

**INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION  
OF SILTY CLAYS SOILS CASE STUDY: NAKIVUBO PRIMARY SCHOOL IN KAMPALA  
METROPOLITAN**

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**UGANDA CHRISTIAN  
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## ABSTRACT

Silty clay soils are fine-grained soils widely distributed over the world and present quite a number of construction-related issues such as increased compressibility, decreased shear strength, and a propensity for shrinkage and swelling tendencies.

This research focuses on stabilization of the silty clay soils using hydrated lime and rice husk ash to improve the properties of silty clay soils. Hydrated lime reacts with clay minerals to form calcium silicate hydrate (CSH), a cementitious compound which strengthens the soil and reduces its compressibility. Rice husk ash contains silica and alumina, which further contributes to pozzolanic reactions and enhances the soil's strength. The combination of these two stabilizers significantly improves compressive and shear strength, reduce shrinkage-swell potential, ensuring stable foundations and long-term durability making them more suitable for construction applications.

Laboratory tests confirmed the soil's classification as A-7 (high plasticity) with a low CBR of 8%. Rice husk ash satisfied the pozzolanic material criteria. The optimal stabilization combination involved 4% hydrated lime and 8% rice husk ash, significantly reducing plasticity index and increasing CBR to 35%. This combination achieved the minimum UCS requirement of 0.5MPa for durability. The mechanism involves pozzolanic reactions between rice husk ash's silica and hydrated lime's calcium, leading to improved strength and reduced moisture sensitivity.

**DECLARATION**

I,.....hereby declare that this report proposal is my original work and has not been submitted previously. The Department of Civil and Environmental Engineering, Faculty of Engineering, Design and Technology at Uganda Christian University has approved its submission, with the consent of both the project supervisor and the student.

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**APPROVAL**

I hereby certify that this Final Year Project report has been prepared under my supervision and guidance, and this report is approved for submission to Uganda Christian University's Department of Engineering and Environment.

**SUPERVISOR: MR. KENNETH ECONI**

SIGNATURE:.....

DATE:.....

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## LIST OF ACRONYMS

AASHTO	American Association of State Highways and Transportation Officials
ASTM	American Society for Testing and Materials
BS	British Standards
CBR	California Bearing Ratio
CML	Central Materials Laboratory
GM	Grading Modulus
LL	Liquid Limit
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
PI	Plasticity Index
PL	Plastic Limit
PSD	Particle Size Distribution
RHA	Rice Husk Ash
UCU	Uganda Christian University
UCS	Unified Compressive Strength
USCS	Unified Soil Classification System
XRF	X-Ray Fluorescence

## CHAPTER ONE: INTRODUCTION

### 1.1 Background

Silty clay soils are globally distributed over the world and present quite a number of construction-related issues because of their natural characteristics. These soils exhibit notable characteristics, such as increased compressibility, decreased shear strength, and a propensity for shrinkage and swelling tendencies, due to the significant concentration of silt and clay particles (Consoli, 2016). Silty clay soils are fine-grained soils that are composed primarily of silt and clay particles, with silt-sized particles ranging from 0.002 to 0.06 mm diameter and clay-sized particles being smaller than 0.002 mm (Mitchell and Soga, 2005).

High compressibility in soils indicates an inclination to undergo excessive deformation in response to applied stresses which presents a significant risk to the general integrity of structures located above them as well as the stability of foundations (Consoli, 2016). The settling of foundations that results from limited load-bearing capacity causes uneven subsidence, which can lead to structural failures marked by cracking, deformation, and eventual collapse (Mitchell and Zornberg, 2016). Further, Uganda's silty clay soils have exceptionally low shear strengths, which makes them more vulnerable to breakdowns in the bearing capacity. Foundations are susceptible to uneven settlement or, in the worst situations, catastrophic collapse due to this vulnerability to concentrated loads (Bowles, 1988; Das, 2015).

Additionally, these soils' unique shrinkage and swell tendencies increases the complexity to the engineering of foundations in Ugandan situations. Reduced moisture

content leads to soil particle contraction, which causes shrinkage and the formation of fractures that could penetrate foundations and compromise their structural integrity (Fredlund and Rahardjo, 1993; Duncan Craig, 2015) while higher moisture content causes soil particles to swell and put pressure on foundations, which exacerbates cracking and deformation and hence increases the risk of structural damage (Nelson et al., 2006). This research proposal focuses on the complex interactions among these variables and seeks to study the unique qualities and difficulties associated with silty clay soils in particular Ugandan locations. Understanding the subtleties of their actions, this study aims to formulate comprehensive mitigation strategies which are tailored to the unique conditions of these soils, hence informing sustainable and resilient foundation engineering practices in Uganda's diverse geotechnical contexts.

Soil stabilization methods are employed to enhance the engineering properties. Diverse methods of stabilization are used, which include mechanical compaction, chemical stabilization, and deep mixing techniques (Consoli, 2016) and they play a pivotal part in enhancing the overall performance of silty clay soils by mitigating issues the issues of high compressibility, decreased shear strength, and susceptibility to shrinkage and swelling tendencies. Mechanical compaction involves application of force to reduce soil volume and increase density, chemical stabilization involves use of additives to alter soil properties while deep mixing techniques incorporate reinforcing materials into the soil to reinforce its structure.

Hydrated lime, a common soil stabilizer and it reacts with the clay minerals in the soil, enhancing its strength and reducing its compressibility (Bell, 2015; Little and Vinson,

1971). The increase of hydrated lime to silty clay soils promotes flocculation and agglomeration of clay particles, resulting in denser and more cohesive soil matrix. This stabilization method effectively reduces the plasticity index of silty clay soils, thereby minimizing shrinkage and swell potential (Sherwood, 2002).

