

Original Research

Effect of Cow Bone Ash on A Stabilized Lateritic Soil for Road Work

¹Abdulrauf Toyin KURANGA, ²Sulaiman Olayinka SUBAIR and ³Habeeb SOLIHU

^{1,2,3} Department of Civil Engineering, Kwara State University, Malete, Nigeria

Received: 12 April 2025

Accepted: 03 May 2026

Published: 05 May 2026

Abstract

This research investigates the potential of cow bone ash (CBA) as a stabilizer for lateritic soil, aiming to improve its geotechnical properties for road construction and mitigate environmental pollution from bone waste disposal. Lateritic soil samples were collected from Peke Airport Road and stabilized with varying percentages of CBA (0%, 2%, 4%, 6%, 8%, and 10%). Standard laboratory tests, including specific gravity, particle size distribution, Atterberg limits, compaction, and California Bearing Ratio (CBR), were conducted according to British Standards (BS 1377: 1990 and BS 1924: 1990). demonstrating improved geotechnical properties such as increased unsoaked and soaked CBR values (from 51.0% to 57.0% with 10% CBA), reduced Atterberg limits (LL decreased from 44.5% to 30.0% with 10% CBA), and enhanced compaction characteristics (MDD increased from 1660 kg/m³ to 1770 kg/m³ with 10% CBA), while also considering the trade-off of increased optimum moisture content (OMC) from 12.0% to 17.5% with increasing CBA content, necessitating further analysis to determine the optimal CBA percentage for optimal stabilization.

Keywords: Cow Bone Ash, Lateritic Soil, Geotechnical Tests, Road Stabilization, Road Work

1. Introduction

1.1 Background and Rationale

Soil stabilization plays a vital role in achieving durable and dependable structures using locally sourced earth materials. It enhances the engineering performance of soils by improving strength, increasing particle bonding, minimizing voids, and reducing volume changes associated with moisture fluctuations. In addition, stabilized soils exhibit greater resistance to environmental effects such as erosion, rainfall, and wind action. Stabilization techniques are generally classified into mechanical, physical, and chemical methods [1].

The choice of construction materials is largely influenced by their availability and cost. In many developing nations, the high cost of conventional building materials poses a major challenge to

affordable housing delivery. This situation highlights the need to explore alternative materials derived from locally available resources that are both economical and sustainable [1].

In Nigeria, cow bones are generated in significant quantities as waste products from abattoirs. These bones can be processed into bone ash, providing a useful alternative material for engineering applications. Current disposal practices, such as indiscriminate dumping and open-air burning, contribute to environmental pollution and health risks. The conversion of cow bones into ash for use in road construction, particularly in rigid pavement systems, offers multiple advantages. These include improved waste management, reduction in landfill usage, decreased environmental pollution, and potential economic benefits for local stakeholders. Furthermore, producing bone ash consumes less energy compared to the manufacture of Portland cement, thereby reducing dependence on imported materials and conserving foreign exchange [2].

The properties of soil have a direct impact on the performance and stability of civil engineering structures such as roads, buildings, and dams. For any construction project to be successful, the underlying soil must possess adequate engineering characteristics. Poor understanding of weak soil behavior can result in structural failures. Moreover, the inherent variability of soil across different locations makes it difficult to predict its behavior accurately. Therefore, proper site investigation and soil testing are essential prior to construction. In cases where the natural soil is unsuitable, stabilization techniques provide a more economical alternative to complete soil replacement by improving the in-situ properties of the soil [3].

Broadly, soil stabilization encompasses a range of methods aimed at modifying soil properties to enhance its engineering performance [4]. It is widely applied in infrastructure projects, particularly in the construction of highways and airfield pavements, where improved strength and durability are required. The primary objective is to increase soil stability while reducing construction costs through the use of readily available materials. Additional benefits of soil stabilization include energy conservation, dust suppression, water resistance, and improved long-term durability [5].

