

# **Analysis of Influences of Locally Available Additives on Geotechnical Properties of Ekiti State Soil, Southwestern, Nigeria**

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**ABSTRACT:** This piece of research work analyzed the influences of some locally available additives (i.e. Palm Kernel Shell Ash - PKSA and Sawdust Ash - SDA) on geotechnical properties of Ekiti state soil and the Study area is within Efon Alaaye Local Government Area. Samples of soil were obtained at some locations within the study area and carried to laboratory for some tests (i.e. Compaction, Particle Size Analysis and Atterberg Limit tests). The additives were added to the soil samples at 0%, 2%, 4%, 6% and 8% proportions. The results showed that Maximum Dry Density (MDD) values range between 1600 and 2,106 Kg/m<sup>3</sup>, Liquid Limit (LL) values range between 12 and 25%; and Plasticity Index (PI) values range between 1.65 and 11.9%. It showed that the LL, PI and MDD values decrease with increase in additives contents. It implied that the additives were able to stabilize the soil. The soil samples also responded more to SDA additive than PKSA additive. It also portrayed that the soil is Silty or Clayey Gravel / Sand with high moisture content and the soil moisture content even increase after additives treatment. It has general rating as Subgrade with excellent to good material constituents. These results indicated that addition of the additives really improve the geotechnical properties of the soil in the study area, thus making it good for construction purpose. There is also need for further study on these findings.

**KEYWORDS:** Additive, Liquid limit, Maximum Dry Density, Plasticity Index, Plastic Limit, Nigeria.

## **I. INTRODUCTION**

The need for affordable construction materials in providing basic infrastructure for the world population (especially third world countries) is of utmost importance. In the third world countries (of which Nigeria belongs), the ever increasing cost of construction materials continue unabated as the majority of the population continues to fall below the poverty line. This is serious problem to all construction stakeholders i.e. client, developers, contractors etc and even the world as a whole. This has negatively affected many people who tried to use less quality materials during construction (to reduce cost of construction) leading to the infrastructural failures. Since most of these Third World countries are poor, agriculturally dependent, still struggling to be above board in their economy. At the same time, there is need for their citizens to have access to better infrastructure; consequently, as “necessity is mother of all invention”, it is necessary to use what you have to get what you need which comes about “waste to wealth policy” in a country like Nigeria. This is due to the fact that wastes are everywhere all over Nigeria ([8], [9], [10], [11]).

All over the World today, waste materials are usually generated in enormous quantities. Thus safe disposal of these waste materials are seriously of paramount consternation – these waste products on their dumpsites cause both environmental hazard and disposal problems. However, if these waste products are properly treated, used or modified, they become structural components of pavement. Some of these wastes were locally available materials and of agricultural and industrial origin. These include pulverized fuel ash, Palm Kernel Shell Ash (PKSA), Saw Dust Ash (SDA), slag, rice husk, fly ash, coconut shell ash, maize cobs, Reclaimed Asphalt Pavement (RAP) etc. They were produced from milling stations, thermal power stations, waste treatment plants, existing failed pavement etc. They

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could be stabilized with other materials or additives to improve their Engineering properties and be used as new construction material ([8], [9], [10], [11]).

## II. RELATED WORK

The past research works of [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22] among others carried out systematic inquiries and established the usefulness of the locally available materials as additives for improvement of Engineering properties of construction materials like soil. Certainly, this will reduce total construction cost. Thus, in this piece of research work, influences of locally available additives (such as PKSA and SDA) on Geotechnical properties of Ekiti State soil would be analyzed. These additives are in large quantities in the study area and its environs. As earlier stated, “waste to wealth policy” will be adopted in this piece of work, which will not only solve problems of disposal of some waste materials, but also will help in making available Engineering data of Ekiti State soil. It will also establish their suitability (ies) as additives in stabilizing construction materials like soil.

