International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 1 ‖ January. 2013 ‖ PP.25-30

Effect of Locust Bean Pod Ash on Compaction Characteristics of Weak Sub Grade Soils

Andrew Y. Adama[1], Yinusa A. Jimoh [2] and Stephen S. Kolo[3]

[1](*Chief Design Engineer, Civil Engineering Services Department, Niger State Ministry of Works and Infrastructural Development, Minna, Nigeria)*
[2](*Professor, Department of Civil Engineering Faculty of Engineering and Technology University of Ilorin, Ilorin, Nigeria)*
[3](*Lecturer II, Department of Civil Engineering, School of Engineering and Engineering Technology, Federal University of Technology Minna, Nigeria)*

ABSTRACT: *Chemical stabilization of weak sub grade soils using Locust Bean Pod Ash (LBPA) was studied with respect to compaction characteristics and appropriate recycle of Waste Agricultural Biomass (WAB). The soils used in this study were obtained from old borrow pits along Minna-Kataeregi-Bida road in northern Nigeria and analyzed for their main index properties and compaction. The experimental results revealed that Locust Bean Pod Ash reduces the maximum dry density from 1.68-1.62, 1.33-1.304 and 1.62-1.50 respectively for the various soil samples while it increases the optimum moisture content from 10.4-11.5 %, 18.0-19.5% and 12.03-18.50 % respectively thus, improving the compaction properties. Considering compaction characteristics and economy, 6-10 % weight of stabilizer to the soils was considered the required optimum values for satisfactory accomplishment of the stabilization of the weak soil as road sub base. The conversion of the WAB to a pozzolanic material for soil stabilization provided at least three significantly desirable components in modern day total quality development of highways; environmental pollution control, recycling of waste for new useful material and rejuvenation of an exhausted source of construction materials (borrow pits).*

Keywords— *Locust Bean Pod Ash (LBPA), Particle size distribution, Pozzolan, stabilizing agent, Waste Agricultural Biomass (WAB) .*

I. INTRODUCTION

Unsuitable soils are often encountered in road construction across tropical regions of which Nigeria is inclusive .In some cases even the existing sub grade soils lacks the capacity to support the design loads to be imposed on them, also suitable borrow to fill materials to be used for the construction of the sub base and base courses which are the main load bearing components of the road pavement are not usually available within a given locality ;in such instances the engineer has to stabilize the unsuitable soils using either mechanical or chemical stabilization methods as may be appropriate in the prevailing circumstances so as to improve on the engineering properties of the soils.

Based on the foregoing this research focuses on inventing new environmentally friendly and renewable source of chemical stabilizer and assure its potency for road works. And Locust Bean Pod Ash could be a cheaper alternative if found to be mechanically suitable, owing to the relative abundance of the raw material even as the locust bean tree is being cultivated over a wide area within the African sub region i.e occurs in a belt between 5° N and 15°N, from the Atlantic coast in Senegal to Sudan and northern Uganda. The belt is widest in West Africa (maximum 800km) and narrows to the east. About 201,000 ton of the locust bean fruit is being produced in northern Nigeria annually [1] thus this assures of continual supply of the raw material.

Locust bean pod which is a Waste Agricultural Biomass (WAB) and obtained from the fruit of the African locust bean tree (Parkia Biglobosa) is the material resource required for the production of Locust Bean Pod Ash (LBPA). 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% by weight of the fruits while the mealy yellowish pulp and seeds make up 61% see plate 01[2].

Plate 01 Close up view of Locust Bean fruit.

According to [2] the results of the particle size distribution and chemical analysis of Locust Bean Pod Ash (LBPA) confirms that it has pozzolanic properties and can be classified under class ‘’C’’ group of Pozzolans on The American Society for Testing and Materials (ASTM) classification system. As such, it can be recommended for use as a chemical stabilizing agent in weak soils for road construction, the chemical composition of Locust Bean Pod Ash is shown on Table 1 below:

Table 1: Chemical Composition of Locust Bean Pod Ash

Na_2O (%)	K_2O (%)	MgO (%)	Pb_2O_5 (%)	Fe_2O_3 (%)	Al_2O_3 (%)	CaO (%)	Sio_2 (%)	L.O.I (%)
1.21	**5.62**	**2.01**	**5.82**	**11.51**	**13.05**	**15.71**	**39.01**	**6.00**

The primary objective of this study is the evaluation of Locust Bean Pod Ash as it affects the compaction characteristics of weak sub grade soils for road construction.

