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RESEARCH ARTICLE

COMPARATIVE ANALYSES OF EKITI STATE SOIL STABILIZED WITH DIFFERENT ADDITIVES

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ABSTRACT

This study is aimed at investigating the effects of three different additives - Sawdust Ash (SDA), Palm Kernel Shell Ash (PKSA) and Groundnut Shell Ash (GSA) on the geotechnical properties of Ido- Ekiti soil in Ido-Osi Local Government Area (LGA) of Ekiti State. Soil samples collected from the study area were subjected to various laboratory tests (i.e. Grain Size Analysis, Atterberg Limits and Compaction tests) in its treated and untreated state. The additives were added to the soil sample at different percentage - 2%, 4%, 6% and 8%. The results of the tests carried out on the untreated soil sample indicated that the soil could be generally classified as Granular soil material and is Silty or Clayey Gravel and Sand with general Subgrade rating of Excellent to good. The soil samples belong to A-2-4 group and slightly plastic. Though treatment of the soil with additives did not change its configuration, GSA additive followed by PKSA additive improved on it. GSA encourages effective compaction as there is need for more moisture contents with increasing Maximum Dry Density (MDD). Whereas reverse is the cases of PKSA and SDA, though PKSA is better than SDA. GSA is adjudged to be the best additive applied on the soil with best result(s) followed by PKSA and then SDA. Further research work needs be done on this study in other to ascertain any other suitable hidden properties of the additives.

INTRODUCTION

The present and future states of any Civil Engineering structures lie majorly on the soil beneath its foundation. Most of the soil that is readily available within our vicinity does not contain all the nutrients needed to make them suitable for some important Civil Engineering structures, hence they were being discarded. This usually results in seeking for expensive materials from far away burrow pit. At times, huge amount of money were being used in stabilization process of the available soil in other to suit the construction purpose. Unknowingly, some materials classified as waste (s) are lying fallow within human environments with public crying to Government for its disposal. These materials could serve the purpose (s) of expensive / imported materials such as Cement and Lime that are being used in stabilizing poor soil. They are now turning to be the enemies of the community because of its unused state. When recycled or used as stabilized materials (i.e. in construction industries), the materials would help reduce the burden of seeking for imported materials in the construction firm and therefore improve the standard of living of people. The rate of encouraging imported materials in developing nations is alarming and one of the reasons the poor remain poorer. Waste Recycling has been a business that gives great fame to many developed nations of the world.

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In lieu of this fact, the available "Waste" and other resources in this community are to be implored as materials to increase the standards of living of the community in form of shelter materials, road construction materials and as a means of generating income to the families within the community and thereby increasing the GDP of the nations. Scholars across the globe had worked on different materials (Cementitious and Non-cementitious materials) such as 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 (PFA), Locust Beans Ash (LBA), Fly Ash, Groundnut Shell Ash (GSA), etc. which were usually products of milling stations, thermal power stations, waste treatment plants, breweries etc. as replacement or additives and it has been found to be useful in most cases (Adetoro & Adekanmi, 2015; Adetoro & Dada, 2015; Thaki & Gajera, 2015; Otoko & Karibo, 2014; Raheem & Sulaiman, 2013; Mahmoud *et al*., 2012; Nwofor & Sule, 2012; Olutoge *et al*., 2012). In this study, comparative analyses of the effects of Palm Kernel Shell (PKSA), Groundnut Shell Ash (GSA) and Sawdust ash (SDA) as additives on Geotechnical properties of Ido-Ekiti soil would be assessed. These would help in providing first hand technical information / data for Ekiti State soil, and in establishing the suitability of the additives for the same type of soil for stabilization purpose (s) instead of wasting huge amount of money on Cement or Lime since the additives were found in large quantities within the study area and its environment.

Study Area: Ido-Ekiti is town situated in Ido-Osi Local government area of Ekiti State, Nigeria. Geographically, it is situated on Latitude 7º45’23”N and Longitude 5º15’27”E in the northern part of the state where the routes from Oyo, Osun and Kwara states respectively meets as shown in Fig.1. The town is blessed with industries like saw mills, printing press and a Federal medical centre. Ido-Ekiti which also serves as the sit of Ido/Osi local council headquarter is bounded in the east by Ipere and Iludun, in the south by Igbole and Ifinsin axis and in the north and northwest by Usi and Ilogbo – Ekiti. The temperature of the town ranges between 21ºC and 28ºC with high humidity. (EKSDICT, 2015; Wikimedia, 2015).