**Study Area:** The study area is Efon - Alaaye Local Government Area of Ekiti State in South-western part of Nigeria. The topography of the study area is mountainous situated on an elevation of about 500 metres above sea level. It is located on latitude 7.6<sup>0</sup> North and longitude 4.8<sup>0</sup> East. It shares boundaries with Ijebu – Ijesa in Osun State in the west, Erio Ekiti in the east, Esa – Oke in Osun State in the north and in the south with Ogotun Ekiti as shown in Figure 1. It is in the tropical part of South-western, Nigeria [1].

Geologically, Ekiti State (where the study area is situated) is underlain by metamorphic rocks of the Precambrian basement complex of Southwestern part of Nigeria, the great majority of which are very ancient in age. These basement complex rocks show great variations in grain size and in mineral composition. The rocks are quartz gneisses and schists consisting essentially of quartz with small amounts of white mizageous minerals. In grain size and structure, the rocks vary from very coarse-grained pegmatite to medium-grained gneisses. The rocks are strongly foliated and occur as outcrops. The soils derived from the basement complex rock are mostly well drained, having medium to coarse in texture. The geological nature of the study area and its increased urbanisation make it more vulnerable and of public health concern when it comes to water quality [2], [3].

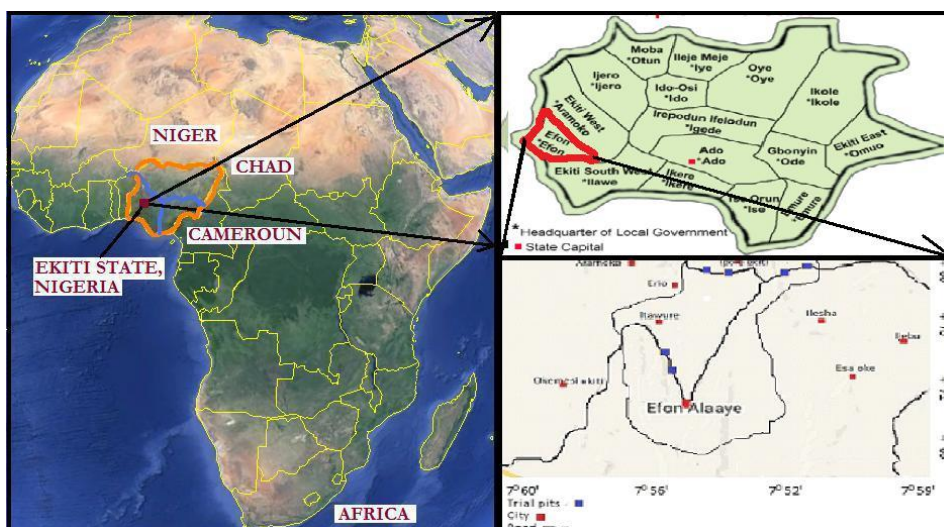


Figure 1: Location of the Study area – Emure / Ise – Orun Local Government Area [4]

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### III. MATERIALS AND METHODS

**Palm Kernel Shell Ashes (PKSA):** Palm kernel shells are the crushed outer part of palm kernel nut derived after the extraction of palm oil. It is the hard endocarp of palm kernel fruit that surround the palm seed. It is obtained as crushed pieces after the seed is removed through threshing or crushing which is used in the palm kernel oil production [23]. Palm kernel shell is an industrial waste and it is available in large quantities especially in palm oil producing area of the southern part of Nigeria. Palm kernel shells have very low ash (about 3% weight) and sulphur (about 0.09% weight) contents (Edeh et al, 2012). The PKSA is produced by subjecting some cleaned quantities of palm kernel shells obtained from the study area to furnace temperature of about 900 – 1000<sup>o</sup> C at laboratory of the Federal University of Technology, Akure, Nigeria. PKSA passing through sieve cell of 75µmm was used for this study.