II. THEORY

2.1 Production of Ash from Waste Agricultural Biomass

Waste Agricultural Biomass (WAB) which includes rice husks, saw dust, palm kernel shells, locust bean pod e.t.c constitutes the precious resource of recycled material and or energy to reduce pressure on natural resources and ensures economic development and improved living standards, [3].

Silica is usually the major chemical compound contained in most ash residue after the combustion process of Waste Agricultural Biomass and this has health issues arising because all forms of crystalline silica represent a very serious health hazard, [4]. The forms that develop at high temperatures ie crystobalite and tridymite are particularly harmful. Exposure to crystalline silica via inhalation can lead to a number of diseases, the most common being silicosis, [5]. Although Amorphous ash is the form produced at lower temperatures less than 1000^oc does not contain more harmful forms of silica, it can pose respiratory hazard particularly if finely ground [6]. Crystalline silica is classified as carcinogenic to humans, and the International Agency for Research on Cancer (IARC) concluded that there was sufficient evidence in humans for the carcinogenity of crystalline silica, [7].

2.2 Pozzolanic Activity

Pozzolanic materials by nature usually react with soil particles to form calcium silicate cement. This reaction is water insoluble. The cementing agents are exactly the same as for the case ordinary Portland cement. The difference is that the calcium silicate gel is formed from the hydration of anhydrous calcium silicate (cement), whereas with the pozzolanic materials, the gel is formed only by the removal of silica from the clay minerals of the soil. The silicate gel proceeds immediately to coat and bind clay lumps in the soil together and to block off the soil voids in the soil structure. In time this gel gradually crystallizes into well defined calcium silicate hydrates and the micro crystals also interlocking .The reaction ceases on drying; as very dry soils will not react with pozzolanic materials or cement, [8]. Fly ash is produced by burning coal and is generally high in silica and alumina; therefore the addition of fly ash to lime stabilized soil speeds up the pozzolanic action. See equation 1:

Pozzolana + calcium hydroxide + water →C–S–H (gel) (1)

This reaction is called the pozzolanic reaction. The characteristic of pozzolanic reaction is first slow; with the result that heat of hydration and strength development will be accordingly slow. The reaction involves the consumption of $Ca(OH)_2$ and the reduction of the $Ca(OH)_2$ improves the durability of the cement paste by making the paste dense and impervious; [9].

2.3 Material

The Locust Bean Pods used in this research were sourced from Doko town in Niger state of Nigeria. The material is usually available as a waste product of agricultural processing of the locust bean fruits during the harvest season. Locust Bean Pod Ash (LBPA) was produced by incineration attaining 500^{o}c, after which the ash was ground into fine powdery form. The weak sub grade soils were obtained from old borrow pits at chainage 6+950,22+150 and 33+200 locations along existing Minna-Kataeregi-Bida road in Niger state, Nigeria.

III. TEST RESULTS

3.1 Analysis of soil samples

The results of particle size distribution of the soil samples from the three sample locations are shown in Figs' 1.1-1.3(particle size distribution curves), while that of consistency limits of natural soil samples, LBPA stabilized soil samples and AASHTO classification are shown in table 2 accordingly. Improvements can be noticed in the values of consistency limits for the stabilized soil samples.