Laterite is a naturally occurring material rich in iron and aluminum, typically found in tropical and subtropical regions characterized by high temperature and rainfall. Its distinctive reddish coloration is due to the presence of iron oxides. Lateritic soils are formed through intense weathering and leaching processes that remove soluble minerals, leaving behind iron and aluminum-rich residues. While some researchers classify laterite as a rock, others consider it a type of soil depending on its formation and characteristics [6].

Lateritic soils are widely used in construction due to their availability and relatively good engineering properties. They are formed from the weathering of parent rock and are generally characterized by a high content of iron and aluminum oxides, with relatively low silica content. However, their properties can vary significantly depending on location and environmental conditions, making them less uniform compared to other soil types [5].

2. Materials And Methods

2.1 Cow Bone Ash (CBA)

The cow bone ash was produced from calcined cow bones locally purchased from an indigenous community abattoir in (Akerebiata, sobi road, Ilorin, Kwara State) already burnt and broken down into smaller pieces. This was later milled to a powdery form using ball mills at the Mineral

Resources Engineering department of University of Ilorin. It was then passed through 425 μm [7] (U.S. No. 40) sieve before being used to stabilize the lateritic soil.



Figure 1: Grinded and calcined Cow bone ash

2.2 Lateritic Soil (LS)

Lateritic soils for this research were obtained from a depth of 1.2m below ground level and the laterite material considered was obtained from a borrow pit located along (Peke) airport road, Ilorin, Kwara State, Nigeria.

The lateritic soil samples were collected air-dried at room temperature and brought to the soil laboratory at University of Ilorin, Nigeria, indicating the soil description, sampling depth and date of sampling.



Figure 2: Laterite Soil

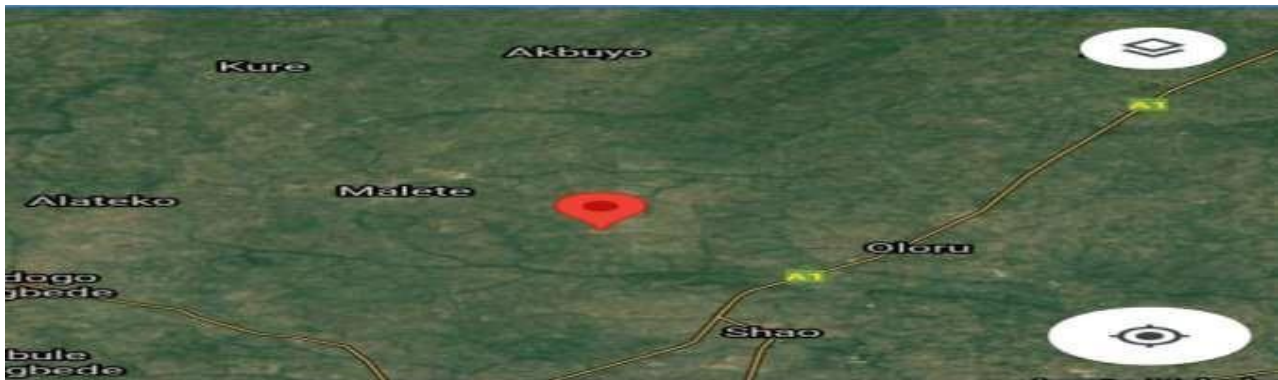


Figure 3: Location of lateritic soil sample (Google map)

2.3 Geotechnical Test

Preliminary tests, including natural moisture content, specific gravity, sieve analysis, and Atterberg limits, were conducted on samples of lateritic soil. The different percentages of cow bone ash (2%, 4%, 6%, 8% and 10%) were used in the stabilization of the lateritic soil samples. The samples obtained were used for the CBR, Compaction, and Atterberg limits tests at various proportions.

