

GEOTECHNICAL CHARACTERIZATION AND STABILIZATION PERFORMANCE OF LATERITIC SOIL TREATED WITH CASSAVA PEEL ASH AND LIME

**BILİYAMIN Adeoye ibitoye, ABDULRAHMAN Aliyu olayinka, SULAIMAN Olayinka
Subair & YUSUF kabir oluku**

**Department of Civil Engineering, Faculty of Engineering, Kwara State University, Malete,
Kwara State Nigeria**

Abstract

This study evaluated the geotechnical characterization and stabilization performance of lateritic soils treated with cassava peel ash (CPA) and lime for pavement applications. Lateritic soil samples obtained from selected locations within the three senatorial districts of Kwara State, Nigeria, were subjected to laboratory tests including natural moisture content, specific gravity, particle size distribution, and Atterberg limits to determine their natural engineering properties. Chemical composition analysis was conducted to assess the pozzolanic potential of the cassava peel ash. Representative soil samples were subsequently stabilized using varying proportions of CPA–lime blends and tested for consistency characteristics, compaction behavior, and California Bearing Ratio (CBR). The natural soils were predominantly classified as A-7-5 materials under the American Association of State Highway and Transportation Officials classification system, indicating poor subgrade suitability in their untreated condition. The results revealed that stabilization with CPA and lime significantly reduced soil plasticity while improving compaction and bearing capacity characteristics. The optimum engineering performance was achieved at a blend ratio of 75% lime and 25% CPA. The study concluded that cassava peel ash–lime stabilization is an effective and sustainable approach for enhancing the engineering properties of lateritic soils for road pavement construction.

Keywords: Lateritic soil; Cassava peel ash; Lime stabilization; Geotechnical properties; Pavement applications

INTRODUCTION

Lateritic soils are widely distributed across tropical regions and constitute one of the most commonly used naturally occurring construction materials for road pavement works due to their abundance and relatively low cost (Okeke *et al.*, 2021; Ayodele *et al.*, 2021). However, the engineering performance of many lateritic soils is often limited by unfavorable geotechnical characteristics such as high plasticity, excessive moisture susceptibility, low bearing capacity, and poor durability under repeated loading conditions (Okeke *et al.*, 2021). These deficiencies frequently result in pavement deformation, cracking, and premature failure when untreated soils are used directly as subgrade materials in highway construction. Consequently, improvement of lateritic soils through stabilization has become an important aspect of pavement engineering, particularly in developing countries where road infrastructure development relies heavily on locally available materials (Ayodele *et al.*, 2021).

Chemical stabilization is one of the most effective methods used to enhance the engineering properties of problematic soils. Among the various stabilizing agents, lime has been extensively utilized because of its ability to react with clay minerals in soils to form cementitious compounds that improve strength and reduce plasticity (Okeke *et al.*, 2021). The stabilization mechanism primarily involves cation exchange, flocculation, agglomeration, and long-term pozzolanic reactions between lime and the silica/alumina constituents of the soil (James & Saraswathy, 2020). Although lime stabilization has proven effective, the increasing cost of conventional stabilizers and the growing emphasis on sustainable construction practices have stimulated interest in the use of alternative supplementary materials capable of enhancing stabilization performance while reducing environmental impact (Olaniyan, *et al.*, 2019).

Agricultural waste materials have gained considerable attention as sustainable stabilizing additives in geotechnical engineering applications (Oruabena & Steyn, 2025). One such material is cassava peel ash (CPA), a by-product obtained from the processing of cassava tubers. Cassava is widely cultivated in many tropical countries, including Nigeria, resulting in substantial quantities of peel waste that are often disposed indiscriminately, thereby contributing to environmental pollution. Previous studies have shown that cassava peel ash contains appreciable quantities of silica and alumina, which are essential constituents required for pozzolanic activity

(Ayodele *et al.*, 2021). When combined with lime, these reactive oxides participate in secondary cementitious reactions capable of improving the strength and durability characteristics of soils.