Studies show that the reactivity of lime and clay in the presence of moisture and low temperature is carried out slowly. So to accelerate the reaction, addition of rice husk ash containing abundant silica with higher specific surface area is suitable.

Rice husk ash is a by-product of rice husk incineration, obtained by burning rice husks at temperatures of 500°C to 800°C. Approximately 260,000 tonnes of rice are produced each year in Uganda. Rice husks are agricultural wastes got from the production of rice during milling and in Uganda, rice is grown in Nwoya, Butaleja, Budaka, Bugweri, Bugiri, Masaka, Arua districts among many others.

Rice husk ash contains alumina and silica which makes it pozzolanic and hence contributes to soil stabilization by forming cementitious bonds (Saito and Murata, 2000; Sridharan et al., 2001). The addition of rice husk ash to silty clay enhances long-run strength of soil by promoting pozzolanic reactions, hence formation of calcium silicate hydrate gel, a cementitious material that binds soil particles together (Shahu et al., 2006) which boosts the soil's engineering properties.

## **1.2 Problem Statement**

During construction of a double-story, nine-classroom building at Nakivubo Primary School in Kampala Metropolitan, challenges came up as a result of high compressibility plus low shear strength of the silty clay soil which led to substantial

settlement risks resulting in uneven foundations. The low shear strength increased vulnerability to geotechnical hazards, particularly slope instability and foundation bearing capacity failure because of moist conditions in the area. The shrinkage and swell behavior which is influenced by water content, led to foundation cracks as the soil dried out (Construction of a double- nine classroom block, Twesigye Augustus, 2022)

This research focuses on stabilization of the silty clay soils using hydrated lime and rice husk ash to improve the properties of silty clay soils. Hydrated lime reacts with clay minerals to form calcium silicate hydrate (CSH), a cementitious compound which strengthens the soil and reduces its compressibility. Rice husk ash contains silica and alumina, which further contributes to pozzolanic reactions and enhances the soil's strength. The combination of these two stabilizers significantly improves compressive and shear strength, reduce shrinkage-swell potential, ensuring stable foundations and long-term durability making them more suitable for construction applications.



**Figure 1: Silty clay soils foundation challenges.**

### **1.3. Research Objectives**

#### **1.3.1 Main Objective**

To investigate the use of hydrated lime and rice husk ash in the stabilization of silty clay soils.

#### **1.3.2 Specific Objectives**

1. To determine the engineering properties of silty clay soils.
2. To determine the chemical composition of rice husk ash.
3. To determine the engineering properties of silty clay soils with varying percentages of hydrated lime and rice husk ash.

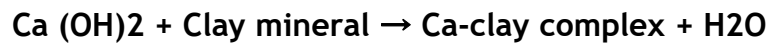
#### **1.4 Research Questions**

1. What are the engineering properties of the silty clay soils?
2. What is the chemical composition of rice husk ash?
3. What are the engineering properties of the silty clay soils with varying percentages of hydrated lime and rice husk ash?

#### **1.5 Justification**

Hydrated lime through its interaction with clay minerals promotes cation exchange plus flocculation, and pozzolanic reactions. The calcium ( $\text{Ca}^{2+}$ ) ions from lime replace weaker cations like sodium ( $\text{Na}^+$ ) and potassium ( $\text{K}^+$ ), causing clay particles to clump together (flocculation), improving strength and reducing plasticity. Additionally, lime reacts with water and amorphous silica ( $\text{SiO}_2$ ) present in clay to form calcium silicate hydrate (CSH), a cementitious gel that binds soil particles, further enhancing strength and stiffness (Consoli, N.C., et al, 2016). The formation of calcium-clay complexes

reduces the surface area and cation exchange capacity of clay particles because the calcium ions bind to the clay particles, making them less reactive and more cohesive. This process effectively lowers soil plasticity.



Rice husk ash is rich in silica ( $\text{SiO}_2$ ) and alumina ( $\text{Al}_2\text{O}_3$ ), which exhibit pozzolanic properties. Rice husk ash reacts with moisture and to form additional calcium silicate hydrate, further enhancing strength (Addullah, H., et al, 2014). The rice husk ash particles act as fillers, occupying voids within the soil matrix and improving its packing density which reduces compressibility and enhances shear strength (Babu, G.L.S., et, 2018).



The formation of C-S-H leads to improved strength and durability of RHA-stabilized soils. C-S-H is a strong and durable material that is also resistant to water and chemicals. This makes it ideal for use in soil stabilization applications.

## **1.6 Significance of the research**

This focuses on approaching the issues related to constructing buildings on silty clay soils, defined by inadequate compressive strength, limited permeability, and insufficient shear strength contributing to unsuitability for structural support. The study searches into the combined impact of hydrated lime and rice husk ash in strengthening the soil strength and its ability to bear weight of buildings.

## **1.7 Scope of the study**

### **1.7.1 Content Scope**

The research is focused on utilizing hydrated lime and rice husk ash as a stabilizer in silty clay soil samples for foundation requirements. This was achieved by investigating the engineering properties of the neat soil samples and determining the strength brought by the addition of the stabilizers .

### **1.7.2 Time Scope**

The scope was conducted from April, 2023 to March, 2024.

### **1.7.3 Geographical Scope**

This study is focused on Nakivubo Primary School, located in Kampala and situated at 0.3476<sup>0</sup> N latitude and 32.5825<sup>0</sup>E longitude. The scope encompasses the specific site of the school where the challenge posed by silty clay soils are most pronounced.

Hydrated lime was got from a hardware in Mukono and rice husk ash was got from Arua and burnt at 700°C in an incinerator in Uganda Christian University.

