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Effect of Calcium-Sodium Carbonate Mixture on Geotechnical Properties of Laterite Soil for Road Applications

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Abstract

Laterite soils have been found to exhibit swelling-shrinkage behaviours whenever there are seasonal and environmental changes. These phenomena negatively affect the strength and stability of the soil. Consequently, this study investigated the effect of calcium carbonate ($CaCO_3$) and sodium carbonate (Na_2CO_3) mixtures, at ratios of 1:1 and 3:1 ($CaCO_3$:Na_2CO_3), in stabilizing a tropical laterite soil. Stabilization was carried out at additive contents of 0 – 10% (at 2.5% incremental interval) by dry weight of soil sample. Consistency limits, compaction [West African Standard (WAS) and British Standard Light (BSL)] and California Bearing Ratio (CBR) tests were carried out to assess the impact of stabilization on compaction characteristics and strength performance. Results showed that Plasticity Index (PI) reduced from 16.9-5.3% and 16.9-0.40% as the carbonate dosage increased from 0-10% under the 1:1 and 3:1 carbonate ratios, respectively, indicating reduced swelling potential and enhanced workability. The Optimum Moisture Content (OMC) declined while the Maximum Dry Density (MDD) for WAS rose from 1.72-1.78 g/cm^3 and 1.72-1.81 g/cm^3 with increasing carbonate treatment up to 7.5% under 1:1 and 3:1, respectively. Similarly, the corresponding WAS soaked CBR values increased from 20.4-37.6% and 20.4-49.0% with increasing stabilizer content from 0-7.5%, transforming the soil from weak subgrade to a material meeting Nigerian specifications for sub-base applications (CBR > 30%). These results revealed that 3:1 mix ratio consistently outperformed the 1:1 mixture. The outcome also indicated that the combined use of $CaCO_3$ and Na_2CO_3, up to 7.5%, improved the properties of laterite soil, thereby enhancing its suitability for pavement construction.

Keywords: Calcium carbonate, Geotechnical properties, Laterite soil, Sodium carbonate.

Introduction

In tropical and sub-tropical areas, laterite soils are severely weathered residual soils that result from the laterization of rock (Maichin *et al*., 2021). These soils can be purple, rusty red, or dark reddish brown in colour, with particle sizes varying from sand/gravel to clay/silt. Sesquioxides concretions are usually applied to the particles because of laterization, providing them cementitious properties (Osinubi *et al*., 2017; Shaqour, 2024; and Adedokun *et al*., 2024). The iron oxide (Fe_2O_3), lepidocrocite ($FeO(OH)$), and goethite ($HFeO_2$) are found in it, along with other oxides of aluminium, among which gibbsite ($Al_2O_3 \cdot 3H_2O$) is the most prevalent (Budihal *et al*., 2023). Laterites are well-known building materials that are readily available and reasonably priced, frequently exhibiting satisfactory engineering properties in addition to their intrinsic aesthetic appeal (Oyelami and Van Rooy, 2016; Basu and Sinha, 2021). Studies have verified that lateritic materials are a good fit for the "Green maintenance" concept when used for construction, providing sustainable and cost-effective solutions for infrastructure development (Oyelami and Van Rooy, 2016; Obianyo *et al*., 2021; and Akinwumi *et al*., 2021).

Recent studies have evaluated different additives for modifying laterite soils. Chemical stabilization techniques have been widely investigated for improving laterite soil properties through various additives (Afolayan *et al*., 2022; Al-Bared and Marto, 2021; and Adedokun *et al*., 2025). Latifi *et al*. (2014) investigated sodium silicate-based stabilizers on laterite soil properties, finding that the addition raised soil alkalinity and enhanced strength properties through formation of cementitious substances. Wahab *et al*. (2021) examined cement-treated lateritic soil for pavement construction, demonstrating that cement addition increased maximum dry density and achieved significant improvements in unconfined compressive strength through formation of cementitious gels. Rozman *et al*. (2025) investigated cement stabilization of laterite soil for low-volume roads, revealing optimal performance at specific cement contents with progressive strength development. Okonkwo *et al*. (2022) examined Portland cement-sand stabilization of laterite soil for road pavement, achieving satisfactory performance for sub-base applications. However, these studies were primarily focused on single-stabilizer systems and did not examine the synergistic effects of combined carbonate treatments or their long-term environmental implications.

