

## **EFFECT OF BRITISH STANDARD LIGHT COMPACTIVE EFFORT ON THE LATERITIC SOIL TREATED WITH CALCIUM CHLORIDE SALT**

**Ishola, K.<sup>1\*</sup>, Olawuyi, M.Y.<sup>2</sup> Oyeniyani, W.O. <sup>2</sup>, Ajala, A.K., <sup>2</sup> and Otunola, O.O.<sup>2</sup>**

<sup>1</sup>Department of Civil Engineering, Osun State University, Osogbo, Osun State, Nigeria.

<sup>2</sup>Department of Civil Engineering, Federal Polytechnic Offa, Kwara State, Nigeria

**\*Corresponding author: isholakzm@gmail.com**

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### **Abstract**

This study investigated the impact of calcium chloride salt (CCS)–treated lateritic soil using the British Standard Light compaction method to assess its suitability as a pavement material for highway construction. Laboratory tests conducted included specific gravity, particle size distribution, and compaction on both natural and stabilized soils, all following the British Standard Light method. Lateritic soil was stabilized with varying concentrations of CCS (0%, 4%, 8%, 12%, and 16%), and the results were analyzed using the Analysis Tools pack in Microsoft Excel 2013. The findings revealed that the gradation of lateritic soil improved with increasing CCS content. Additionally, the maximum dry density (MDD) of untreated lateritic soil initially decreased from 1.63 Mg/m<sup>3</sup> to 1.45 Mg/m<sup>3</sup> at 4% CCS, before increasing to 1.97 Mg/m<sup>3</sup> at 16% CCS. The optimum moisture content (OMC) increased from 19.47% to 24.0% at 4% CCS and continued to increase with higher CCS concentrations up to 16%. Statistical analyses of variance on the lateritic–CCS mixtures showed significance for all the tests except the MDD test, which indicated no significant difference. Based on the MDD results, it was concluded that an 8% CCS–lateritic soil mixture could be used to improve the quality of low-traffic roads.

**Keywords:** Compaction, Calcium chloride salt, Lateritic soil, Particle size distribution.

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### **1. INTRODUCTION**

Compaction serves as a fundamental parameter frequently employed by geotechnical engineers to assess soil densification within construction projects. The determination of strength involves the application of mechanical energy to enhance soil properties. In this process, compacted soil particles are restructured and voids between them are eliminated (Alhassan and Mustapha, 2017). During compaction, soil particle arrangement reduces the void ratio in the soil matrix, constraining water movement. This technique finds widespread use in the construction of embankments, including dams and roadways (Ishola *et al.*, 2019).

Laterite, a soil type that develops through weathering processes like laterization, is commonly found in drained soils of humid tropical regions (Alhassan and Mustapha, 2017; Oke and Olowoyo, 2019). The presence of iron and aluminum facilitates the formation of laterite, particularly in hot and humid climates (Oluremi *et al.*, 2016). Additionally, due to significant iron oxide content, most lateritic soils exhibit a distinctive rusty red hue (Alhassan and Mustapha, 2017). Despite this, engineers in Nigeria and other regions often utilize laterite as a common soil material for road pavement construction due to the presence of cementing agents (sesquioxides) in these soils (Joel and Agbede, 2011). However, some lateritic soils contain excessive clay minerals that compromise their strength, stability, and ability to bear intended traffic loads. Such categories of laterites are typically characterized by behaviors like swelling or expansion, depressions, and lateral movement (Obeahon 1993). When compared to lateritic soils primarily composed of kaolinite and chlorite minerals, certain laterite soils contain swelling clay minerals such as illite and montmorillonite, which decrease shear strength, elevate pore pressure, and increase swelling potential (Gidigas 1976)

Certain lateritic soils lack the engineering qualities necessary for use as sub-base and base materials in road pavements due to the prevalence of these clay minerals (Francis and Venantus 2013). This predicament has motivated researchers to explore various methods for enhancing the geotechnical properties of soils, especially those known to be problematic in construction (Joel and Agbede, 2011; Ishola *et al.*, 2019). Traditional soil improvement additives like cement, lime, and bitumen have been employed, but their cost-effectiveness remains questionable. As a result, researchers have turned their

attention to waste materials sourced locally from industries and agriculture, including iron ore tailings, steel slag, locust beans, rice husk ash, and plantain peel ash, among others (Ishola *et al.*, 2019; Oluremi *et al.*, 2017).

