeria. Palm kernel shells have very low ash (about 3% weight) and sulphur (about 0.09% weight) contents. Palm kernel shell ash (PKSA) is a by-product of the combustion of palm kernel shells under a controlled temperature of between 600 and 1000oC. Utilization of PKSA is minimal and unmanageable while its quantity increases annually and most of the PKSA are disposed as waste in landfills causing environmental problems. The Palm Kernel Shells incinerated to ashes for this study were obtained from Ago-Aduloju-Ekiti in Ekiti State. They were obtained in dry form and sundried to facilitate complete incineration to ashes. The Palm kernel shells were placed in incinerator and were allowed to burn at a temperature of about 800^{0}C – 1000^{O} C in the laboratory at the Federal University of Technology, Akure, Nigeria. The PKSA was also made to pass through 75μmm sieve [6].

Soil samples were collected at random from trial pits within the study area as shown in table 1 at depth varying from 1.0m to 1.5m in its disturbed state. The soil samples collected were stored in polythene bags to maintain its natural moisture contents. The samples were then taken to the laboratory where the unwanted materials such as roots were removed. The samples were air dried, pulverized with mortar and pestle and set to pass through a set of sieve (i.e. from 3/4" Sieve (19.5mm) to Sieve No.200 (0.075mm)) to remove the large particles from the samples. Moulding of test specimens was started as soon as possible after completion of identification.

The additives were mixed with the soil samples in the proportion of 0 – 8%. All tests were performed according to standard methods in [2]. Their features were examined and determined to ensure that all relevant factors would be available for establishment of relationships among them. The tests carried out on each of the selected samples are Grain Size Distribution, Atterberg limits and Compaction. The results were compared to the standard specified values and grouped in accordance with [8] and [9].

Table 1: Details of the location of the Soil Samples taken

SAMPLE CODE	LOCATION	CHAINAGES	GEOG. COORDINATES	
			LATITUDE	LONGITUDE
ROUTE A1	IDO - IJERO ROAD	2+000	7.64014^{O}	5.37683^{O}
ROUTE A2	IDO - IJERO ROAD	6+000	7.63256^{O}	5.39757^{O}
ROUTE B1	IDO – USI ROAD	2+000	7.43989^{O}	5.45085^{O}
ROUTE B2	IDO - USI ROAD	4+000	7.07761^{O}	5.4166^{O}
ROUTE C1	IDO - IGEDE ROAD	2+000	7.42454^{O}	5.45929^{O}
ROUTE C2	IDO - IGEDE ROAD	6+000	7.39757^{O}	5.47984^{O}
ROUTE D1	IDO – IFAKI ROAD	2+000	7.4861^{O}	5.42052^{O}
ROUTE D2	IDO – IFAKI ROAD	6+000	7.4981^{O}	5.4804^{O}

GRAIN SIZE DISTRIBUTION - The samples were washed with Sieve No. 200 and Grain Size Distribution test were performed on the dry samples that retained in the sieve after washing. This test is used in the description of soil particles (i.e. clay, sand and gravel fraction), group the particles into different ranges of sizes and to ascertain the relative proportion by mass of the untreated soil samples. The results of this test on the soil samples were classified according to [9] classification system ([6]).

ATTERBERG LIMITS - Liquid Limit (LL) and Plastic Limit (PL) tests were conducted on the soil samples at treated and untreated states in other to examine the reactions of the samples to water. The results were compared to the standard specified values in accordance with [8] and [9] ([6]).

COMPACTION - The standard proctor (BSL) type of compaction test was adopted for the samples at treated and untreated state. The importance of this test is to confirm the relationship between the soil's Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) at treated and untreated soil state ([6]).

III. RESULTS AND DISCUSSION

The results derived for the untreated soil samples as shown in Table 2, portray that the soil samples had percentages finer passing through 0.075mm fractions varied between 8.2% and 63.2% - All the soil samples have their percentages finer passing through 0.075mm fractions as 35% and below except that of A1which is 63.2%. The untreated soil samples B2 – D2 could be generally classified as Granular soil materials while untreated soil sample A1 could be generally classified as Silt – Clay soil materials.

