# Evaluation of Strength Characteristics of Compacted Deltaic *Chikoko* Clay Stabilized with Rice Husk Ash

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**ABSTRACT**

One of the key parameters usually considered in soil improvement techniques is strength gain. *Chikoko* clay is a muddy weak clay soil commonly found along the coastal shelf Rivers, Bayelsa, Delta and other coastal states of Nigeria. Deltaic *chikoko* clay is a weak soil with low bearing capacity that requires some forms of stabilization and strength enhancement. *Chikoko* clay obtained from Eagle Island in Port Harcourt, Nigeria was stabilized with 2, 4, 6 and 8% of Rice Husk Ash. The engineering characteristics of Reduced British Light (RBL) compacted Deltaic *Chikoko* clay were assessed. Unconfined Compressive Strength (UCS) was taken after 7, 14 and 28 days curing. The UCS values decreased with increase in water content relative to optimum for the compactive efforts. Addition of Rice husk Ash from 4 – 6% increased the UCS of the compacted stabilized *chikoko* soil by 14.7%. However, further increase to 8% reduced the UCS by 8.5%. The UCS also decreased by 4.6% after 21 days curing. A maximum unconfined compressive strength (UCS) value of 152 kPa at 6% RHA corresponding to17.8% increment was recorded. Optimal stabilization of Deltaic marine *chikoko* clay was achieved at 6% RHA. Stabilization of *chikoko* clay improved its unsoaked CBR value from 8.6% to 17.4%, thereby making the stabilized soil suitable for sub-grade application.

**Keywords:** *Chikoko soil, Compaction, Deltaic clay, Lateritic soil, Rice husk ash, Stabilization.*

## 1 INTRODUCTION

The quest for sustainable soil improvement methods has led researchers to the discovery of novel and innovative methods. Another emerging innovative method called microbial induced calcite precipitation (MICP), a multi-disciplinary studies that involve civil engineering, microbiology, chemical engineering and chemistry has found application in soil stabilization (Achal and Pan 2014; Dawoud *et al*., 2014; Feng and Montoya, 2016; Hamdan *et al*., 2011; 2016; Ijimdiya, 2017; Mujah *et al*., 2019; Osinubi *et al*., 2017; 2018; 2019). Research is still on going on modern soil improvement and stabilization and enhancements.

When building on soil with inadequate strength properties, the need to stabilize soil and enhance its properties becomes a necessity (Ogunsanwo, 1985). Working in marine and especially difficult terrain, right from the onset of planning any construction work, the necessity to enhance soil properties readily comes to mind. Lateritic soil is one of the most widely used filled or backfill material. Proper understanding of the geotechnical properties of this lateritic soil is therefore paramount in evaluating their performance when used as construction material (Atolagboye and Talabia, 2014).

Soil stabilization becomes an option when soil encountered is vast, and/or the process of replacement is uneconomical. In general, a stabilized soil is a composite material produced from combination and optimization of properties in individual constituent material (Basha *et al*., 2005). The enhanced engineering properties of various soils, resulting from the usefulness of by-products including Agricultural wastes, bring about environmental and economic importance (Walid & Hariahance, 2010). It is way of converting what is presently being considered as waste into a productive use.

Several works have been done on the suitability or otherwise of Rice husk ash for soil stabilization. Alhassan & Mustapha (2007) examined cement stabilized lateritic soil; Alhassan (2008) studied potential of rice husk ash for soil stabilization; Otoko & Aitsebaomo, (2009); Otoko (2014); Otoko & Karibo (2014); Otoko & Onuoha (2015) studied the physical properties and engineering characteristics of Nigerian Deltaic clay (*Chikoko*) soil.

Rice husk, an agricultural waste is generated in a large quantity as rice crop is frequently produced and processed in a large scale in Ebonyi state and other parts of Nigeria. One of the common ways of improving such materials is by burning them to produce ash. This study is focused on the use of Rice husk ash to enhance the engineering properties of compacted stabilized Deltaic Chikoko clay soil.