Calcium chloride, an inorganic salt produced as a byproduct of sodium carbonate production, emerges as a viable alternative. It was chosen over lime due to its convenience in forming a calcium-charged supernatant (Petry and Armstrong, 1989). Hausmann (1990) discussed the eco-friendly use of calcium chloride to suppress dust on unpaved roads, mining haul roads, and as a secondary additive to enhance the strength of soils treated with cement or lime. Shon *et al.* (2010) revealed that soil treated with calcium chloride experiences increased density and strength upon compaction. Furthermore, Zumrawi and Eltayeb (2016) observed that elevated  $\text{CaCl}_2$  content boosts dry density, reduces optimal moisture content, and enhances strength. Sani *et al.* (2018) also noted improved geotechnical properties of lateritic soil from Shika, Zaria, through  $\text{CaCl}_2$  treatment. However, limited research exists on the use of  $\text{CaCl}_2$  to enhance Oke bale lateritic soil. Consequently, this study aims to investigate the effects of calcium chloride on the compaction characteristics of lateritic soil. The study also aims to contribute to the limited research and data on the utilization of  $\text{CaCl}_2$  for soil improvement.

## **2. MATERIALS AND METHODS**

### **2.1 Materials**

#### **2.1.1 Lateritic Soil**

The lateritic soil utilized for this work was gathered from Oke bale area Osogbo, Osun State, Nigeria. An investigation of the geographical and soil maps of Nigeria after (Bello *et al.*, 2015) depicted the original material in the study area as a basic igneous rock which when weathered forms weakly developed lateritic soils.

#### **2.1.2 Calcium chloride**

The calcium chloride was obtained at a chemical laboratory shop in Osogbo.

### **2.2 Methods of Testing**

The laboratory tests conducted on the natural soil include particle size distribution, Atterberg limit, compaction. The properties of the soil were tested using (BS 1377, 1990) while the modified tests were carried in line with (BS 1924, 1990) procedures. California Bearing Ratio (CBR) tests were established at the optimum moisture contents (OMC) and maximum dry densities (MDD). British Standard Light (BSL) compactive efforts were utilized for soil- $\text{CaCl}_2$ . The tests especially CBR were guided as stated in the (Nigeria general specification, 1997). The compacted soil samples were allowed to cure for six days prior to testing at a steady stacking rate.

#### **2.2.1 Atterberg limits**

The liquid limit test was performed using the Cassagrande apparatus in accordance with ASTM standards (ASTM D4318-10). The plastic limit test was carried out in accordance with ASTM standards (ASTM D4318-10). The purpose of these tests was to see how adding salt affected the consistency limits.

#### **2.2.2 Compaction**

A 3kg lateritic soil sample was obtained and passed through the No. 4 sieve to remove clods. The weight of the soil mass and the mold without the collar ( $W_m$ ) was determined. The soil was placed on a flat tray, and water was gradually added to the soil to reach the desired moisture content ( $w$ ). Lubricant was applied to the collar, and the soil was placed in the mold in 3 layers, with each layer receiving 25 blows using a 2.5 kg hammer. The drops were applied manually at a steady rate. The soil mass was allowed to fill the mold and extend into the collar, but not more than 1 centimeter. The collar was carefully removed, and the soil extended above the mold was trimmed with a sharpened straight edge. The soil with the mold was weighed and extruded from the mold using a metallic extruder. The water content from both the top and bottom of the sample was determined. The process was then continued by adding more water in order to achieve a higher water content,  $w$ .

### 3. RESULTS AND DISCUSSION

#### 3.1 Soil Index Properties

The soil underwent various tests for characterization, including particle size analysis, specific gravity of soil solids, liquid limit, plastic limit, plasticity index, and moisture-density relationships. The Particle size distribution curve of the natural soil is illustrated in Figure 1. Table 1 provides an overview of the soil properties, while Table 2 presents the physiochemical composition of the Lateritic soil.

**Table 1: Index properties of the natural soil**

<b>Properties</b>	<b>Quantity</b>
Natural Moisture Content (%)	19.3
Specific Gravity	2.67
Liquid Limit (%)	60.05
Plastic Limit (%)	45.37
Plasticity Index (%)	14.68
Linear shrinkage (%)	8.6
Percentage Passing BS No 200 Sieve	37.14
AASHTO Classification	A-7-6 (5)
Optimum Moisture Content (%)	19.47
Maximum dry density, Mg/m <sup>3</sup>	1.63

**Table 2: Physiochemical Composition of Lateritic soil**

<b>Oxide Composition</b>	<b>Lateritic Soil</b>
SiO <sub>2</sub>	35.60
Al <sub>2</sub> O <sub>3</sub>	27.40
Fe <sub>2</sub> O <sub>3</sub>	24.0
P <sub>2</sub> O <sub>5</sub>	-
SO <sub>3</sub>	0.85
K <sub>2</sub> O	-
TiO <sub>2</sub>	-
MnO	2.00
Na <sub>2</sub> O	-
CuO	-
CaO	0.28
ZnO	0.09
MgO	-
Loss of Ignition	14.6

