Engineering Properties of Black Cotton Soil Stabilized with Plantain Peel Powder

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Abstract

Assessment of black cotton soil (BCS) steadied with plantain peel powder (PPP) was investigated. BCS are said to be an extensive soil and mostly disposed to volumetric changes in moisture, because of the influence of mineral montmorillonite present in it, which has an extensive lattice. Various material has been used in the past to stabilize BCS but in this study, an attempt was made by stabilizing with plantain peel powder (PPP), the BCS was obtained from Yola, Adamawa state, Nigeria. The BCS was stabilized in (0, 2, 4, 6, 8, 10) % proportion respectively. To determine the Engineering properties of the BCS when stabilized with PPP, several laboratory tests, such as Grain Size Analysis, Natural Moisture Content, Linear Shrinkage, Specific gravity, Plastic Limit and Liquid Limit, which were all carried out in line with the British Standard code of practice. The laboratory preliminary tests on the soil results showed that the percentage passing sieve 200 is greater than 35% while Grain Size Analysis gave 26%, Natural Moisture Content 14%, Linear Shrinkage 14%, Plastic Limit 20% and Liquid Limit 48 % respectively.
The American Association of State Highway and Transportation Officials (AASHTO) and Unified Soil Classification System (USCS) classified the soils as A-7-5 which describe the soil as Clay of High Compressibility. The effect of PPP on the engineering properties showed that the LL %, PI % and Ls % varied between 48 and 32 for LL %, varied between 28 and 13 for PI % and varied between 14 and 7.5 for Ls % for (0, 2, 4, 6, 8, 10) PPP admixture which indicate that the higher the PPP the lower the clay content and the better the engineering properties examined. It was determined that with the mixing of PPP with the BCS, it enhances the engineering properties of the BCS sampled. Thus, Plantain Peel Powder (PPP) is suitable for stabilizing material for roadworks

Keywords: Admixture, Black cotton Soil, Engineering properties, Plantain Peel Powder, stabilization.

1.0 Introduction

Plantain is popularly known as Musa Spp., which are cultivated expansively across the tropical and subtropical provinces of the world. Daniells (2003) illustrated in his study that plantain serves as a fruit crop which its usefulness and benefits exceeds that of the orange by thirty-seven million, and in terms of its yearly trade, its exceeds orange in about ten million ton per year. In his study, he characterized plantain as an orange-yellow in color which exhibits a complex tepal of its flower head and its fruit tissue at maturity(Daniells, Englberger & Lorens, 2003:). Plantain serves an important food crop which is cultivated in the humid tropics of sub-Saharan African. Apart from the local food called 'Amala' in Nigeria, plantain can be used to produce different varieties of other food, snacks etc. However, the waste from plantain has been discovered to be a useful ingredient for the stabilization of many engineering concrete ingredients.

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In this research, we will be experimenting the use of the waste product of plantain, which is the peel of it, generated into powdering form (plantain peel powder) on a black cotton soil, we will be examining the properties of the black cotton soil when steadied with the plantain peel powder. Plantain waste, which is the peel gotten from its cover, is said to have many usages. Jekayinfa (2012) in his study, explained how the remains of a decomposed plantain peels waste can be used to produce biogas, which will be another source of electricity generation for the rural communities. The plantain peel waste, if not properly discarded, can turn to be a harmful substance due to its decomposition which will produce noxious gases such as ammonia and hydrogen sulfide, these harmful activities is a threat to the life of the people living in that environment(Jekayinfa, Ola, Afolayan & Ogunwale, 2012:339-343).

Stabilization of soil is a process of improving the engineering soil properties of the soil for a super pavement system performance. There are several means of testing the behavior of soil in water, the plastic index has been identified as one of the notable properties of soil to be characterized to identify the soil properties. The black cotton soil is found in the northern part of Nigeria, black cotton soils are said to be inorganic clays, which has a compressibility factor of moving from medium to high to form a substantial soil. In Nigeria, black cotton soils are known for its shrinkage and swelling nature, they are noticed and seen in the northern part of Nigeria. Black cotton soils have been a highly challenging material for the construction engineers due to its high swelling rate as well as its shrinkage characteristics. Though Black cotton soils tend strongly in its dry state, when it's in a wet situation, it tends to lose its strength outrightly. The soil if been exposed to water, in the process of drying, tends to have some cracks, this illustration can be seen in the picture below, tagged figure 1.

Figure 1: A picture of a black cotton soil at its drying state

This study aims at investigating the engineering properties of black cotton from Yola Adamawa State stabilized with PPP with a view to study its suitability for road construction pavement materials.