Table 2: Summary of the Particle Size Analysis Tests of Untreated Soil Samples

S / CODE	A1	A2	B1	B2	C1	C2	D1	D2
Sieve Size	% Wt Passing	% Wt Passing	% Wt Passing	% Wt Passing	% Wt Passing	% Wt Passing	% Wt Passing	% Wt Passing
9.50	99.2	97.6	95.6	94.4	95.4	94.0	93.6	94.2
4.75	89.2	80.4	83.0	80.6	82.6	78.6	77.8	78.8
2.36	77.2	61.2	69.3	65.2	69.2	60.8	59.8	61.2
1.18	72.4	52.2	60.2	54.0	59.4	47.2	46.2	47.4
0.60	69.2	45.2	52.2	44.0	50.8	35.2	34.8	35.4
0.30	66.4	39.2	45.6	35.4	43.8	24.6	25.4	24.8
0.15	64.4	34.8	40.0	28.2	38.4	15.6	17.4	15.8
0.075	63.2	32.8	35.0	22.0	33.6	8.2	10.4	8.2

From Table 3, the results portray that untreated soil samples A1, B1, B2 and C1 were not having enough gravel material constituents when compared with the required limits. Untreated soil samples A1, A2,B1 and C1 were not also having enough sand material constituents , while C2 and D2 were having more sand material constituents when compared with the required limits. The results also showed that silt – clay material constituents were very high for untreated soil samples A1, A2, B1, B2 and C1. While that of untreated soil samples C2, D1 and D2 were alright when compared with the required limits.

Table 3: Summary of the Soil Classification of the Soil Samples according to AASHTO Classification ([9])

SAMPLE CODE	A1	A2	B1	B2	C1	C2	D1	D2	REQUIRED LIMITS
% GRAVEL	22.8	38.8	30.7	34.8	30.8	39.2	40.2	38.8	35.0 - 50.0
% SAND	14.0	28.4	34.3	43.2	35.6	52.6	49.4	53.0	43.0 - 51.0
% SILT-CLAY	63.2	32.8	35.0	22.0	33.6	8.2	10.4	8.2	7.0 - 14.0

With reference to [9] and the available data from Table 4, the untreated soil samples A1 fell under group classification of A–4, A2, B1, C1, C2, and D1 fell under group classification of A – 2 - 4 while D2 fell under group classification of A – 1 - a. The untreated soil sample A1 has significant constituent materials of mainly silty soil. The untreated soil samples A2 to D1 have significant constituent materials of mainly silty or clayey gravel and sand. While D2 has significant constituent materials of stone fragments, gravel and sand.

The general rating of all the untreated soil samples (except A1) as sub-grade materials is excellent to good. Though that of D2 (i.e. A – 1 – a) is the best. While that of sample A1 is fair to poor and the worst. All the soil samples met the required specifications for subgrade (i.e. LL ≤ 80%, PI ≤ 55%), subbase and base (i.e. LL ≤ 35% and PI ≤ 12%) course materials in their liquid limits (LL) and plasticity indices (PI), but did not met the requirements for the maximum dry density (i.e. MDD >1760Kg/m3 for Subgrade and MDD > 2000Kg/m3 for Subbase and Base).

Table 4: Summary of the Atterberg limits and Compaction Test Results of Untreated Soil Samples

SAMPLE CODE	COMPACTION TEST		ATTERBERG LIMITS		
	MDD(Kg/m^3)	OMC (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)
A1	1512.0	14.0	15.3	11.5	3.8
A2	1413.0	16.0	14.3	9.3	5.0
B1	1498.0	18.7	13.9	10.1	3.8
B2	1398.0	16.3	16.1	9.1	7.0
C1	1439.0	14.8	10.8	5.2	5.7
C2	1489.0	13.3	14.7	7.3	7.4
D1	1397.0	15.0	13.9	5.1	8.9
D2	1489.0	14.7	11.3	6.1	5.2

Graphs were plotted from Table 5 for LL values against Additives contents (AC) for all the treated soil samples as shown in Fig. 2. It could be seen from the graphs that LL values were not easily predictable as the movements (i.e. increase or decrease with Additives contents increment vary from sample to sample). Soil samples A1, C1, C2 and D2 LL values increase as Additives contents increase. Soil samples A2, B1 and D1 LL values increase with increase in PKSA contents and decrease with increase in SDA contents. While soil sample B2 LL values decrease with increase in the Additives contents. Maximum LL value has increased from 16.10% (untreated soil) to 21.50% (PKSA treated soil sample C2 @ 6%) and 17.10% (SDA treated soil C2 @ 4%). This portrayed that the percentages of finer particles than 0.075mm of the soil samples slightly increase which make the soil less suitable.