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 Introduction

This chapter looks into various studies on improving stability of silty clay soils through using hydrated lime and rice husk ash and assist in identifying gaps in knowledge that needs addressing to achieve a more effective stabilization of silty clay soil. The literature is reviewed in conjunction with the objectives outlined in the research proposal, facilitating a broad understanding and pursuit of these objectives. Furthermore, the chapter explores the characteristics of the materials—silty clay soils, hydrated lime, and rice husk ash—and evaluates their suitability for achieving soil stability. It incorporates fundamental definitions, essential properties of silty clay soils, and guidelines for selecting a stabilizer and as an exploration of the numerous stabilization mechanisms utilized in construction projects and discusses how each stabilization method enhances soil characteristics.

### 2.2 Soil Classification

Before initiating soil stabilization, it is necessary to classify soil to determine its need for stabilization. Soil classification involves grouping soils with similar characteristics together (Notes and Cameron, n.d.). The most precise method for characterizing silty clay soils is laboratory testing, specifically particle size distribution analysis. This involves sieving and hydrometer analysis to separate coarse-grained particles from fine-grained particles and further divide fine-grained particles into silt and clay fractions. Silty clay soils are classified as CL in the Unified

Soil Classification System (USCS) (ASTM D2487-09), 2009 and as A-6, A-7, or A-7-6 in the AASHTO Soil Classification System (Bowles, 1996).

**2.2.1 Unified Soil Classification Systems (ASTM D2487-09, 2009)**

Soil samples retained on sieve No. 200 (particles >75 mm excluded) are assessed and grouped as either coarse-grained or fine-grained based on weight estimation. Soil containing over 50% particles by weight is designated as coarse-grained, whereas soil with less than 50% is termed fine-grained. For primarily coarse-grained soil, determination as gravel or sand depends on if 50% and above of the coarse grains, by weight, exceeds or fall below 4.75 mm (No. 4 sieve size). Gravel is further classified as either clean (fines <5%) or dirty (fines <12%). Clean gravels are sub-categorized as well-graded (GW) or uniform/gap-graded (GP), while dirty gravels are segmented as silty fines (GM) or clayey fines (GC).

**2.2.2 Soil Classification according to AASHTO**

General Classification	Granular Materials (35% or less passing the 0.075 mm sieve)							Silt-Clay Materials (>35% passing the 0.075 mm sieve)			
	A-1		A-3	A-2				A-4	A-5	A-6	A-7
Group Classification	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5 A-7-6
Sieve Analysis, % passing											
2.00 mm (No. 10)	50 max	...	...	...	...	...	...	...	...	...	...
0.425 (No. 40)	30 max	50 max	51 min	...	...	...	...	...	...	...	...
0.075 (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of fraction passing 0.425 mm (No. 40)											
Liquid Limit	...	...	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min	41 min
Plasticity Index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min
Usual types of significant constituent materials	stone fragments, gravel and sand		fine sand	silty or clayey gravel and sand				silty soils		clayey soils	
General rating as a subgrade	excellent to good							fair to poor			

Note: Plasticity index of A-7-5 subgroup is equal to or less than the LL - 30. Plasticity index of A-7-6 subgroup is greater than LL - 30

**Table 1: AASHTO Soil Classification Chart.**

The classification part of AASHTO system involves categorizing soils into various groups according to the engineering properties, as determined by their particle size distribution and plasticity characteristics. Soils are grouped into two main groups: cohesive soils (A-1 through A-7) and granular soils (A-1 through A-3), with further subdivisions based on specific soil properties.

For cohesive soils, the classification considers the plasticity characteristics of the fines fraction (silt and clay) and their particle size distribution. Soils with low plasticity and fine particle sizes are categorized as A-1, while soils with higher plasticity and coarser particle sizes fall into groups A-2 through A-7. Within these groups, specific subcategories exist based on the soil's plasticity index, liquid limit, and particle size distribution, providing detailed information about the soil's engineering behavior.

On the other hand, granular soils are classified primarily based on particle size distribution. Sands and gravels are categorized as A-1 through A-3, with A-1 representing well-graded sands and gravels, A-2 representing poorly-graded sands and gravels, and A-3 representing sands and gravels with a uniform particle size distribution. Similar to cohesive soils, granular soils may also have further subdivisions based on specific particle size and gradation characteristics.

### **2.3 Silty clay soils.**

Silty clay soils which are a blend of silt and clay particles, avail a unique set of challenges for foundation construction because of their inherent properties of high compressibility plus low shear strength, and susceptibility to shrinkage and swell

tendencies make them a problem in any engineering works (Alsaadi and Al-Rawas, 2014; Estabil et al., 2019; Puppala et al., 2019). These characteristics lead to significant foundation settlements, differential movements, and compromised structural stability which ultimately threaten structural integrity and safety (Akbulut et al., 2007; Chen et al., 2013; Singh et al., 2016).

Fine-grained nature and weak interparticle bonds of silty clay soils make them highly compressible (Al-Rawas et al., 2012; Puppala et al., 2019) and under increased loading, soils tend to deform and compact thereby leading to excessive settlements (Chen et al., 2013; Estabil et al., 2019). This compressibility poses a major concern for foundation design because it can cause uneven settlement patterns, potentially cracking and damaging overlying structures (Akbulut et al., 2007; Singh et al., 2016). Shear strength refers to the ability of soil to resist deformation under shear stress. Silty clay soils exhibit relatively low shear strength compared to coarser soils (Al-Rawas et al., 2012; Puppala et al., 2019). Low shear strength in silty clay soils makes them susceptible to lateral movement and landslides, especially when saturated with water (Chen et al., 2013; Estabil et al., 2019) which poses a risk to foundations situated in areas prone to landslides or lateral earth pressures (Alsaadi and Al-Rawas, 2014; Akbulut et al., 2007).