2.0 LITERATURE

Black Cotton Soils are the form of extensive soils that can be found anyplace in the world, but they are mostly limited to semi–arid and arid provinces, these areas are naturally categorized by noticeable parched and rainy periods with truncated rain, deprived drainage as well as high afternoon temperatures. The climate condition is such that the annual evaporation exceeds the precipitations. They are found in South Africa and other Eastern African nations. They are also seen in India, South- Western USA, Australia, and Israel (Ola, 1978; Tomlinson, 1999.Ola, 1978) reported 70 % montmorillonite in the Nigerian black cotton soils. Generally, black cotton soils have comparatively high percentage of clay, more than 90 % with substantial proportions of silt and sand. Their organic content is low, and they are alkaline in composition with a pH greater than 7.0. The soil is black to grey in color and it contains a very high percentage of humus (i.e., 3

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to 15 %). Pontual (1997) describes expansive clay formations as being favored by the geology, climatic condition and the environment of extreme disintegration, strong hydration and restrained leaching. Expansive soils swell and shrink considerably with changes in moisture content Due to the problems associated with these soils, road and building construction on this type of soil demand special knowledge which is in the hands of relatively small group of experts. An engineering definition of these soils is a murky grey which possess a substantial content of mud sand, usually Called clay, it has a montmorillonite which is the principal clay mineral are said to be extensive. Morin (1971), illustrated that several attentions has been given to the use of other reliable materials as an alternative to the existing ones, which also possess better engineering properties than the old-style materials and are relatively available at low cost. In any construction work, especially earth dams as well as earth canal construction, soil is an important constituent in which its involvement in construction projects and work can't be ruled out. Basically, most of the necessary resistance features needed for any construction projects are provided by soil which gives a better insight of its importance. Clay soils are regularly used in engineering construction works, particularly the lax clay soils which is said to possess reliable plastic properties which enhances the moisture outcomes in their diminished shear strength as well as their compressive strength and their volume changes.

Plantain known as Musa Spp plays a significant and a strategic role in the Nigeria food production. It is considered the third among the starchy foods. In Nigeria, plantain is cultivated in massive quantities. Ondo State as well as Edo state are highest producers of Plantain in Nigeria. There are other states who also engaged in commercial cultivation of plantain. Nigeria plantain production was said to be doubled in the last two decades, due to both state governments and individual massive cultivation, especially in the south western part of the country (Akinyemi et al, 2015). Plantain cultivation in African is estimated to be 50% of the worldwide production. Nearly 82% of the plantains cultivated in African are done in the plains area of Guinea Liberia to the dominant basin of the Democratic Republic of Congo. It is estimated that about 70 million people in West and Central Africa derive more than 25% of their carbohydrates from plantains, making them one of the most important sources of food energy throughout the African lowland humid forest zone. Nigeria is one of the largest plantain producing countries in the world (FAO, 2006). It has been estimated that Nigeria generates about 20kg of metropolitan solid waste per capita annually (FAO, 2013), and which has continued to increase with increasing population (FIDA, 2013). Biogas technology has played and will continue to play a role in waste management (GUARDIAN, 2013).
In Nigeria, it is considered that most of the menace and accumulated urban wastes can be eliminated via the use of Biogas technology, by converting the wastes into Biogas production materials, by generating gas through this process for other use (IISD, 2013). Plantain, banana and rice constitute major food crops in Nigeria. As a result, large quantities of wastes are frequently produced from the peels and husks. discriminate disposal of these wastes and their concomitant decomposition often yield noxious gases like H_2S, NH_3 etc., which pose bad environmental hazards.
This study aims to investigate the index properties of black cotton soil Stabilized with plantain peel powder.

2.1. Materials

Black study soil sample was taken from Yola Adamawa state, Nigeria. The sample was exposed to air to ensure it's in a solid dry state. It was later sieved to remove the unwanted substance from it. After the proper sieving process is done, the sample is subjected to heat via oven, the sample is placed inside the oven to ensure its really dried.

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3.0. LABORATORY EXPERIMENTAL PROCEDURE

A laboratory test was performed on the sample in compliance with BS 1377 [1990] which is British Standard code of practice Specification

Particle Size Gradation

British standard (BS) sieve was used to sieve the soil sample. The main reason for using the sieve was to ensure the procedure is in conformity with the BS 1377 (1990) test 7a standard. The sieving process was conducted on the sample when it the sample was wet. Another important reason for using the specified sieve was because it was able to cover the total area of the aperture size of the 63-micron sieve excluding the lid. The sample, which is the soil, was spread on the 0.2cm sieve, a clean water was splashed on it to clean the sample. The water was drained through the sieve for a while, to allow the water to be properly drained from the sample. The sample was later transferred into a tray and subjected to heat with the aid of an oven under the temperature of 105°C. Afterward, the sample was brought out from the oven and exposed to air, to allow it cool. The soil sample was then sieved again after it has been dried using the oven. The percentage weight left out and the percentage passing through the sieve was gotten using a standard mechanical sieve shaker.

