

STABILIZATION OF LATERITIC SOIL USING COW BONE ASH AND SAWDUST ASH

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Abstract

This study investigates the geotechnical properties of lateritic soils and evaluates the effects of cow bone ash (BA) and sawdust ash (SDA) as stabilizers for road construction. Lateritic soil samples were collected from two locations within Ile-Ife, Osun State, Southwest Nigeria. The soils were classified as A – 2 – 7 with intermediate to high plasticity. Mixtures with different proportions of cow bone ash and sawdust ash (2%, 4%, 6%, and 8% by weight) were studied to determine the optimum mix. The unsoaked California bearing ratio (CBR) values increased significantly, reaching a range of 2.17% to 13.20% and 1.74% to 22.82% from the initial value of 1.8% and 2.98% for collected samples A and B, respectively. The results revealed that the mix proportion of 4% bone ash and 2% sawdust ash exhibited the most favourable outcomes, including increased maximum dry density and CBR and decreased moisture content. The addition of BA and SDA improved the soils' engineering properties. These findings highlight the potential of bone ash and sawdust ash as effective stabilizers for lateritic subgrade soils in road construction.

KEYWORDS: Sawdust Ash, Cow Bone Ash, Lateritic soils, California bearing ratio, Optimum Moisture Content.

1. INTRODUCTION

In Civil engineering, soil stabilization is a technique for refining and improving the engineering properties of soils. These properties include mechanical strength; permeability, compressibility, durability, and plasticity. Physical or mechanical improvement is mostly referred to as stabilization of chemical improvement in the soil properties by adding chemical admixtures [1].

Soil improvement can take the form of either soil modification or soil [2]. Modification refers to short-term soil improvement that occurs during or shortly after mixing (within hours). This process reduces the plasticity of the soil, thereby improving its consistency to the desired level and increasing its short-term strength (strength derived immediately and within about 7 days after compaction). Even without remarkable pozzolanic or cementitious reactions, the textural changes accompanying consistency improvements usually result in measurable strength improvement [3].

Stabilization, on the other hand, occurs when a significant longer-term reaction takes place. This reaction can be attributed to the hydration of calcium silicates and calcium aluminates in Portland cement or class C fly ash or due to pozzolanic reactivity between free lime and the soil pozzolan or added pozzolan. A strength increase or greater (of the stabilized soil strength compared to the untreated soil strength under the same conditions of compaction and cure) serves as a reasonable basis for stabilization [3].

According to [4], soil stabilization is the process of altering the geotechnical properties to meet engineering requirements. It has been used in landfill mines, road construction, aircraft runways, earth

drains, embankments, erosion control, and in reducing costs by employing stabilized soil for building houses in undeveloped regions of the world [5].

The concept of soil stabilization is of utmost necessity in civil engineering projects, such as roadways, building foundations, and dams, among others, given that most lateritic soils, in their natural states, commonly have low bearing capacity and low strength due to high clay content. When lateritic soil consists of highly plastic clay, the plasticity of the soil may cause cracks and damage to civil engineering projects. Consequently, improving the strength and durability of lateritic soil has become imperative, leading researchers to explore the use of stabilizing materials that can be sourced locally at a very low cost. These local materials can be classified as either agricultural or industrial wastes [6].

One type of agricultural waste of great concern in both rural and urban areas of Nigeria is abattoir or slaughterhouse waste. Abattoir wastes often contain blood, bones, horns, fat, organic and inorganic solids, and salts and chemicals added during the processing operation. The bones, when partially burnt, are seen around slaughterhouses in market areas of major towns in Nigeria. Its ash is obtained as the powdered residue left from the burning of bones [7].

Wood ash is a solid residue of the combustion of sawdust or wood in air, composed of carbonates and oxides of metals (e.g., calcium and potassium) originally compounded in the plant's woody tissues, which are present in the residue [8]. Most woods contain approximately 0.05 – 2.0 % by weight of non-combustible materials, predominantly potassium oxide (K_2O) [8]. This ash has been confirmed to be a good source of potassium, phosphorus, magnesium, and calcium [9][10]. Previous studies have indicated that wood ash has similar liming effects as commercial lime [11][12].