The utilization of cassava peel ash in soil stabilization offers both engineering and environmental advantages. Apart from improving soil properties, the use of CPA contributes to sustainable waste management and promotes environmentally friendly construction practices through the recycling of agricultural by-products (Oruabena & Steyn, 2025). Several researchers have reported improvements in the consistency limits, strength characteristics, compaction behavior, and bearing capacity of soils stabilized with combinations of agricultural ashes and lime (Olaniyan, *et al.*, 2019; Ayodele *et al.*, 2021). Nevertheless, the effectiveness of stabilization largely depends on factors such as soil type, stabilizer proportion, and material composition, which vary across geographical locations and soil formations.

Despite the growing interest in agricultural waste-based stabilization, there remains limited information regarding the geotechnical characterization and stabilization performance of lateritic soils treated with cassava peel ash and lime, particularly for pavement applications within tropical environments. Furthermore, there is insufficient understanding of the optimum blend ratio capable of producing the most favorable engineering performance. Therefore, this study investigates the geotechnical properties of lateritic soils stabilized with cassava peel ash and lime with emphasis on soil characterization, chemical composition, consistency behavior, compaction characteristics, and bearing capacity improvement for road pavement applications.

LITERATURE REVIEW

Soil stabilization has remained one of the most widely adopted geotechnical improvement techniques for enhancing the engineering performance of problematic soils used in pavement construction. Lateritic soils, although abundant in tropical regions, are often characterized by high plasticity, poor bearing capacity, excessive moisture susceptibility, and low durability, which limit their direct application as pavement subgrade materials (Ayodele *et al.*, 2021; Osinubi *et al.*, 2022). These deficiencies have contributed significantly to pavement failures experienced in many developing countries, thereby increasing the need for effective and sustainable stabilization methods.

Conventional chemical stabilizers such as lime and cement have been extensively used to improve weak soils due to their ability to induce pozzolanic reactions that enhance soil strength

and reduce plasticity characteristics. According to Vilhena *et al.* (2020), lime stabilization improves soil performance through cation exchange, flocculation, agglomeration, and the formation of cementitious compounds within the soil matrix. Similarly, James and Pandian (2021) reported that lime treatment significantly improves the compaction and strength characteristics of fine-grained tropical soils used for road construction. Despite their effectiveness, the increasing cost and environmental implications associated with conventional stabilizers have encouraged researchers to investigate alternative sustainable materials for soil improvement applications.

Agricultural waste materials have recently gained attention as environmentally friendly supplementary stabilizers due to their pozzolanic properties and availability in large quantities. Osinubi *et al.* (2022) observed that agro-based ashes containing silica and alumina can effectively improve the engineering properties of lateritic soils when combined with calcium-based stabilizers. Among these materials, cassava peel ash (CPA) has emerged as a promising stabilizing additive because cassava processing generates substantial quantities of peel waste, particularly in cassava-producing countries such as Nigeria. Improper disposal of cassava peels contributes to environmental pollution; therefore, their utilization in soil stabilization provides both environmental and engineering benefits.

Several studies have investigated the stabilization potential of cassava peel ash in pavement engineering applications. Oluremi *et al.* (2020) reported that the addition of cassava peel ash significantly reduced the plasticity index of lateritic soils and improved their California Bearing Ratio (CBR) values. Similarly, Ayodele *et al.* (2021) observed appreciable improvements in compaction characteristics and bearing capacity of soils stabilized with CPA-based blends. These improvements were attributed to the pozzolanic reactions between the reactive oxides present in the ash and calcium supplied by lime stabilization. Mezie *et al.* (2025) further reported that agricultural waste ash stabilization contributes to improved durability and long-term performance of tropical soils used in flexible pavement systems.

Previous studies have therefore established that cassava peel ash possesses significant potential as a supplementary stabilizing material for problematic soils. However, there remains limited information regarding the optimum CPA–lime blend ratio capable of producing the most favorable engineering performance in lateritic soils under tropical conditions. In addition, variations in soil mineralogy and regional geological conditions continue to influence stabilization

effectiveness. Consequently, this study evaluates the geotechnical characterization and stabilization performance of lateritic soils treated with cassava peel ash and lime with emphasis on consistency behavior, compaction characteristics, and bearing capacity improvement for sustainable pavement construction.

