

A Study on Subgrade Soil Using Locust Bean Pod Waste Ash as Admixture

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ABSTRACT

Locust bean pod husk is by-product of agricultural processing of the African locust bean fruit. The husks are been abandoned in a dumping site and this causes environmental nuisance. The empty pods are the needed raw material which was burnt by furnace to become ash which was aimed at using as an admixture to improve the geotechnical properties of sub grade soil.

A soil sample and the locust bean pod were collected within the study area, and the ash was used to examine the effect as admixture on the subgrade materials for construction purposes. The sample was subjected to the following tests: Natural moisture content, Oxide test, Grain size analysis,, Specific Gravity test, Atterberg limit tests, Compaction test (BSL, WAS, and AASHTO), CBR using BS, WAS, and AASHTO compactive efforts for both soaked and unsoaked conditions, UCS using BS, WAS, and AASHTO compactive efforts, and Microstructural analysis test (SEM).

The natural moisture content and the Oxide test were determined. The specific gravity for the natural soil and LBPA were also determined. The grain size analysis was determined and the results show that percentage passing through Sieve number 0.075mm equal to 31.48%. the (LL) ranges from 29 to 35%, (PL) ranges from 18 to 23%, and the (PI) ranges from 9 to 15%. The (MDD) ranges between 1.71 to 1.81g/cm³ by using compactive effort of (BS), by using (WAS) compactive effort, MDD ranges from 1.91 to 2.02g/cm³, while using (AASHTO) compactive energy, MDD ranges from 2.02 to 2.07g/cm³, and Optimum Moisture Content (OMC) ranges from 9.6 to 12.5% when using (BS) Compactive effort, when using (WAS), OMC ranges from 8.3 to 12.4%, and when using (AASHTO) Compactive effort, OMC ranges from 8.9 to 13.5%. The CBR values for unsoaked ranges from 18 to 27% while soaked condition ranges from 6 to 16% when using (BS) Compactive effort, using (WAS) Compactive effort, unsoaked CBR values ranges from 32 to 50%, while the soaked condition ranges from 21 to 38%, and when using (AASHTO) Compactive energy, the unsoaked CBR values ranges from 54 to 81%, while the soaked CBR values ranges from 22 to 36%. The (UCS) values when using (BS) Compactive effort, the UCS values ranges between 181 to 224Kpa and the shear strength also ranges from 91 to 112Kpa. By using (WAS) Compactive effort, the UCS values ranges between 192 to 296Kpa and the shear strength ranges from 96 to 148Kpa, and using (AASHTO) Compactive energy, the UCS values ranges between 645 to 1040Kpa, and the shear strength values ranges from 323 to 520Kpa. The more the percentage of ash, the lesser the voids.

Key words: Locust bean pod ash, Subgrade and Admixture

1.0 INTRODUCTION

Soil is any uncemented accumulation of mineral particles formed by weathering of rocks. Soil is generally used as foundation or as construction materials. A class of soil known as expansive soils, when used as foundation materials is usually affected by environmental conditions and they undergo detrimental volumetric and hydraulic conductivity changes because of the variation in moisture content (Nelson and Miller, 1992). Expansive soils are, therefore, soils with potential for shrinking and swelling under changing moisture condition (Fredlund and Rehardjo, 1993). These soils

causes more damage to structures, particularly light building and pavements, than any other natural hazards, including earthquakes and flood (Jones and Holtz 1973)

Subgrade soil (Lateritic soil) is a type of expansion soil that lies below ground level and extends to such depth as may affect the supports of the pavement. Subgrade soil is brownish clays that are produced from the breakdown of basic sedimentary rocks where seasonal variation of weather is extreme (Osinubi et al 2008). Although subgrade soil (Lateritic soil) are mostly poor and undesirable for some engineering purposes, its properties could therefore be improved to meet standards specification by modification/stabilization processes (Osinubi et al 2008).

Bello (2013) reported that lateritic soils on the basis of their hardening property, which is the ability of a soft red material to harden on expose to air. He also stated that the word laterite was suggested to denote a building material used in the mountain region of India. He also reported that laterite is divided into true laterite, silicate laterite and laterite clay on the basis of the hydroxide content. He also summarized the morphological, physical and chemical concepts proposed by many researchers as follows: laterite is a highly weathered material, rich in secondary oxides of iron, aluminium or both. It is nearly void of bases and primary silicates, but it may contain large amount of quartz and kaolinite. It is either hard or capable of hardening on exposure of wetting and drying.

Locust bean pod husks are a waste by-product of agricultural processing of the African locust bean fruit. The harvested fruits are ripped open while the yellowish pulp and seeds are removed from the pods. The empty pods are the needed raw material. The pods make up 39% of the weight of the fruits while the mealy yellowish pulp and seeds make up 61%. Substantial quantities can be found across northern Nigeria during the harvest season most especially from Doko village around Bida in Niger State and Malali village in Kaduna State of northern Nigeria. The locust bean pod husks are been abandoned in a dumping site in the above mentioned village. This means of disposing the locust bean pod husk causes environmental pollution to the villagers. However, some villagers burn the locust bean pod husks, which also causes environmental pollution and it is hazardous to the community. Across the globe, much research efforts in recent times are geared towards possible ways of recycling these wastes for reuse to keep the environment clean and safe.

Stabilization of the soil with chemical admixtures is a common preventives method used to reduced the swelling and shrinkage tendencies of the soil and it also makes the soil less plastic (Ola,1983, Balogun, 1991, Osinubi, 1999).

Cement stabilization is also one of the most widely and commonly method of stabilization used to improve the shrinkage and swelling characteristics of the subgrade soil (Matawal and Tomarin 1996).