Preliminary tests such as moisture content, and Atterberg limits were conducted on the natural soil sample and further stabilized with varying percentages of 2, 4, 6, 8 and 10% respectively cow bone ash. Tests were conducted to determine the maximum dry density (MDD) and optimum moisture content (OMC). The procedures for various tests were carried out in accordance with BS 1377 – 1990:1-8 and the results compared with FMWH [7][8][9] Standards.

3. Results And Discussions

3.1 Sieve Analysis Result

The result of the particle size distribution in percentage weight of soil sample is as shown in Fig. 1. The percentage of soil (35.92%) passing 0.075µm sieve shows that the sample is clayey soil material [10].

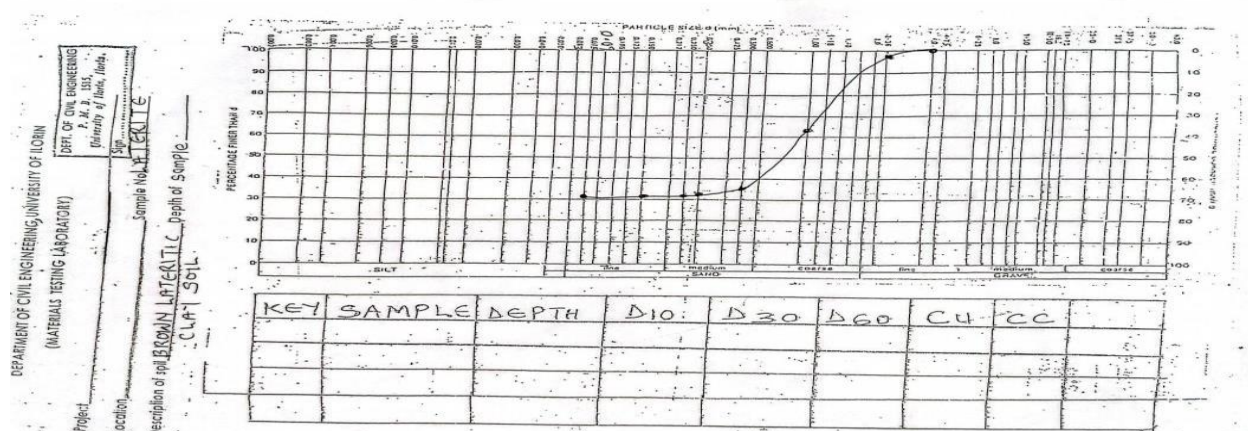


Fig. 4: Particle Size Distribution Curve

Table 1: Engineering Properties of natural lateritic soil sample

Engineering properties	Values
Liquid limit, LL (%)	44.5
Plastic limit, PL (%)	21.1
Plasticity index, PI (%)	23.4
Natural moisture content (%)	13.6
Plasticity Chart Classification	clay
OMC (%)	12
MDD(kg/m3)	1.66
CBR(soaked) %	25
CBR(uns soaked) %	51

3.2 Effect of Cow Bone Ash Stabilization on CBR of Lateritic Soil Sample

From the laboratory test results with 0%, 2%, 4 %, 6%, 8%, and 10% cow bone ash, the CBR values are as shown in Figure 2 below. The Unsoaked CBR increased from 3.2 51.0% for the untreated soil to 57.0% with 10% CBA content. , the Soaked CBR increased from 25.0% to 26.0%. These increases in CBR values indicate an improvement in the soil's strength and load-bearing capacity, which is crucial for road construction as it ensures that the pavement can withstand traffic loads and environmental conditions.