Calcium carbonate ($CaCO_3$) is a naturally occurring mineral composed of calcium, carbon, and oxygen, frequently found in rocks like marble and limestone. It typically appears as a white solid poorly soluble in water, with a density of approximately 2.71 g/cm^3 and a melting point of around 825°C. In soil stabilization, calcium carbonate has been investigated for enhancing the mechanical qualities of soils through precipitation and cementation mechanisms (DeJong *et al*., 2022; Pacheco *et al*., 2022). Studies on calcium carbonate precipitation techniques have shown promising results for soil improvement. Zhu *et al*. (2021) analyzed chemically induced calcium carbonate precipitation (CICP) for improving expansive soil, finding that sequential addition of $CaCl_2$ and Na_2CO_3 solutions enhanced workability and stability by forming calcium carbonate precipitates that bind soil particles. Naeimi *et al*. (2023) employed microbially induced calcium carbonate precipitation (MICP) for dune fixation and soil stabilization, demonstrating effectiveness in enhancing soil strength. Zhao *et al*. (2026) provided a comprehensive review of MICP for soil solidification and erosion mitigation, emphasizing its environmental benefits and engineering applications. Wang *et al*. (2022) optimized MICP treatment protocols using microfluidic experiments for strength improvement of the sandy soil. These biotechnological approaches represent innovative alternatives to traditional chemical stabilization methods, though their field applicability requires further validation.

Sodium carbonate (Na_2CO_3) has been investigated for its potential to stabilize and enhance the physical characteristics of soil. Chemical stabilizers using sodium-based compounds can improve the cohesiveness and compaction of soil particles through alkali activation and ion exchange mechanisms (Kumar *et al*., 2018). Research on alkali-activated soil stabilization indicates that sodium-based activators can increase soil pH and promote cementitious reactions, thereby improving soil stability (Liu *et al*., 2020). These alkali-activation processes can improve drainage properties and reduce soil erosion, thereby increasing the lifetime and durability of infrastructure (Zhang and Zhang, 2020; Chandra and Sharma, 2020).

This study focuses on examining the combined effects of calcium carbonate and sodium carbonate admixtures in stabilizing tropical laterite soil at different proportions (1:1 and 3:1 $CaCO_3$:Na_2CO_3 ratios), addressing gaps in previous research by evaluating their combined effects on index, compaction and strength properties of treated laterite soil under various curing conditions and dosage levels.

Materials and Methods

Materials

The soil specimen was sourced from an active borrow pit in Imota, Ikorodu [6° 40' 14'' N, 3° 39' 10'' E] as disturbed samples. The obtained samples were transported in tight containers to the soil laboratory of the University of Lagos for analyses. Sodium Carbonate and Calcium Carbonate powders were purchased from Turraco Industrial Ltd, a local manufacturer and supplier of chemical compounds at Lawanson, Lagos. The two additives were combined in two mix ratios (1:1 and 3:1 $CaCO_3$:Na_2CO_3) and blended with air-dried laterite soil at varying contents of 0-10% (2.5% increments) by dry weight of soil. Thorough dry mixing was carried out to ensure equitable distribution of the carbonates with the soil matrix before moisture addition for subsequent testing.

Experimental methods

Chemical test

The chemical compositions of the soil sample were determined using X-ray Fluorescence (XRF) analyser. *Atterberg limits*: The liquid limits, plastic limits, and plasticity indices of the natural and calcium-sodium carbonates treated soil samples were determined in accordance with sequential steps outlined by AASHTO (2021), BS 1377 (2022) and BS 1924 (2018). The liquid limit was obtained using the Casagrande apparatus at 25 blows, while the plastic limit was determined by rolling soil threads to 3 mm diameter.

Compaction

Compaction tests were performed in conformity with the BS 1377 (2022) and BS 1924 (2018) standards through British Standard Light (BSL) and West African Standard (WAS) energy levels for the carbonate treated and untreated samples. The procedure also aligned with that of the Nigerian General Specification, NGS (1997). For BSL compaction test, 3 kg of soil was thoroughly combined with 10% water to obtain a homogenous mixture. The moist soil was then placed in a 1000 mm^3 mould and compacted in 3 layers, with each layer receiving 27 blows from a 2500 g rammer that dropped from 0.30 m height. The extension collar was removed after compaction and the surface of the specimen trimmed using a straight edge. Mould was then weighed including the compacted soil, the weight of the empty mould was then subtracted to obtain the weight of the specimen. The results were then used to obtain the MDD and OMC using the moisture content-dry density relationship charted on a compaction curve. For WAS compaction method, 2.5 kg of soil was thoroughly combined with 10% water to obtain a homogenous mixture. The moist soil was then placed in a 1000 mm^3 mould and compacted in five equal layers, with each layer receiving 10 blows from a 4500 g rammer that dropped from 0.45 m height.

Strength

The California bearing ratio (CBR) tests were carried out under BSL and WAS compaction methods based on the OMC determined from the compaction tests in accordance with BS 1377 (2022) and 1924 (2018) for the untreated and treated soil specimens, respectively. For soaked CBR specimens, the mold assembly was soaked in water for 24 hours, based on the minimum soaking period recommended by NGS (1997). The UCS specimens were cured for 7 and 14 days before testing to evaluate strength development over time.