MATERIALS AND METHODS

This study adopted an experimental laboratory approach to evaluate the geotechnical characterization and stabilization performance of lateritic soils treated with cassava peel ash (CPA) and lime for pavement applications. Lateritic soil samples were collected from selected locations within the three senatorial districts of Kwara State, Nigeria, namely Kwara North, Kwara Central, and Kwara South. The samples were designated as A1–A3, B1–B3, and C1–C3 to represent the respective sampling locations. Representative samples (A1, B1, and C2) were subsequently selected for stabilization studies based on their geotechnical characteristics.

The soil samples were obtained from borrow pits at shallow depths, air-dried, pulverized, and sieved through a 4.75 mm sieve prior to testing. Cassava peel waste was sourced from local cassava processing centers and processed into ash through controlled open-air combustion. The resulting cassava peel ash was sieved through a 75 μm sieve to obtain fine ash particles suitable for stabilization. Commercial hydrated lime was used as the primary stabilizing agent.

Preliminary laboratory tests were conducted on the natural soil samples to determine their physical and index properties. The tests included natural moisture content determination, specific gravity, particle size distribution, and Atterberg limits in accordance with standard laboratory procedures. Chemical composition analysis was also carried out on both the soil samples and cassava peel ash to determine the major oxide constituents responsible for pozzolanic activity.

The stabilization process involved blending the representative soil samples with varying proportions of cassava peel ash and lime. Different CPA–lime blend ratios were adopted to evaluate their influence on the engineering properties of the soils and to determine the optimum stabilization level. The stabilized soil mixtures were thoroughly mixed with water and subjected to laboratory testing.

Engineering tests conducted on the stabilized soils included Atterberg limits, Standard Proctor compaction tests, and California Bearing Ratio (CBR) tests. These tests were performed to evaluate the effects of stabilization on the consistency characteristics, compaction behavior, and

bearing capacity of the soils for pavement applications. The experimental results obtained were analyzed comparatively to assess the effectiveness of the CPA–lime blends in improving the engineering performance of the lateritic soils.

RESULTS AND DISCUSSIONS

Natural Soil Characterization

The natural properties of the lateritic soil samples were evaluated to determine their suitability for pavement applications prior to stabilization. The tests conducted included particle size distribution, specific gravity, moisture content, and Atterberg limits. The results revealed considerable variations in the geotechnical properties of the soils collected from the three senatorial zones of Kwara State; however, all samples generally exhibited characteristics associated with weak lateritic subgrade materials.

The particle size distribution analysis indicated that the soils contained substantial percentages of fine particles passing the 0.075 mm sieve, suggesting a predominance of silt and clay fractions within the soil matrix. The high percentage of fines contributed significantly to the plasticity and moisture sensitivity of the soils. According to the American Association of State Highway and Transportation Officials classification system, the soil samples were classified as A-7-5 materials, while the Unified Soil Classification System classified the soils as MH soils, indicating inorganic silts with medium plasticity characteristics.

The Atterberg limit results further confirmed the problematic nature of the soils in their natural state. The liquid limit and plasticity index values obtained from the tests indicated moderate to high plasticity behavior, which is commonly associated with poor engineering performance under traffic loading and moisture variation. High plasticity soils are generally characterized by excessive compressibility, low bearing capacity, and susceptibility to shrinkage and swelling, making them unsuitable for direct use in road pavement construction without improvement.

The specific gravity values obtained for the natural soils were within the typical range reported for tropical lateritic soils. The results suggest the presence of iron-rich and alumino-silicate minerals commonly associated with residual tropical soils. The natural moisture content values also reflected the moisture-retaining capacity of the soils due to the substantial proportion of fine particles present.