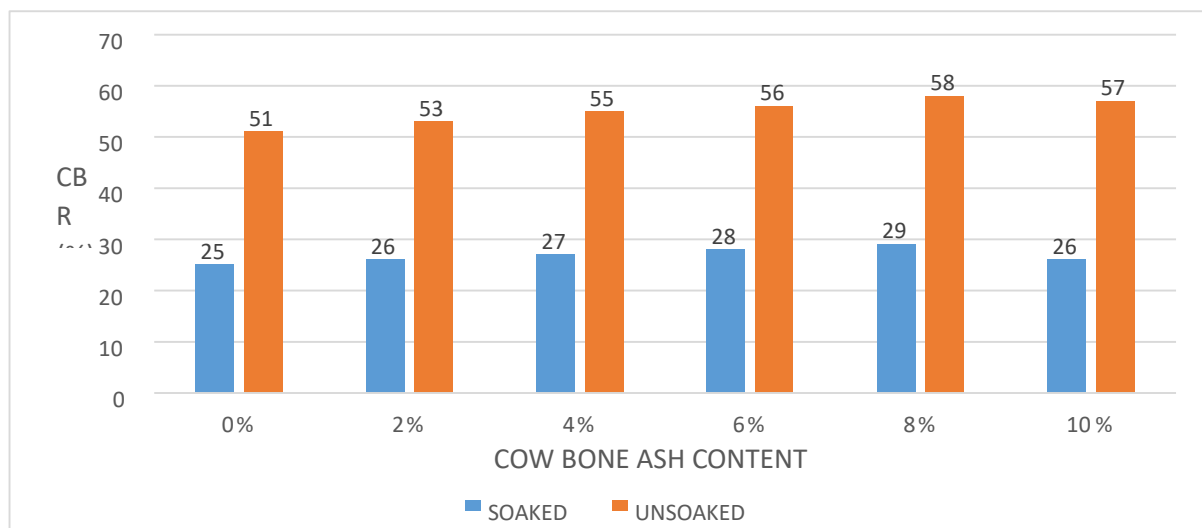


Figure 5: California Bearing Ratio against Cow bone ash.

The results show a clear increasing trend in both unsoaked and soaked CBR values with increasing CBA content. For instance, the unsoaked CBR increases from 51.0% for the control sample to 57.0% with 10% CBA. This indicates that CBA significantly improves the load-bearing capacity of the lateritic soil, making it more suitable for road construction.

3.3 Effect of Cow Bone Ash on Atterberg Limits of The Stabilized Soil

Table 2: Atterberg limit Values for Cow Bone Ash stabilized lateritic soil

	Percentages	Liquid limit	Plastic limit	Plasticity index
Control	0%	44.5	21.1	23.4
CBA	2%	40	17.2	22.8
	4%	37.5	15.1	22.4
	6%	34	16.3	17.7
	8%	36	18.1	17.9
	10%	30	16.6	13.4

Table 1 above illustrates that the Liquid Limit (LL) decreased from 44.5% for the untreated soil to 30.0% with 10% CBA content. Similarly, the Plastic Limit (PL) decreased from

21.1% to 16.6%. This reduction in LL and PL resulted in a significant decrease in the Plasticity Index (PI) from 23.4% to 13.4%, and so on for varying percentage respectively. Indicating a reduction in the soil's plasticity and an increase in its stiffness. This is desirable as it improves the soil's stability and reduces its susceptibility to volume changes due to moisture fluctuations.

The soil sample in its natural state has plasticity index value greater than 11% show the sample as clayey materials. The sample was classified according to AASHTO (1986) as A-7- 6.

3.4 Compaction Test Result

Table 3: compaction values for Cow Bone Ash stabilized lateritic soil

	Percentage	MDD kg/m ³	OMC %
Control	0%	1660	12
CBA	2%	1670	14
	4%	1690	14.5
	6%	1720	15
	8%	1750	16
	10%	1770	17.5

From Table 1 above, the Maximum Dry Density (MDD) increased from 1660 kg/m³ for the untreated soil to 1770 kg/m³ with 10% CBA content. This indicates an increase in the soil's density and compaction potential, which is beneficial for achieving higher strength and stability. However, the Optimum Moisture Content (OMC) increased from 12.0% to 17.5% with increasing CBA content. This suggests that more water is required to achieve maximum compaction with higher CBA percentages.

4. Conclusion

The final conclusion was that Cow Bone Ash can be used to improve the engineering properties of the laterite soil.