In addition to this, sawdust from any logging industry needs to be properly handled and adequately disposed of. Sawdust, though an inert material, could pose a serious threat to the geotechnical properties of soil wherever it is found because it is highly biodegradable. It is obtained in large quantities from logging industries where timber is processed into various useful forms. Large quantities of it can be found in Nigeria around sawmills and wood-based industries [13]. This large quantity of sawdust produced, usually in large heaps around sawmills and wood-based industries, normally poses environmental disposal problems. Therefore, many sawmill operators resort to uncontrolled burning [14][15][16]. The burning process produces smoke and offensive gases like carbon dioxide and carbon monoxide, which are hazardous to human health.

Some studies have been carried out using industrial waste (sawdust ash) or agricultural waste (bone ash) to improve the geotechnical properties of laterite soil. However, this study's scope entails the application of a combination of the two stabilizers. This approach is expected to not only efficiently affect the stability of the lateritic soil but also reduce the construction cost as the materials can be locally obtained.

2. MATERIALS AND METHODS

2.1 Materials

Lateritic soil, sawdust ash, and cow bone ash were employed for this research. Disturbed lateritic soil samples were collected from two locations namely: *Soil A (Lat. 4° 31' 24" N and Long. 7° 31' 19" E)* and *Soil B (Lat. 4° 31' 59" N and Long. 7° 31' 11" E)* respectively in Ile – Ife, Nigeria, at a depth of approximately 1.50 meters below the ground level. Cow bone ash (BA) was obtained from abattoirs, sun-dried, incinerated at 750°C for 4 hours, ground, and sieved through a 75 µm aperture. Sawdust from a local sawmill in Ile - Ife, Osun State, was air-dried, calcined at 600 °C, and sieved through a 75 µm sieve, using only the resulting fine ash for laboratory work.

2.2 Methods

The following tests were carried out on lateritic soil differently and marked as control samples before the addition of sawdust ash and cow bone ash to the samples. Mixtures with different proportions of cow bone ash and sawdust ash (2%, 4%, 6%, and 8% by weight) were studied to determine the optimum mix. The tests are moisture content test, particle size distribution, Atterberg limit tests, specific gravity test, compaction test, and California bearing ratio (CBR) test. These tests were carried out under ASTM Standard Methods [17; 18, 19] of testing soil for Civil Engineering purposes.

3. RESULTS AND DISCUSSIONS

3.1 Preliminary test on the soil samples

The engineering properties of the soil samples were determined as summarized in Table 1. The natural moisture content of the soil samples is 21.57 % and 25.46 %. The specific gravity values are 2.68 and 2.16 for samples A and B respectively.

Table 1: Result of tests on lateritic soil (Control Samples)

Test	Results	
	Sample A	Sample B
Natural moisture content	21.57%	25.46%
Optimum moisture content	32.00 %	20.20%
Maximum dry density	14.80 kN/m ³	17.41 kN/m ³
Liquid limit	48.22%	56.38%
Plastic limit	27.54%	31.88%
Plasticity index	20.68%	24.50%
Specific gravity	2.68	2.16
% of soil passing BS Sieve No. 10	70.21%	64.80%
% of soil passing BS Sieve No. 40	31.23%	29.00%
% of soil passing BS Sieve No. 200	2.40%	1.00%
AASHTO Classification of soil	A -2 -7	A -2 -7
USCS Classification of soil	SP	SP
California Bearing Ratio (CBR)	1.80 %	2.98 %

The Atterberg limit state revealed that the liquid limit (LL) values are 48.22% and 56.38% respectively for lateritic soil sample A and B while 27.54% and 31.88% were got for plastic limit (PL). The plasticity index (PI) was also determined to be 20.68% and 24.50% sample A and B respectively.