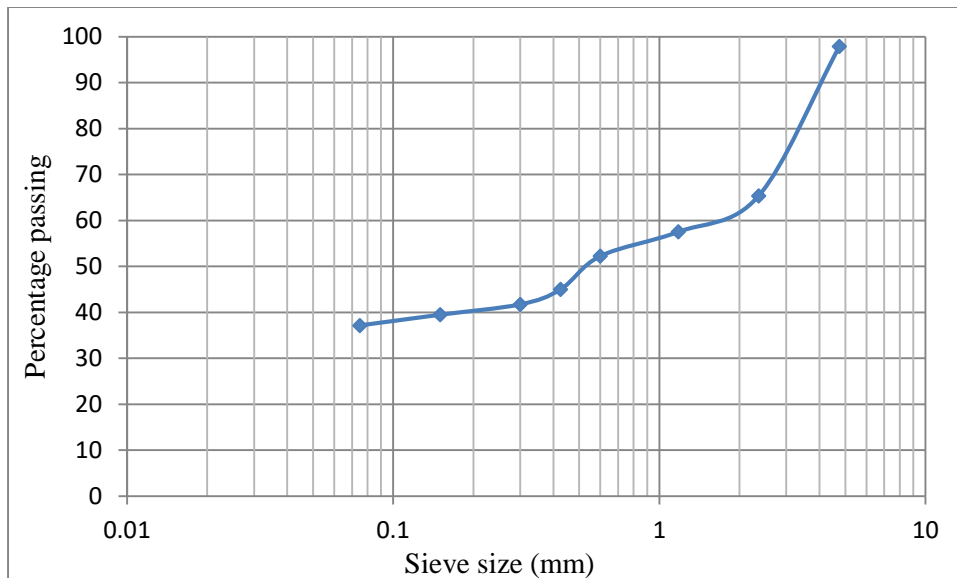


Figure 1: Particle size distribution curve of the natural soil

### 3.2 Atterberg Limits

The Atterberg limits of CCS- lateritic soil mixture is shown in Figure 2 as the CCS treatment increased with a corresponding decrease in the liquid limits (LL), plastic limits (PL), and plasticity index (PI). The liquid limit and Plastic limit decreased from 60.05 to 35.55%; 45.37 to 17.95% up to 16% CCS content respectively. The plasticity index initially decreased from 14.68 to 11.49% at 12% CCS content; thereafter, further addition of CCS increased to 15.6%. The possible reason for these results was attributed to the complete chemical hydration of CCS in the lateritic soil mixture which resulted in the aggregation and cementation of particles into larger clusters (Chew *et al.* 2004; Osinubi *et al.* 2012).

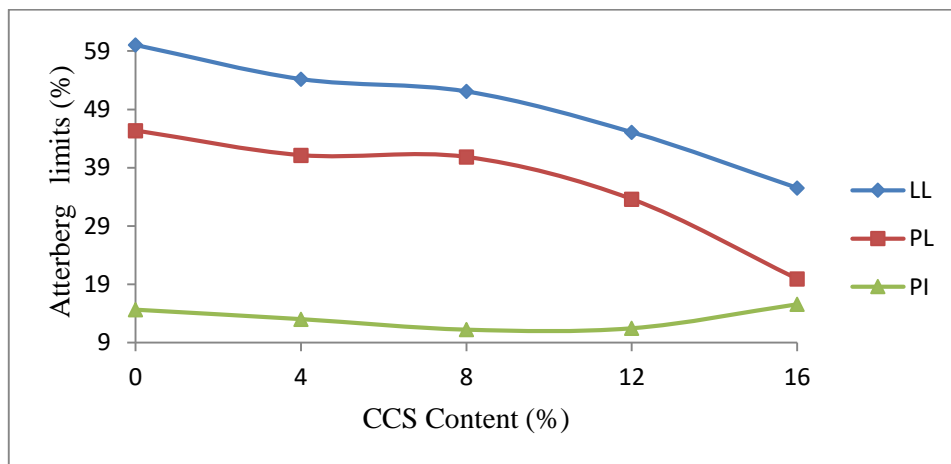


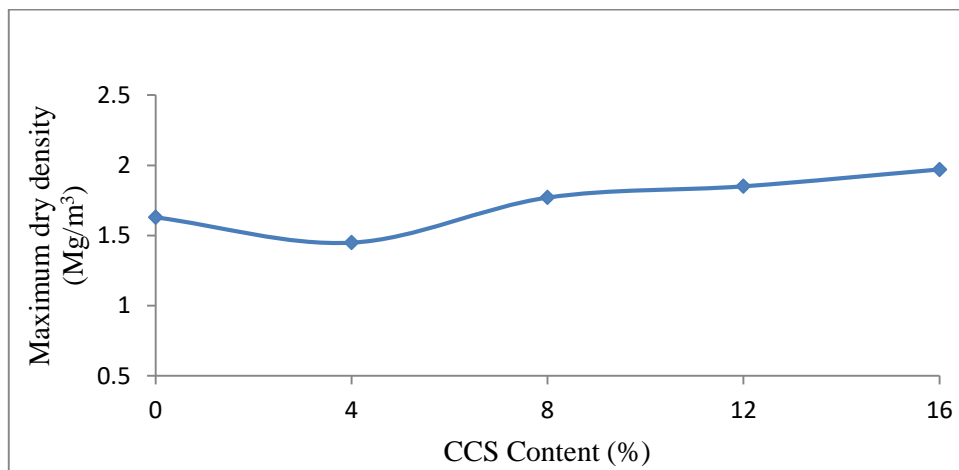
Figure 2: Variation of Atterberg limit of lateritic soil treated with calcium chloride salt