Plasticity index is the ability of soil to change volume due changes in moisture content. Silty clay soils are susceptible to shrinkage and swell due to their high plasticity index (Puppala et al., 2019; Singh et al., 2016). When silty clay soils lose moisture, they shrink and crack and when they absorb moisture, they swell and expand (Alsaadi and Al-Rawas, 2014; Chen et al., 2013). These volume changes can

lead to significant movements in foundations, causing structural damage and compromising the stability of the structure (Estabil et al., 2019; Singh et al., 2016).

### **2.3.1 Identification of silty clay soils.**

Silty clay soils can be characterized by a particle size distribution between silt and clay fractions which are prevailing in various environments. Their engineering properties which include low permeability, high compressibility, and moderate shear strength, play a pivotal role in foundation design hence accurately identifying silty clay soils is essential for proper engineering considerations.

#### ***2.3.1.1 Field Identification Methods***

Several field tests can be employed to identify silty clay soils for example the dry strength test which involves rolling a small amount of soil into a thread. If the thread breaks when bent then the soil is likely silty clay [(ASTM D2487-09), 2009]. The plasticity test assesses the soil's ability to be kneaded into a long, thin thread without breaking and if the soil can be moulded into such a thread, it signifies silty clay (Bowles, 1996). In addition, silty clay soils typically exhibit a smooth, silky feel (Mitchell and Soga, 2005).

#### **2.3.1.2 Laboratory Identification Methods**

Particle size distribution analysis laboratory testing is the most precise method for identifying silty clay soils and it involves sieving and hydrometer analysis to separate coarse-grained from fine-grained particles and further divide fine-grained particles into silt and clay fractions. Silty clay soils are classified as CL in the USCS [(ASTM D2487-09), 2009] and as A-6, A-7, or A-8 in the AASHTO system [(Bowles, 1996)].

## **2.4 Soil stabilization**

Soil stabilization is important to improve soil strength through bonding the soil particles together. It is the process of blending and mixing materials to improve certain properties of soil for example the desired gradation or mixing or texture or plasticity plus act as a binder to cement the soil (Behak and Musso ,\_2016).

There are two methods of soil stabilization, namely mechanical and chemical stabilization.

### **2.4.1 Mechanical Stabilization**

This involves addition of a different material to the soil to improve the grading or lower the plasticity of the original material and it is usually achieved without any chemical reaction. Mechanical stabilization aims to mix the different soil material to provide an anticipated stability of the after compaction. Blending of the two or more materials usually happens at the construction site, a borrow area and the blended materials are compacted to required densities by the conventional methods. Mechanical stability of soil aggregate mixture depends on plasticity features of the binder soil, gradation, mechanical strength of aggregate, mineral composition of the material and compaction effort compaction and this type of soil improvement increases the drain ability, improves in bearing capacity and soil stability.

### **2.4.2 Chemical stabilization.**

Cementitious materials are used through the process of stabilization. The choice of the material for stabilization depends on the soil properties that have to be modified.

The key properties include volume stability, strength, compressibility, permeability and durability (Sherwood, 1993).

Chemical stabilization provides various solutions to address the issues of low shear strength in soils, crucial for ensuring stability and supporting structures and mitigate the detrimental effects of high compressibility in soils by minimizing settlement and improving stability hence ensures the longevity and performance of structures built on treated soils.

Portland cement is among the most effective stabilizers which forms strong cementitious bonds between soil particles through hydration reactions, leading to significant increases in shear strength (Bell, 2004). Lime also proves effective by modifying plasticity of clay minerals and promoting flocculation, resulting in a more cohesive and stable soil matrix (Naik and Singh, 2003). Additionally, fly ash is a sustainable alternative to cement to improve shear strength while reducing compressibility hence enhancing soil performance (Mitchell, 1993). Furthermore, fly ash offers long-term strength benefits and it reduces the potential for future settlement (Al-Mukhtar et al., 2014). Common stabilizers like Portland cement and lime provide immediate strength gains, limiting particle movement and preventing excessive deformation under load hence reducing compressibility (Consoli et al., 2009).

The use of polyelectrolytes and polymers as stabilizers supports flocculation of clay particles, resulting in increased pore space and improved water flow through the soil (Ingles and Metcalf, 1972) which enhances drainage hence reducing the risk of erosion

and ensures better performance of stabilized soil structures. Also, specific salts, like sodium chloride improve permeability by modifying the electrical properties of the soil and facilitating water movement (Al-Rawas and Hago, 2010).

#### 2.4.2.1 Criteria for Chemical Selection

An appropriate stabilizer can be selected and depends on plasticity and particle size distribution of material to be treated according to the criteria below.

**Table 2: Criteria for determining the type of stabilizer.**

Stabilizer type	Type of stabilization					
	More than 25% 0.075mm sieve			Less than 25% 0.075mm sieve		
	PI ≤ 10	10 < PI ≤ 20	PI > 20	PI ≤ 6 PP ≤ 60	PI ≤ 10	PI > 10
Cement	Yes	Yes	0	Yes	Yes	Yes
Lime	0	Yes	Yes	No	0	Yes

**Source:** (International Labour Organization, 2013)

### 2.5 Stabilization of silty clay soils using different admixtures.

#### 2.5.1 Hydrated Lime Stabilization

The lime employed in soil stabilization is hydrated lime. Practical experience indicates that lime reacts with fine-grained soils thereby decreasing plasticity, increasing workability, reducing swell, and increasing strength.

According to AASHTO classification, soils falling under types A-4, A-5, A-6, A-7, and some A-2-6 and A-2-7 are considered to be suitable for stabilization with lime (Nair, 2010). Interaction between hydrated lime and clay particles involves the transfer of calcium ions from hydrated lime to the surface of clay particles during mixing. This process replaces water plus other ions, rendering the soil granular, assisting more effective mixing and compaction. The Plasticity Index of soil decreases significantly, along with a reduction in swell potential.