3.2 Tests on Lateritic Soils

Table 2 presents the results of unsoaked California Bearing Ratio (CBR), Optimum Moisture Content (OMC), and Maximum Dry Density (MDD) for lateritic soil samples A and B when used with and without the stabilizers. The variation of CBR values of the soil samples with the addition of stabilizers is shown in Figure 1 and Figure 2. It was observed that the CBR of the soil samples significantly increased upon stabilization with bone ash and sawdust ash. This improvement is attributed to the pozzolanic reaction that enhances the strength properties [20]. Generally, there was an improvement in the CBR values of the stabilized soil samples, as indicated in Figure 1 and Figure 2 (except for 6% BA plus 2% SDA, 6% BA plus 4% SDA, and 6% BA plus 2% SDA treatments on sample B). This suggests that the soil's load-bearing capacity increased with the stabilizers' content, consequently enhancing the engineering properties of the soil. An increase in CBR is a positive indication of soil improvement [21].

However, the gradual decrease in CBR value after 4% BA, 6% SDA, and 4% BA plus 2% SDA in both samples indicates that excessive content of stabilizers might not have fully participated in the reaction, thus occupying spaces within the soil sample.

Table 2: Summary of the compaction and CBR tests for different percentages of bone ash and saw dust ash for samples A and B

%Bone ash	%Sawdust ash	OMC (%)		MDD (kN/m ³)		CBR (%)	
		Sample		Sample		Sample	
		A	B	A	B	A	B
0	0	27.80	20.20	15.90	17.41	1.80	2.98
2	0	30.20	20.90	15.25	18.51	3.35	4.71
4	0	29.60	19.00	15.11	18.19	8.93	18.72
6	0	26.00	17.12	14.80	18.23	10.17	32.00
8	0	29.00	23.50	14.99	17.30	6.51	3.10
0	2	26.30	18.50	15.65	18.20	4.22	17.36
0	4	28.00	19.70	15.40	18.22	13.58	19.10
0	6	30.00	19.60	16.36	17.73	16.12	35.84
0	8	30.10	20.30	15.10	18.05	4.09	32.24
2	2	27.50	17.10	15.30	17.32	5.02	14.63
2	4	29.00	20.00	15.28	17.10	3.04	5.21
2	6	26.10	18.90	15.25	17.42	10.91	12.03
4	2	24.50	17.00	16.30	17.65	13.20	22.82
4	4	27.50	18.00	15.20	17.10	8.00	18.35
4	6	28.60	21.50	15.32	16.73	3.60	2.60
6	2	27.50	21.70	14.78	16.92	4.15	1.74
6	4	29.00	24.50	14.85	15.80	4.22	1.86
6	6	29.00	20.00	14.90	16.90	2.17	1.86

