



Stabilization of Deltaic Marine Clay (Chikoko Soil) using Blend of Quarry Dust and Lime

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ABSTRACT

This research work was designed to evaluate the suitability of quarry dust and lime for stress-strain strength development characteristics of Chikoko soil. The laboratory works involved preliminary investigations to identify the index properties of the soil samples at various boreholes. Results revealed that the soil belonged to the A-7-6 class of soil in the American Association of State Highway and Transportation (AASHTO) classification system. The soil samples from two different boreholes were stabilized with concentration of 0% to 15% quarry dust and lime. Results showed that the soil sample from (Borehole 1) with quarry dust and lime stabilization increased with the highest Maximum dry density of 2400kg/m³ at 5/10% also with an increased optimum moisture content of 13.8kg/m³ for bore hole 1 at 0 to 3/5% quarry and lime percentages. It was also observed that the cohesion and friction angle of 18kN/m² and 16.0° (Borehole 2) were the highest values at 7/15% of quarry dust and lime. The normal stresses, deviator stresses and shear stresses increased at an optimum value of 125kN/m², 241kN/m² and 159kN/m² at 5/10% quarry dust and lime for the different boreholes. The 5% quarry dust and 10% lime mixture appear to be the Optimum stabilization level, providing the best balance between increased resistance to compression and reduced void space. Therefore, this mix is likely to offer the most favorable engineering performance in terms of strength, settlement reduction and long-term stability of the marine clay.

Keyword: Chikoko Soil, Bearing capacity, Settlement, Shear strength, Stabilization.

1. INTRODUCTION

The increasing demand for construction materials and the need to address environmental concerns have prompted the exploration of alternative materials and soil stabilization techniques in civil engineering projects. The reduction in natural sand sources has led to a search for substitute materials for fine aggregates in concrete production. Quarry dust, a by-product of quarrying activities, has emerged as a potential alternative due to its properties such as pozzolanic characteristics, which can enhance the performance of concrete (Chandana *et al.*, 2013). Quarry dust is commonly used as a substitute for sand in construction projects, such as concrete and masonry work. When mixed with soil, it can improve the load-bearing capacity, and reduce shrinkage, swelling, and erosion. It can also be used as base material for roads and pavements, in the production of bricks, blocks, and other building materials. Its effective utilization not only addresses the scarcity of natural sand but also leads to cost savings and improved material properties.

In addition to quarry dust, lime, a versatile chemical compound derived from limestone, has been widely used to improve the engineering properties of soil. It reduces plasticity, increases strength, and enhances the load-



bearing capacity of soil, making it suitable for road construction and foundation stabilization. Furthermore, lime is also known for its ability to enhance the properties of concrete, thereby reducing shrinkage and improving workability (Negi *et al.*, 2013). Lime is a highly valuable and versatile material with a wide range of applications in construction, agriculture, water treatment, and environmental protection. Its ability to improve the properties of materials and neutralize acidic substances makes it indispensable in many industries.

Moreover, the unique properties of deltaic marine clay (Chikoko soil), a type of soil found in deltaic environments where rivers meet the sea, present challenges in construction due to its highwater content, low shear strength, and high compressibility. This soil type is prone to settlement and deformation, necessitating soil stabilization techniques for construction purposes. Various soil stabilization techniques, such as the addition of lime, cement, or other binding agents, are often required to improve the properties of deltaic marine clay for construction purposes. Adding lime to Chikoko soil can improve its engineering properties by reducing plasticity, increasing shear strength, and enhancing workability. Mixing cement with deltaic marine clay creates a hardened material that has improved strength and reduced compressibility (Otoko & Iheanyi, 2015). This is particularly useful in constructing foundations and embankments. The addition of lime or cement to Chikoko soil has been identified as an effective means of improving its engineering properties, reducing its plasticity, increasing its shear strength, and enhancing workability (Otoko, 2015).

The objectives of this study are to:

- i. To analyze the natural soil using preliminary tests.
- ii. To measure the increase in shear strength parameters due to addition of Quarry dust and lime stabilization.
- iii. To analyze the stabilization characteristics under load, including the potential for excessive settlement or failure.
- iv. To determine the relationship between the moisture content of a soil and its dry density under a specified compaction effort.
- v. To determine the optimal mix proportions of quarry dust and lime for maximum stabilization.