Addition of lime and water in proper proportions raises the soil alkalinity to above 10.5, leading to the breakdown of clay particles. This breakdown releases silica and alumina, which combine with calcium from the lime to form cementitious products like calcium-silicate-hydrates (CSH) and calcium-aluminate-hydrates (CAH) and contribute to the general strength of the soil. Consequently, the soil undergoes a transformation from a granular state to a hard, relatively impermeable material with substantial load-bearing capacity.

Research informs that soil-quicklime mixtures generally exhibit greater strength development compared to those with hydrated lime. Quicklime has demonstrated rapid stabilization of waterlogged sites or very wet materials (Beckham and Hopkins, 1997). On the other hand, hydrated lime finds extended use in stabilizing soils with high clay content, and the primary advantage lies in improving plastic limit of the clay soil. Materials comprising of high reactive silica are suitable used to be lime-pozzolan mixes as substitution of Portland cement (Payá, et al., 2001) The chemical constituents of these additives, as presented in the table by Beckham and Hopkins (1997), are detailed below.

**Table 3: Constituents of Hydrated Lime**

<b>Constituent</b>	<b>Component</b>	<b>Percentage (%)</b>
Primary Constituent	Calcium hydroxide	70-80
Secondary Constituents	Magnesium hydroxide	5-35
	Silica	1-5
	Alumina	1-3
	Calcium carbonate	<5
	Iron oxide	<1
	Water	15-20

**Source:** (Beckham and Hopkins, 1997)

### **2.5.1.1 Mechanism of Hydrated Lime Stabilization**

#### **a. Cation Exchange**

When hydrated lime mixes with soil, calcium ions ( $\text{Ca}_{2+}$ ) from lime readily exchange with sodium ions ( $\text{Na}^+$ ) or other cations present in the surface of clay particles (Yong and Yan, 2013). Cation exchange results in a reduced electrostatic repulsion between clay particles and as the repulsion between particles decreases, they tend to come closer together and flocculate hence forming larger aggregates (Bell, 2011) which significantly reduces in the plasticity of the soil, making it more workable and less susceptible to erosion (Pu et al., 2010).

## **b. Pozzolanic Reaction**

Hydrated lime undergoes a pozzolanic reaction with silica ( $\text{SiO}_2$ ) and alumina ( $\text{Al}_2\text{O}_3$ ) present in clay minerals which forms cementitious compounds, primarily calcium-silicate-hydrate and calcium-aluminate-hydrate (Yong and Yan, 2013) which bind the clay particles to form a stable and cohesive soil matrix (Bell, 2011). The pozzolanic reaction is relatively slow but it significantly adds to the long-term strength and durability of lime-stabilized soils (Pu et al., 2010).

## **c. Dissolution and Precipitation**

Addition of hydrated lime increases soil pH, often to a value above 10 (Yong and Yan, 2013) which causes the dissolution of aluminium ( $\text{Al}^{3+}$ ) and iron ( $\text{Fe}^{3+}$ ) oxides present in the soil (Bell, 2011). The dissolved oxides reacts with the excess calcium ions from lime to form additional cementitious compounds for example calcium hydrotalcite ( $\text{CaMgAlCO}_3$ ) and calcium aluminate ferrate ( $\text{Ca}_2\text{AlFeO}_4$ ) (Pu et al., 2010). These compounds further contribute to strength and durability of stabilized soil (Yong and Yan, 2013).

The combination of cation exchange, pozzolanic reaction, and dissolution and precipitation mechanisms lead to significant advancement in engineering properties of soil, including increased strength, reduced plasticity, improved workability, and enhanced durability (Bell, 2011). These improvements make hydrated lime stabilization a valuable tool for a wide range of geotechnical applications (Pu et al., 2010).

### ***2.5.1.2 Impact of hydrated lime on Soil Properties***

Hydrated lime stabilization significantly enhances the compressive strength of soil, reducing its susceptibility to deformation and failure under load (Gidigas, 2007) which improves strength due to formation of cementitious compounds (Yong and Yan, 2013) which bind the clay particles to form stronger and more cohesive soil matrix (Collins and Khaleghi, 2016) and hence, hydrated lime stabilization significantly reduces the susceptibility of soil to deformation and failure under load (Gidigas, 2007). This enhanced strength benefits geotechnical applications where the soil is subjected to compressive stresses, such as road bases, embankments, and foundations (Consoli et al., 2010).

The cementitious compounds formed during stabilization continue to react and strengthen over time, providing a sustained increase in strength and resilience (Yong and Yan, 2013). Additionally, the cementitious matrix reduces the permeability of soil, limiting ingress of water and preventing erosion, weathering, and shrinkage (Collins and Khaleghi, 2016). This improved durability makes lime-stabilized soils more resistant to environmental degradation and ensures their long-term performance in various geotechnical applications (Consoli et al., 2010).

Hydrated lime stabilization significantly improves the workability of soil making it easier to mix, compact, and shape (Consoli et al., 2010). Flocculation of clay particles caused by cation exchange reduces plasticity of the soil, making it less sticky and easier to handle (Yong and Yan, 2013). Additionally, the cementitious compounds formed during stabilization act as a lubricant, further enhancing the workability of the soil (Bell, 2011). Improved workability is crucial for various geotechnical

applications, as it facilitates efficient mixing, compaction, and shaping of the soil, leading to better overall performance and reduced construction costs (Consoli et al., 2010).