Results and Discussion

Properties of the natural soil

Table 1 shows that the natural laterite soil exhibited a liquid limit of 42.5%, plastic limit of 24.8%, and plasticity index of 17.7%, classifying it as an A-7-6 and CL soil according to AASHTO and USCS classification systems. The specific gravity was 2.65, typical of laterite soils in tropical regions. Particle size analysis revealed 59.5% fines (passing No. 200 sieve), indicating significant silt-clay content. These properties suggest moderate plasticity with potential volume change issues requiring stabilization for construction applications. Soils in this category are typically weak, moisture-sensitive, and highly compressible, often leading to excessive deformation under load. Such characteristics explain the relatively low bearing capacity of the natural soil observed in the CBR tests and highlight the necessity for stabilization with stabilizers to improve its engineering properties.

Table 1: Properties of the natural soil

Properties	Value
Colour	Reddish-brown
Percentage Passing Sieve 0.075 mm	59.49
LL (%)	42.5
PI (%)	16.94
Specific Gravity	2.61
Natural Moisture Content (%)	13.8
Swell Index (%)	15.4
Group Index	8
AASHTO Classification	A-7-6
USCS Classification	CL
MDD (BSL) (g/cm^3)	1.68
OMC (BSL) (%)	19.0
MDD (WAS) (g/cm^3)	1.715
OMC (WAS) (%)	17.8
Soaked CBR (BSL) (%)	14.82
Unsoaked CBR (BSL) (%)	27.2
Soaked CBR (WAS) (%)	20.4
Unsoaked CBR (WAS) (%)	36.8

The chemical compositions of the laterite soil sample determined using X-Ray Fluorescence (XRF) spectroscopy are presented in Table 2. The major oxides present are SiO_2, Al_2O_3, and Fe_2O_3, which collectively dominate the soil composition, consistent with typical laterite soils. The high silica and alumina content may suggest good pozzolanic potential, while the substantial iron oxide content contributes to the reddish colouration typical of laterites. A high composition of SiO_2 (50%), Al_2O_3 (21.08%) and Fe_2O_3 (19.79%) can be seen in the soil specimen based on outcomes of the chemical test. The soil sample can be grouped into either laterite or lateritic depending on its dominant oxide compositions. Since the silica to sesquioxides ratio (1.22) of the analysed soil is less than 1.33, the natural soil can be categorized as a laterite (Bell, 1993).

Table 2: Chemical composition of laterite soil

Oxide	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	MnO	SO_3	CuO	K_2O	Cl	P_2O_5	Cr_2O_3	CoO	V_2O_5	ZrO_2	Others
Composition (%)	50.0	21.08	19.79	3.56	1.48	0.32	0.18	1.13	0.14	0.16	0.99	0.06	0.05	0.07	0.18	0.38	< 0.1

Effect of carbonate treatment on consistency limits

Figure 1 shows the impact of the carbonate treatments ($CaCO_3$:Na_2CO_3 in 1:1 and 3:1) on the consistency limits of the natural laterite soil. The natural soil exhibited a LL of 42.5%, PL of 25.56%, and PI of 16.94%, classifying it as medium plastic clay (CL) according to USCS and A-7-6 per AASHTO classification. For the 1:1 $CaCO_3$:Na_2CO_3 mixture, the liquid limit decreased progressively from 42.5% to 22.8% at 10% additive content, while the plastic limit reduced to 16.23% at 2.5% before gradually increasing to 17.5% at 10%. The plasticity index decreased substantially from 16.94 to 5.3% at 10% additive contents, representing a 68.7% reduction at maximum dosage. The 3:1 mixture demonstrated superior performance, the plasticity index reduced continuously with the increasing content of the carbonate mixture, achieving the PI value of 0.4% at 10% additive level—a 97.6% reduction. At 7.5% additive content, the 3:1 mixture achieved PI of 1.9% compared to 6.8% for the 1:1 mixture, representing 72% greater effectiveness. The plastic limit remained relatively stable (24.31% to 25.2%), while the liquid limit decreased from 42.5% to 25.6%, effectively transforming the soil to non-plastic classification.

The superior performance of the 3:1 ratio is attributed to higher calcium content facilitating extensive cation exchange reactions. Calcium ions (Ca^{2+}) replace monovalent sodium and other exchangeable cations on clay surfaces, reducing the diffuse double layer thickness and decreasing water affinity through flocculation-agglomeration reaction. The reduction in liquid limit indicates decreased water-holding capacity, while the stabilized plastic limit suggests formation of a stiffer, more cohesive matrix. Pozzolanic reactions form cementitious compounds that bind particles and fundamentally reduce plasticity. Both mixtures satisfy Nigerian Federal Ministry of Works specifications requiring PI below 12% for subbase materials. The 3:1 mixture achieves non-plastic characteristics (PI < 2%) at 7.5% and 10% contents, indicating minimal shrink-swell behaviour under varying moisture conditions. This dimensional stability is critical for preventing pavement cracking and rutting associated with expansive soils. The 7.5% dosage with 3:1 ratio provides optimal performance, achieving near-zero plasticity while avoiding issues from excessive additive content.