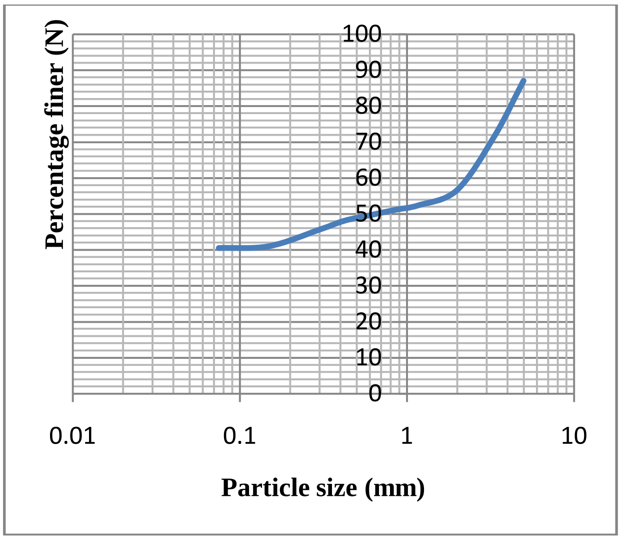

Figure 1.1: Particle size distribution curve Ch6+950

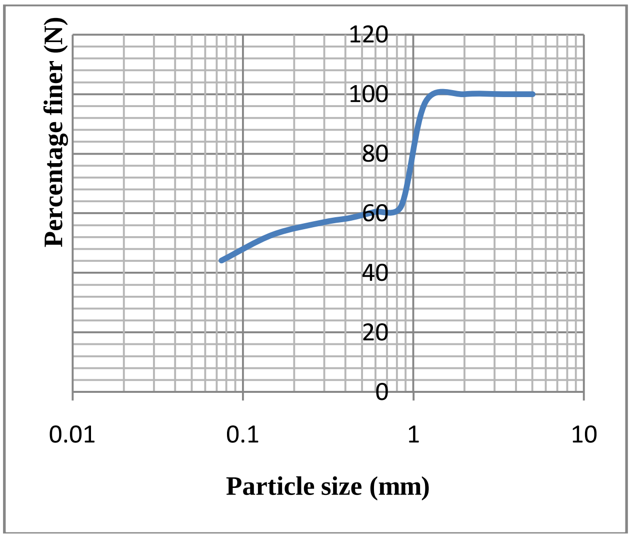

Figure 1.2: Particle size distribution Ch22+150

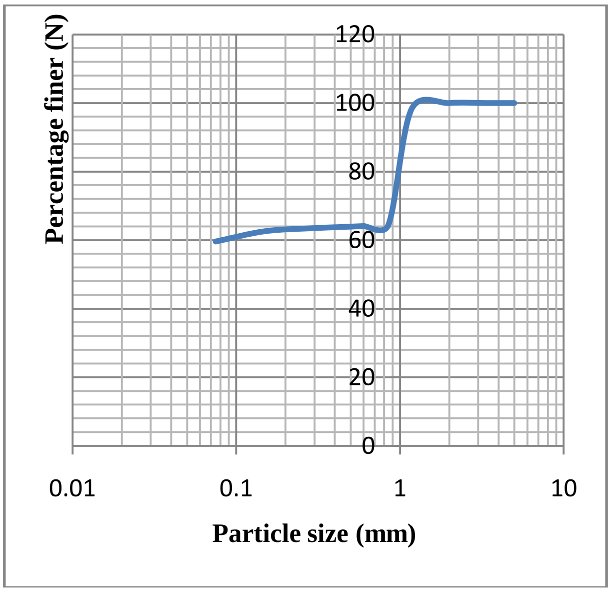

Figure 1.4: Particle size distribution Curve of Soil Sample from Ch33+200

Table 2. Summary of Consistency Limits and Soil Classification

S/NO	LOCATION	LIQUID LIMIT (LL)		PLASTIC LIMIT (PL)		PLASTICITY INDEX (PI)		AASHTO
		A	B	A	B	A	B	
2	6+950	39	43	16	32.8	23	10.2	A-6(4)
5	22+150	44	46	24	28	20	18	A-7-6(5)
7	33+200	49	51	28	41	21.3	10	A-7-6(11)

***Sample A= Natural soil sample, *Sample B= Sample stabilized using Locust bean pod (LBPA) at 10% content**

3.2 Compaction Characteristics of Stabilized Soils

The compaction test gave the maximum dry density and the corresponding optimum moisture content (OMC) of the soils at varying stabilizer content. The summary of the results is presented in table V. Comparing the OMC and MDD of the natural soil samples with those of stabilized soil samples at different levels of concentrations of the stabilizing agent are shown in table 3 and displayed in figs. 1.4-1.5.

Table 3. Effect of Stabilizing Agent (LBPA) on the Soil Samples.

ADDITIVE	CONTENT	Ch 6+950		Ch 22+150		Ch 33+200	
		OMC (%)	MDD g/cm^3	OMC (%)	MDD g/cm^3	OMC (%)	MDD g/cm^3
LBPA	0	10.40	1.68	18.00	1.33	12.03	1.62
‘’	2%	10.60	1.66	18.00	1.31	15.00	1.58
‘’	4%	12.20	1.66	18.90	1.35	17.00	1.61
‘’	8%	11.50	1.66	19.00	1.38	17.00	1.55
‘’	12%	11.50	1.62	19.50	1.304	18.50	1.50