Hydrated lime stabilization also reduces the permeability of soil, limiting the infiltration of water and preventing erosion (Horpibul et al., 2013). The flocculation of clay particles and the formation of cementitious compounds reduce the pore spaces within the soil, causing more difficult for water to flow through (Pu et al., 2010). This reduction in permeability is particularly beneficial for applications where water infiltration is undesirable, such as landfill liners and foundation soils (Horpibul et al., 2013). By limiting water infiltration, hydrated lime stabilization helps prevent erosion, maintain soil stability, and minimize environmental impacts (Pu et al., 2010).

### **2.5.2 Rice husk ash in soil stabilization**

Rice husk ash (RHA) is composed of silica ( $\text{SiO}_2$ ), alumina ( $\text{Al}_2\text{O}_3$ ), and other oxides, exhibiting pozzolanic activity akin to volcanic ash (Rahman et al., 2007). When combined with lime and water, RHA undergoes a chemical reaction hence formation of calcium silicate hydrate which effectively bind soil particles, leading to increase in the overall strength of soil (Alhassan, 2014). Incorporation of RHA also brings about improvements in pore size distribution and a reduction in plasticity, contributing to enhanced mechanical properties of soil (Indraratna et al., 2013).

Various studies show substantial improvement in Unconfined Compressive Strength (UCS) due to incorporation of Rice Husk Ash (RHA) and lime blends. Optimal RHA content varies based on the soil type and lime dosage. The peak UCS and CBR values

tend to occur within the range of 6-8% RHA addition (Rahman. 2007 and Ghosh et al. 2020).

Rice Husk Ash (RHA) combined with lime in stabilizing blends has demonstrated the capacity to diminish soil permeability, thereby mitigating water infiltration and minimizing potential swelling issues (Puppala et al. 2019). This permeability reduction contributes to improved soil behavior and enhanced stability. Moreover, the utilization of RHA presents notable advantages in terms of cost-effectiveness and environmental considerations compared to traditional stabilizers (Indraratna et al. 2013). These findings underscore the multifaceted benefits of RHA-lime blends in soil stabilization, inclusive of both performance improvements and sustainability considerations.

#### ***2.5.2.1 Mechanism of RHA Stabilization.***

Effectiveness of RHA in soil stabilization is rooted from its unique chemical composition and physical properties. RHA primarily consists of silica ( $\text{SiO}_2$ ), which acts as a pozzolanic material reacting with calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ) present in the soil hence formation of cementitious compounds for example calcium-silicate-hydrate (Siddique and Singh, 2004). These cementitious compounds adhere the soil particles together, increasing the strength and stability of the soil matrix.

RHA can significantly increases the void ratio (measure of the pore spaces) within the soil. The increased void ratio is a due to flocculation of clay particles caused by the addition of RHA. Flocculation decreases the repulsive forces between clay particles, allowing them to pack more closely together and form larger aggregates which create

more pore spaces within the soil matrix, leading to an increased void ratio (Indraratna et al., 2005).

The increased void ratio evoked by RHA addition directly improves the permeability of soil. Permeability is the ability of soil to allow water to flow through it and as the void ratio increases, the pore spaces within the soil become larger and more interconnected hence providing easier pathways for water to flow. The enhanced permeability facilitates drainage and prevents water from accumulating in the soil and causing problems such as erosion and landslides (Dheeravath and Babu, 2009).

The optimal percentage of RHA for soil stabilization depends on specific soil characteristics and the desired engineering properties although studies have shown that RHA percentages range from 5% to 15% can effectively enhance soil drainage by increasing both void ratio and permeability (Indraratna et al., 2005; Dheeravath and Babu, 2009).

## CHAPTER THREE: METHODOLOGY

### 3.1 Introduction

This section elaborates on the description of laboratory test procedures conducted in the context of the research to assess the engineering properties of the untreated soil samples in accordance with BS standards and to analyze the chemical composition of rice husk ash following guidelines outlined in the ASTM standard.

### 3.2 Sample collection

#### 3.2.1 Silty Clay Soils

The silty clay soil was sourced from Nakivubo Primary School in the Kampala Metropolitan area, extracted at a depth ranging between 1m to 1.5m beneath the ground surface, following removal of the topsoil containing substantial organic matter. Subsequently, the excavated soil was collected in sacks and transported to Stirling Civil Engineering Limited laboratory for testing to assess the soil's physical properties.



**Figure 2: Sample preparation for air drying.**

### 3.2.2 Rice Husk Ash

The rice husks were got from the Pakele District Located in Northern Uganda. Subsequently, controlled combustion was carried out at temperatures of 700°C for a duration of 24 hours at UCU Art laboratory. Additionally, a representative sample was transported to analytical laboratory for comprehensive testing of its chemical composition.



**Figure 3: Rice husk ash before burning**



**Figure 4: Rice husk ash preparation**

### **3.2.3 Lime Preparation**

Hydrated lime was got from a hardware in Mukono and the chemical composition was known hence it was considered basing on the literature of previous studies.

## **3.3 Tests on the materials**

### **3.3.1 Particle size distribution test - (BS 1377:1990)**

This procedure assesses the particle size distribution of soil by letting pass through a series of arranged sieves with varying aperture sizes then measuring the mass of particles retained on each sieve as a fraction of the whole mass. It helps to determine the relative proportions of different sizes of particles which affects engineering properties of a material with reference to BS 1377: Part 2: 1990.

#### **Aim of Sieve Analysis**

- To classify soil based on particle sizes using Unified Soil Classification System (USCS).
- To easily identify soils mechanical properties.
- To foretell quality and performance of soil.

#### **Preparation and procedure**

A sample of 1500g was weighed on a balance for use in the sieve analysis test arranged from largest aperture size to smallest with the receiver at the bottom and the sample was placed at the top most sieve and sieves shaken by the sieve shaker apparatus, until no more sample could pass through any sieve for a period of about 15 minutes.

