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Stabilization of Lateritic Soil with Mahogany (Hardwood) Sawdust Ash

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Abstract: Most naturally occurring laterites possess poor engineering properties despite their extensive uses for filling and subgrade materials. Few works have been reported on the use of mahogany sawdust ash (MSA) for the stabilization of lateritic soils. This investigation explores the effect of Hardwood Sawdust on the performance of lateritic soils as an engineering material. Particle size distribution, natural moisture content, specific gravity and consistency limits tests were conducted on soil samples obtained from burrow pits at Oke-Baale roundabout of Osogbo West-Bye pass road under construction for classification purpose. Engineering behaviour was also investigated through compaction and unsoaked California Bearing Ratio (CBR) performed on natural and admixed specimens, with the inclusion of 2, 4 and 6% MSA by weight of soil. Preliminary tests indicate that the natural samples were well-graded and rated medium as subgrade material in road construction. Reduction in the plasticity index (PI) of samples from 17 to 14% at 4% MSA were observed. MDD decreased to 1.54, 1.38 and 1.45 Mg/m^3 at 2, 4 and 6% MSA respectively. The CBR increased to 18.8, 20.2 and 20.4% at 2, 4 and 6% MSA respectively. The research demonstrated that there is an impressive potential for MSA to enhance the mechanical properties of lateritic soils.

Keywords: Hardwood Sawdust Ash, Compaction, California bearing ratio, Stabilization, Laterite

I. Introduction

Laterite is extensively used for filling and as subgrade material in Civil Engineering. Most naturally occurring laterites possess poor geotechnical ratings such as high swelling and shrinkage response to moisture variation, high permeability and compressibility of the soil mass, low bearing capacity especially in soils supporting structures, and instability [1, 2, 3]. Many researchers have worked on various means of enhancing the engineering properties of Lateritic Soils [2, 3, 4, 5, 6.]

The enhancement of lateritic soils to meet engineering requirements could be via modification and/or stabilization. Soil modification is the inclusion of modifier such as cement, lime among others, to a soil to alter its index properties, while soil stabilization is the treatment and subsequent compaction of perceived weak soils to enhance their strength and durability such that they become viable for a specific engineering purpose beyond their original classification [5]. The excessive usage of industrially sourced additives such as cement, lime among others keeps the cost of constructing stable roads financially high [2]. It becomes imperative to obtain a locally available, naturally occurring material that could effectively be used to ameliorate the engineering performance of lateritic soil. This led to studies on agricultural by-products that possess pozzolanic properties. Bello *et al.,* [2] observed that rice husk ash improves the bearing capacity of lateritic soil. [3] concluded in a study using cassava peel ash-lime admixture that there is an improvement in the qualities of soil samples. The stabilizing effects of cement-bamboo leaf ash admixture were also observed in another

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study [7]. Sugar cane straw ash was also found to be an efficient lateritic soil stabilizer [4]. Gbenga and Oluwatosin [6] observed that softwood ash has a higher influence on soil CBR than hardwood ash. Despite the abundance of hardwood sawdust in our numerous sawmills, with most hardwoods having a higher density than most softwoods, studies have not shown the stabilizing effects of hardwood sawdust ash on lateritic soils. Thus, this study investigates the stabilization effect of mahogany (hardwood) sawdust ash on lateritic soil.

II. Materials and Methods

A. Materials

i. Lateritic Soil

The disturbed samples of the lateritic soil used in this study were obtained from Oke-Baale roundabout of Osogbo West-bye pass road under construction by Osun State Government from a borrow pit at the depth of between 1.0 m and 2.0 m. Geological maps and soil study of Nigeria after [8,9] indicates that the area of study lies within the South Western Nigeria basement complex (latitude 7^{o}55'N and longitude 4^{o}23'E) in which the predominant compositions are folded gneisses, migmatite, schist, and quartzite of the Precambrian age. Samples were collected in medium-sized moisture preserving bags and transported to the Soil Mechanics Research Laboratory of the Department of Civil Engineering, Osun State University, Osogbo, Osun State. The Soil Samples were air-dried under laboratory conditions after taking representative specimens for natural moisture content determination.