Most of the recent works in the field of geotechnical engineering focus on the search for cheaper and locally available materials for the purposes and uses in stabilization, and a large percentage of such materials are mostly from Agricultural waste that produce cementitious compounds on exposure to moisture. As a result of making use of this agricultural waste, the studies will therefore match the need for safe and environmental disposal of waste for the society and also will meet engineer's need for better and cost effective construction materials

2.0 MATERIALS AND METHODS

2.1 Materials

The materials used for this study are: lateritic soil, locust beans pod ash.

2.1 Sampling

The experimental program was design to study the effect of locust bean pod ash (LBPA) on the index and strength properties of subbase soil. The percentages (%) of the (LBPA) used were, 0%, 2%, 4%, 6%, 8%, and 10% respectively

The soil sample of the unsuitable soil was obtained at an on-going construction work at Oyun local government, Kwara, Nigeria. The chainage of the unsuitable soil is between 3+800 to 4+000. The samples were taken within 200meters. The map of the study area is shown in figure 1.

The top soils were removed to a depth of 0.5m before the soil samples were taken, and sealed in plastic bags and put in sack to avoid loss of moisture during transportation. The soil samples was then be allow to dry before pulverizing to obtain particles passing sieve BS No. 4.75mm.

The locust bean waste ash (LBPA) that was used will be obtained locally within the study area (Igbawere) in Kwara State. The husks were completely burnt with a furnace at a temperature of 600⁰C. The ash were passed through British Standard No 200 sieve and kept before mixing with the soil in the appropriate percentages. The locust bean pod husks shown in the Plates 2

The oxide composition of the ash was determined at the SMO Laboratory Ibadan. Locust bean pod ash (LBPA) is a pozzolan as classified based on the properties of pozzolanas as given by ASTM C618-78.



Plate 1 Map of kwara state showing the sampling areas

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Plate 2 Locust bean pod husks

2.3 Methods

In order to achieved the target of this study some laboratory tests were employed viz-a-viz

2.3.1 Natural Moisture Content

The natural moisture content of the soil as obtained from the site was determined in accordance with BS 1377 (1990) Part 2. Three weighing containers which were cleaned and weighed to the nearest 0.01g as M_1 . The sample as collected was crumbled and placed loosely in the containers, and the containers with the samples were weighed together to the nearest 0.01g as M_2 . The containers were then placed in the oven and dried at 105°C - 110°C for 24hours. The containers and the samples were then removed and weighed dry to the nearest 0.01g as M_3 . The natural moisture content (as collected from the site) is then calculated as the average as given by equation below

$$w = \frac{M_2 - M_1}{M_3 - M_1} \times 100 \quad \text{equ 1}$$

Where w is the moisture content in percentage (%)

2.3.2 Sieve Analysis Test

The purpose of the sieve analysis test in this study is to determine the fineness modulus of fine and coarse aggregate.

2.3.3 Specific Gravity

The determination of specific gravity was carried out according to BS 1377 (1990) TEST (B) for fine grained soils. The density bottle and the stopper were weighed to the nearest 0.01g as M_1 . The air dried soil was transferred into the density bottle, and the bottle content and the cover were weighed to the nearest 0.01g as M_2 . Water was then added just enough to cover the soil, the solution is gently stirred to remove any air bubbles. The bottle was then completely filled up and covered. The covered bottle was then wiped dry and the whole sample was weighed to the nearest 0.01g as M_3 . The bottle was subsequently emptied and filled completely with water, wiped dry and weighed to the nearest 0.01g as M_4 . The specific gravity was then calculated using equation below

$$G_s = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_1)} \quad \text{equ 2}$$

2.3.4 Atterberg Limits

The test includes the determination of the Liquid Limits (LL), Plastic Limits (PL) and the Plasticity Index (PI) for the natural soil and the stabilized soils. They were also conducted in accordance with Test1 (A) BS1377 (1990) PART 2 for the natural soil and BS 1924 (1990) for the stabilized soils.

$$PI = LL - PL \quad \text{equ 3}$$

2.3.5 Compaction Characteristics

This test includes the determination of maximum dry density and corresponding optimum moisture content for the natural soil and the stabilize soils.

2.3.6 Strength Characteristics

This test includes the determination of the unconfined compressive strength and California bearing ratio strength properties for the natural soil and stabilized soil at different percentage mix of

locus bean pod ash (LBPA) which includes Unconfined Compressive Strength (UCS) and California Bearing Ratio (CBR) test

$$\text{Compressive Strength} = \frac{\text{Failure load}}{\text{Surface Area of Specimen}} \quad \text{equ 4}$$

$$\text{CBR} = \frac{\text{Measured load}}{\text{Standard load}} \times 100\% \quad \text{equ 5}$$

Where standard load = 13.24kN of 2.5mm penetration
 = 19.96kN of 5.0mm penetration

2.3.7 Procedure for SEM

Little sample was obtained from the compacted sample from UCS using BS, WAS, and AASHTO compactive efforts. The sample was cut to the specification/dimension needed for the sample to be able to hold firmly using Ultra trim cutting machine. A blower machine was then used to blow the top surface of the sample so as to remove the other particles present on the sample; the bottom of the sample was then scraped to be well placed tight on the sample holder to hold it firmly. The sample holder with sample was then placed in a PSEM stage, and then closed to start scanning.