The weight of soil individually retained on each sieve was obtained and results tabulated including mass on each sieve, percentage mass retained, cumulative percentage mass retained and percentage passing.

The portion passing the 75 $\mu$ m sieve was calculated. The mass of the fines lost due to washing, was added to mass of dry fine material passing the 75 $\mu$ m sieved and the grading plotted.

### **3.3.2 Atterberg limit tests-(BS 1377:1990)**

Atterberg limits determine moisture content, at which soil changes from solid to plastic and plastic to liquid states.

Soil consistency is the resistance of soil to deformation and rupture and defines the degree of stiffness of soil. The consistency of fine-grained soils is described in four states including liquid state, plastic state, semi-solid state and solid state.

Albert Atterberg, a Swedish Agricultural Engineer, shows the importance of these limits in order to understand the behavior of fine-grained soils hence 'Atterberg Limits.'

#### ***3.3.2.1 Liquid Limit***

Water in large quantities is added to fine-grained soils, thereby resulting suspension known as the liquid state. This suspension does not resist flow and hence flows like a liquid and thus the soil in this state has no shear strength.

Liquid limit is an is moisture content at which a soil passes from liquid state to plastic state and aids in identifying and classifying fine-grained cohesive soils with knowledge of the plastic limit, with reference to **BS 1377: Part 2: 1990**.

## Preparation and Procedure

A sample of 400g was removed from the paste sieved soil then positioned on the glass plate and thoroughly mixed with distilled water and the moisture content was adjusted to correspond to cone penetration ranging from 15 mm and 25 mm, aiming for proximity to 20 mm. Verification with the cone penetrometer device was performed and the mixture was stirred for a minimum of 10 minutes.

A part of the mixed soil was pushed in a cup with a palette knife to avoid air entrapment. Excess soil then removed with a straightedge to create a smooth surface and the supporting assembly was lowered to touch the soil surface. Proper positioning was confirmed when a slight movement of the cup marked the soil surface.

The cone was lifted out, carefully cleaned to prevent scratching, and a small amount of additional wet soil was added to the cup, ensuring no air was trapped and the surface was smoothed.

The above procedures were repeated up to when two consecutive tests yielded cone penetration readings within 0.5 mm and bulk soil, plus the zone penetrated by the cone, was removed from the cup and placed in a suitable container for moisture content determination.

A graphical representation illustrating the correlation between moisture content and cone penetration was drawn with moisture content on the x-axis and cone penetration on the y-axis, both depicted on linear scales and liquid limit identified as the moisture content corresponding to penetration depth of 20mm.

### **3.3.2.2 Plastic Limit and Plasticity Index**

This is the minimum moisture content which alters soil from solid (dry state) to a plastic (mould-able) state and at which soil changes from plastic state to semi-solid state.

Plasticity index is a range of water content where soil stays in plastic state. It is also defined as the difference between the numerical value of the liquid limit and plastic limit and depends on the clay mineral quantities which are in the soil. A PI shows excess of clay mineral in the soil leading to greater plasticity of the soil while a small value of PI indicates soil is plastic for a very short range of water content. If the moisture content in the suspension is decreased, soil gets stiffer and starts developing resistance to shear and becomes plastic, and in this state, it can be moulded into different shapes without rupturing. PL is used together with the LL to determine the PI and when plotted against the LL is used in classifying cohesive soils.

This test is carried out with reference to **BS 1377: Part 2: 1990**.

#### **Procedure**

20g was set aside for plastic limit test from the 400g prepared earlier, put on a glass plate and the sample mixed very well with water using a spatula. The sample was kept in free air for about 24 hours to be dry enough/plastic enough to be molded and rolled.

A ball was molded and rolled between palms until cracks appeared on the surface cracked threads placed in a moisture tin and combined weight of moisture tin and wet cracked threads. They were then oven dried for 24 hours and combined weight after oven drying also obtained and the weight of the moisture tin recorded. A second trial was done to

obtain a second moisture content. The mean of the 2 moisture contents was then calculated giving the plastic limit value.

### **3.3.2.3 Linear Shrinkage**

This is the reduction in length of a wet soil sample after drying. Any reduction in moisture content of soil causes an almost equal reduction in volume of soil mass. A point is reached where continued reduction in water content leads to a constant volume of soil and at this point soil mass transforms from semi-solid state to solid state.

Shrinkage limit is moisture content where soil stops shrinking. It is lowest moisture content at which soil is fully saturated. The linear shrinkage value is a form of determining the amount of shrinkage of clayey material. It is important in the converse state of expansion due to wetting. This test was done with reference to **BS 1377: Part 2: 1990**.

#### **Procedure for linear shrinkage**

The linear shrinkage mould was cleaned, a thin film of grease added and the initial volume measured knowing the diameter of the mould. The mould was gently tamped against a strong surface to remove any air pockets in the mixture, then leveled on the top of the mould using a palette knife and all soil on the rim of the mould removed with a moist cloth.

The mould was put to slowly air dry up to when it shrunk from the sides of the mould and drying is by transferring to an oven at temperatures of 110°C for 24 hours until the sample completely shrunk and the mould was cooled and sample measured. The volume of the oven dried sample is measured.



**Figure 5: The shrinkage of the specimen.**

### **3.3.3 Dry density-moisture content relationship (BS 1377 PART 2:1990) Proctor Test**

This is used to ascertain the relationship between moisture content and density and was named after a scientist R. Procter. This test helps to establish the alteration of unit weight of soil and degree of compaction with the moisture content. It also helps to obtain MDD and OMC for the highest practical density which are later used in the calculations involved in CBR. The moisture-density relationship affects the compaction of soil, while other factors include type of soil, type of load, compaction effort and soil gradation.

Compaction is the process by where solid particles are packed together normally by mechanical means, hence improving the dry density of soil. It reckons compaction levels and the quantity of water in soil.