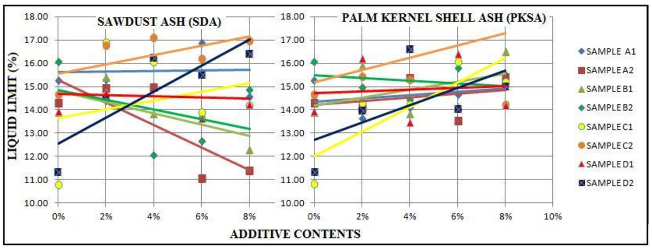

Fig. 2: Graphs of the Liquid Limits Tests for the Treated Soil Samples

Graphs were plotted from Table 5 for PI values against Additives contents (AC) for all the treated soil samples as shown in Fig. 3. It could be seen from the graphs that PI values were also not easily predictable as the movements (i.e. increase or decrease with Additives contents increment vary from sample to sample). Soil samples A1PI values increase with increase in SDA contents and decrease with increase in PKSA contents. Soil samples A2, B1, C1 and C2 PI values increase with increase in PKSA contents and decrease with increase in SDA contents. Soil samples B2 and D1PI values decrease with increase in

Additives contents. While soil sample D2 PI values increase with increase in the Additives contents. Maximum PI value has increased from 8.90% (untreated soil) to 12.13% (PKSA treated soil sample C2 @ 6%) and 10.82% (SDA treated soil A1 @ 6%). This buttressed the observation for the LL values thus showed that the soil samples is now re-grouped as or tending towards A – 2- 6 soils.

Table 5: Summary of the Atterberg Limits and Compaction Test Results of Treated Soil Samples

SAMPLE CODE	ADDITIVE CONTENTS	SAW DUST ASH (SDA)					PALM KERNEL SHELL ASH (PKSA)				
		LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	MDD (Kg/m^3)	OMC (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	MDD (Kg/m^3)	OMC (%)
A1	0%	15.28	11.50	3.78	1512.00	14.00	15.28	11.50	3.78	1512.00	14.00
	2%	15.31	6.50	8.81	1579.00	12.80	13.63	6.99	6.64	1598.00	11.00
	4%	16.26	7.95	8.38	1617.00	11.00	14.10	9.43	5.30	1678.00	9.00
	6%	16.89	6.07	10.82	1756.00	8.00	14.66	7.87	6.79	1736.00	7.90
	8%	14.60	7.35	7.25	1798.00	7.30	15.50	12.50	3.00	1797.00	7.00
A2	0%	14.30	9.30	5.00	1413.00	16.00	14.30	9.30	5.00	1413.00	16.00
	2%	14.94	10.31	4.63	1497.00	15.10	14.08	11.75	2.33	1598.00	13.00
	4%	14.96	8.25	6.71	1589.00	12.90	15.35	10.50	4.84	1682.00	11.00
	6%	11.07	7.87	3.20	1613.00	9.00	13.53	11.00	5.43	1745.00	8.00
	8%	11.40	8.45	2.93	1704.00	7.70	15.40	9.30	6.10	1821.00	6.90
B1	0%	13.90	10.10	3.80	1498.00	18.70	13.90	10.10	3.80	1498.00	18.70
	2%	15.40	11.17	4.23	1579.00	15.00	15.91	12.60	3.31	1529.00	15.00
	4%	13.83	9.00	4.83	1610.00	13.80	13.82	8.57	5.25	1579.00	13.30
	6%	13.83	9.00	4.83	1698.00	12.70	14.13	7.55	6.58	1688.00	11.20
	8%	12.30	9.50	2.75	1734.00	10.40	16.50	7.70	8.80	1798.00	8.90
B2	0%	16.07	9.05	7.02	1398.00	16.30	16.07	9.05	7.02	1398.00	16.30
	2%	14.40	9.12	5.28	1415.00	14.90	14.97	11.25	3.72	1532.00	13.90
	4%	12.08	9.00	3.08	1518.00	12.00	14.42	9.92	4.50	1611.00	10.50
	6%	12.66	7.87	4.79	1609.00	10.10	15.79	10.50	5.29	1747.00	8.00
	8%	14.88	10.50	4.40	1746.00	8.60	15.07	9.50	5.57	1874.00	6.70
C1	0%	10.83	5.15	5.68	1439.00	14.80	10.83	5.15	5.68	1439.00	14.80
	2%	16.92	9.00	7.92	1589.00	13.00	14.30	7.70	6.60	1499.00	14.00
	4%	16.07	7.50	8.60	1618.00	11.00	14.23	8.60	5.63	1569.00	11.70
	6%	13.93	9.60	4.33	1698.00	10.60	16.06	5.85	10.20	1781.00	9.00
	8%	14.22	10.00	4.75	1715.00	8.20	15.18	7.49	7.69	1871.00	7.90
C2	0%	14.66	7.28	7.38	1489.00	13.30	14.66	7.28	7.38	1489.00	13.30
	2%	16.78	6.65	10.13	1568.00	11.40	15.44	10.65	4.79	1673.00	11.00
	4%	17.10	10.50	6.60	1689.00	9.80	15.30	10.37	4.93	1698.00	10.50
	6%	16.20	8.75	7.45	1713.00	9.10	21.50	9.37	12.13	1745.00	9.80
	8%	16.95	10.56	6.39	1810.00	7.20	14.25	9.50	4.75	1892.00	8.30
D1	0%	13.94	5.05	8.89	1397.00	15.00	13.94	5.05	8.89	1397.00	15.00
	2%	14.73	10.25	4.48	1459.00	13.50	16.21	8.07	8.14	1712.00	11.00
	4%	16.31	11.50	4.81	1519.00	12.60	13.50	9.50	4.00	1797.00	10.30
	6%	13.63	9.00	4.63	1725.00	10.00	16.42	6.40	10.02	1826.00	8.90
	8%	14.25	12.00	2.25	1798.00	9.30	14.22	10.00	4.22	1879.00	8.20
D2	0%	11.33	6.12	5.21	1489.00	14.70	11.33	6.12	5.21	1489.00	14.70
	2%	14.45	12.62	2.00	1563.00	14.20	13.98	9.00	4.98	1673.00	12.00
	4%	16.23	14.50	2.00	1681.00	13.10	16.61	11.38	5.23	1747.00	11.60
	6%	15.50	8.30	7.20	1736.00	11.71	14.03	8.85	5.18	1811.00	8.68
	8%	16.40	8.91	7.49	1801.00	9.30	15.00	9.50	5.50	1889.00	7.50