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 800^0C – 1000^O C in the laboratory at the Federal University of Technology, Akure, Nigeria. The PKSA was also made to pass through 75µmm sieve (Adetoro & Adekanmi, 2015).

Sawdust Ashes (SDA): Sawdust is a by-product of cutting, grinding, drilling, sanding or otherwise pulverizing wood with a saw or other tool.

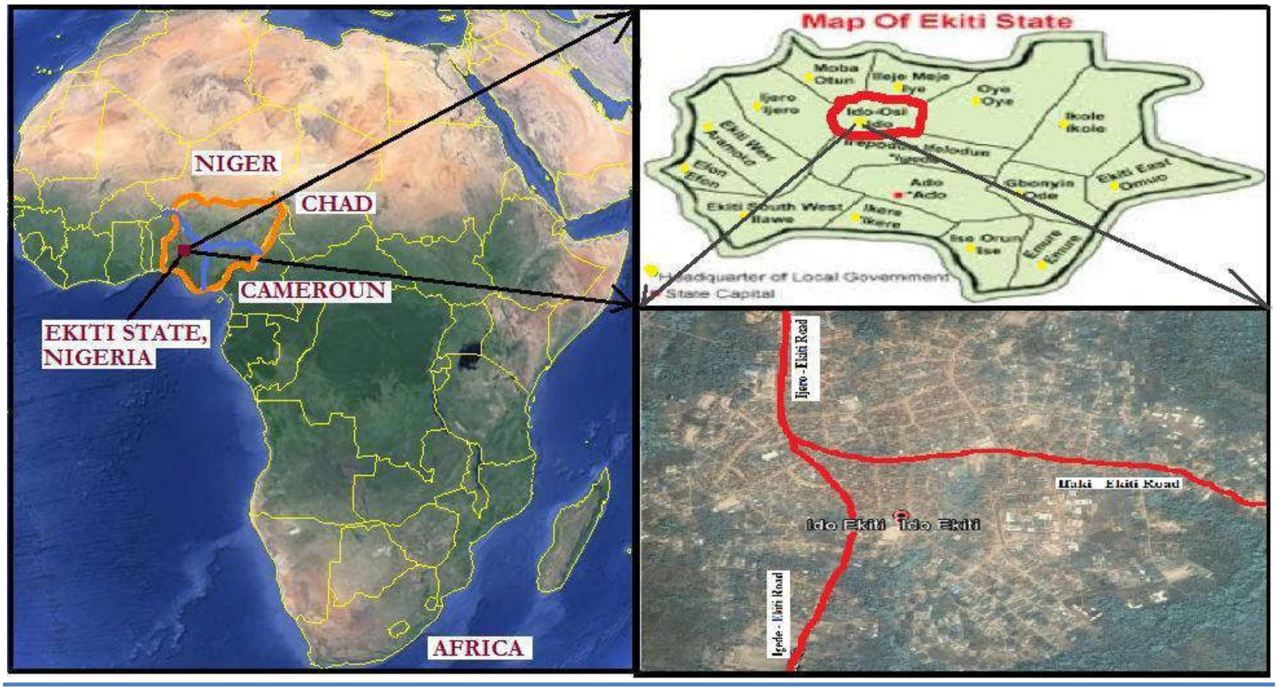

Figure 1. Location of the Study Area- Ido-Ekiti (Source: Google, 2015)

MATERIALS AND METHODS

Groundnut Shell Ash (GSA): Groundnut Shell is an agricultural waste acquired from groundnut milling with more than 20 million hectares of groundnut cultivated per year all over the world. Groundnut Shell Ash (GSA) as shown in Table 1 has pozzolanic material (s) which makes it a better replacement of industrial additives in soil stabilization. Cleaned quantities of Groundnut shells obtained from the study area were burnt to ashes in laboratory at the Federal University of Technology, Akure, Nigeria. GSA contents passing through sieve no. 75µmm was used for this study (Adetoro & Dada, 2015).