2. MATERIALS AND METHODS

2.1 Materials

Chikoko Soil: Chikoko Soil used for this research was gotten deltanic marine area at Eagle Island in Nkpolu-Oroworokwo community in Port Harcourt local government area of Port Harcourt, Rivers State, Nigeria. Nkpolu-Oroworokwo is located at latitude 4.7814N and longitude 6.9803E on google map and Agip in Mgbuosimini community in Port Harcourt local government area of Port Harcourt, Rivers State, Nigeria. Mgbuosimini is located at latitude 4.80836N and longitude 6.97270E on google map.

The distributed samples was unearthed using hand auger at the depth of 1.5m. samples were collected in polyethene bags to prevent loss of natural moisture. The collected samples were taken to the soil mechanics laboratory of the department of civil engineering, Rivers State University for testing.

The materials used for this research are;

- Chikoko soil (deltanic clay)
- Quarry dust
- Hydrated lime
- Water



2.2 Methods

The laboratory tests were carried out on the materials (Chikoko soil, Quarry dust and Limestone powder) in accordance with the procedures and requirements specified by British standards (BS 1377, 1990).

Preliminary classification tests following the (BS 1377-2) was used to establish the physical and index properties. The result obtained was used for proper classification of the soil samples.

The tests conducted includes;

- Natural moisture content
- Atterberg limit Test
- Specific gravity Test
- Particles Size Distribution Test (sieve analysis)
- Proto compaction Test
- Triaxial Test
- Consolidation Test

We will elaborate more on these three tests; Proto compaction test, Triaxial test and consolidation test because they played a major role in the improvement of strength capacity of the soil with percentages of Quarry dust and Lime added as stabilizers.

Compaction Test: The test was carried out on the soil specimen (Chikoko soil) with its stabilizers (quarry dust and lime) blended together into the soil in percentages (3%, 5%, 7% of quarry dust and 5%, 10%, 15% of lime), to measure the optimal moisture content (OMC) and the maximum dry density (MDD) stabilized soil when compacted under controlled conditions.

Triaxial Compression Test: This test was carried out on the soil specimen (Chikoko soil) with stabilizers (quarry dust and lime) blended together in percentages (3%, 5%, 7% of quarry dust and 5%, 10%, 15% of lime), the cell pressures varies from 100, 200, 300 kPa, to determine the shear strength, the cohesion (cu) and the angle of shearing resistance of the soil (ϕ).

Consolidation Test: The test was carried out on the soil specimen (Chikoko soil) with stabilizers (quarry dust and lime) blended together in percentages (3%, 5%, 7% of quarry dust and 5%, 10%, 15% of lime). The soil specimen is subjected to Axial stress (σ) in series of (25, 50, 100, 200, 400, 800 kPa) using a lever arm loading frame to evaluate its compressibility characteristics to determine the void ratio (e) and the coefficient of consolidation (cv).

All the tests were conducted in accordance with BS 1377, 1990 which is the standard method of carrying out tests for soils for Civil Engineering Purposes.

3.0 RESULTS AND DISCUSSION

Table 3.1: Summary of Index Properties of the Preliminary Test on Chikoko Soil;

Properties of Natural Soil	BH1	BH2
	(Agip Island)	(Eagle Island)
Natural moisture content (%)	25.70	17.36

Liquid limit (%)	25.0	36.0
Plastic limit (%)	14.0	12.9
Plasticity index (%)	11.0	23.1
Particle Size Distribution (%)	60.47	48.30
Specific gravity	2.95	2.64
Bulk density	1280	1680
Sample colour	Dark gray	Dark gray
AASHTO Classification	A-7-6	A-7-6
Specific gravity for Quarry Dust	3.29	

Index Properties of Chikoko Soil

The test shows the properties of the natural soil which are summarized as shown in Table 3.1. The natural moisture content was determined at 25.70% and 17.36%. The soil has a liquid limit of 25.0% and 36.0%. Plastic limit of 14.0% and 12.9%. plasticity index of 11.0% and 23.1%. These are typical values for clays. The specific gravity of the soil was found to be 2.95 and 2.64. The bulk density was 1280, 1680. The specific gravity for the quarry dust and lime as additive was given as 3.39 and 3.37 AASHTO classification system puts the soil under A-7-6 group, which are fair to poor when used as subgrade materials. The particle size distribution shows 60.47% and 48.30% of the soil which passes through No. 200 sieve. The sample colour is determined by mineral composition, element concentration, organic matter, and moisture content.