3.0 RESULTS AND DISCUSSION

3.1 Natural Moisture Content

Preliminary tests conducted to determine the natural properties of the soil revealed that the soil has high moisture content of 17.55%, due to the period its collection (during wet season). the soil is reddish brown in colour (from wet to dry states)

3.2 Chemical composition test

The chemical composition test was carried out on the locust bean pod ash (LBPA). The summary of the result of chemical laboratory analysis test are as shown in Table 1

Table 1 Summary of the result of chemical composition analysis test on LBPA

S/N	Parameters	Percentages (%)
1	SiO ₂	60.45
2	Al ₂ O ₃	1.29
3	Fe ₂ O ₃	1.24
4	MgO	1.8
5	CaO	10.52
6	Na ₂ O	3.35
7	K ₂ O	3.12
8	SO ₃	0.33
9	LOI	9.86

3.3 Sieve Analysis of soil.

The test sieve was carried out with sets of sieves with nominal sizes between 0.075mm to 20.00mm The results grading curve from which the proportion of the various particle sizes was determined in Figure

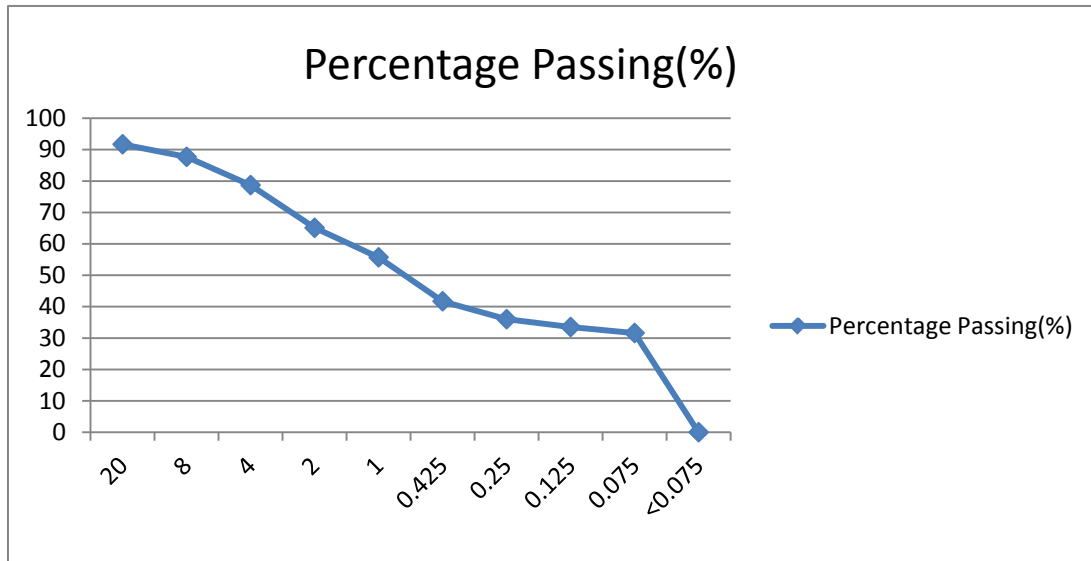


Figure 1 Sieve Analysis Result and Graphical Representation

3.4 Specific gravity of soil

The specific gravity of the soil solids test was carried out on both soil and the locust bean pod ash (LBPA) which is 2.32 and 1.50

3.5 Atterberg Limit test:

This comprises the liquid limit, plastic limit and plasticity index properties of the soil used with additives of locust bean pod ash at 2, 4, 6, 8, and 10%. The summary of the test results obtained are as shown Figure 2. The result shows that the value for the liquid limit for the natural soil is 35%, plastic limit is 20%, and plasticity Index is 15%. Therefore there is decrease in the liquid limit throughout the stabilization and there is also a decrease in plasticity Index throughout the stabilization.

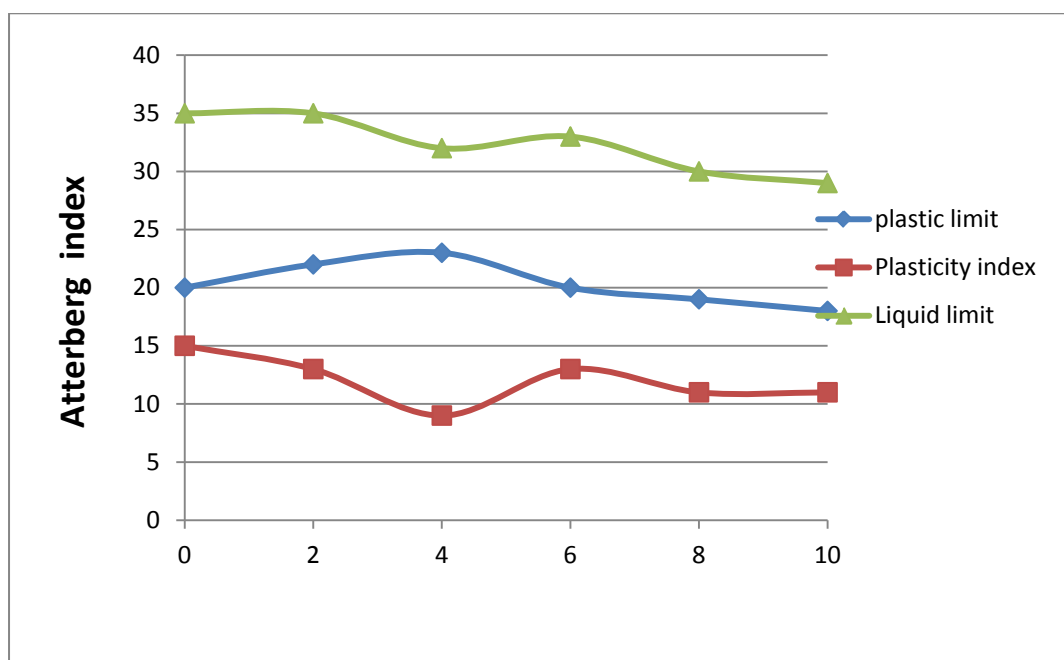


Figure 2 Graphical Representations for Liquid Limit, Plastic Limit and Plastic Index Properties against Percentage of LBPA.