The outcomes of this study are consistent with those of existing studies. Osinubi et al. (2017) observed that lime and carbonate stabilizers lower LL and PI by reducing water affinity, while improving soil cohesion. Nazir *et al*. (2013) noted that sodium carbonate reduced PI by inducing flocculation, though excessive contents produced inconsistent behaviour—similar to the less stable performance of Na_2CO_3 in the present study. The stable reductions achieved with $CaCO_3$ are also in line with Yan *et al*. (2022), who found that calcium carbonate precipitation improved soil stability and reduced water sensitivity.

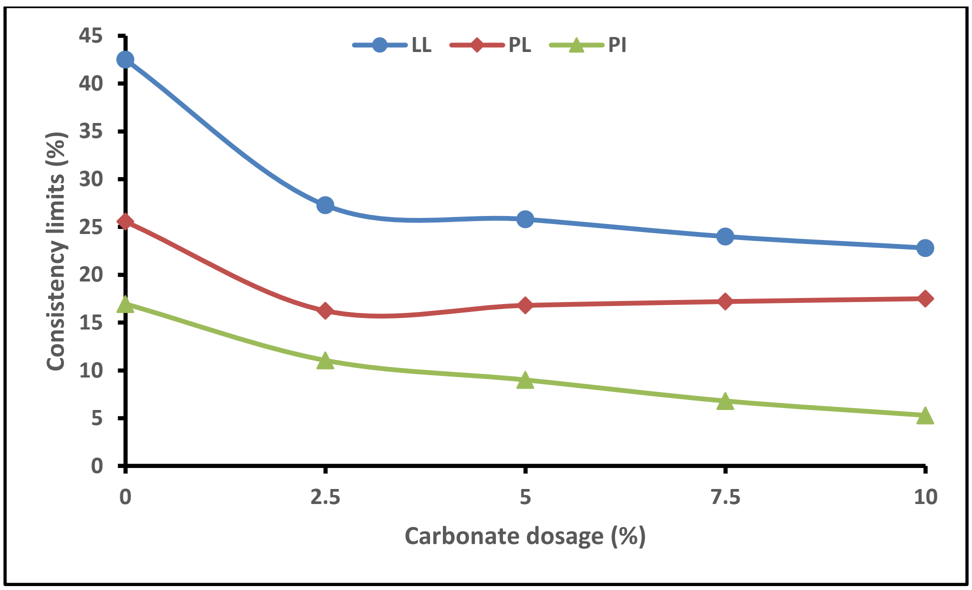

Figure 1a: Effect of carbonate mixture (1:1 $CaCO_3$:Na_2CO_3) on the consistency limits of the laterite soil

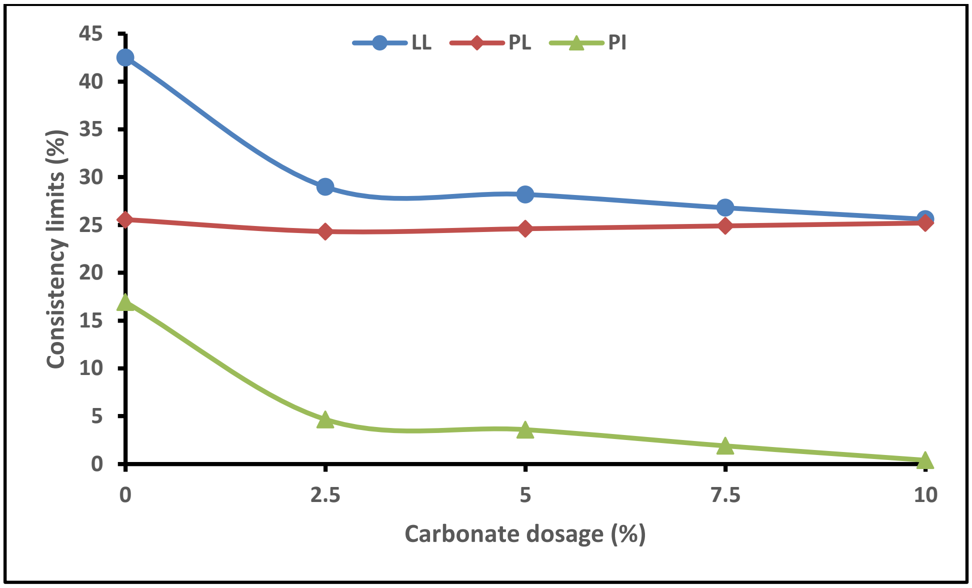

Figure 1b: Effect of carbonate mixture (3:1 $CaCO_3$:Na_2CO_3) on the consistency limits of the laterite soil