## 2 MATERIALS AND METHODS

### 2.1 MATERIALS

**Soil**: The soil used in this study was collected using the disturbed sampling technique at depths of between 0.5 m and 2.0 metres from three clusters A, B and C from the

Eagle Island River behind the Rivers State University campus, Port Harcourt, Nigeria. It is a lateritic soil classified as CL and CH or A – 6, and A – 7 – 6 according to USC and AASHTO soil classification systems respectively.

**Rice husk ash**: The rice husk ash used in this research was sourced from Ebonyi State Mill, Abakaliki, Nigeria. The Rice husk were burnt to ashes and then sieved through sieve No 200 of the BS sieve to get very fine grain ash. It was thereafter stored in air tight containers to prevent moisture loss/gain and any form of contamination plate I.

**Plate I**: Rice Husk Ash Preparation

## 2.2 METHODS

**Index properties**: Natural moisture content, specific gravities, particle size analysis and Atterberg limits tests were conducted in accordance with tests procedures specified in BS 1377: 1990.

**Compaction characteristics**: Compaction of stabilized RHA-Chikoko clay specimens was conducted in accordance with the guidelines specified in BS 1377 (1990) to compute the required parameters. The reduced British Standard light (RBSL) compactive effort was used. The RBSL compaction is the energy resulting from 2.5 kg rammer falling through a height of 30 cm onto three layers, each receiving 15 blows.

**Unconfined compressive strength (UCS):** The UCS test was conducted in accordance with the procedure specified in BS, 1377: (1990). The treated specimens were prepared with RHA of 2, 4, 6 and 8 % relative to OMC and compacted with RBSL compactive energy. The compacted specimens were cured for 24 hours in the moulds before extrusion and trimming as well as further cured for another 7, 14, 21 and 28 days in the laboratory at temperature of 24 ± 2ºC. The average of six (6) crushed specimens was recorded and used for the computation of the unconfined compressive strength.

**California bearing ratio (CBR)**: The unsoaked CBR of stabilized RHA-Chikoko clay specimens was conducted in accordance with the guidelines specified in BS 1377 (1990) to compute the required parameters as shown in Plate II. 6 kg of pulverized mixed samples divided to five parts were poured into CBR mould and rammed with 4.5 kg rammer into five layers, each receiving 62 blows. The attached upper and lower dial gauges measures the upper and lower penetrations of the plunger.

**Plate II**: California Bearing Ratio test of samples

## 3 RESULTS AND DISCUSSION

**Index properties of the natural and treated soil**:
The index properties of the natural and RHA-treated Chikoko clay soil are shown in Figure 1 and Table 1. The fraction passing No 200 sieve is 53.1%. The soil is classified as CL and CH or A – 6, A – 7 – 6 according to USC and AASHTO soil classification systems respectively (AASHTO, 1986; ASTM, 1992). The oxide composition of the soil is summarized in Table 2 indicates that the soil is lateritic with silica - sesqueoxide ratio value {that is $SiO_2$ / ($Al_2O_3$ + $Fe_2O_3$)} of 1.54 which is within the 1.33 – 2.00 threshold recommended for lateritic soils by Bell, (1993). X-Ray Diffraction (XRD) analysis of the sample shows that the dominant clay minerals are orthoclase, anorthite, anorthoclase and montmorilonite which are indicated in Table 3 and Figure 2.