Natural Moisture Content

While testing for the natural moisture content, a container was used, the containers were weighed initially before the sample was added and its reading was 0.1g, the reading was denoted as m1. The soil sample was then poured into the container, the reading of the container containing the soil sample was also taken and recorded, was noted as m2. Container, containing the soil specimen was positioned in the oven at about 105°C temperature for about 24 hours, which was later brought out of the oven to subject it to air for cooling.
The processed specimen was weighed, and the value gotten was recorded as m3. The natural moisture content was evaluated from the results of the weight of the water over the weight of the dried soil

Specific Gravity

To know the specific gravity of the soil sample, three density bottles were used, before the experiment, we ensured the bottles were thoroughly cleaned, sun-dried. The first procedure after the cleaning process has been done on the bottles was to weigh the bottles. We weighed the bottles to the nearest 0.001g, the value was noted as W1. A soil sample of about 50 to 150g was collected via dividing the initial sample after it has gone through a sieving process. All the samples in the bottles were weighed as well. Also, we applied distilled water to the sample, we then weighed the samples in the bottles after it has been mixed with the distilled water and recorded the sample as W3. After the previous process, the bottles were completely emptied, cleaned and filled with distilled water and was subjected to a temperature of about 18°C. The bottle containing the distilled water was weighed and recorded as W4.
The specific gravity was calculated as (W2-W1) / (W4-W1) - (W3- W2).

Atterberg Limits Test

The liquid limit test was done in accordance with the American Society of the International Association for Testing and Materials (ASTM) method D423 standard. A soil sample of about 250g was obtained, the sample was mixed with 20ml of distilled water and was been stirred together with a spatula in a porcelain dish. The sample was thoroughly stirred together with the addition of about 3ml more. Few portions of the sample which is already mixed were pressed with the aid of the spatula and were spread into a spot with proper avoidance of sting of air bubbles.
The liquid limit was derived as the moisture content corresponding to 25 blows.

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Plastic Limit

The plastic limit test of the sample was determined by strict compliance of the BS 1377 (1990) test 3 standard. Exactly 20g of the sampled soil, having gone through about 0.425 sieving process, was adopted for the test. There was a thorough mixing of the collected sampled material with distilled water and was squeezed together for almost 15 minutes to enable it to produce a plastic ball
The produced plastic ball then was massaged with palms in a way the heat enacted while rolling with palms was able to deliberately dry it. To determine the plastic limit, the sample was further rolled in between fingers using a steady pressure, which resulted to drastic reduction of the diameter of the sample to 3mm, same steady pressure was considered until the thread eventually crushed. This crushing point was said to be the plastic limit

Linear shrinkage test

Linear shrinkage test of the sample was done in the standard of the BS 1377 (1990) test 5, which is a generally accepted standard in Nigeria. Exactly 150g of an air-dried soil which has passed through 0.425mm sieving process was used for this test. We cleaned the mold up and dried it, applied a thin film silicone lubricant to the innermost surface to ensure soil does not stick to the mold. We ensured we placed the soil on a glass late, mix it with a water which is said to be a distilled one for almost 15 minutes until we obtain a consistent paste, which signifies the liquid limit. Venire caliper was used to measure the length of the bar of the soil for both the top and bottom surfaces. Mean value of the two lengths were considered as the day length

4.0 RESULTS AND DISCUSSION

Grain size analysis

As illustrated in Figure 2 and Table 1 below, the graph of grain size analysis was performed on the black cotton soil, about 0.0075 fractions which is greater than 35% as noticed, which is said to be a high percentage. Hence, the soils are described as (A-7-5) a Clay of high compressibility (CH). the implication of the result shows that soil of higher clay content is regarded as unsuitable material in roadworks which will require stabilization for strength improvement

Table 1: Grain size analysis of the Black cotton soil.