### 3.3 Compaction Characteristics

#### 3.3.1 Maximum Dry Density

The curve of the soil maximum dry density is depicted in Fig. 2 for BSL compactive efforts. The MDD value initially decreased from 1.63 Mg/dm<sup>3</sup> to 1.45 Mg/dm<sup>3</sup> at 4% CCS<sub>2</sub> thereafter increased with higher percentage of CCS. A similar trend was reported by (Edeh *et al.*, 2014) where sawdust ash was used to improve lateritic soil properties. The observed

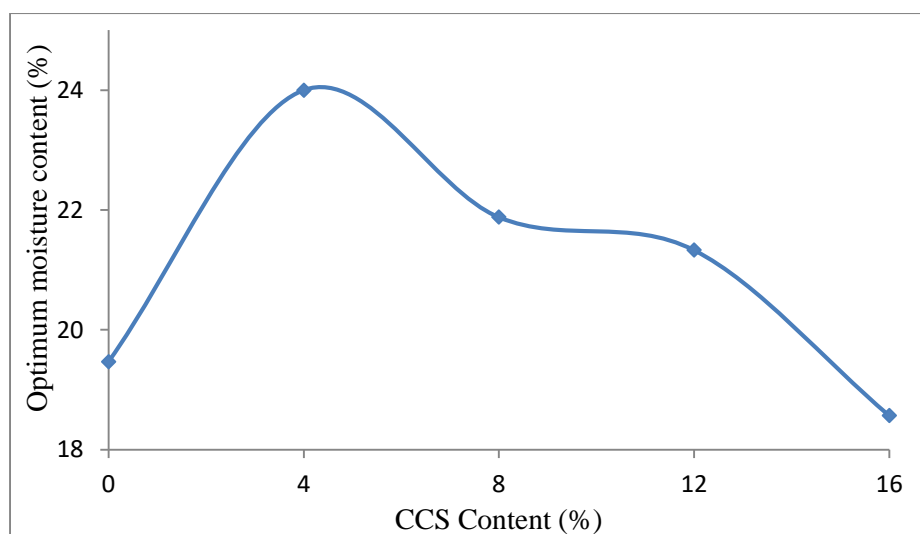
MDD trend was probably due to agglomeration of the CCS and the fine fraction of lateritic soil. The lateritic soil aggregates occupied larger spaces, thus increasing their volume and consequently decreasing their dry densities (Osinubi *et al.*, 2012). The increase in MDD was due to CCS occupying the space found in the soil moisture leading to the flocculation and agglomeration of the clay particles as a result of the ions exchange (Salahudeen *et al.*, 2014). An analysis of variance (ANOVA) of the MDD BSL results show no significant effect of CaCl<sub>2</sub> on the lateritic soil (FCAL = 4.90 < FCRIT = 5.31)



**Figure 3: Variation of MDD of lateritic soil treated with calcium chloride salt**

### 3.3.2 Optimum Moisture Content

The variation of Optimum moisture content with CCS- lateritic treated soil is shown in Fig. 4. The OMC for British Standard Light (BSL) compactive effort increased from 19.47% to 24% at 4% CCS thereafter decreased with higher content of CCS up to 16%. The increase in OMC was attributed to the higher content of CCS in the lateritic soil which increased the surface area of the particles, thus requiring more water to lubricate the entire matrix of the mixes (Ishola *et al.*, 2019). An analysis of variance (ANOVA) of the OMC for BSL results show a significant effect of CaCl<sub>2</sub> (FCAL = 19.12 > FCRIT = 5.31) on the lateritic soil mixture



**Figure 4: Variation of OMC of lateritic soil treated with calcium chloride salt**

#### 4. CONCLUSIONS

Based on this study the following conclusions were drawn:

- i. The lateritic soil used was classified as A-7-6 (5) and CL using AASHTO soil characterization and USCS respectively.
- ii. The plasticity index of the CCS – lateritic treated soil decreased up to 12% CCS content.
- iii. The compaction characteristics of the natural lateritic soil show an improvement as the MDD increased with a corresponding OMC decrease up to 4% CCS content in the lateritic soil.

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