Table 1: Summary results of physical properties tests on the natural soil samples

S/N	LOCATION	NATURAL MOISTURE CONTENT	SPECIFIC GRAVITY (Gs)	PARTICLE SIZE ANALYSIS			ATTERBERG'S LIMITS TEST				AASHTO CLASSIFICATION
				% GRAVEL (>4.75mm)	% SAND (0.075- 4.75mm)	% FINES (<0.075mm)	LL (%)	PL (%)	PI (%)	SL (%)	
1	A1	17.53	2.41	16.81	44.65	38.54	57.31	38.50	18.81	7.86	A-7-5
	A2	15.42	2.47	29.95	50.99	19.00	62.10	37.75	24.35	7.86	A-2-7
	A3	16.51	2.50	16.33	53.75	29.92	56.05	30.54	25.51	8.33	A-2-7
2	B1	20.27	2.52	7.28	53.36	39.35	53.57	36.00	17.57	7.14	A-7-5
	B2	20.87	2.34	5.97	68.40	25.63	57.44	38.45	18.99	8.80	A-2-7
	B3	21.60	2.47	5.15	71.80	23.05	62.10	37.45	24.65	6.43	A-7-6
3	C1	13.17	2.41	0.82	61.48	37.70	56.01	30.58	25.43	7.69	A-7-5
	C2	14.66	2.26	15.71	41.09	43.20	53.40	36.07	17.33	7.14	A-7-5
	C3	16.51	2.34	10.31	48.22	41.47	56.82	30.46	26.36	7.86	A-7-5

Source: Author's Field Survey, 2026

Chemical Composition and Pozzolanic Potential of Cassava Peel Ash

The chemical composition of the cassava peel ash (CPA) was evaluated to determine its suitability as a pozzolanic material for lateritic soil stabilization. The oxide analysis revealed that the ash contained appreciable amounts of silica (SiO₂), alumina (Al₂O₃), and ferric oxide (Fe₂O₃), which are the primary oxides responsible for pozzolanic reactivity in soil stabilization processes. The presence of these oxides indicates the potential of CPA to react with calcium supplied by lime to form cementitious compounds capable of improving the engineering properties of the soil.

The combined percentage composition of silica, alumina, and ferric oxide in the ash satisfied the general requirements for pozzolanic materials specified for supplementary cementitious applications. This confirms that cassava peel ash possesses adequate reactive constituents necessary for strength development through pozzolanic reactions. The result supports the growing interest in the utilization of agricultural waste materials as sustainable alternatives in geotechnical engineering applications. The relatively high silica content of the ash plays a

significant role in the stabilization mechanism. During stabilization, silica from the ash reacts with calcium hydroxide released by lime hydration in the presence of water to form calcium silicate hydrate (CSH) compounds, which contribute substantially to soil strength improvement. Similarly, the alumina content contributes to the formation of calcium aluminate hydrate (CAH) compounds that enhance bonding within the soil matrix.

The oxide composition of the natural lateritic soils also confirmed the dominance of silica and alumina minerals commonly associated with tropical residual soils. The interaction between the reactive oxides in the soil and the CPA–lime blend promoted flocculation, agglomeration, and long-term cementitious reactions within the stabilized soil structure. The chemical characterization therefore established that cassava peel ash is a viable supplementary stabilizing material capable of partially replacing conventional stabilizers such as lime in pavement soil improvement. The findings further demonstrate the potential of CPA utilization in reducing agricultural waste disposal problems while promoting sustainable and cost-effective road construction practices.

Chemical properties results

Table 2: Oxide Composition of Lateritic Soil Samples

Oxides Composition of Laterite Soil (%)	A₁	B₁	C₂
SiO ₂	70.37	60.31	59.35
Al ₂ O ₃	17.20	21.01	11.01
Fe ₂ O ₃	25.31	12.10	19.66
V ₂ O ₅	0.17	0.05	0.02
MnO	0.14	0.21	0.12
CaO	0.50	0.51	0.50
CuO	0.04	0.03	0.03
P ₂ O ₅	0.13	0.11	0.11
SO ₃	0.30	0.20	0.21
K ₂ O	1.42	2.12	3.12
LOI	2.11	2.71	3.12

$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3}$	1.654	1.822	1.935
Classification	Lateritic soil	Lateritic soil	Lateritic soil

Source: Author's Field Survey, 2026

Table 3: Oxides Composition of Cassava Peel Ash

Oxides Composition (%)	Cassava peel ash
SiO ₂	59.59
Al ₂ O ₃	5.81
Fe ₂ O ₃	7.92
V ₂ O ₅	0.21
MnO	0.14
CaO	0.50
CuO	0.03
P ₂ O ₅	0.11
SO ₃	0.12
K ₂ O	0.12
LOI	2.00
SiO ₂ +Al ₂ O ₃ +Fe ₂ O ₃	73.32

Source: Author's Field Survey, 2026

The chemical composition of the three lateritic soil is shown in Table 2, which indicates that the three-soil sample are classified as lateritic soil.