Sieve number(mm)	Weight (gm)	%Ret	% passing
9.5	10	2.0	98
4.75	20	4.0	94
2.36	15	3.0	91
1.18	25	5.0	86
0.6	20	4.0	81
0.3	35	7.0	74
0.15	30	6.0	68
0.075	40	8.0	60

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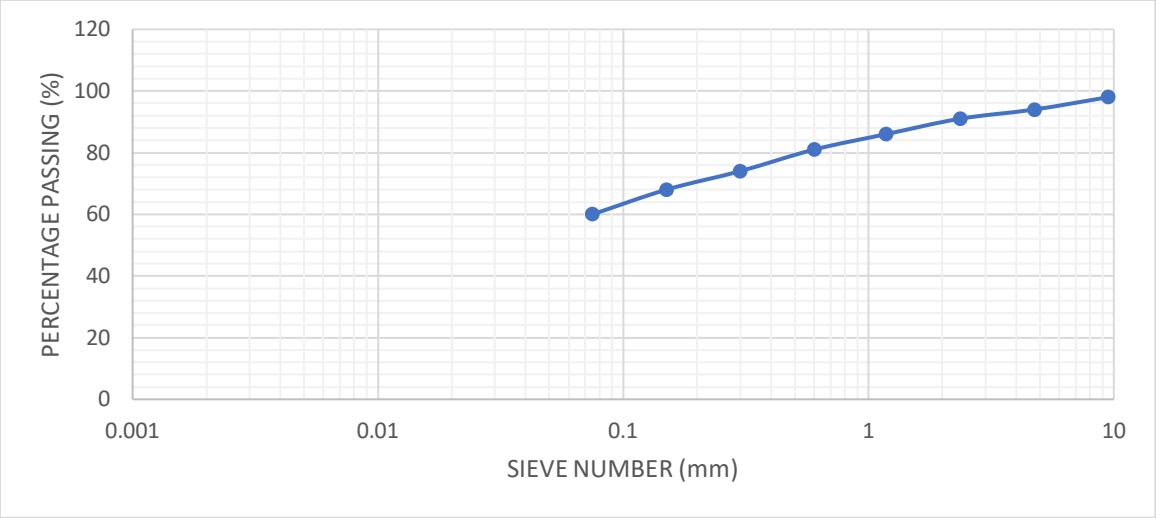

Figure 2: Graph of grain size analysis

Consistency Limit test

Table 2 and figure 3 illustrated the results of the liquid limit which is denoted by (LL %), as well as the plasticity index denoted by (PI %), which was eventually evaluated on the Natural soil and on the stabilized soil which gave 48 % and 20%respectively at natural state of the soil while the stabilized varied between 48-32% and 20-13% respectively for (0-10) % PPP admixture addition, the results indicate that the higher the PPP the lower the clay content and the better the index properties examined as showed in figure 1 and 2. In Nigeria, the specification of the ministry of works at the federal level requirements for roads and bridges established was in 1994. The recommendation was that the liquid limit test of the Nigerian roads and bridges must not be greater than 80 percent for the sub-grade, the sub-base as well as the base must not be greater than 35 percent too. Likewise, the requirement for the plasticity index of the sub-grade must not be greater than 55 percent and that of the sub-base and the base must not be greater than 12% as well. The results of our test on the sampled soil falls within this required specification. The above analysis showed that the PPP has enhanced the index properties of the black cotton soil. Thus, making the unsuitable material appropriate for both the roads and bridges construction work.

Table 2: Summary results for consistency test of the PPP blended with black cotton soil

% OF PPP ADDITION	LIQUID LIMIT (LL%)	PLASTIC LIMIT (PL%)	PLASTICITY INDEX (PI%)	LINEAR SHRINKAGE (LS%)
0	48.0	20.0	28.0	14.0
2	40.0	18.0	22.0	12.5
4	39.0	19.0	20.0	11.0
6	35.0	17.0	18.0	10.0
8	33.0	17.0	16.0	9.0
10	32.0	19.0	13.0	7.5

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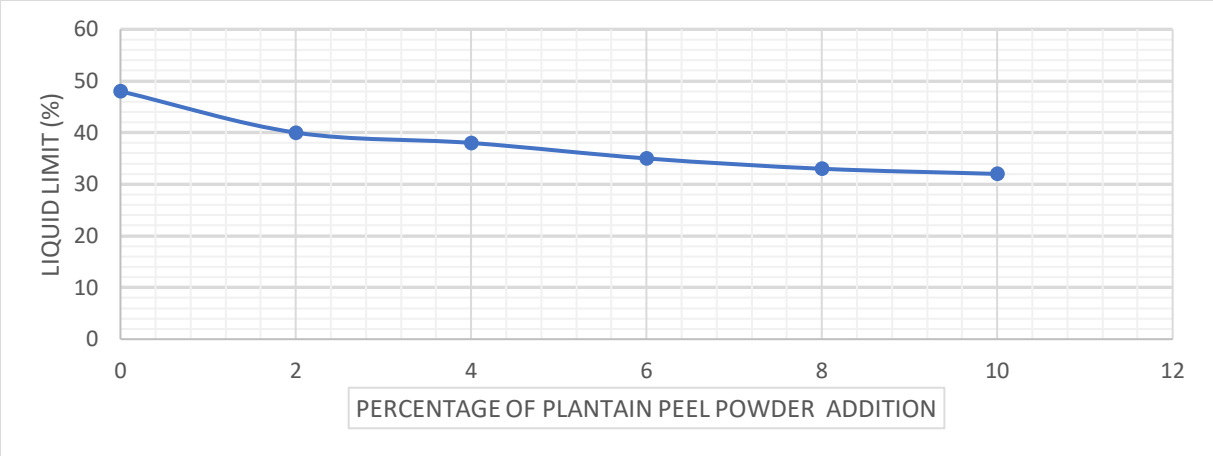