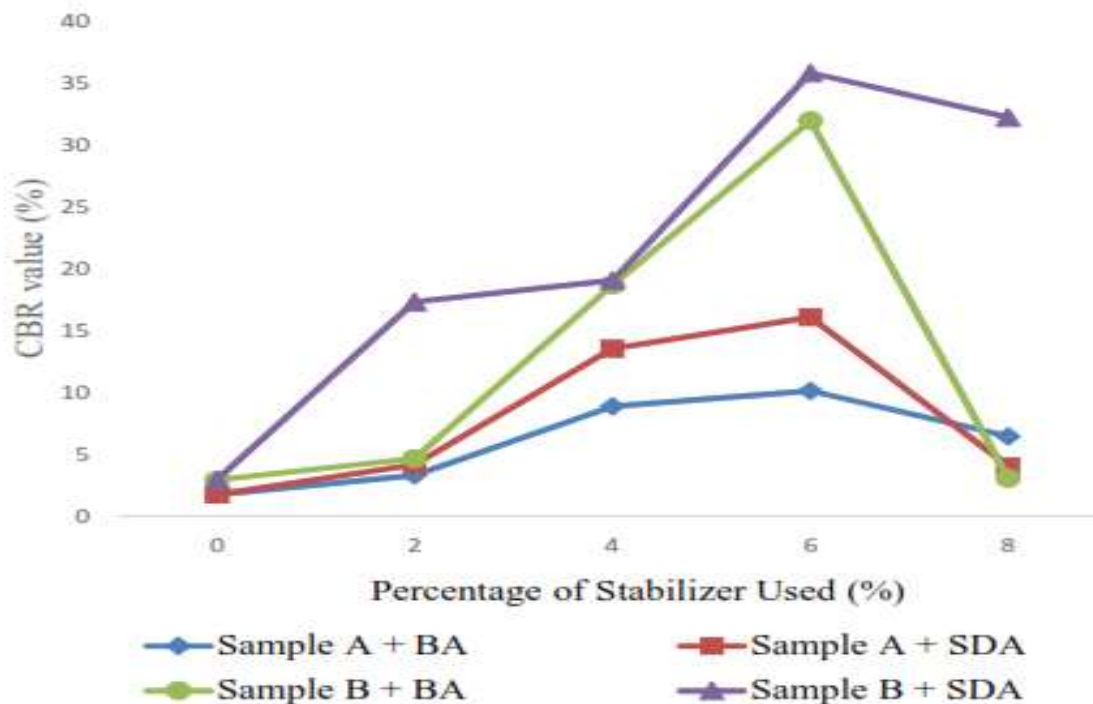


Figure 1: Variation of California Bearing Ratio with BA and SDA

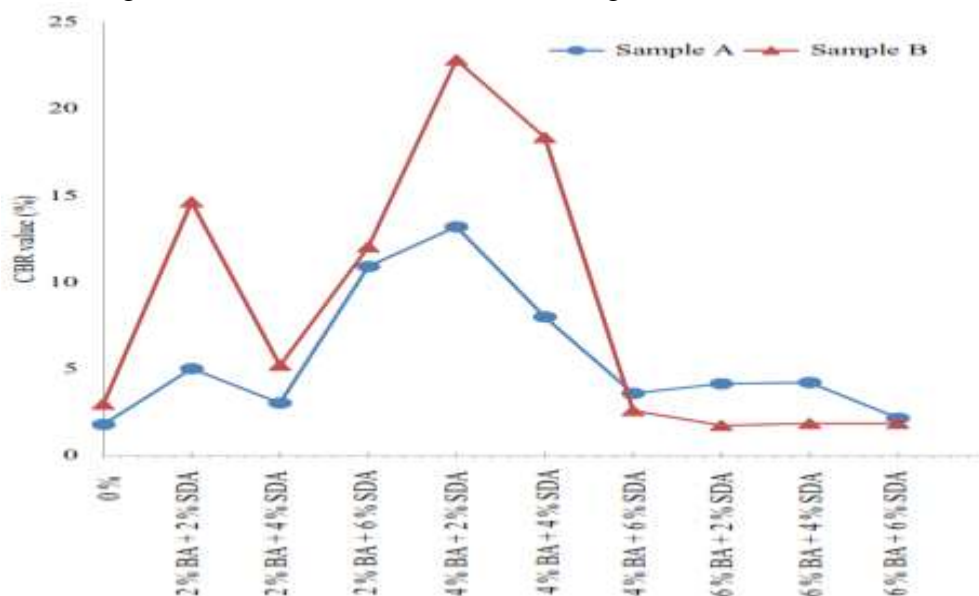


Figure 2: Variation of California Bearing Ratio with a mixture of BA and SDA.

With the use of the two stabilizers on the soil sample B in varying percentages, it was observed there was a general decrease in the OMC as shown in Figure 3 (except at 4 %BA plus 6 % SDA, 6 %BA plus 2 % SDA and 6 %BA plus 4 % SDA) and MDD as shown in Figure 4 (except at 4 %BA plus 2 % SDA) in the variations. Their treatments with sample A resulted in fluctuating increases and decreases in the OMC as shown in Figure 5 with the lowest recorded at 4 % BA plus 2 % SDA. Figure 6 shows the variation of maximum dry density with a mixture of BA and SDA.