**Sawdust Ashes (SDA):** Sawdust can be defined as loose particles or wood chippings obtained as by-products from sawing of timber into standard useable sizes. 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 [23]. The SDA is produced by subjecting some cleaned quantities of sawdust obtained from the study area to laboratory furnace at the Federal University of Technology, Akure, Nigeria. SDA passing through sieve cell of 75µmm was used for this study.

**Soil Sample Collection and Analysis:** Soil samples were collected at random from trial pits (depth between 1m to 2.5m) in the Study area as shown in table 1 using method of disturbed sampling. After collection, soil samples were stored in polythene bags to prevent loss of moisture contents. The samples were then taken to the laboratory where the deleterious materials such as roots were removed. The samples were air dried, broken down with mortar and pestle and passed through a set of sieve (*i.e. from Sieve No. 10 (18.75mm) to Sieve No. 1 (0.075mm)*) to remove large particles. Moulding of test specimens was started as soon as possible after completion of identification.

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

LOCATION	SAMPLE CODE	CHAINAGES	COORDINATES
EFON TO ITAWURE	A	1+100	Lat.7.60294 <sup>o</sup> N, Long.4.80562 <sup>o</sup> E
	B	2+100	Lat.7.61478 <sup>o</sup> N, Long.4.80736 <sup>o</sup> E
EFON TO IPOLE EKITI	C	3+250	Lat.7.59984 <sup>o</sup> N, Long.4.80176 <sup>o</sup> E
	D	2+250	Lat.7.63777 <sup>o</sup> N, Long.4.80195 <sup>o</sup> E
EFON TO EXPRESSWAY	E	5+200	Lat. 7.70136 <sup>o</sup> N, Long.4.80392 <sup>o</sup> E
	F	4+200	Lat. 7.69987 <sup>o</sup> N, Long.4.80215 <sup>o</sup> E

The additives were mixed with the soil samples in the proportion of 0 – 8%. All tests were performed according to standard methods contained in [5]. Their properties were studied and determined to ensure that all relevant factors would be available for establishment of correlations among them. The tests carried out on each of the selected samples are Particle size distribution, Atterberg limits and Compaction. The results were compared to the standard specified values and grouped in accordance with [6] and [7].

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**Particle Size Distribution:** This test is used in analyzing the 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 AASHTO in [6].

**Atterberg Limits:** These tests (i.e. Liquid Limits (LL), Plastic Limit (PL) and Plasticity Index (PI)) were carried out on both the treated and untreated soil samples and help in assessing the samples spontaneous reactions to water. The results were compared to the standard specified values in accordance with [6] and [7] as earlier stated.

**Compaction:** The essence of this test is to ascertain the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the treated and untreated soil samples. Edeh et al (2012) expressed that *“materials with high MDD at relatively low moisture content are indicative of good materials that can be used for sub-grade, sub-base or base course and as fill embankments”*.

## IV. RESULTS AND DISCUSSION

Table 2 showed summary of results of the Particle Size Distribution, Atterberg limits and Compaction (i.e. MDD and OMC) tests for the untreated soil samples. From Table 2, the results show that all the soil samples had less percentages finer than 0.0075 fractions (i.e. <35%), which varied between 10% and 22%. Hence, general rating as sub-grade in accordance with [6] is excellent to good materials. They have significant constituent materials of mainly silty or clayey gravel and sand. It is also observed that the LL, PI and MDD values varied from 15.20% to 25.00%, 3.90% to 11.40% and 1930Kg/m<sup>3</sup> to 2088Kg/m<sup>3</sup> respectively. These soil samples met the required specifications for subgrade course materials (i.e. LL ≤ 80%, PI ≤ 55% and MDD > 1760kg/m<sup>3</sup>). All the soil samples except A and B did not met specifications for base and subbase course materials (i.e. LL ≤ 35% and PI ≤ 12% and MDD > 2000kg/m<sup>3</sup>). Thus, they could be suitable for subgrade course materials and are grouped into A-2-6, A-6 and A-7 (A-7-5 or A-7-6) in AASHTO classification system [6]. Soil samples A and B could also be suitable for subbase and base course materials. Table 2 also showed that OMC values varied between 9.10% and 12.50%. This portrayed that the moisture content in the study area is very high compared to specified values in accordance with [6] and [7].