3.6 Compaction test.

The compaction test was carried out by using three compactive energies and Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were determined. The compaction test result for the natural soil sample using British Standard produces MDD of 1.78g/cm^3 and OMC of 12.5%. and for the stabilized soil, the values for the MDD ranges from $1.71\text{-}1.81\text{g/cm}^3$, and OMC ranges from 9.6-12.1% which shows that there is a little increase for MDD at 2% and 6% and decreases in OMC throughout the stabilization(Figures 3a and 3b)

By using west African standard (WAS) compactive effort, the value of MDD for the natural soil is 2.02g/cm^3 and OMC value is 12.4%. and for the stabilized soil, the values of MDD ranges from 1.91 to 2.00g/cm^3 and OMC ranges from 8.3 to 11.8%. This shows that there is decreases at MDD throughout the stabilization and also decrease at OMC throughout the stabilization (Figures 4a and 4b)

And by using AASHTO compactive effort, the value for the natural soil is 2.07g/cm^3 and OMC is 13.5%,and for the stabilized soil, the values for the MDD ranges from 2.02 to 2.17g/cm^3 and OMC ranges from 8.9 to 13.0%. This shows that there is only in MDD at 6% compare to the value at the natural state, and also there is decrease in OMC throughout the stabilization (Figures 5a and 5b)

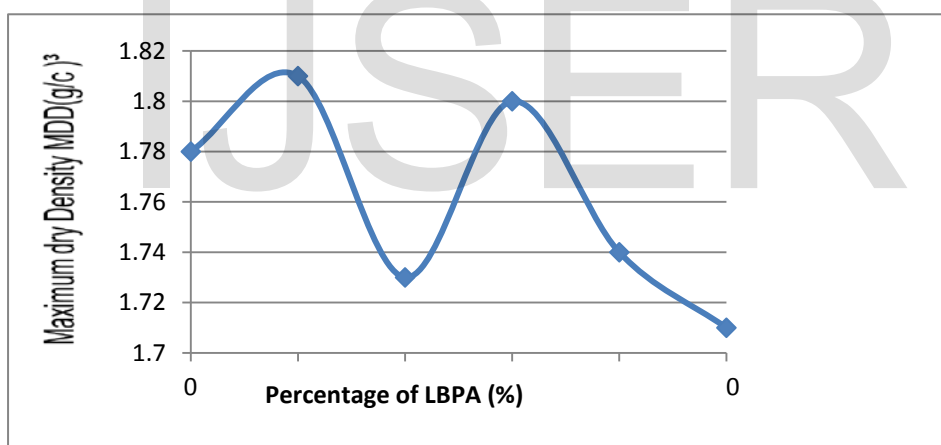


Figure 3a Maximum Dry Density against percentage of LBPA using British Standard (BS) compactive effort

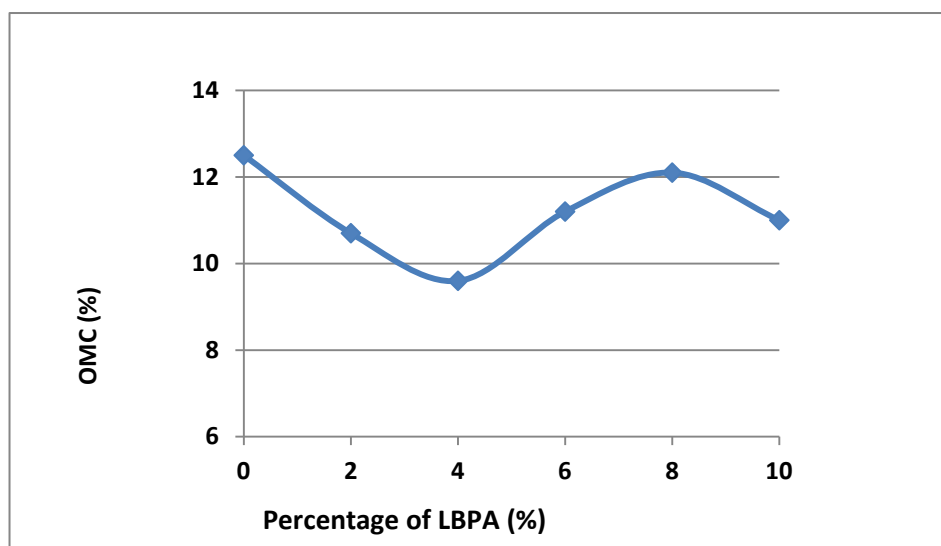


Figure 3b Optimum Moisture Content against percentage of LBPA using British Standard (BS) compactive effort

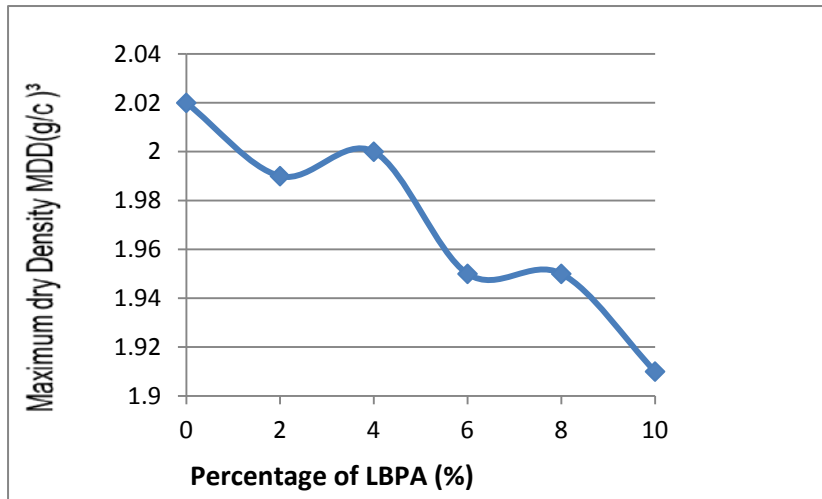


Figure 4a

Maximum Dry Density against percentage of LBPA using West Africa Standard (WAS) compactive effort