ii. Mahogany (Hardwood) Sawdust Ash The mahogany sawdust ash used in this study was obtained from a sawmill in the vicinity of Oke-Baale, Osogbo, Osun State, South-Western Nigeria. The Saw Dust was calcinated under a controlled temperature of about 700^{o}C – 800^{o}C to obtain the ash. The sieving of the sawdust ash was done through BS Sieve No 200 and the fraction passing through the sieve was used for the study. Air-tight containers were used to store the sieved ash immediately after sieving to prevent pre-hydration when left in the open air or during storage.

iii. Water

Portable water was used for the preparation of the specimens at the various moisture contents

B. Methods

i. Sieve Analysis

Particle size distribution of the clay-size (<0.002mm) fraction of fine-grain soil can be determined using hydrometer analysis when the percentage finer than sieve no. 200 is greater than 10%. 250 g of the soil sample was measured, soaked in potable water for 48 hours to soften dry clods and washed through BS No: 200 (0.075mm) sieve. The soil retained after washing through 0.075mm opening sieves was transferred into a small metal bowl, oven-dried and sieve as outlined in [10] for three replicates for each specimen. Less than 10% of the soil pass through sieved 0.075mm opening, hence the minimum requirement for sedimentation analysis to be done was not met.

ii. Atterberg Limit

Standard procedure as outlined in [10] was observed in the determination of liquid and plastic limits.

iii. Natural Moisture Content and Specific Gravity

Natural moisture content and specific gravity determination followed the standard as outlined in [10]

iv California Bearing Ratio (CBR) Tests

This test was performed by measuring the pressure required to penetrate a soil sample with a plunger of standard area. The recorded pressure is divided by the penetration on the standard crushed rock material. The procedure conforms to that outlined in [6].

III. Results and Discussion

A. Index Properties

Table 1 shows the particle size distribution of the natural sample, while Table 2 shows the identification properties which include liquid limit, plastic limit, specific gravity, and percentage passing sieve No. 200 of the natural sample used for this research reveals that the natural soil sample is A-7-5 according to the AASHTO and as SM according to USCS classification systems, having a medium plasticity index of 17.46%.

Table 1: Particle size distribution of the control sample

Opening (Mm)	Mass Retained (G)	Percentage Passing
4.72	18.2	90.20
2.36	28.2	76.8
1.18	21.16	6.25
0.6	12	60.25
0.425	27.2	46.65
0.3	5.0	44.15
0.212	3.2	42.55
0.125	4.5	40.2
0.075	2.5	38.95
PAN	77.9	9

Table 2: Index property of the control sample

Properties	Soil sample
Colour	Reddish-brown
Natural moisture content, %	20.13
Specific gravity	2.22
Liquid limit, %	52.23
Plastic limit, %	34.77
Plasticity index. %	17.46
% Passing BS No. 200 sieve	38.95
Group Index	6.0
AASHTO classification	A-7-5
USCS classification	SM
Maximum dry density (Mg/m^3)	1.92
Optimum moisture content (%)	17.39

B. Atterberg Limit

The results of the MSA stabilization on the Atterberg limit of the samples are shown in Figure. 1. For the untreated sample, the liquid limits (LL), Plastic limits (PL) and the PI are 52.23, 34.77 and 17.46% respectively. According to [11], when LL falls below 35% the soil is of low plasticity, from 35% to 50% it is of intermediate plasticity, from 50% and 70% high plasticity and very high plasticity when above 70%. Thus the natural sample is of high plasticity. The addition of different percentages of MSA to the soil sample produced changes in the LL and PL of the sample in the range of 50 – 56% and 34 – 41% respectively. The minimum PI (14%) occurred at 4% MSA treatment. A reduction in PI values indicates more stable soil with increased workability [3]. This indicates that the optimum stabilization mix is 4% of MSA in sample.

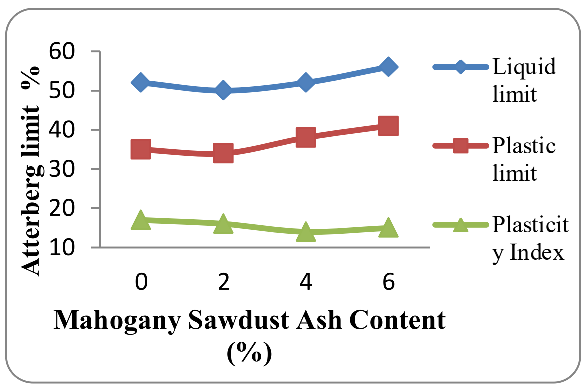

Figure 1: Atterberg limit of stabilized soil sample

C. Compaction

The compaction characteristics of the stabilized specimens are presented in Figures. 2 and 3. The treatment of the soil with MSA produced a general decrease in MDD from 1.99 Mg/m^3 at control to a minimum of 1.38 Mg/m^3 at 4% treatment. The OMC increases from 17.3% at control to a maximum value of 23.12% at 4% treatment making the soil sample less workable. An increase in MDD indicates amelioration of specimen parameters and a reduction in OMC gives good workability of the soil. The increase in OMC might be due to increased water demand by the cations in the additive and clay mineral particles to undergo hydration [12, 13].