**Table 2:** Summary of the Tests Results of Untreated Soil Samples

SOIL SAMPLE	PARTICLE SIZE DISTRIBUTION			ATTERBERG LIMITS			MDD (Kg/m <sup>3</sup> )	OMC (%)
	> 4.25mm (%)	4.25 - 75µmm (%)	< 75µmm (%)	LIQUID LIMIT(%)	PLASTIC LIMIT(%)	PLASTICITY INDEX (%)		
A	6.0	76.0	18.0	25.0	16.03	8.97	2012.0	9.50
B	4.0	74.0	22.0	24.0	14.60	9.40	2088.0	12.50
C	10.0	80.0	10.0	22.0	13.50	8.50	1964.0	9.10
D	4.0	77.0	19.0	23.0	11.60	11.40	1962.0	10.00
E	7.0	74.0	19.0	15.2	11.30	3.90	1970.0	9.10
F	4.0	76.0	20.0	16.5	10.30	6.20	1930.0	11.70

Table 3 showed summary of results of the Atterberg limits and Compaction (i.e. MDD and OMC) tests for the treated soil samples using 0% to 8% proportion by weight of locally available additives (i.e. SDA and PKSA). It also showed that OMC values for the treated soil samples varied between 7% and 15%. This portrayed that the moisture content remains very high compared to specified values in accordance with [6] and increased when compared with that of untreated soil samples.

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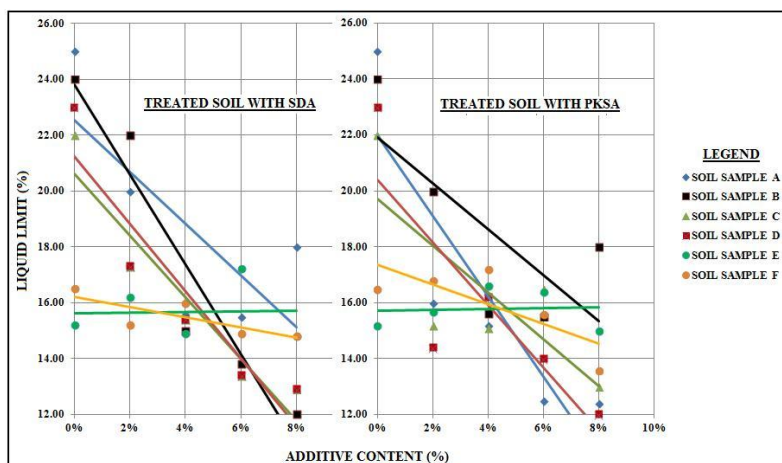
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**Table 3:** Summary of the Tests Results of Treated Soil Samples