***LBPA=Locust Bean Pod Ash**

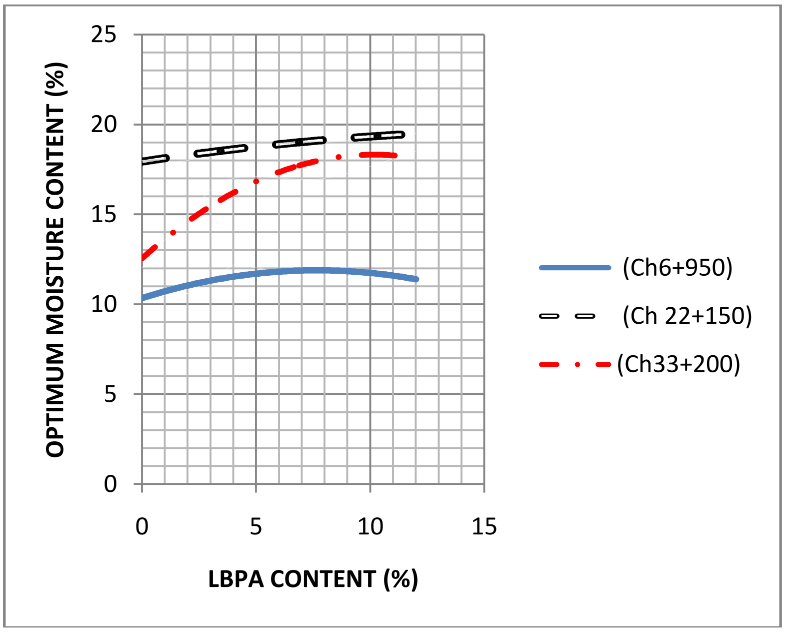

Figure 1.4: Variation of OMC with LBPA content

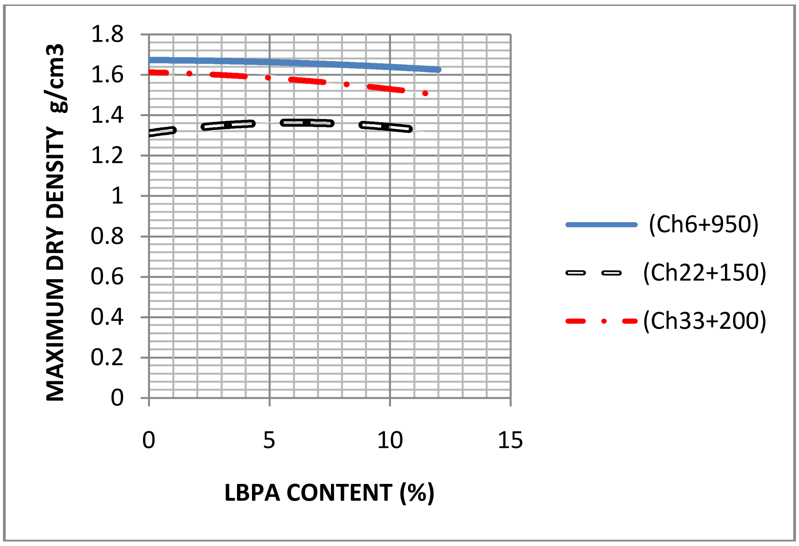

Figure 1.5: Variation of MDD with LBPA content

IV. DISCUSSION OF RESULTS

The trends of the effect of LBPA on compaction characteristics of the various soil samples at varying LBPA content are shown on figs.1.4-1.5. The optimum values of 6-10 % of LBPA will suffice considering pattern of the output on figs. 1.4-1.5. Also there was general increase in OMC values of LBPA stabilized samples as compared to the natural sample likewise there was general decrease in the values of MDD. The increase in OMC values suggests that additional water was held in the soil structure resulting in LBPA interaction with the soil particles involving ionic exchange to form calcium silicate cement. This reaction is water insoluble. As with pozzolanic materials a gel is formed by the removal of silica from the clay minerals of the soil to combine with calcium, alumina and silica from LBPA. The silicate gel proceeds immediately to coat and bind clay lumps in the soil to block off the soil voids in the soil structure. In time this gel gradually crystallizes into well defined calcium silicate hydrates. The micro crystals also interlock and the reaction ceases on drying; as very dry soils will not react with pozzolanic materials. On the other hand the decrease in MDD values suggests a possible effect of the LBPA on the particle size and specific gravity of the soil. The decrease in MDD indicates that low compactive energy is needed to attain the maximum dry density; as a result, the cost of compaction will be reduced thus make working with LBPA stabilized weak soils (AASHTO class A6- A7) more economical than in the natural state.

V. CONCLUSION

The results of the compaction characteristics of LBPA stabilized soil samples and that of natural soil samples showed that LBPA had effect on the compaction characteristics of the soils by increasing the optimum moisture content (from 10.4-11.5 %, 18.0-19.5% and 12.03-18.50 % respectively for the various soil samples) and reducing the maximum dry density (from 1.68-1.62, 1.33-1.304 and 1.62-1.50 respectively for the various soil samples) thus, improving the compaction properties of the soil and making it more suitable to carry heavier loads. As such, it can be recommended for use as a chemical stabilizing agent in weak soils for road construction.

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