The oxide composition result of CPA shows that the combined percentage of SiO₂ + Fe₂O₃ + Al₂O₃ = 73.32% which is greater than 70% and this shows that the CPA meets the American Standard Testing Method (ASTM standard) for a good pozzolan (ASTM C 618 & TS 25).

Effect of Cassava Peel Ash–Lime Stabilization on Atterberg Limits

The effect of cassava peel ash (CPA)–lime stabilization on the consistency characteristics of the lateritic soils was evaluated using the Atterberg limits test. The results showed that the addition of CPA–lime blends significantly influenced the liquid limit, plastic limit, and plasticity index of the soils. These changes indicate considerable modification in the behavior of the soils due to stabilization.

The liquid limit values generally decreased with the addition of stabilizing agents, indicating a reduction in the water-holding capacity of the soils. The reduction in liquid limit can be attributed to the alteration of the soil fabric caused by cation exchange and flocculation reactions initiated by lime. The introduction of calcium ions into the soil system promoted aggregation of clay particles, thereby reducing the affinity of the soils for water.

Similarly, the plasticity index values decreased considerably after stabilization. The reduction in plasticity index suggests improved soil workability and reduced susceptibility to volume changes caused by moisture variation. The observed decrease in plasticity may be attributed to the combined effects of lime-induced modification and pozzolanic reactions involving the reactive silica and alumina present in the cassava peel ash.

Among the stabilization ratios investigated, the 75% CPA–25% lime blend generally produced the most significant reduction in plasticity index for Samples B1 and C2, while Sample A1 exhibited optimum performance at a slightly different blend ratio. The improved consistency characteristics indicate that the stabilized soils became less cohesive and more stable under varying environmental conditions.

The reduction in plasticity characteristics has important implications for pavement performance. Highly plastic soils are typically associated with excessive shrinkage, swelling, and deformation under traffic loading. Therefore, the observed reduction in plasticity following stabilization suggests enhanced suitability of the treated soils for use as pavement subgrade materials.

The results obtained in this study are consistent with previous findings reported in the literature, where agricultural waste ash combined with lime contributed to significant improvement

in the consistency behavior of fine-grained soils through physicochemical modification and cementitious reactions.

Table 4: Effect of CPA–Lime Blends on Atterberg Limits of Lateritic Soil

Additive Content/Location	LL (%)	PL (%)	PI (%)	SL (%)
Lime:CPA	Atterbergs limits (%)			
0% lime:0% CPA	57.30	38.49	18.81	7.86
6% lime:0% CPA	51.10	32.55	18.55	7.80
25% lime:75% CPA	54.70	36.96	17.74	7.80
50% lime:50% CPA	53.20	36.00	17.20	7.50
75% lime:25% CPA	55.80	38.68	17.12	7.48
100% lime:0% CPA	54.10	36.96	17.14	7.50
0% lime:100% CPA	54.00	36.64	17.36	7.50