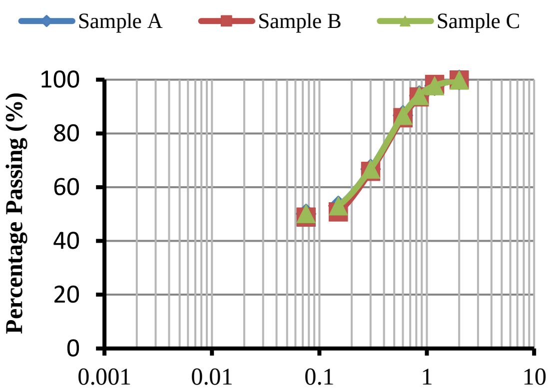


**Figure 1**: Sieve size analysis of deltaic chikoko clay

TABLE 1: PROPERTIES OF NATURALDELTAIC CHIKOKO CLAY

| **Properties (Average)** | **Sample A** | **Sample B** | **Sample C** |
|---|---|---|---|
| Specific gravity of soil | 2.74 | 2.65 | 2.68 |
| Natural moisture content (%) | 29.0 | 29.6 | 30.6 |
| **Atterberg Limits** | | | |
| Liquid limit (%) | 37.5 | 32.8 | 44.5 |
| Plastic limit (%) | 25.7 | 20.5 | 26.13 |
| Shrinkage limit (%) | 9.64 | 9.21 | 10.0 |
| Plasticity index | 11.8 | 12.3 | 18.37 |
| % Passing BS No. 200 sieve | 51.9 | 52.7 | 54.7 |
| **Classification** | | | |
| USCS | CL | CH | CH |
| AASHTO | A-6 | A-6 | A-7-6 |

TABLE 2: OXIDE COMPOSITION OF DELTAIC CHIKOKO CLAY

| **Chemical Constituent** | **Percentage Composition (%)** |
|---|---|
| $SiO_2$ | 31.6 |
| $A1_2O_3$ | 8.8 |
| $Fe_2O_3$ | 11.7 |
| CaO | 13.3 |
| MgO | 6.4 |
| $SO_3$ | 1.6 |
| $Na_2O$ | 1.4 |
| $K_2O$ | 1.1 |
| $TiO_2$ | 1.0 |
| $P_2O_5$ | 1.0 |

TABLE 3: MINERALOGICAL COMPOSITION OF DELTAIC CHIKOKO CLAY

| **Description** | **Quantity** |
|---|---|
| Quartz (%) | 50.00 |
| Anorthite (%) | 8.35 |
| Calcium Silicide (%) | 6.25 |
| Montmorillonite (%) | 8.23 |
| Ankerite (%) | 6.25 |
| Sodium Aluminium/ Silicate Hydrate | 6.25 |
| Anothoclase | 8.33 |
| Orthoclase | 10.07 |

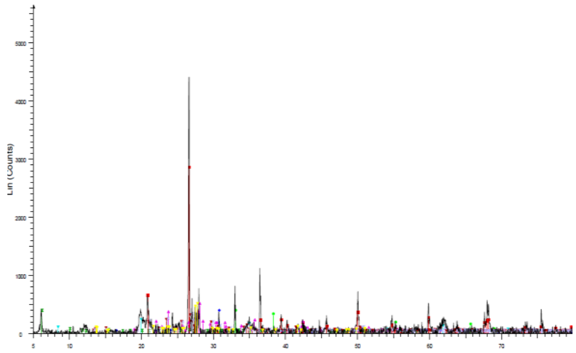

**Figure 2**: X-ray Diffraction of deltaic chikoko clay

**Effect of curing age on UCS of *Chikoko* clay**

The effect of curing age on unconfined compressive strength (UCS) of *chikoko* clay was investigated. It was observed that the unconfined compressive strength increased by 1.6% from 14 to 21days curing age, and 2.3% from 21 to 28 days curing for specimens compacted at the reduced British Standard light (RBSL) energy level as shown in Figures 3 – 5. Also, it was noted that unconfined compressive strength increases with curing age.