- i. The geotechnical properties of lateritic soil in (Compaction, and Atterberg limit). Atterberg limit state revealed that the liquid limit (LL) value is 44.5 for the lateritic soil while 21.1 for

the plastic limit. The plasticity index was also determined to be 23.4. In soaked CBR value was revealed to be 25 whereas unsoaked CBR value was 51 for lateritic soil. The compaction value i.e the MDD and OMC are 1660kg/m³ and 12.0% respectively at control.

- ii. The geotechnical properties of the lateritic soil used in this study enabled us to determine the effect of CBA on the California bearing ratio of the soil. For lateritic soil the maximum amount of CBA that would allow for an increase in soaked CBR value was revealed to be 29 at 8% whereas unsoaked CBR value was 58 at 8%. Atterberg limit i.e the liquid limit was revealed to be 36.0 at 8%, plastic limit to be 18.1 at 8% and plasticity index value was 17.9 at 8%.
- iii. Cow bone ash addition at 2%,4%,6%,8%, and 10% with the soil sample showed that the OMC values of the lateritic soil were constantly increasing. These variations range from 14% to 17.5%. Also, the addition of CBA (2%-10%) to the soil sample resulted in an improvement in MDD values. These variations range from 1670kg/m³ to 1770kg/m³. Cow bone ash addition was shown to work best at 8% content for soil sample.

5. Recommendations

- i. Conduct a cost-effectiveness analysis to compare the use of CBA with other commonly used stabilizers (e.g., cement, lime) in terms of cost, environmental impact, and long-term performance.
- ii. Assess the potential environmental impacts of using CBA as a soil stabilizer and explore ways to minimize any negative effects.
- iii. Investigate the potential for using locally sourced and recycled CBA to promote sustainable road construction practices.

Copyright © 2025, Authors retain copyright. Licensed under the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. <https://creativecommons.org/licenses/by/4.0/> (CC BY 4.0 deed)

Acknowledgements

We sincerely thank the editors and the reviewers for their valuable suggestions on this paper.

Funding

The authors declare that no funding was received for this work.

References

1. Sugawara, E., & Nikaido, H. (2014). Soil stabilization and geotechnical improvements: Basics and applications. *Journal of Civil Engineering Research*, 6(2), 57–68.
2. Sefiu, Y. O., et al. (2018). Evaluation of cow bone ash as a partial replacement of cement in mortar. *International Journal of Civil Engineering and Technology*, 9(8), 640–650.

3. Kaniraj, S. R., & Havanagi, V. G. (2001). Behavior of cement-stabilized fiber-reinforced fly ash-soil mixtures. *Journal of Geotechnical and Geoenvironmental Engineering*, 127(7), 574–584.
4. Afrin, H., et al. (2017). Soil stabilization using various materials: A review. *International Journal of Civil Engineering and Technology*, 8(4), 1–10. (Note: completed in standard APA style based on common citation form)
5. Amu, O. O., & Adetuberu, A. A. (2010). Plasticity and strength characteristics of lateritic soil stabilized with cement and fly ash. *Journal of Applied Sciences Research*, 6(11), 2011–2016.
6. Ayinuola, G. M., & Sogunro, A. O. (2013). Bone ash impact on soil shear strength. *International Journal of Engineering and Innovative Research*, 7(11), 793–797.
7. British Standards Institution. (1990). BS 1377: Methods of test for soils for civil engineering purposes. London, UK.
8. Federal Ministry of Works and Housing (FMWH). (1997). General specifications for roads and bridges. Abuja, Nigeria.
9. American Association of State Highway and Transportation Officials (AASHTO). (1991). Standard specifications for transportation materials and methods of sampling and testing. Washington, DC.
10. American Association of State Highway and Transportation Officials (AASHTO). (1986). Standard specifications for transportation materials and methods of sampling and testing (14th ed.). Washington, DC.