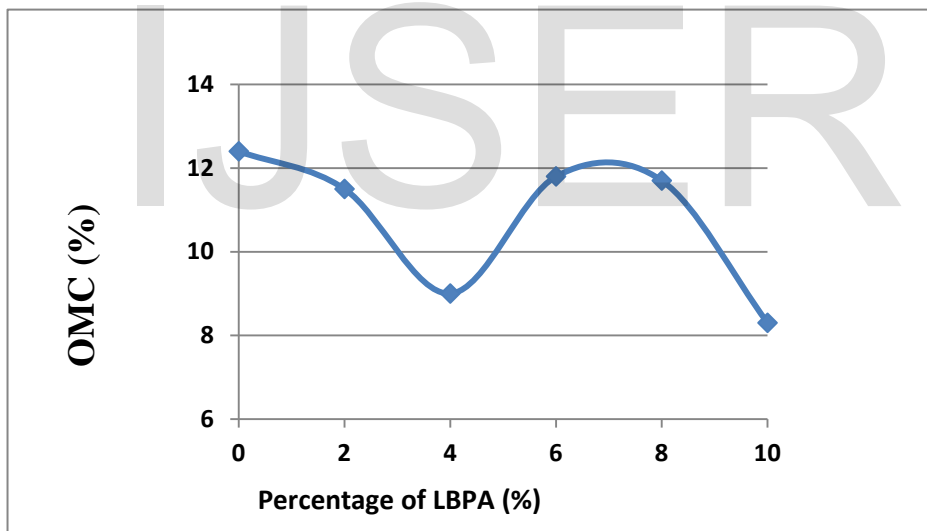


Figure 4b Optimum Moisture Content against percentage of LBPA using West Africa Standard (WAS) compactive effort

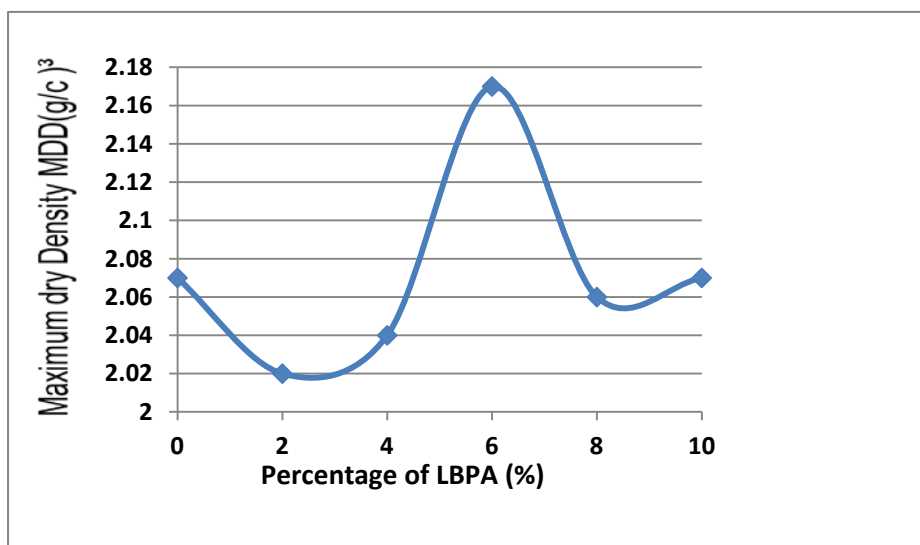


Figure 5a Maximum Dry Density against percentage of LBPA using (AASHTO) compactive effort

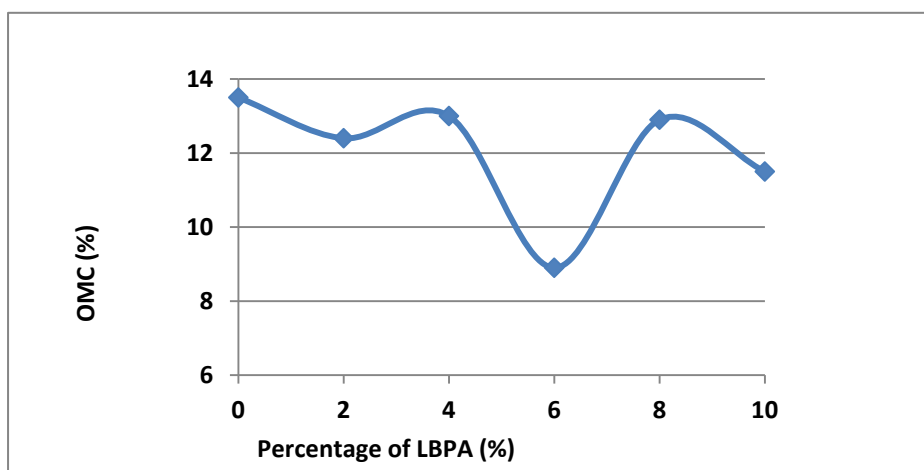


Figure 5b

Optimum Moisture Content against percentage of LBPA using (AASHTO) compactive effort

3.7 California Bearing Ratio (CBR):

The California bearing ratio test was carried out for 0, 2, 4, 6, 8, and 10%, of locust bean pod ash (LBPA) as a stabilizing agent and the compactive effort employed were British standard code (BSL), West African standard (WAS) and American Association of state highway transport officer (AASHTO).