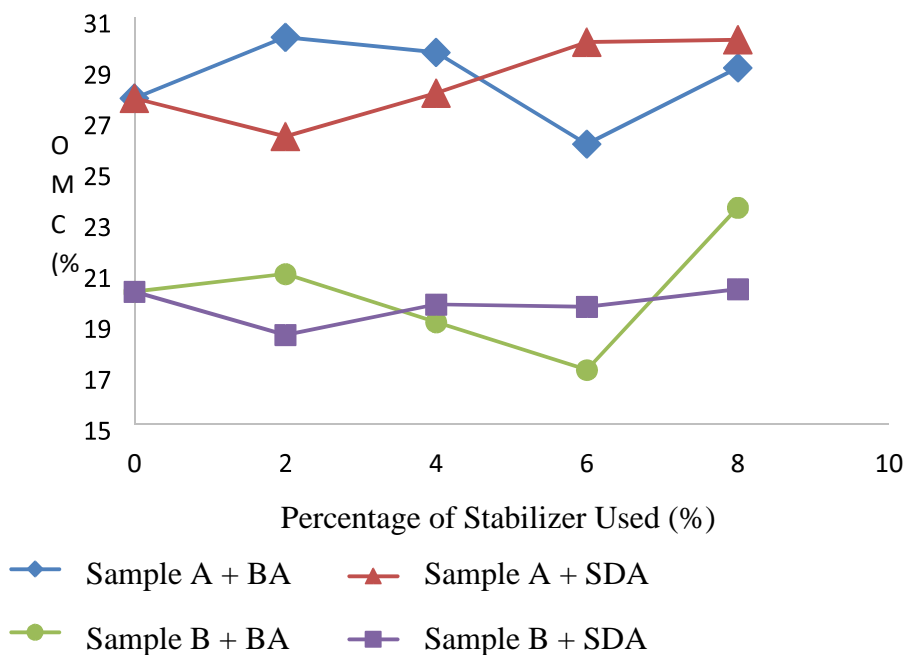


Figure 3: Variation of Optimum Moisture Content with BA and SDA.