Palm Kernel Shell Ashes (PKSA): Palm kernel shell is an industrial waste which is readily available in large quantities in palm oil producing area especially the southern part of Nigeria. Palm kernel shells have very low ash and sulphur 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.

It comprises of fine particles of wood and is also the by-products 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 (Adetoro & Adekanmi, 2015).

Table 1 .Chemical Composition of the Additives used

CHEMICAL COMPOSITION	SiO_2	CaO	K_2O	Al_2O_3	Fe_2O_3	MgO
SDA (%)	65.31	4.21	11.09	6.09	3.49	3.39
PKSA (%)	54.81	8.79	6.25	11.40	0.36	6.11
GSA (%)	26.96	9.50	20.02	5.82	0.50	5.60

(Sources: Raheem & Sulaiman, 2013; Mahmoud *et al*., 2012; Olutoge *et al*., 2012)

Soil Sample Collection and Analysis: Soil samples were collected from a trial pit within the study area at depth of 0.75m in its disturbed state. The soil samples collected were stored in polythene bag to maintain its natural moisture contents. The samples were then taken to the laboratory where the deleterious 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 to standards as in (BS 1377, 1990). Their features were examined to verify the impacts of each additive on the soil samples. The tests carried out on the samples were Grain Size Distribution, Atterberg limits and Compaction. The results were compared to the standard specified values and grouped in accordance with FMWH (1997) and AASHTO (1986).

Atterberg Limits - These tests were also called CONSISTENCY TESTS and consist of Liquid Limits (LL), Plastic Limit (PL), Plasticity Index (PI) and Shrinkage Limit tests. They were carried out on the soil sample(s) in other to assess the samples natural interactions with water. The results were then compared with FMWH (1997) and AASHTO (1986) standard specified values as above-mentioned (Adetoro & Adekanmi, 2015; Adetoro & Dada, 2015).

Compaction – This test (s) is usually carried out on soil samples (treated and untreated state) in other to ensure the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of the soil samples (Adetoro & Adekanmi, 2015; Adetoro & Dada, 2015).

Grain Size Distribution – This test is used in assessing particles / grains, grouping of the particles into sizes and relative proportion by mass of soil samples (i.e. clay, sand and gravel fraction). The results would then be grouped in accordance with AASHTO (1986) (Adetoro & Adekanmi, 2015; Adetoro & Dada, 2015).

RESULTS AND DISCUSSION

Table 2. Grain Size Analysis Test Results for the Natural Soil Sample

SIEVE SIZE (mm)	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
% Passing	94	78.6	60.8	47.2	35.2	24.6	15.6	8.2
Required limits	80-94	65-82	50-65	36-51	26-40	18-30	13-24	7-14.

Graph was plotted from Table 2 for the Grain size distribution test results as shown in Fig.2. It showed that the soil sample met the requirement (s) as it falls within the specified limits. From Table 3, the results of the properties of the natural (i.e. untreated) soil samples showed that the soil samples had percentage finer passing through 0.075mm fractions as 8.2%, which is far below 35%. Hence, the soil could be generally classified as Granular soil material. With reference to AASHTO (1986) and the available data from Table 3, the

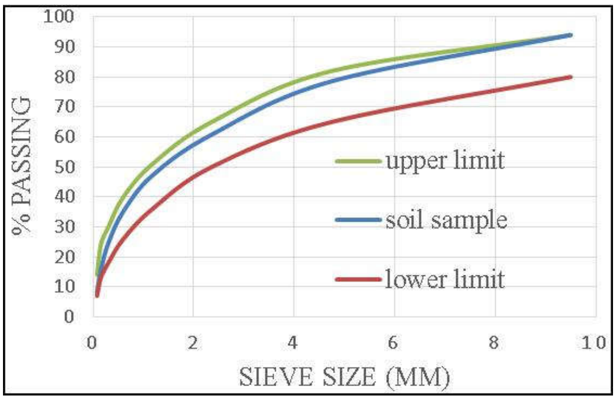

Figure 2. Graphs of the Grain Size Distribution Test for the Natural Soil Sample

Table 3. Properties of the Untreated Soil Sample

SOIL PROPERTIES	Natural Moisture Content (%)	Specific Gravity	% Passing Sieve #200	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index (%)	Colour	Max. Dry Density (g/cm^3)	Optimum Moisture Content (%)
DESCRIPTION	3.42	2.57	8.2	12.1	20.6	8.5	Reddish brown	1.49	13.3

untreated soil sample fell under group classification of A – 2 - 4. It has significant constituent materials of mainly silty or clayey gravel and sand. Its general rating as sub-grade materials is excellent to good. The soils sample also 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 requirements for maximum dry density (i.e. MDD >1760Kg/m3 for Subgrade and MDD > 2000Kg/m3 for Subbase and Base).