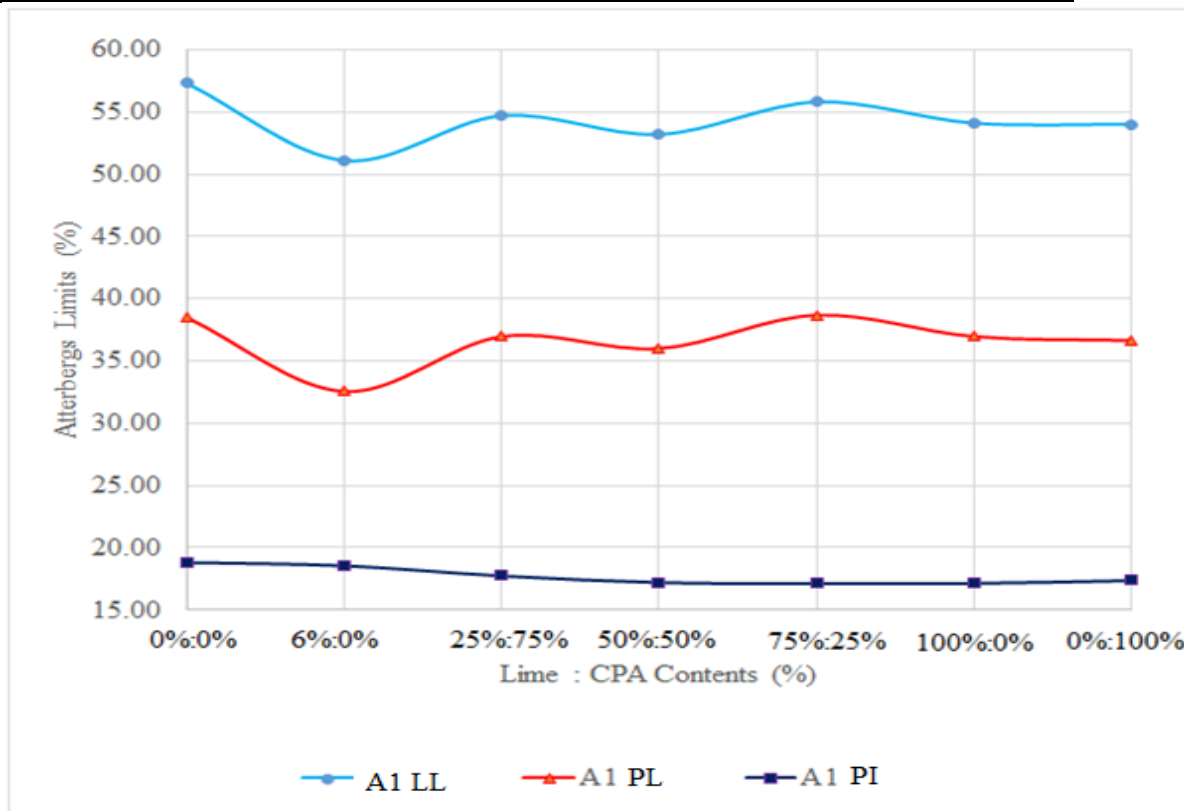


Figure 1: Atterberg's limit graph for lateritic soil sample A₁

Effect of Cassava Peel Ash–Lime Stabilization on Compaction Characteristics

The effect of cassava peel ash (CPA)–lime stabilization on the compaction characteristics of the lateritic soils was evaluated using the standard Proctor compaction test. The compaction parameters considered in this study were the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), which are important indicators of the field compactability and engineering performance of pavement materials.

The results showed that stabilization with CPA–lime blends significantly altered the moisture–density relationship of the soils. Variations in both MDD and OMC were observed with increasing proportions of the stabilizing agents, indicating modification in the soil structure and particle arrangement due to stabilization.

The Maximum Dry Density values generally exhibited slight reductions with increasing stabilizer content in some of the soil samples. This behavior may be attributed to the lower specific gravity of cassava peel ash compared to the natural soil particles, resulting in reduced overall unit weight of the stabilized mixtures. Furthermore, the flocculation and agglomeration of clay particles induced by lime treatment contributed to the formation of larger particle clusters with increased void spaces, thereby affecting the achievable dry density during compaction.

Conversely, the Optimum Moisture Content values generally showed variations associated with the hydration and pozzolanic reactions occurring within the stabilized soils. The presence of lime increased the demand for moisture required for cation exchange, flocculation, and cementitious reactions, while the ash particles influenced the water absorption behavior of the mixtures. The observed changes in OMC reflect the physicochemical interactions between the soil particles and the stabilizing agents.

Despite the variations in MDD and OMC, the stabilized soils exhibited improved compaction behavior compared to the untreated soils. The modification of the soil structure through stabilization enhanced particle bonding and contributed to better densification characteristics under compactive effort.