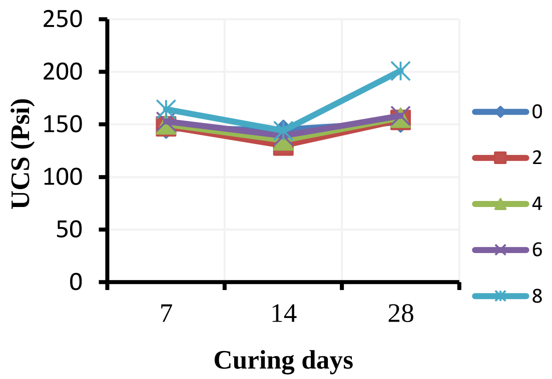


**Figure 3**: Variation of UCS values with curing days for Location A Samples

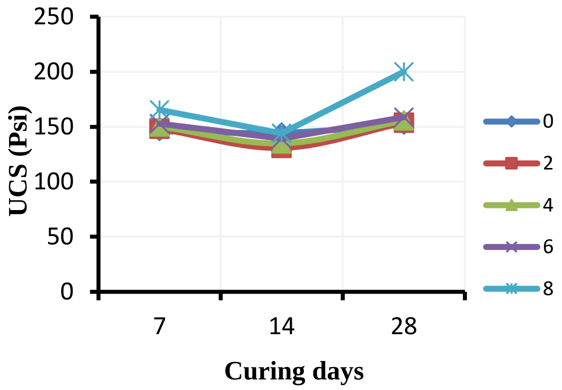


**Figure 4**: Variation of UCS values with curing days for Location B Samples

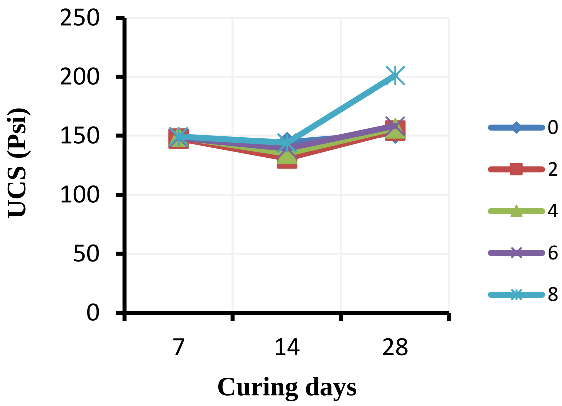


**Figure 5:** Variation of UCS values with curing days for Location C Samples

**Effect of RHA addition on Compaction Characteristics of Chikoko clay**

An increase in OMC of compacted stabilized *chikoko* clay was observed. This was due to the additional water required for wetting the large surface area of the fine rice husk ash particles Figures 6 - 10. The increase in OMC is also probably due 'to the additional water held within the flocculent soil structure due to excess water absorbed as a result of the porous property of rice husk ash. The decrease in MDD of all treated *chikoko* clay was due to the partial replacement of relatively heavy soils with light weight rice husk ash (with Specific gravity of 1.36). This decrease in density could also be influenced by increase in porosity of all compacted soil samples due to addition of rice husk ash. In addition, the decrease can also resulted from the flocculation and agglomeration of clay particles, caused by the cation exchange reaction, leading corresponding increase in volume and decrease in dry' density as advanced by Lees *et al*., (1982) and corroborated by the findings of Basha *et al*., (2005).

**Effect of RHA addition on UCS of *Chikoko* clay**

The UCS values decreased with increase in water content relative to optimum for the compactive efforts. Addition of Rice husk Ash from 4 – 6% increased the UCS of the compacted stabilized *chikoko* soil by 14.7%. However, further increase to 8% reduced the UCS by 8.5%. The UCS also decreased by 4.6% after 21 days curing. A maximum unconfined compre**ssive strength (UCS) value of 152** kPa at 6% RHA corresponding to17.8% increment was recorded. Optimal stabilization of Deltaic marine clay was achieved at 6% RHA. Stabilization of *chikoko* clay improved its unsoaked CBR value from 8.6% to 17.4%.