D. California bearing Ratio

The results of the CBR tests of the stabilized soil as shown in Figure. 5 indicate a general increase in CBR to an optimum value of 20.2% at 4% treatment. This indicates strength increase and is attributed to the presence of calcium which is required for the formation of calcium silicate hydration (CSH), the major element for strength gain. The specification requirement under clause 6201 of the Federal Ministry of Works & Housing (F.M.W & H) is that after not less than 48 hours of soaking, minimum strength for subgrade/fill must not fall below 10% unsoaked CBR. In this regard, the soil samples are suitable for subgrade/fill as the CBR values meet the specification of the Federal Ministry of Works and Housing.

IV. Conclusion and Recommendation

The natural soil sample used in this study is classified as A-7-5 according to the AASHTO and as SM according to USCS classification systems. The consistency limits give an indication of soil improvement as the PI reduces to a minimum of 14 % at 4 % MSA treatment. Also at the instance of the MSA, the compaction characteristics followed the trend of decreasing MDD and a corresponding increase in OMC. An unsoaked CBR value of 20.2 % is obtained at 4 % MSA treatment and this satisfies the minimum 10 % requirement for subgrade material. This study shows that the use of MSA improved the strength of lateritic soil. An optimum value of 4% MSA has the ability to efficiently stabilize laterites that have California Bearing Ratio (CBR) value below specification for subgrade in pavement construction.

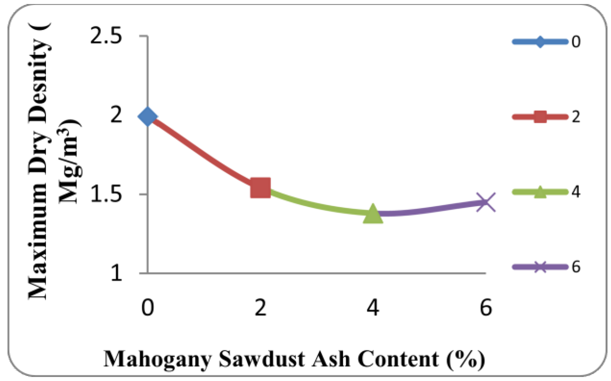

Figure 2: Maximum dry density against MSA content

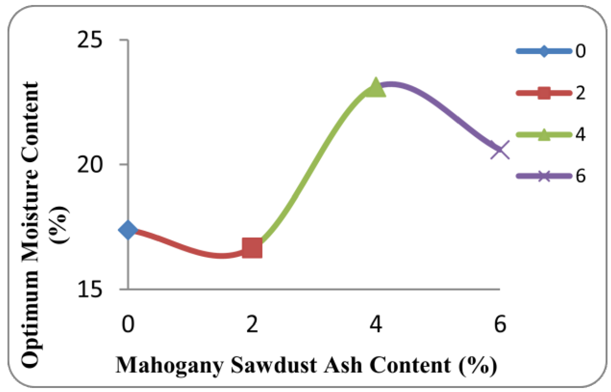

Figure: 3: Optimum moisture content against MSA content

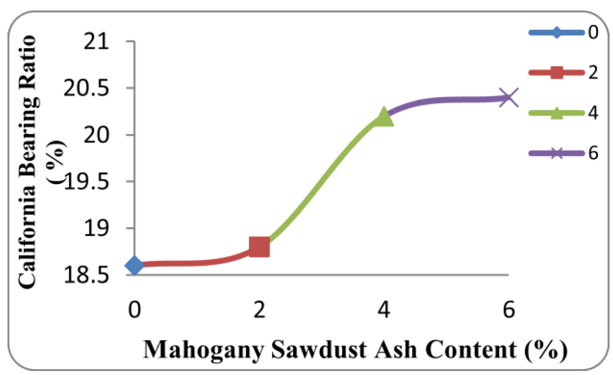

Figure 4: California bearing ratio against MSA content

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