Effect of carbonate treatment on compaction characteristics

Figure 2 presents the effect of the carbonate mixtures ($CaCO_3$:Na_2CO_3 in 1:1 and 3:1) on the compaction parameters of the natural laterite soil. Under BSL compaction energy, the OMC (Fig. 2a) increased from 19% for natural soil to maximum of 21.2% and 21.0% at 10% for the additive contents 1:1 and 3:1 respectively, indicating a slightly lower OMC values for the 3:1 mixture than 1:1 across each dosage. Conversely, maximum dry density (Fig. 2b) for 3:1 mixture increased from 1.68 g/cm^3 to a peak of 1.77 g/cm^3 at 7.5% additive content, then marginally decreased to 1.75 g/cm^3 at 10%. The 1:1 mixture exhibited similar trends but with less pronounced improvements, achieving MDD of 1.74 g/cm^3 at 7.5% content. The reduction in OMC indicates that carbonate treatment reduces the water requirement for optimal compaction, while the increase in MDD suggests improved particle packing and densification. The reduction in MDD beyond the 7.5% dosage can be linked to the coating of soil grains by excessive carbonate particles, which hindered direct contact and particle interlocking. This indicates that while moderate stabilizer content improves compaction, excessive additions disrupt the soil matrix and reduce achievable dry density. The decline in density beyond optimum dosage in the present study also mirrors the behaviour observed by Bello *et al*. (2015), Osinubi *et al*. (2017) and Yan *et al*. (2022), who found that over-stabilization introduces voids and reduces soil densification.

For the WAS compaction method, the results followed similar patterns to BSL but with higher absolute values due to greater compaction effort. The MDD improved from 1.72 g/cm^3 for the natural soil and reached 1.81 g/cm^3 and 1.78 g/cm^3 at 7.5% additive content for 3:1 and 1:1 mixtures, respectively. These improvements are attributed to pozzolanic reactions between carbonate compounds and clay minerals, forming cementitious products that enhance particle bonding and reduce void spaces. The optimum moisture content, which ranged from 17.8 – 19.8 for 3:1 mixture and 17.8 – 20.0 for 1:1 mixture, were much lower than those of the BSL due to increased compaction energy facilitated better particle rearrangement. The increased MDD and reduced OMC with increased calcium carbonate would facilitate more economical construction by requiring less water and achieving better compaction.

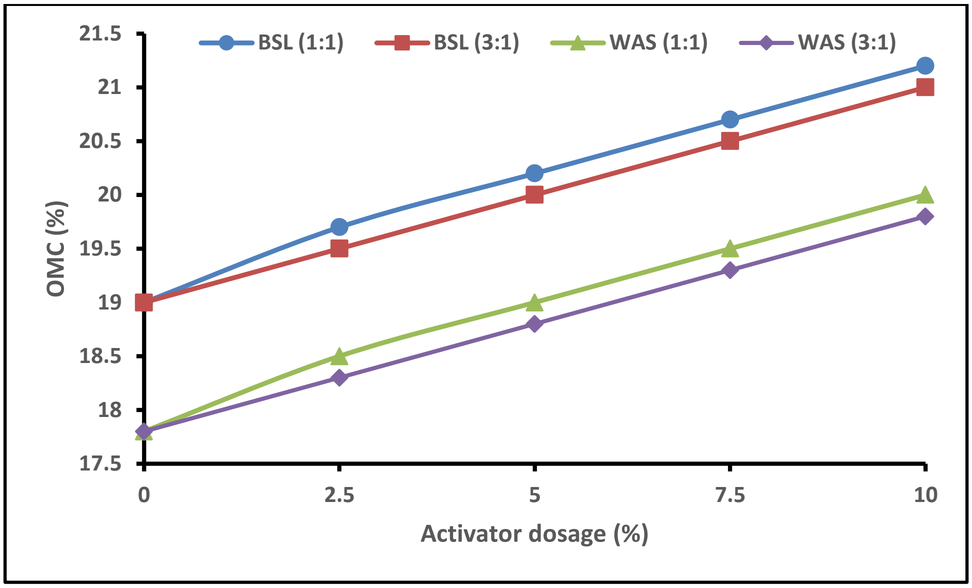

Figure 2a: Effect of carbonate mixture ($CaCO_3$:Na_2CO_3) on the OMC values of the laterite soil