Proctor Compaction

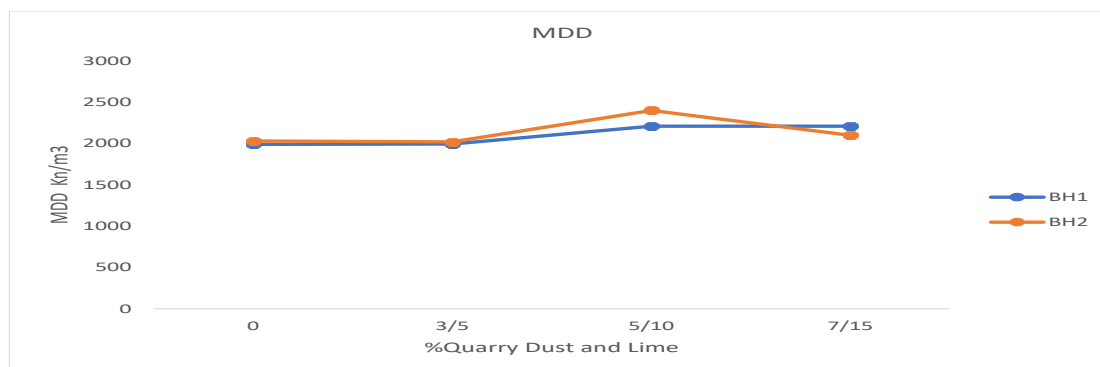


Figure 3.1: Maximum Dry Density with Quarry Dust and Lime.

It can be observed that (BH2) has the highest (MDD) of 2400kg/m³ at 5/10%, compared to (BH1). The increment of the Maximum dry density for (BH2) and (BH1) is due to the high specific gravity of the quarry dust and lime, this enhancement is due to the replacing of the clay minerals by the quarry dust and lime. The quarry dust and lime percentages increased the MDD between (BH1) and (BH2)

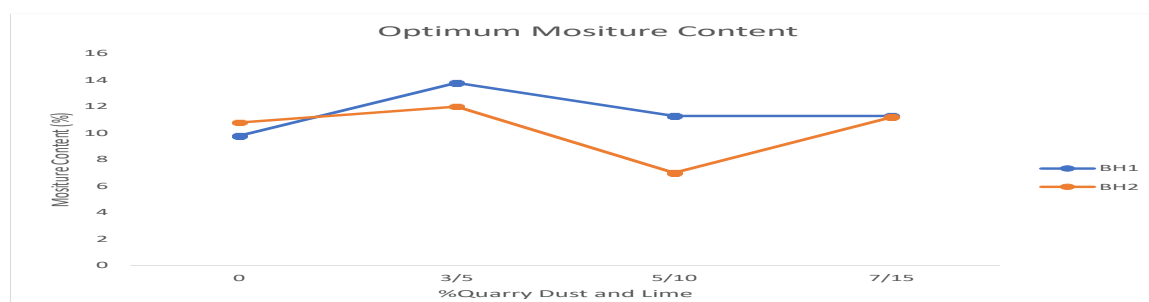


Figure 3.2: Optimum Moisture Content with Quarry Dust and Lime.

Figure 3.2 graphs shows the variation summary of the Optimum moisture content (OMC) with percentages of quarry dust and lime. It can be observed that (BH1) with value of 13.8kg/m³ and (BH2) with value of 12.0kg/m³ increased from 0 to 3/5% at the point of Maximum condition. The (BH1) increased from 0% to 3/5% and (BH2) increased from 0 to 3/5%. The variation between (BH1) and (BH2) is as a result of the addition of quarry dust and lime, that shows the decrease in water content, leading to increase in maximum dry density of the soil.