The CBR values for the natural soil sample by using British Standard (BS) compactive energy for soaked and unsoaked are 8 and 23%. The CBR value ranges from 18 to 27% for unsoaked condition and the soaked CBR values ranges from 6 to 16%. These shows that there is increase in the value of CBR at unsoaked condition at 6% but the soaked condition there was only decrease at 6%. The California Bearing ratio for the natural soil sample using West African Standard (WAS) is 38%, for both soaked and unsoaked conditions. For the stabilized soil, the values of stabilized CBR at unsoaked conditions range from 32 to 50% and at the soaked conditions ranges from 21-27%. These shows there is increase in the value of CBR at unsoaked conditions at 2, 4 and 6% But the soaked condition for the CBR vales when compared with natural soil sample, the value of CBR were decreasing through-out the stabilization. And using AASHTO compactive energy, the CBR value for the natural soil for unsoaked and soaked condition are 70 and 36% the CBR values ranges from 54 to 81% for unsoaked condition, while the soaked CBR values ranges from 22 to 32%. These shows that there was only increase at 4% unsoaked value but there was totally decreasing values through-out the stabilization at soaked condition as could be depicted from Figures 6,7 and 8.

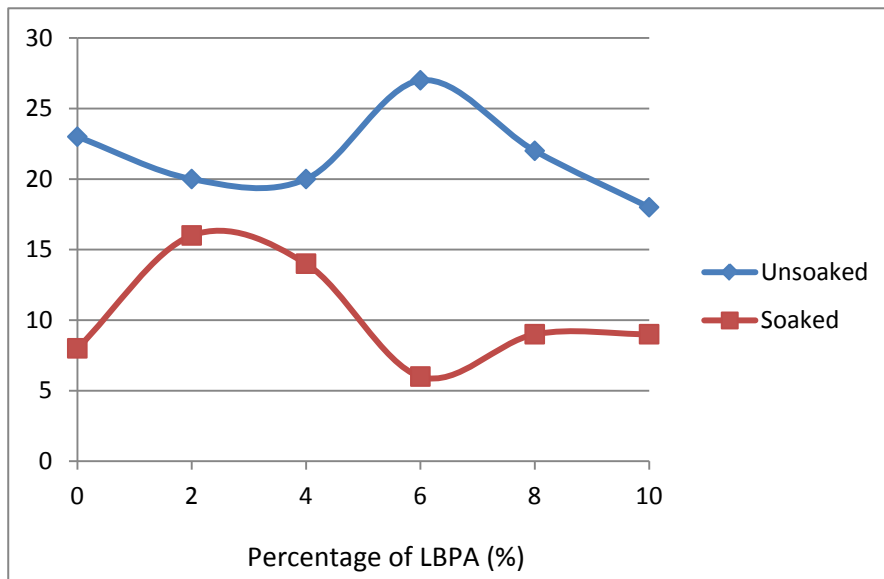


Figure 6 Graphical Representation of CBR result for both soaked and unsoaked condition against Percentage of LBPA using BS compactive energy

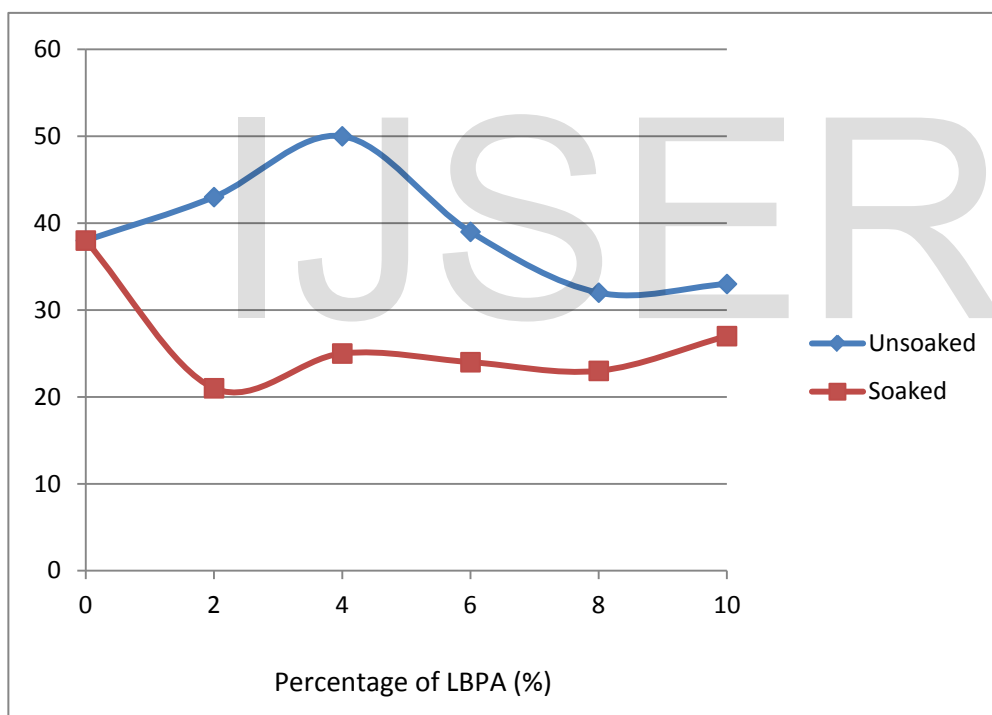


Figure 7 Graphical Representation of CBR result for both soaked and unsoaked condition against Percentage of LBPA using WAS compactive energy.