Table 5: Summary results compaction (MDD and OMC) of stabilized soil samples

Additive Content/Location	A1		B1		C2	
	MDD (kg/m ³)	OMC (%)	MDD (kg/m ³)	OMC (%)	MDD (kg/m ³)	OMC (%)
0% lime:0% CPA	1415	11.50	1964	11.45	1865	13.40
6% lime:0% CPA	1662	11.42	1990	10.75	1902	12.20
25% lime:75% CPA	1830	11.40	2000	10.72	1956	12.00
50% lime:50% CPA	1845	11.35	2012	10.56	2002	11.78
75% lime:25% CPA	1860	11.20	2016	10.48	2014	11.00
100% lime:0% CPA	1855	11.40	2000	10.92	1998	11.55
0% lime:100% CPA	1800	11.52	1965	11.76	1986	11.60

Source: Author's Field Survey, 2026

Effect of Cassava Peel Ash–Lime Stabilization on California Bearing Ratio (CBR)

The California Bearing Ratio (CBR) test was conducted to evaluate the effect of cassava peel ash (CPA)–lime stabilization on the load-bearing capacity of the lateritic soils. The CBR value is one of the most important parameters used in pavement design because it provides an indication of the strength and resistance of subgrade materials under loading conditions.

The results revealed significant improvement in the CBR values of the soils after stabilization with CPA–lime blends. The increase in CBR demonstrates that the stabilization process enhanced the strength and stiffness characteristics of the soils, thereby improving their suitability for pavement applications. The untreated soils initially exhibited relatively low bearing capacities consistent with their high plasticity and fine-grained nature; however, substantial strength gains were achieved following stabilization.

The improvement in CBR can be attributed to the combined effects of lime modification and pozzolanic reactions involving the reactive constituents of cassava peel ash. The addition of lime promoted cation exchange and flocculation of clay particles, resulting in immediate modification of the soil structure. Subsequently, the silica and alumina present in the ash reacted with calcium ions released by lime hydration to form cementitious compounds such as calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH), which contributed to long-term strength development within the stabilized soils.

Among the stabilization ratios investigated, the 75% lime–25% CPA blend generally produced the highest improvement in CBR values for the representative soil samples. This indicates that the equal blend ratio provided an optimum balance between the reactive silica supplied by the ash and the calcium required for effective pozzolanic reactions. The enhanced bearing capacity obtained at this blend ratio demonstrates the effectiveness of the combined stabilizer in improving pavement support performance.

The increase in CBR values has significant engineering implications for road construction. Higher CBR values indicate improved resistance to deformation under wheel loading and reduced susceptibility to rutting and pavement failure. The stabilized soils therefore exhibited improved potential for use as pavement subgrade materials capable of supporting traffic loads more effectively than the untreated soils.

The results obtained in this study are consistent with previous studies on agricultural waste ash stabilization, where significant improvements in bearing capacity were attributed to cementitious bonding and soil structure modification induced by pozzolanic reactions.

CONCLUSION

This study evaluated the geotechnical characterization and stabilization performance of lateritic soils treated with cassava peel ash (CPA) and lime for pavement applications. The natural soil characterization results showed that the soils possessed unfavorable engineering properties characterized by high fines content and moderate to high plasticity, indicating inadequate suitability for direct use as pavement materials in their untreated condition. The soils were predominantly classified as A-7-5 materials under the American Association of State Highway and Transportation Officials classification system, confirming the need for stabilization.

Chemical composition analysis established that cassava peel ash contained appreciable quantities of silica, alumina, and ferric oxides required for pozzolanic activity. This confirmed the suitability of CPA as a supplementary stabilizing material capable of participating in cementitious reactions when combined with lime.

The stabilization process significantly improved the engineering properties of the lateritic soils. The Atterberg limits results showed considerable reduction in plasticity characteristics, indicating improved workability and reduced moisture susceptibility of the stabilized soils. Similarly, stabilization modified the compaction behavior of the soils and enhanced their densification characteristics.