SOIL SAMPLE	ADDITIVE CONTENT (%)	SAWDUST ASHES(SDA)					PALM KERNEL SHELL ASHES(PKSA)				
		LIQUID LIMIT(%)	PLASTIC LIMIT(%)	PLASTICITY INDEX (%)	MDD (Kg/m <sup>3</sup> )	OMC (%)	LIQUID LIMIT(%)	PLASTIC LIMIT(%)	PLASTICITY INDEX (%)	MDD (Kg/m <sup>3</sup> )	OMC (%)
A	0%	25.00	16.03	8.97	2012.00	9.50	25.00	16.03	8.97	2012.00	9.50
	2%	20.00	12.30	7.70	1850.00	13.00	16.00	11.60	4.40	2031.00	12.90
	4%	15.60	10.80	4.80	1900.00	11.70	15.20	10.30	4.90	2160.00	11.00
	6%	15.50	9.90	5.60	2011.00	9.40	12.50	9.60	2.90	2106.00	11.50
	8%	18.00	8.60	9.40	1600.00	16.00	12.40	9.70	2.70	1908.00	12.10
B	0%	24.00	14.60	9.40	2088.00	12.50	24.00	14.60	9.40	2088.00	12.50
	2%	22.00	10.10	11.90	2080.00	12.50	20.00	9.80	10.20	2100.00	11.00
	4%	15.00	10.80	4.20	1890.00	13.00	15.60	10.60	5.00	1800.00	12.98
	6%	13.80	10.80	3.00	1900.00	12.00	15.50	9.10	6.40	2036.00	11.06
	8%	12.00	9.05	2.95	1665.00	11.10	18.00	8.50	9.50	1941.00	13.00
C	0%	22.00	13.50	8.50	1964.00	9.10	22.00	13.50	8.50	1964.00	9.10
	2%	17.30	9.80	7.50	1812.00	13.20	15.20	9.80	5.40	2030.00	9.30
	4%	15.40	11.00	4.40	1903.00	7.00	15.10	11.30	3.80	2001.00	7.40
	6%	13.40	10.00	3.40	1750.00	10.50	16.50	10.30	6.20	1982.00	10.10
	8%	12.90	9.80	3.10	1725.00	10.30	13.00	7.80	5.20	1800.00	15.00
D	0%	23.00	11.60	11.40	1962.00	10.00	23.00	11.60	11.40	1962.00	10.00
	2%	17.30	10.80	6.50	2034.00	10.70	14.40	11.00	3.40	2100.00	12.50
	4%	15.40	11.90	3.50	2000.00	7.00	16.20	9.60	6.60	1800.00	13.10
	6%	13.40	9.10	4.30	1924.00	11.80	14.00	10.00	4.00	1880.00	12.50
	8%	12.90	8.70	4.20	1671.00	7.70	12.00	10.35	1.65	2000.00	8.00
E	0%	15.20	11.30	3.90	1970.00	9.10	15.20	11.30	3.90	1970.00	9.10
	2%	16.20	9.80	6.40	1980.00	9.00	15.70	10.05	5.65	2100.00	11.10
	4%	14.90	11.10	3.80	1900.00	15.60	16.60	11.15	5.45	2000.00	12.80
	6%	17.20	9.10	8.10	1716.00	13.60	16.40	10.80	5.60	1930.00	13.30
	8%	14.80	11.04	3.76	1846.00	8.30	15.00	11.30	3.70	1970.00	12.00
F	0%	16.50	10.30	6.20	1930.00	11.70	16.50	10.30	6.20	1930.00	11.70
	2%	15.20	11.00	4.20	1909.00	10.70	16.80	9.70	7.10	2100.00	12.50
	4%	16.00	7.90	8.10	2096.00	12.10	17.20	10.30	6.90	1880.00	10.00
	6%	14.90	9.75	5.15	1739.00	15.00	15.60	11.80	3.80	1840.00	10.50
	8%	14.80	9.35	5.45	1611.00	11.80	13.60	10.25	3.35	2040.00	7.00

From Table 3, graph is plotted for LL values against Additive Content (AC) as shown in Figure 2. It can be deduced from Figure 2 that LL decrease as Additives Contents increase (i.e. SDA and PKSA) with exception of soil sample E where it seems the influences of the additives were not so felt.