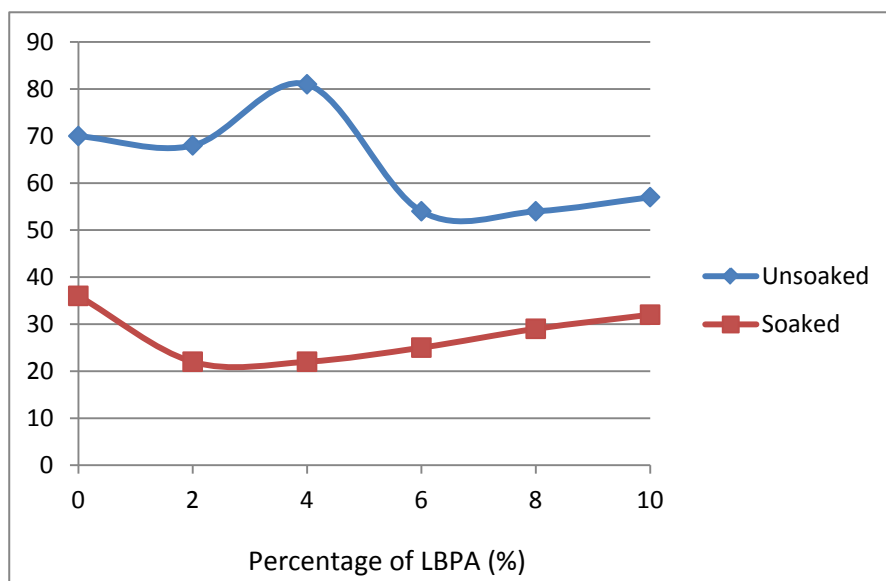


Figure 8 Graphical Representation of CBR result for both soaked and unsoaked condition against Percentage of LBPA using AASHTO compactive energy

3.8 Unconfined Compressive strength (UCS):

The unconfined compressive strength test was carried out using BS, WAS and AASHTO compactive efforts in order to obtain the total stress at load failure and the shear strength of 0, 2, 4, 6, 8, and 10% of LBPA contents.

By using BS compactive energy for the natural soil, UCS value equal to 181Kpa and the shear strength value equal to 91Kpa. The UCS value for the stabilize soil ranges from 192 to 224 Kpa and the shear strength value ranges from 96 to 112Kpa. These show that there is increase at both UCS and shear strength values through-out the stabilization.

By using WAS compactive effort for the natural soil UCS value equal to 192Kpa and the shear strength value equal to 96Kpa. The UCS value for the stabilize soil ranges from 234 to 296 Kpa and the shear strength value ranges from 117 to 148Kpa. These show that there is increase at both UCS and shear strength values through-out the stabilization.

The Unconfined Compressive Strength (UCS) value by using AASHTO for the natural soil is equal to 819Kpa and the shear strength equal to 410Kpa. The UCS values for the stabilize soil ranges from 645 to 1040Kpa. The shear strength of the stabilized soil ranges from 323 to 520Kpa. There is increase in the shear stress compared with natural soil except 2 and 10% LBPA that has decrease in the shear stress value (Figures 9, 10 and 11)

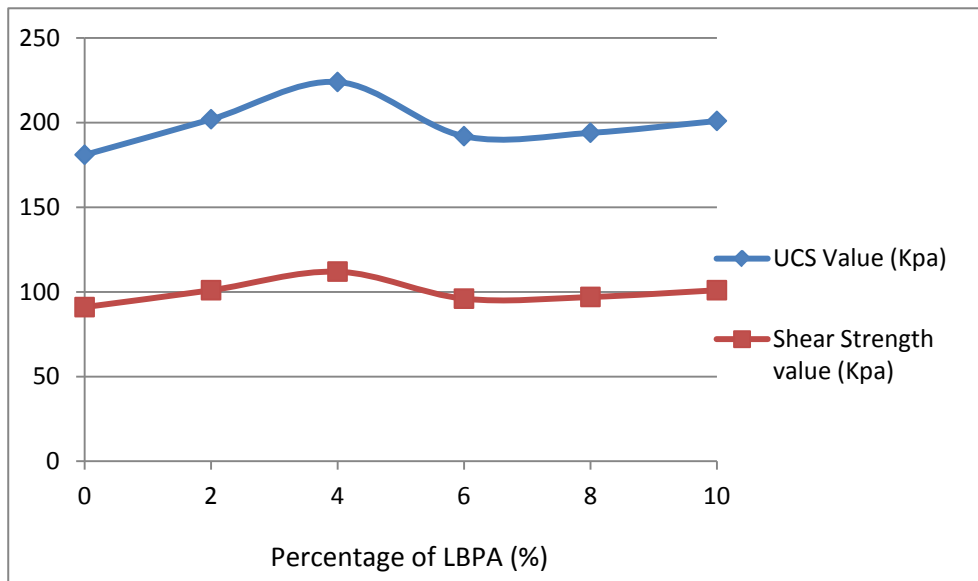


Figure 4.9 Graphical Representation Unconfined Compressive Strength test for LBPA using BS compactive effort