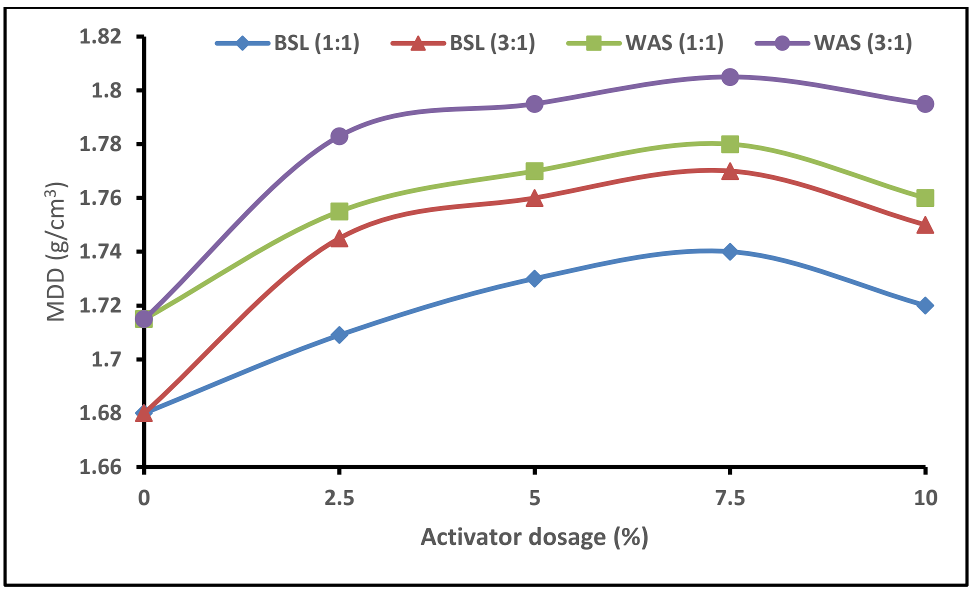

Figure 2b: Effect of carbonate mixture ($CaCO_3$:Na_2CO_3) on the MDD values of the laterite soil

Effect of carbonate treatment on California Bearing Ratio (CBR)

Figure 3 displays the effect of the carbonate mixtures ($CaCO_3$:Na_2CO_3 in 1:1 and 3:1) on soaked and unsoaked CBRs of the natural laterite soil using BSL and WAS compaction methods. Upon stabilization with calcium carbonate ($CaCO_3$) and sodium carbonate (Na_2CO_3), substantial improvements in both soaked and unsoaked CBRs were recorded, though the extent of improvement varied with additive type, dosage, and compaction effort. Natural soil exhibited the soaked CBRs of 14.82% (BSL) and 20.4% (WAS), classifying the soil as a weak road material according to Nigerian specifications (NGS, 1997). The addition of 1:1 $CaCO_3$:Na_2CO_3 mixture (see Fig. 3a) increased CBR values continuously as the carbonate dosage increased from 0-10%. The soaked values increased from 14.82-27.29 (BSL) and 20.4-37.56% (WAS), while the unsoaked CBR rose from 27.2-45.14% (BSL) and 36.8-61.1% (WAS), indicating higher strength for unsoaked condition as well as under WAS compaction method due to increased compactive effort. The improvement in CBR with the incorporation of the additive is attributed to the filler effects of carbonate particles, which reduced void spaces and enhanced particle interlocking, leading to a stiffer soil structure under load.

The 3:1 ratio presented in Fig. 3b demonstrated superior performance with CBR values when compared with the 1:1 mixture across all dosages, compactive efforts, soaking and dry conditions; revealing the significant calcium carbonate in enhancing the bonding properties of the soil through the formation of cementitious substances. For 3:1 mixture, the soaked values increased from 14.82-35.6% (BSL) and 20.4-49.0% (WAS) while the unsoaked CBR rose from 27.2-57.1% (BSL) and 36.8-77.3% (WAS), indicating higher strength than those of 1:1 mixture.

From 7.5% additive content, both mixtures transformed the soil into material meeting Nigerian specifications for sub-base applications (CBR ≥ 30%) under WAS compaction, with the 3:1 ratio achieving higher CBR values. The soaked condition testing is particularly significant as it represents worst-case moisture scenarios, confirming the durability of carbonate-stabilized laterite under adverse conditions. The superior performance of the calcium-rich 3:1 mixture is consistent with findings that calcium-based stabilizers promote stronger pozzolanic reactions and more effective soil matrix modification (Yan *et al.*, 2022). Calcium carbonate consistently provided stronger and more stable improvements compared to sodium carbonate.