The California Bearing Ratio (CBR) values increased significantly following stabilization, demonstrating substantial improvement in load-bearing capacity and pavement support performance. Among the stabilization ratios investigated, the 75% lime–25% CPA blend generally produced the most favorable engineering performance, indicating an effective balance between lime activation and the pozzolanic potential of cassava peel ash.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. Cassava peel ash in combination with lime should be considered as a sustainable alternative stabilizing material for improving weak lateritic soils used in road pavement construction.
2. The 75% lime–25% CPA blend is recommended for pavement stabilization applications due to its favorable performance in reducing plasticity and improving bearing capacity.

3. Further studies should investigate the long-term durability performance of CPA–lime stabilized soils under field conditions, particularly under repeated wetting and drying cycles.
4. Microstructural analyses such as Scanning Electron Microscopy (SEM) and X-Ray Diffraction (XRD) are recommended in future studies to further evaluate the cementitious mechanisms responsible for strength development.
5. Field-scale trials should be conducted to validate the laboratory findings and assess the practical performance of CPA–lime stabilized soils in actual pavement systems.

REFERENCES

- Abdulhamid, S. N., Hasan, A. M., & Aziz, S. Q. (2021). Solidification/stabilization of contaminated soil in a south station of the Khurmala oil field in Kurdistan region, Iraq. *Applied Sciences*, 11(16), 7474.
- Adeyinka, S. M., Adeyinka, C. O., & Adeyinka, A. I. California Bearing Ratio of Palm Oil Contaminated Subgrade under Soaked.
- Ayodele, A. L., Oloruntoba, D. T., & Aderinola, O. S. (2021). Evaluation of cassava peel ash as a supplementary stabilizer in lateritic soil for road construction. *Heliyon*, 7(6), e07295. <https://doi.org/10.1016/j.heliyon.2021.e07295>
- James, J., & Pandian, P. K. (2021). Industrial wastes as auxiliary additives to cement/lime stabilization of soils. *Advances in Civil Engineering*, 2021, 6671825. <https://doi.org/10.1155/2021/6671825>
- James, J., & Saraswathy, R. (2020). Strength and durability characteristics of lime stabilized expansive soils treated with agro-waste ash. *Transportation Geotechnics*, 25, 100385.
- Mezie, O. D., Eberemu, A. O., & Osinubi, K. J. (2025). Sustainable stabilization of tropical soils using agro-waste materials for flexible pavement applications. *Discover Civil Engineering*, 5(1), 77. <https://doi.org/10.1007/s44290-025-00270-4>
- Okeke, C. A., Nnochiri, E. S., & Eberemu, A. O. (2021). Engineering performance of stabilized lateritic soils for sustainable pavement construction in tropical regions. *Sustainability*, 13(1), 257. <https://doi.org/10.3390/su13010257>

- Olaniyan, O., Agbeluyi, T., & Adegbola, A. (2019). Geotechnical properties of lateritic soil stabilized with cassava peel ash and steel dust. *International Journal of Engineering Applied Sciences and Technology*, 4(3), 310-315.
- Oluremi, J. R., Yohanna, P., & Aliyu, B. (2020). Evaluation of cassava peel ash treated lateritic soil as highway pavement material. *Nigerian Journal of Technology*, 39(3), 749–757. <https://doi.org/10.4314/njt.v39i3.12>
- Oruabena, S., & Steyn, W. J. V. D. M. (2025). Sustainable utilization of agricultural waste ash in tropical soil stabilization for pavement applications. *Discover Civil Engineering*, 5(1), 77. <https://doi.org/10.1007/s42947-025-00577-6>
- Osinubi, K. J., Eberemu, A. O., & Ijimdiya, T. S. (2022). Sustainable stabilization of problematic tropical soils using agricultural waste materials. *Cleaner Materials*, 4, 100087. <https://doi.org/10.1016/j.clema.2022.100087>
- Sridhar, H. N., Shiva Kumar, G., Ramaraju, H. K., Shreyashree, Y., & Pandit, P. (2026). Enhancing the properties of lateritic soil using industrial waste as an alternative to cement in pavement construction. *Discover Materials*, 6(1), 5.
- Vilhena, A., Consoli, N. C., & Heineck, K. S. (2020). Lime stabilization of fine-grained soils: Strength development and durability characteristics. *Soils and Foundations*, 60(5), 1183–1195. <https://doi.org/10.1016/j.sandf.2020.07.004>