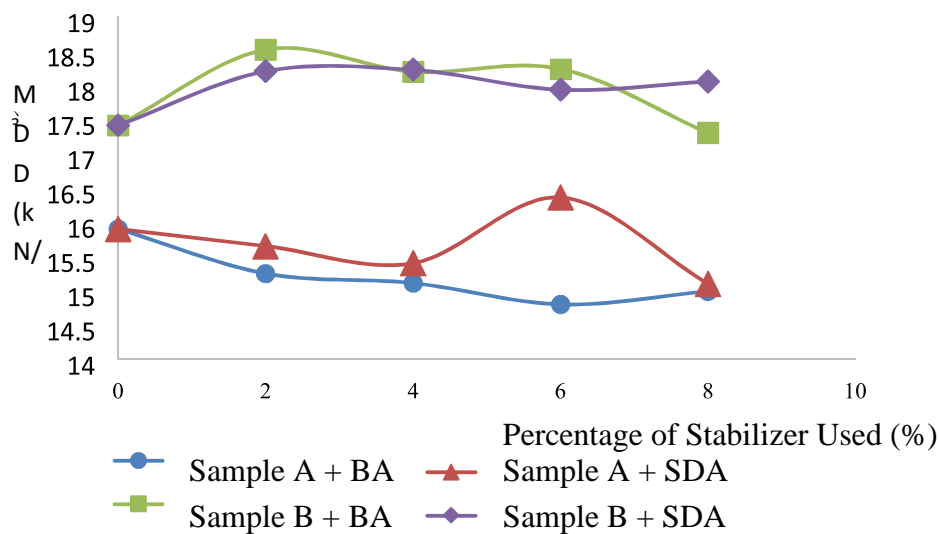


Figure 4: Variation of Maximum Dry Density with BA and SDA

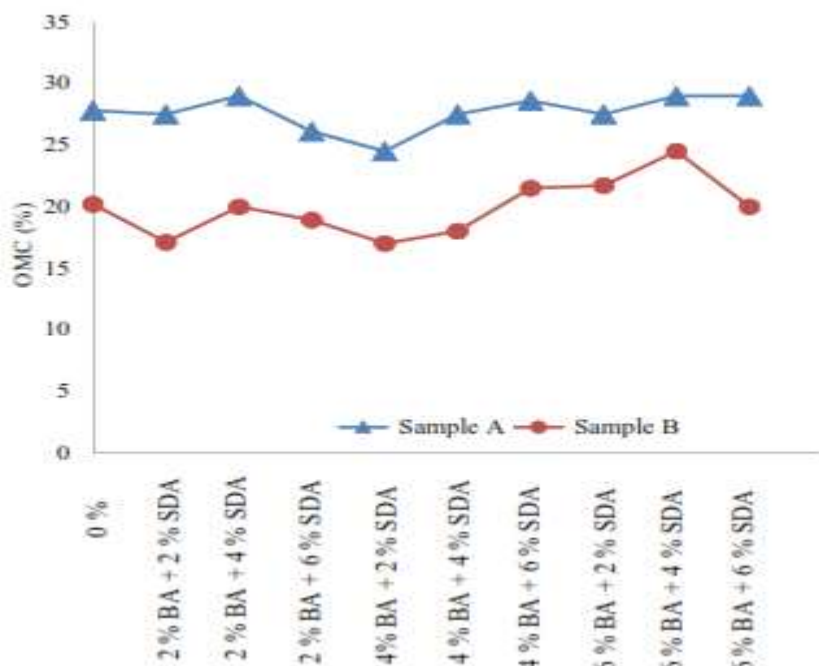


Figure 5: Variation of Optimum Moisture Content with a mixture of BA and SDA

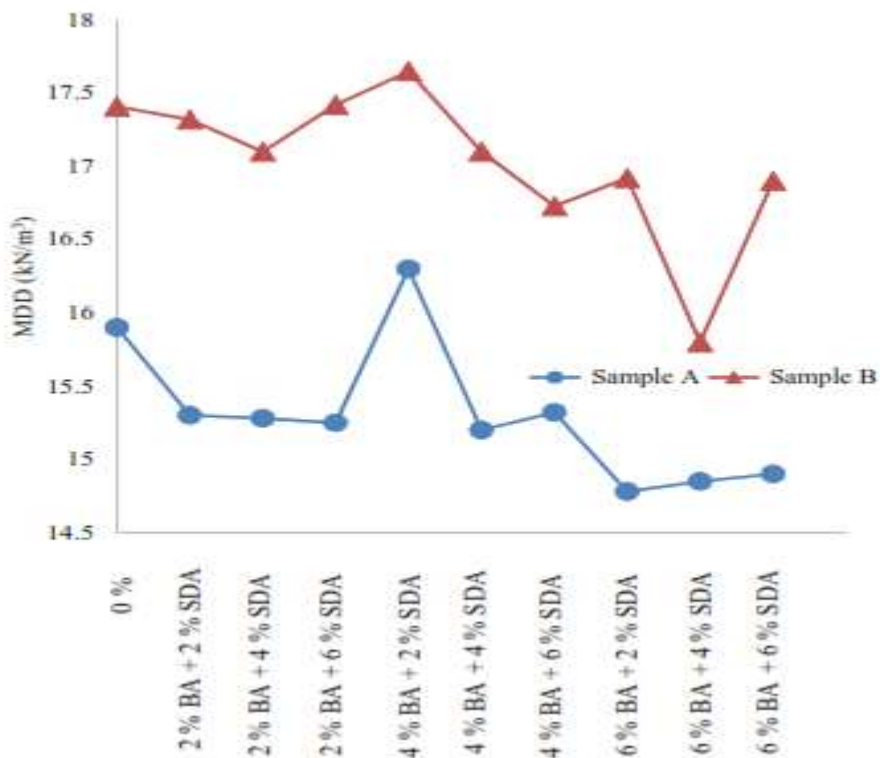


Figure 6: Variation of Maximum Dry Density with a mixture of BA and SDA

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The research work showed from the compaction characteristic and CBR tests, that there was an effective change in the properties of the natural soil samples with the addition of bone ash and saw dust ash in varying percentages. Out of every variation, it was observed that only 4 % BA plus 2 % SDA mixture has the increase in MDD and CBR and a decrease in OMC consistently for both samples following [22] and [21]. In summary, it could be concluded that 4 % bone ash with 2 % saw dust ash can be used to significantly improve the strength of lateritic soil.

4.2 Recommendations

Sequel to the results of the project, it is suggested also that more extensive studies can be carried out to find the effect of bone and saw dust ashes on various groups of lateritic soils.

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