Triaxial Test



Figure 4.11: Shear strength with Quarry Dust and Lime BH1

Figure 3.3 Sheer strength with Quarry Dust and lime BH1

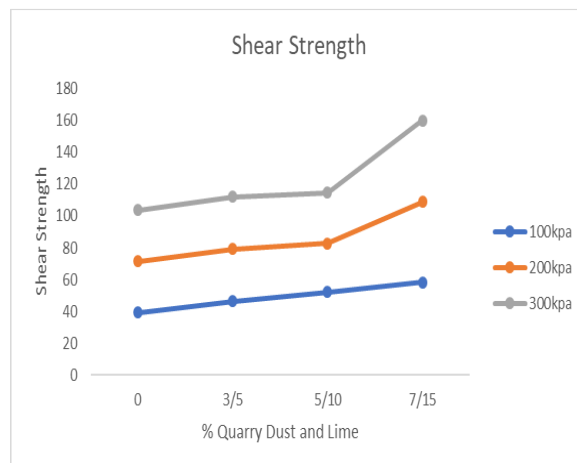


Figure 4.12: Shear strength with Quarry Dust and Lime for BH2

Figure 3.4 Sheer strength with Quarry Dust and lime BH2

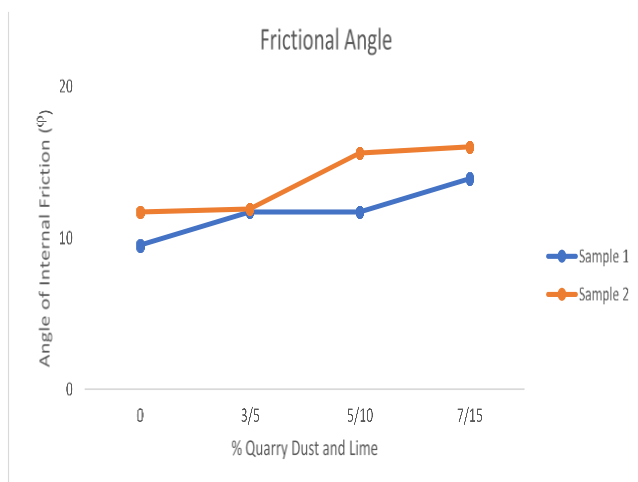


Figure 4.13: Friction angle with Quarry Dust and Lime for BH1 and BH2

Figure 3.5: Friction angle with Quarry Dust lime for BHI and BH2

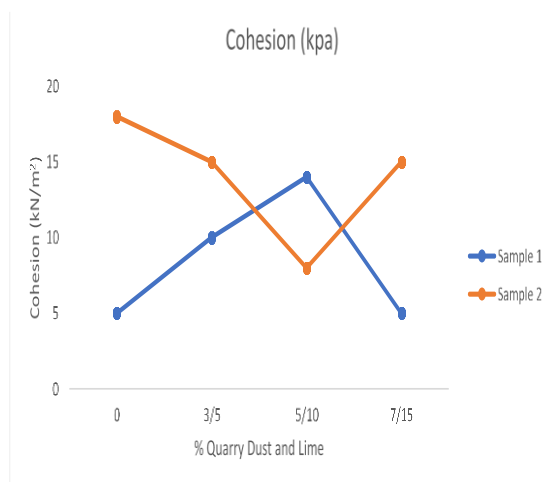


Figure 4.14: Undrained Cohesion with Quarry dust and Lime for BH1 and BH2.

Figure 3.5: Undrained Cohesion with Quarry Dust lime for BHI and BH2

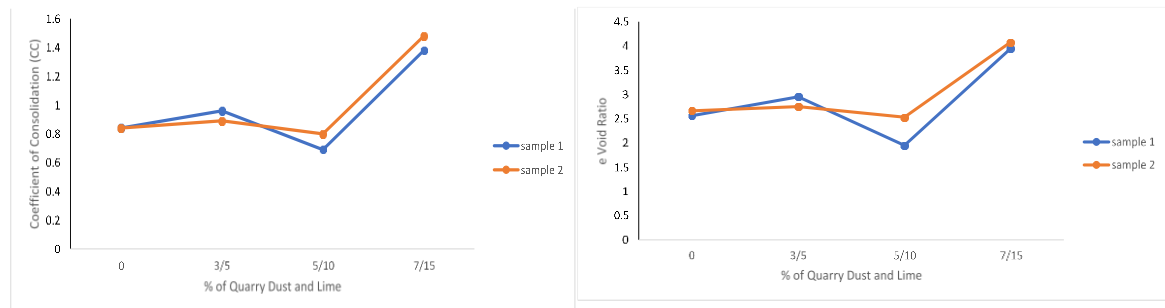
The triaxial compression test results showed a considerable improvement in the shear strength characteristics of the stabilized soil.