Graphs were plotted from Table 4 for LL values against Additives Contents (AC) for the treated soil samples as shown in Fig. 3. It could be observed from the graphs that LL values increase with increase in the additives contents. This was seen in highest degree in LL – AC (GSA) relationship followed by LL – AC (SDA) relationship and slightly seen in LL – AC (PKSA) relationship. Maximum LL value has increased from 20.60% (untreated soil) to 24.60% (PKSA @ 4%), 24.70% (GSA @ 8%) and 24.70% (SDA @ 4%). The results portrayed that GSA has most effects on the LL values followed by SDA, then PKSA. However, this (i.e. the presence of the additives in the soil sample) does not change the configuration of the sample in terms of grouping as the soil sample maintain its A-2-4.

Graphs were plotted from Table 4 for PI values against Additives contents (AC) for the treated soil samples as shown in Fig. 4. It could be observed from the graphs that PI values increment or decrement with increase in Additives Contents vary from additive to additive. PI – AC (GSA) relationship showed that PI value decreases with increase in GSA content. PI – AC (SDA) relationship showed that PI value remains the same with increase in SDA content, while PI – AC (PKSA) relationship showed that PI value increase with increase in PKSA content, though gentle (i.e. slow). Maximum PI value has increased from 8.90% (untreated soil) to 10.60% (PKSA @ 4%), 8.90% (GSA @ 2%) and 10.70% (SDA @ 2%). Though generally, the soil sample still remains slightly plastic (i.e. 3 – 15%) before and after the additives treatment.

Table 4. Summary of the Atterberg Limits and Compaction Tests on Treated Soil Sample

ADDITIVE CONTENT (%)	PALM KERNEL SHELL ASH					GROUNDNUT SHELL ASH					SAWDUST ASH				
	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	MDD (g/cm^3)	OMC (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	MDD (g/cm^3)	OMC (%)	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	MDD (g/cm^3)	OMC (%)
0	20.6	12.1	8.5	1.5	13.3	20.6	12.1	8.5	1.5	13.3	20.6	12.1	8.5	1.5	13.3
2	21.8	15.2	6.6	1.7	11.0	20.1	11.2	8.9	1.5	14.2	22.3	11.6	10.7	1.6	11.4
4	24.6	14.0	10.6	1.7	10.5	23.1	15.5	7.6	1.5	14.3	24.7	14.9	9.8	1.7	9.8
6	24.1	14.3	9.8	1.8	9.8	23.8	15.5	8.3	1.4	14.4	22.8	12.5	10.3	1.7	9.1
8	19.6	12.7	6.9	1.9	8.3	24.7	17.3	7.4	1.4	14.5	23.1	13.9	9.2	1.8	7.2

But the results showed that PKSA was able to reduce the soil clay content to 6.6% @ 2% (initial) and 6.9% @ 8% (final). Though averagely, the soil sample clay content reduced to 8.5% as shown in Fig. 4.