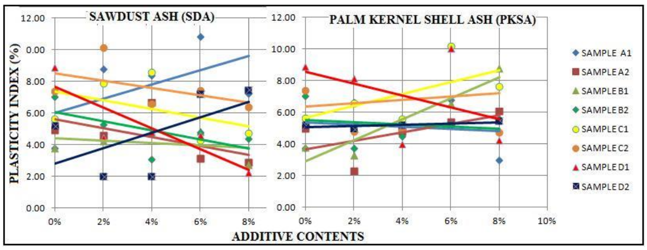

Fig. 3: Graphs of the Plasticity Index Tests for the Treated Soil Samples

Graphs were plotted from Table 5 for MDD values against Additives contents (AC) for all the treated soil samples as shown in Fig. 4. It could be seen from the graphs that MDD values for all the soil samples increase as the Additives contents increase. Though, the effects of PKSA contents were more felt than that of SDA contents. The increments were due to coatings of the soil samples particles by the Additives contents particles. Thus making it denser.

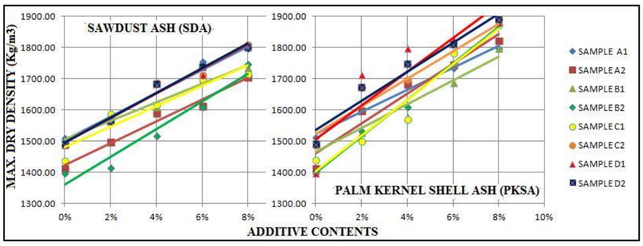

Fig. 4: Graphs of the Maximum Dry Density Tests for the Treated Soil Samples

IV. CONCLUSION

As this study aimed at assessing how the waste in one's environment could be explored and how it could be of help in the improvement of soil's geotechnical properties within the study area, it could thus be concluded from the study that PKSA and SDA additives have influences on the geotechnical properties of the soil. The presence of the additives increases the MDD of the soil which was higher in PKSA than in SDA. With reference to LL and PI values, the soil was re-grouped as A – 2 – 6, though their subgrade general rating still remain "excellent to good". The increment in MDD values as the additives contents increase are likely to make the soil suitable for subgrade, subbase and base course. It can therefore be deduced that PKSA and SDA could be adopted as stabilizing agents in other to discourage the skyrocket rate of purchasing construction materials.

It is of great importance therefore, to make use of these locally available additives in our construction industry especially the job that requires light weight materials as this will help in reducing the environmental hazard issues arising from the disposal of the wastes. Further research work could be done on this study in other to ascertain any other suitable hidden properties of the materials.

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