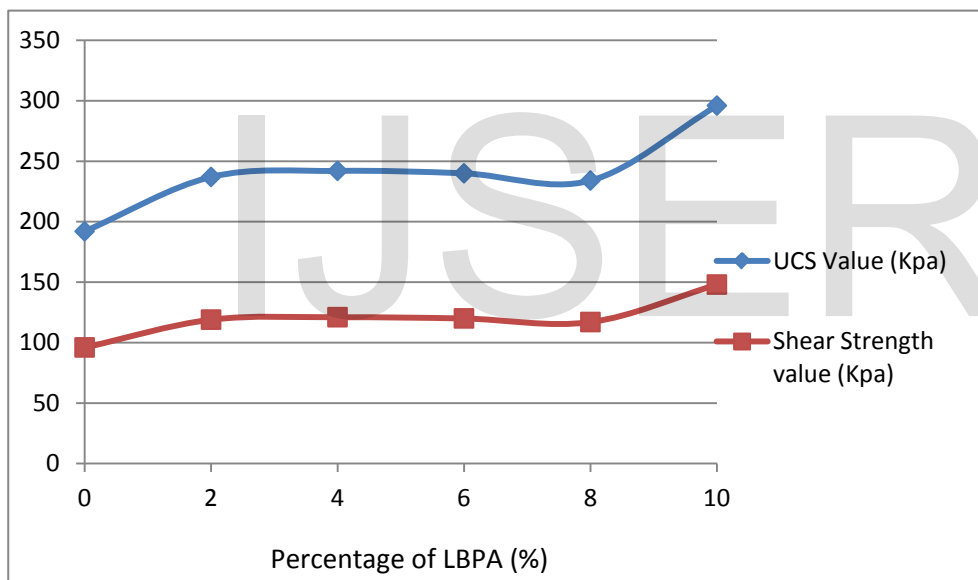


Figure 10 Graphical Representation Unconfined Compressive Strength test for LBPA using WAS compactive effort

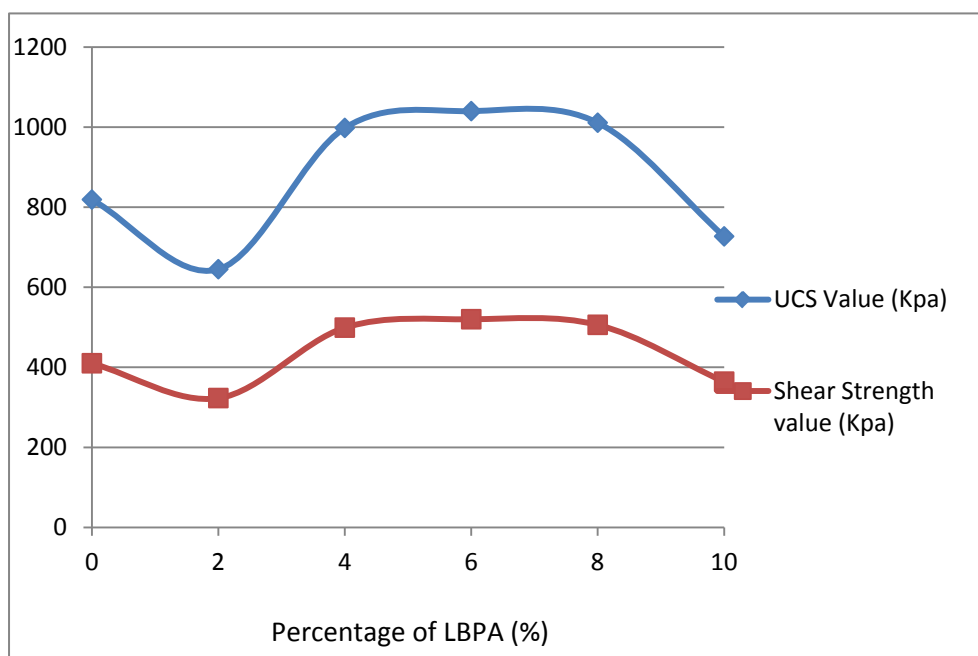


Figure 11 Graphical Representation Unconfined Compressive Strength test for LBPA using AASHTO compactive effort

3.9 Results for scanning electron microscopy (SEM) analysis

Scanning Electron Microscopes (SEM) micrographs clearly reveals the irregular and morphology shapes of the images at different magnifications in terms of void sizes, bonding between the soil and the binder, the distribution of the binder, the general structural density whether it is closely packed or loosely packed and also the location of the binder if it is evenly distributed or it is at one side.

4.0 CONCLUSION

Based on the results of this study, which shows the locust bean pod ash (LBPA) was used as admixture, the following conclusions were made.

- i. The percentage passing sieve 200 is 31.45% , and the particles distribution test shows that the soil sample contain 32% silty clay, 46% sand, and 22% fine to medium gravel.
- ii. The specific gravity of the natural soil is greater than the specific gravity of the LBPA
- iii. For the Atterberg test, compare to the specification standard, the natural soil cannot be used for sub-base and base-course except for filling material because the liquid limit for the natural soil is above 30%, and the plasticity index is above 12%, therefore more percentage of LBPA should be analyse for future researchers since the highest percentage mix of LBPA bring about decrease in liquid limit and plasticity index.
- iv. For the compaction test, using BS compaction, there is increase in MDD at 2% and 6% LBPA and there is decrease in MDD at 4%.8%, and 10% and decrease in OMC throughout the stabilization, Using WAS compaction, there is decrease throughout the stabilization for MDD and OMC, and for AASHTO compaction, there is only increase at 6% LBPA but decrease in OMC throughout the stabilization.
- v. Based on the strength test for the natural soil, the strength increases with increase in compactive energy.
- vi. It is concluded that the increase of LBPA to the soil, does have effect on their microstructure as indicated from the scanning electron microscope (SEM) Images for all percentage replacement. The increase in the LBPA produced little or no voids and adding to the strength of the soil.

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