Figure 3: Liquid Limits results against the percentage of PPP addition

Table 3: Summary results for preliminary tests of the Black cotton soil (index properties)

NMC (%)	GS	%Passing sieve200	LL (%)	PL (%)	PI (%)	LS (%)	CLASSIFICATION	
							AASHTO	USCS
14	2.60	60	48	20	28	14	A-7-5	CH

*NMC (Natural Moisture Content) *GS (Specific Gravity). * LL (Liquid Limit). * PL (Plastic Limit) * PI (Plasticity index). * LS (Linear Shrinkage)

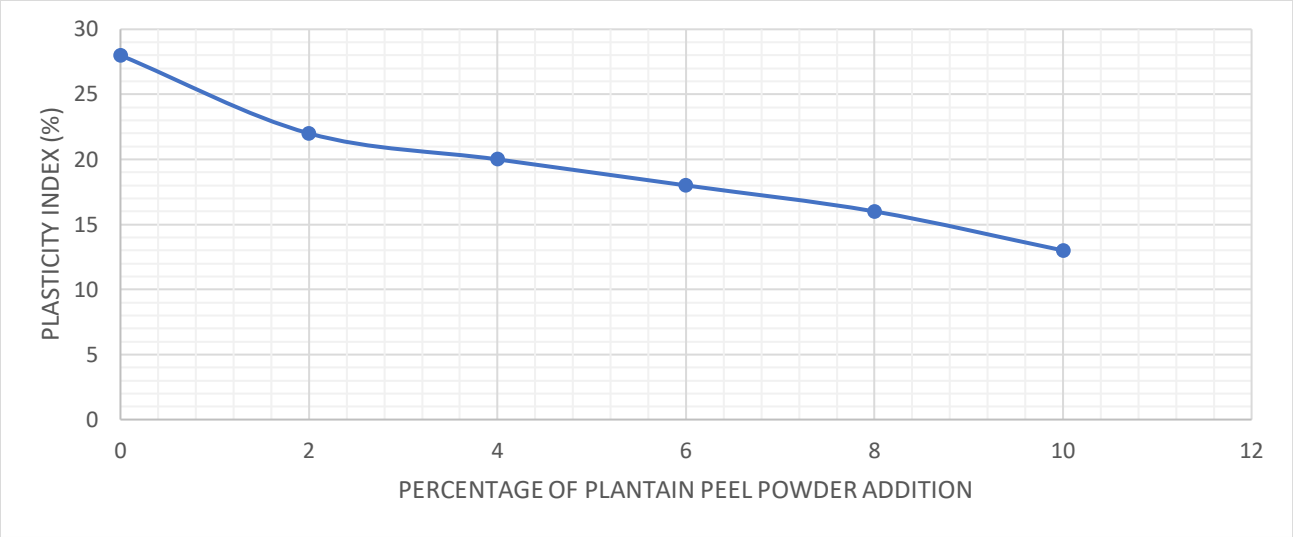

Figure 4: Graph of Plasticity index against the percentage of PPP addition

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5.0 CONCLUSION

The engineering properties of black cotton from Yola Adamawa State stabilized with PPP has been evaluated with a view to study its suitability for road construction pavement materials. Samples of uninterrupted soil were collected and subjected to laboratory tests. Results obtained from the laboratory tests at the natural state of the sample show that it has a percentage of fine greater than 40%, The soils sample were grouped as (CH) and A-7-5 correspondingly. The soil was classified as a Clay of high input compressibility. The black cotton soil was stabilized with PPP, the results varied between 48-32% LL and 20-13% PI respectively at (0-10) % proportion of the PPP admixture addition. The Black cotton soil which was stabilized with Plantain peel powder is therefore found suitable for earth fill, subgrade, subbase and could be used as base course resources in any construction project.

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