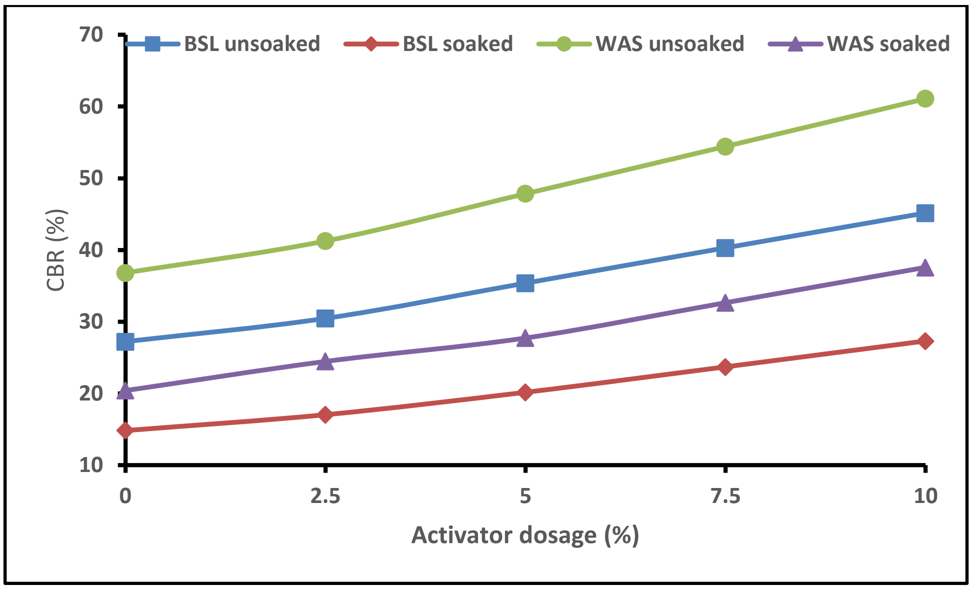

Figure 3a: Effect of carbonate mixture (1:1 $CaCO_3$:Na_2CO_3) on the CBR values of the laterite soil

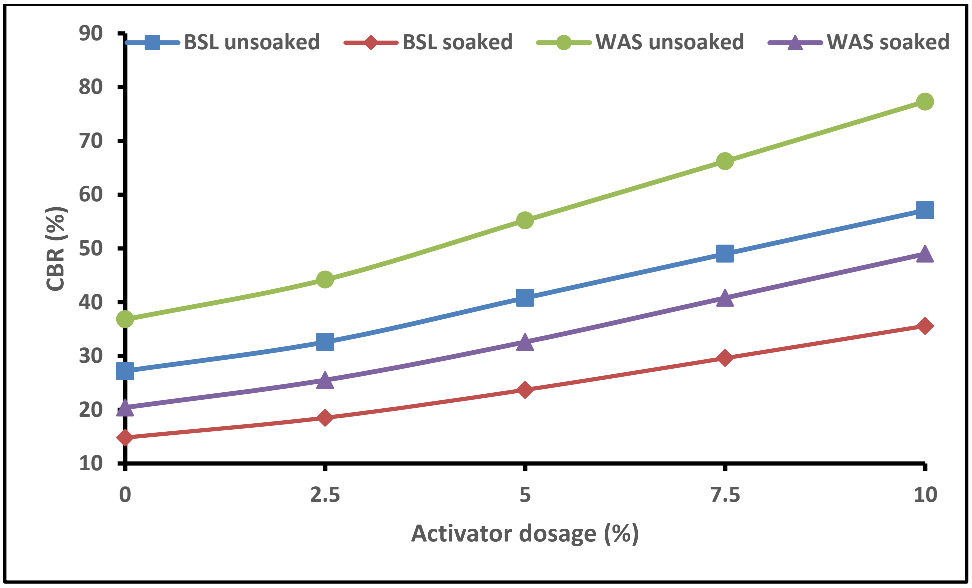

Figure 3b: Effect of carbonate mixture (3:1 $CaCO_3$:Na_2CO_3) on the CBR values of the laterite soil

Effect of carbonate treatment on Unconfined Compressive Strength (UCS)

Figure 4 shows the effect of the carbonate mixtures ($CaCO_3$:Na_2CO_3 in 1:1 and 3:1) on the 7th and 14th day UCS values of the natural laterite soil under the BSL compaction method. The 3:1 $CaCO_3$:Na_2CO_3 mixture achieved 398 kPa at 14 days curing, representing a 12.1% increase over 7-day values and demonstrating ongoing strength development through continued pozzolanic reactions. Both mixtures exhibited progressive strength gain between 7 and 14 days (9.4% to 13.0% improvement), indicating that extended curing periods may yield additional benefits. The decline in strength beyond 7.5% additive content (approximately 5-7% reduction at 10%) suggests an optimal dosage exists where additional carbonate becomes counterproductive, potentially due to excess unreacted material occupying void spaces without contributing to structural bonding.

Throughout all tests, the 3:1 $CaCO_3$:Na_2CO_3 ratio consistently outperformed the 1:1 mixture. This superior performance is attributable to the higher calcium carbonate content, which provides abundant calcium ions for cation exchange reactions and pozzolanic processes. Calcium ions effectively replace exchangeable sodium on clay surfaces, promoting flocculation and formation of cementitious gels that bind soil particles. This enhanced performance is attributed to increased calcium availability for pozzolanic reactions, aiding the formation of cementitious materials. The higher calcium carbonate proportion also facilitates improved particle packing and maintains alkalinity levels conducive to stable cementitious product formation. The 3:1 ratio appears to provide an optimal balance between calcium availability for reactions and sodium carbonate for initial alkaline activation, maximizing stabilization efficiency.