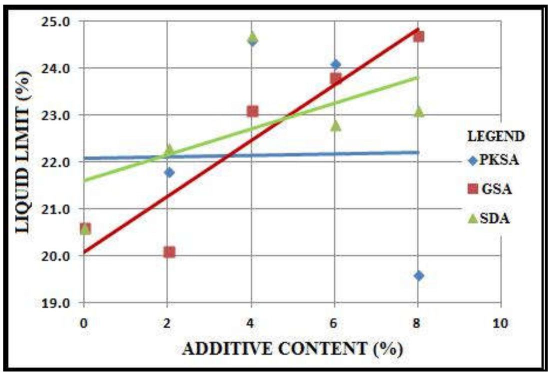

Figure 1. Graphs of the Liquid Limits Tests for the Treated Soil Samples

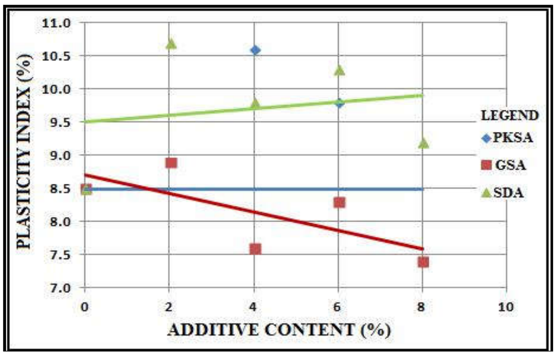

Figure 2: Graphs of the Liquid Limits Tests for the Treated Soil Samples

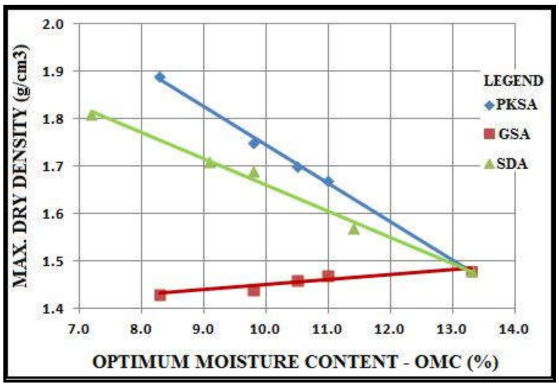

Figure 3. Graphs of MMD – OMC Relationships for the Treated Soil Samples

GSA was able to reduce the soil clay content proportionately to 7.4% @ 8% (final) as shown in Fig. 4. While SDA was able to reduce the soil clay content to 9.8% @ 4% (initial) and 9.2% @ 8% (final). Though averagely, the soil sample clay content increased with increase in SDA as shown in Fig. 4. The above analysed results portrayed that GSA has most effects on the PI values followed by PKSA, then SDA. GSA and PKSA made the soil grouping to be moving towards upper and better one while SDA (as shown in Fig. 4) made the soil grouping to be moving towards lower and fairer / poorer one. Graphs were plotted from Table 4 for MDD values against OMC values for the treated soil samples as shown in Fig. 5. It could be observed from the graphs that MDD values increment or decrement with increase in OMC values vary from additive to additive. MDD – OMC (GSA) relationship showed that MDD value increases as OMC and GSA content increase. This could be due to formation of large surface areas caused by the addition of the additive (i.e. GSA) which decreased the quality of free silt, clay fraction. The need for more water in order to compact the soil – GSA mixture. It could also be as a result of coating of the soil by GSA content which resulted in large particles with larger voids and density.

From Fig. 5, MDD – OMC (PKSA and SDA) relationships showed that MDD values decrease with increase in OMC and SDA content increase, though that of PKSA was more drastic than that of SDA. Generally, the moisture contents of the untreated and treated soil samples were very high as could be seen in Tables 3 and 4. Thus, it is possible that soil space (that could have been filled by the soil grains) were being occupied by the moisture contents and additives grains as the additives contents were being increased and OMC has been reached. Replacement of soil by the PKSA and SDA contents with lower Specific Gravities could bring about hindrance in closer soil grains package and ineffective compaction, thus reduction in MDD.

Conclusion and Recommendation

From the results of the study shown above, the following conclusions were drawn:

- The Untreated soil is generally classified as Granular soil material. With group classification of A – 2 - 4. It has significant constituent materials of mainly silty or clayey gravel and sand. Its general rating as sub-grade materials is excellent to good and slightly plastic.
- The treatments of the soil with additives (i.e. PKSA, GSA and SDA) did not change the configuration of the soil in terms of grouping as it still maintain its A-2-4.

- GSA and PKSA made the soil grouping to be moving towards upper and better one while SDA made the soil grouping to be moving towards lower and fairer / poorer one.
- GSA encourages effective compaction as there is need for more moisture contents with increasing MDD. Whereas reverse is the cases of PKSA and SDA, though PKSA is better than SDA.
- GSA is adjudged the best additive applied on the soil with best result(s) followed by PKSA and then SDA.
- Further research work could be done on this study in other to ascertain any other suitable hidden properties of the additives.

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