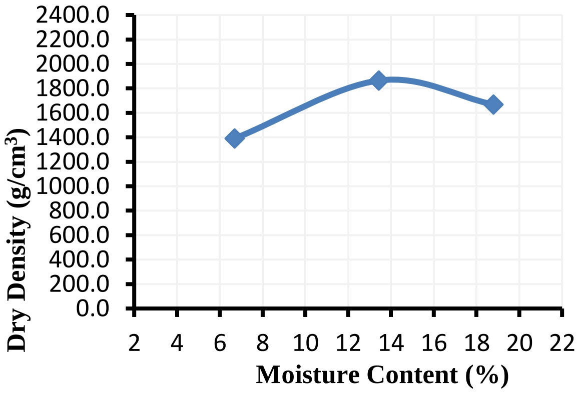


**Figure 6**: Compaction characteristics of stabilized *chikoko* clay 0% RHA

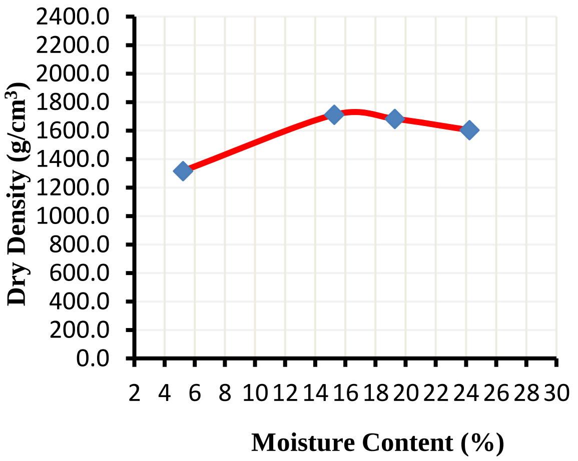


**Figure 7**: Compaction characteristics of stabilized *chikoko* clay 2% RHA

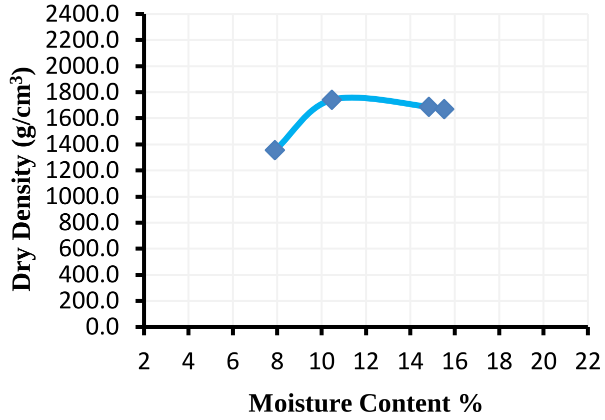


**Figure 8**: Compaction characteristics of stabilized *chikoko* clay with 4% RHA

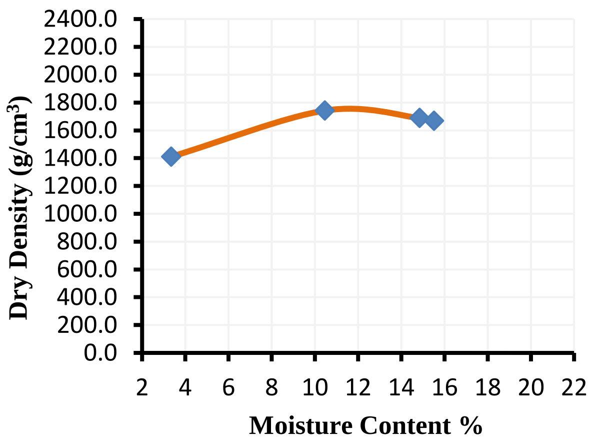


**Figure 9**: Compaction characteristics of stabilized *chikoko* soil with 6% RHA

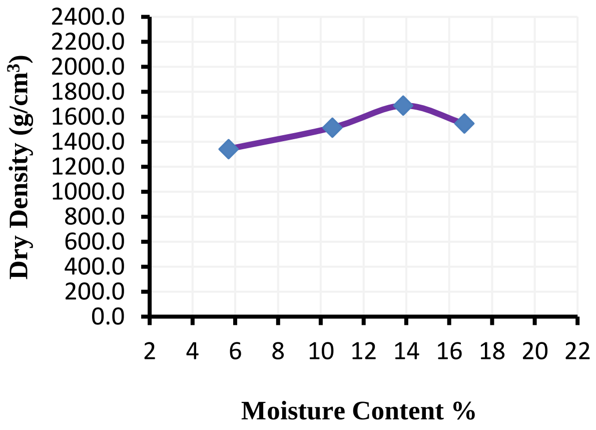


**Figure 10**: Compaction characteristics of stabilized *chikoko* soil with 8% RHA

**Effect of RHA addition on CBR of Chikoko clay**

Generally, a slight increase in CBR was observed for the RHA-stabilized *chikoko* clay specimens compacted at Reduced Standard Proctor energy steadily up to 6% after which it reduced. The effect of soaking on CBR values of the specimens can be seen in Figures 11 – 12. Soaking produced reduction and divergence in the CBR values of stabilized *chikoko* clay.