The findings demonstrate that carbonate stabilization at 7.5% content with a 3:1 $CaCO_3$:Na_2CO_3 ratio effectively transforms weak laterite soil into material suitable for road pavement applications. The UCS results indicate that 7.5% additive content yielded optimal performance for both mix ratios. The 1:1 $CaCO_3$:Na_2CO_3 mixture achieved maximum UCS values of 325 kPa and 366 kPa at 7 and 14 days respectively, while the 3:1 ratio attained 355 kPa and 398 kPa at corresponding curing periods. Beyond 7.5%, strength decreased by approximately 7% (1:1 ratio) and 5% (3:1 ratio) at 10% additive content, suggesting that excess carbonate compounds interfere with effective bonding mechanisms within the soil matrix. The improvements, combined with progressive strength gain over time, suggest that carbonate-stabilized laterite represents a viable option to popular stabilizers like cement or lime, particularly given the local availability and lower cost of carbonate materials.

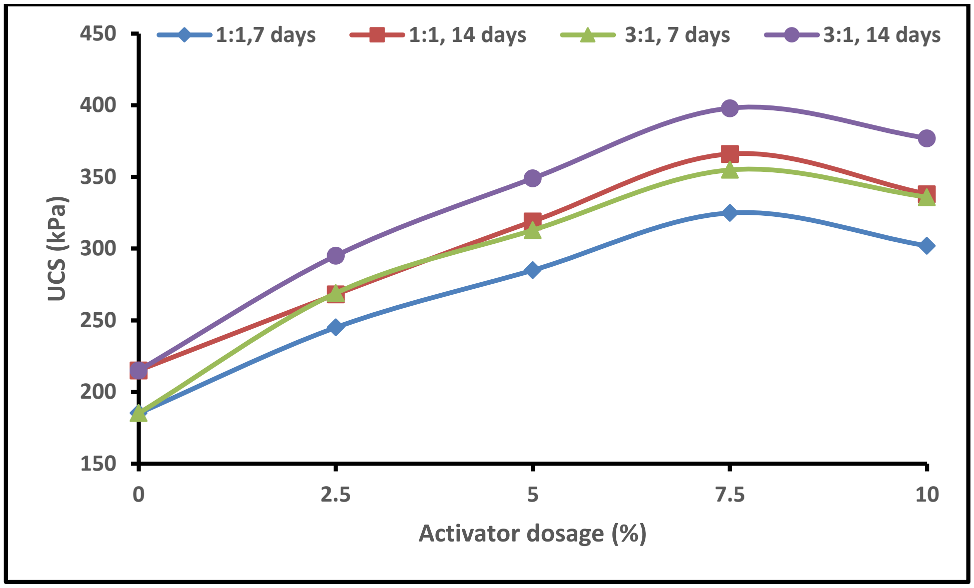

Figure 4: Effect of carbonate mixture ($CaCO_3$:Na_2CO_3) on the UCS values of the laterite soil

Conclusion

Based on the results of the study that investigated the effect of calcium carbonate ($CaCO_3$) and sodium carbonate (Na_2CO_3) mixtures (in ratios 1:1 and 3:1) on the geotechnical properties of laterite soil, the following conclusions were drawn:

i. The initial geotechnical investigations showed that the analysed Imota laterite soil (A-7-6 (8)) exhibited high plasticity (PI = 16.94%), high fine content (of 59.5%) and inadequate strength (soaked CBR = 14.8%), classifying it as unsuitable for sub-base construction according to Nigerian specifications.

ii. The addition of $CaCO_3$ and Na_2CO_3 improved the geotechnical properties of the laterite soil. The 1:1 $CaCO_3$:Na_2CO_3 mixture decreased the Plasticity Index (PI) from 16.94 to 5.3% as the carbonate dosage increased from 0 – 10%, whereas the 3:1 $CaCO_3$:Na_2CO_3 ratio achieved optimal performance, reducing the PI value from 16.94 to 0.4% at 10% additive content, transforming the soil from highly plastic to non-plastic classification.

iii. The maximum dry density increased while the optimum moisture content decreased as the calcium carbonate content in mixture became higher, due to the release of abundant calcium ions for cation exchange reactions and pozzolanic processes, resulting in flocculation and formation of cementitious gels that enhanced the bond between the soil particles. The optimal carbonate content of 7.5% was observed under the two additive combinations and compactive efforts.

iv. The soaked CBR values increased from 14.8 to 35% at 7.5% additive content, exceeding the 30% minimum requirement for sub-base applications. Unconfined compressive strength peaked at 398 kPa after 14 days curing at 7.5% content. The 3:1 ratio consistently outperformed the 1:1 mixture due to higher calcium content which facilitated the cation exchange reactions and formation of cementitious substances. The 7.5% carbonate mixture that met the minimum soaked CBR of 30% for sub base road layer, is recommended for improving the strength of the analysed laterite soil.

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