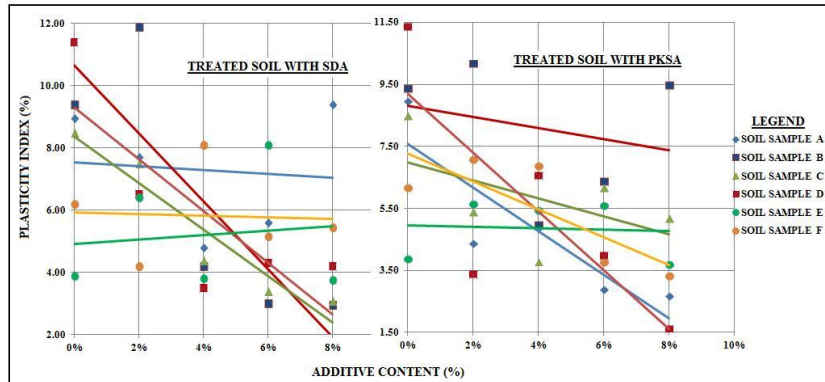
**Figure 2:** Graphs of the Liquid Limits Tests for the Treated Soil Samples

From Table 3, graph is plotted for PI values against Additive Content (AC) as shown in Figure 3. It can be deduced from Figure 3 that PI decrease as Additives Contents increase (i.e. SDA and PKSA) with exception of soil sample E where it seems the influences of the additives were not so felt.

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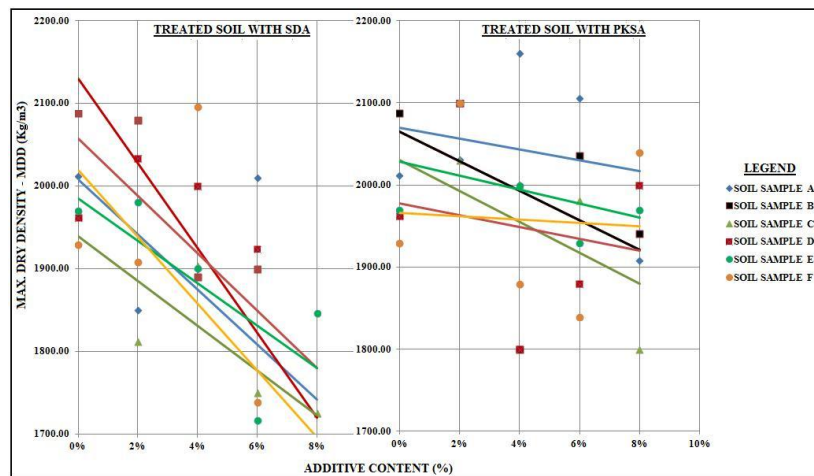
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**Figure 3:** Graphs of the Plasticity Index Tests for the Treated Soil Samples

From Table 3, graph is plotted for MDD values against Additive Content (AC) as shown in Figure 4. It can be deduced from Figure 4 that MDD decrease as Additives Contents increase (i.e. SDA and PKSA).



**Figure 4:** Graphs of the Maximum Dry Density Tests for the Treated

From Figures 2 – 4 and Table 3, it can be seen that the soil samples responded more to SDA additive compared to PKSA additive (i.e. SDA additive has more influences on the soil samples than PKSA additive). With reference to LL and PI values, the treated soils are good for subgrade, subbase and base course materials as they met all the required specified values for LL and PI (i.e.  $12 < LL < 25$ ;  $1.65 < PI < 12$ ) in accordance with [7]. However, with reference to MDD values, almost all the treated soil samples were only suitable for subgrade course materials because they only met the required specified value for subgrade (i.e.  $MDD > 1760\text{kg/m}^3$ ).

## V. CONCLUSION

Generally, it can be seen that the additives (i.e. PKSA and SDA) have positive influences on the geotechnical properties of the soil in the study area. The additives really improve the geotechnical properties, thus making the soil better materials for construction purpose. It can be deduced that PKSA and SDA are locally available additives or stabilizing agents for soil that can foster reduction in construction cost particularly in developing world. This encourages “waste to wealth policy” as it helped in reduction of the burden of management and disposal of agricultural

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and industrial wastes in the study area environment (and Nigeria as a whole if implemented). Nevertheless, there is no difference between the treated and untreated soil samples as both were still generally rated as excellent to good for subgrade course materials. There is also increase in the moisture content of the soil after treatment with additives. An earnest further study is needed on these findings.

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