Both the **cohesion (c)** and the **angle of internal friction (ϕ)** increased following stabilization, indicating enhanced inter-particle bonding and frictional resistance.

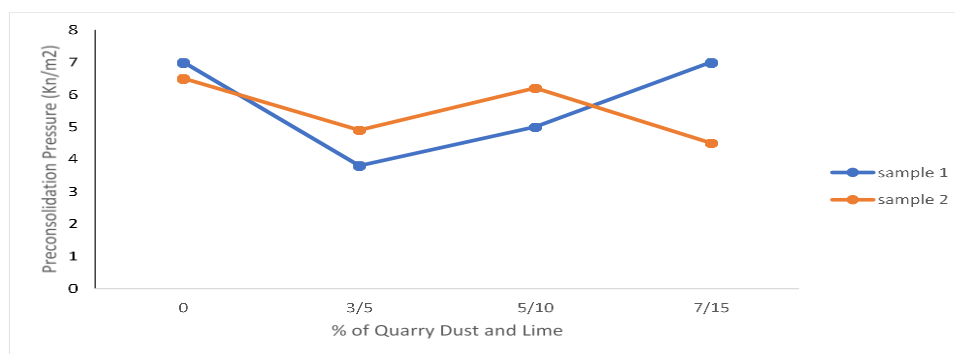
The increase in cohesion resulted from cementitious compounds formed during the pozzolanic reaction of lime with the clay minerals, while quarry dust contributed to improved particle interlocking.

The higher shear strength obtained demonstrates that the stabilized soil possesses greater resistance to shear failure and is therefore more suitable for supporting engineering structures.

Consolidation Test



Coefficient of Consolidation (Cc) of Chikoko Soil with Quarry Dust and Lime for BH1 and BH2. Change in Void Ratio (e) of Chikoko Soil with Quarry Dust and Lime for BH1 and BH2.



Preconsolidation Pressure (Pc) of Chikoko Soil with Quarry Dust and Lime for BH1 and BH2.

The consolidation test results revealed that stabilization significantly reduced the compressibility of the Chikoko soil.

A reduction in the **Compression Index (Cc)** and the magnitude of settlement was observed following stabilization.

The stabilized soil also exhibited improved consolidation characteristics, indicating that settlement occurred more rapidly and with a smaller overall magnitude.

These improvements are attributed to the formation of stronger particle bonds and the reduction in void ratio caused by the combined action of quarry dust and lime.

Consequently, the stabilized soil is expected to experience considerably lower long-term settlement when used as a foundation material.

4. CONCLUSION

The following conclusions were drawn from the research works.

- The addition of the composite stabilizers successfully increased the soil's shear strength, yielding an optimum cohesion of 14 kN/m² in borehole 1 under a 5% quarry dust and 10% lime formulation, and an optimum internal friction angle of 16.0 degrees in borehole 2 under a 7% quarry dust and 15% lime formulation.
- Under vertical loading, the treatment significantly improved consolidation and settlement characteristics, reducing compressibility to its minimum at a 7% quarry dust and 15% lime mix and accelerating pore-water drainage to a peak consolidation coefficient of 1.50 in Sample 2.
- Under compaction effort, the soil's moisture-density relationship was optimized using a 5% quarry dust and 10% lime mix, which increased the maximum dry density to 2400 kN/m³ in borehole 2 and

lowered the optimum moisture content to 7.0% in borehole 1.

- iv. Ultimately, while the 7% quarry dust and 15% lime mix maximizes settlement-specific properties, the 5% quarry dust and 10% lime formulation represents the optimal mix proportion for overall engineering performance and routine construction practice.

5.2. RECOMMENDATION

The following recommendations are provided considering the scope, limitations and general findings;

- i. Based on the study, it is recommended to employ a composite mixture of 5% quarry dust and 10% lime in daily construction practices to effectively strengthen and stabilize weak Chikoko clay.
- ii. The experimental findings from this work should serve as a foundational literature resource to guide subsequent research on deltaic soil stabilization.

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