While unsoaked CBR of stabilized compacted *chikoko* soil from different locations exhibited similar pattern, soaking produced reduction and divergence in the CBR values of stabilized *chikoko* clay from the same locations. The unsoaked and soaked CBR values of all the soil samples increased considerably on stabilization with rice husk ash. This shows that the load bearing capacity of the soil increased with the stabilization mix. The increase in both the soaked and unsoaked CBR may be due to the availability of calcium from the ash for the cementations reaction with the silica and iron oxide from the *Chikoko* clay.

Optimal stabilization of Deltaic marine *chikoko* clay was achieved at 6% RHA. Stabilization of compacted *chikoko* clay improved its unsoaked CBR value from 8.6% to 17.4%, thereby making the stabilized soil suitable for sub-grade application.

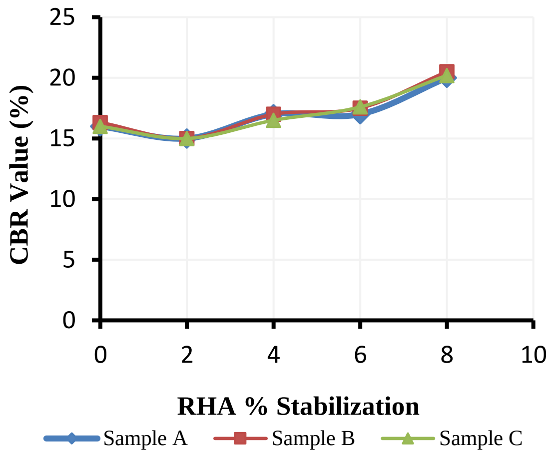


**Figure 11**: Variation of unsoaked C.B.R values for *Chikoko* clay Sample

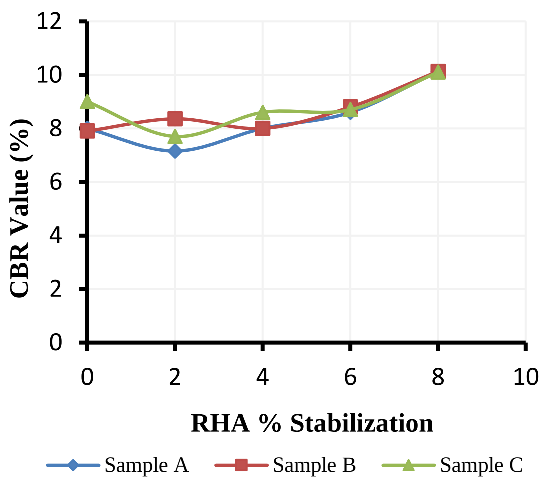


**Figure 12**: Variation of soaked CBR values for Stabilized *Chikoko* Clay Samples

## 4 CONCLUSION

Unconfined compressive strength of *chikoko* clay increased with curing age. A maximum unconfined compressive strength (UCS) value of 152 kPa at 6% RHA corresponding to17.8% increment was recorded. The unconfined compressive strength increased by 1.6% from 14 to 21days curing age, and 2.3% from 21 to 28 days curing for specimens compacted at the reduced standard proctor energy level. Soaking produced reduction and divergence in the CBR values of stabilized *chikoko* clay from the same locations. Optimal stabilization of Deltaic marine *chikoko* clay was achieved at 6% RHA. Stabilization of compacted *chikoko* clay improved its unsoaked CBR value from 8.6% to 17.4%, thereby making the stabilized soil suitable for sub-grade application.

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