**Dry density** refers to the density of oven dried soil where all moisture has been removed from its pores. Oven drying is typically carried out at temperatures not exceeding  $110^{\circ}\text{C}$  for a period of 16-24 hours. The moisture content for the highest dry density is the optimum moisture content for the type of compaction.

**Optimum moisture content** is the content of water in which soil is fully mixed with the water and no water particles replaces soil particles. This facilitates compaction to the maximum dry density.

This test was carried out with reference to **BS 1377: Part 2: 1990**.

#### **Procedure for Proctor Compaction Test.**

A representative sample was obtained by quartering and after passed through a 20mm sieve before 5 portions of 300g each were weighed on an electric weighing machine and a known amount of water from a cylinder added while mixing thoroughly until the soil was compressible in a fist and break at once if thrown to the ground.

The Compaction mould was then cleaned, oiled and its weight plus the base plate obtained without the collar before mixing and dividing it into equal portions to represent the layers to be compacted in the mold. Each layer was placed in the mold then compacted by 27 blows using a 4.5 kg rammer with evenly distributed blows and collar removed and extra mold cut off after. The weight of the mold with the sample and its base plate was obtained then the mold struck on the ground and the wet sample removed, some of which was collected in a moisture tin and their weight recorded. The wet sample in the moisture tin was oven dried for 24 hours then dry weight recorded after the 24 hours.

The moisture content, bulk mass, bulk density, dry density was calculated and the procedures are repeated for the remaining 4 portions and the coordinates obtained were used to plot a graph of dry density against moisture content and the maximum end point read off as the MDD on the vertical axis and OMC on the horizontal axis.



**Figure 6: Soil sample for compaction.**

### **3.3.4 California Bearing Ratio Test (BS 1377 Part 4:1990)**

This is a laboratory test for evaluating the strength and deformation characteristics of soils and base materials for flexible pavement design. It is a penetration test used to calculate the resistance of soil to the penetration of a standard plunger at a controlled rate.

#### **Main Principle of CBR Test**

The CBR test bases on the principle that the penetration resistance of soil is related to its shear strength. The test involves applying a load to a cylindrical plunger that is pushed into a soil sample at a constant rate and force used to penetrate the soil measured and used to calculate the CBR.

The CBR value is the resistance to a penetration of 2.5mm of a standard cylindrical plunger of 50mm diameter, expresses as a percentage of the known resistance of the plunger to 2.5mm in penetration in crushed aggregate, (taken at 13.2Kn)

**Reference to BS 1377: Part 4: 1990**

### **Test Procedure**

The soil was divided into equal parts to within 50g and seal each in an airtight container up to when it is needed to prevent loss of moisture and the first portion of soil into the mould for 62 blows of compaction, so that after 62 blows using rammer, the layer had about one-third of the height of the mould and make sure that the blows are evenly distributed over the surface and then repeated for the different portions of soil such that the final level of the soil surface was not more than 6mm above the top of the mould body.

The collar was removed and soil trimmed at the top of the mould with the scraper, checking with the steel straightedge and weigh the mould.



**Figure 7: CBR Penetration molds soaking**

### **3.3.5 Chemical properties of rice husk ash using X-ray fluorescence(ASTM C 618-2012)**

X-ray fluorescence, or XRF, refers to the generation of distinct secondary x-rays (or fluorescent x-rays) emitted by a substance when it is stimulated through the bombardment of high-energy x-rays or gamma rays.

#### **Principle of the X-ray fluorescence**

When an incident photon in the X-ray range excites an inner shell electron, the subsequent de-excitation involves another electron transitioning from a higher energy level to fill the resulting vacancy. The energy variance between these two electron shells leads to emission of X-rays by the atom. Analyzing the acquired X-ray spectrum during this process reveals distinctive peaks. The energy levels of these peaks facilitate the identification of elements within the sample, allowing for qualitative analysis. Simultaneously, the intensity of the peaks serves to determine the absolute elemental concentration, enabling semi-quantitative or quantitative analysis

### **3.3.6 Unified Compressive Strength**

UCS measures strength of a sample of soil, concrete. It is performed on materials with internal cohesion and at a rapid rate of strain with no confining pressure applied to the sample and no allowance for pore pressure dissipation.

Undrained shear strength is known to vary according to how the failure load is applied and is sensitive to the direction of load application and the strain rate.

As with the sample preparation and casting methods described in the previous section, UCS commonly used standards is *ASTM D2166* (Standard Test Method for Unconfined Compressive Strength of Cohesive Soil),

### Procedure

The soil specimen in the loading device was used to center on the bottom platen and in full contact on the top and bottom and load applied continuously and without shock. The rate of strain was chosen so that the time to failure does not is less than 15 minutes and such that the cylinder would fail in not less than 2 minutes.



**Figure 8: Specimen and UCS performing.**

## CHAPTER FOUR: RESULTS AND DISCUSSION

### 4.1 Introduction

This section shows results and discussions from the tests carried out on both the neat and rice husk ash. The classification tests carried include; particle size distribution and Atterberg limit tests. The strength tests include; modified proctor test and CBR, analyzed in accordance with the literature review.

### 4.2 Neat soil sample

#### 4.2.1 Particle size distribution

It was conducted using both the wet-sieve and dry sieve methods in accordance to BS 1377: Part 2:1990. It reveals the different amounts of specific particle sizes in a dry mass of soil. Which is used to categorize soils for engineering reasons, as the size of particles affects how quickly or slowly water travels through soil.

**Table 4: Table of results for Particle Size distribution of the soil sample.**

Sieve size	63.0	37.5	20.0	5.0	2.0	0.425	0.075
Percentage passing	100	100	100	97	94	73	45

A graph showing percentage passing against sieve size

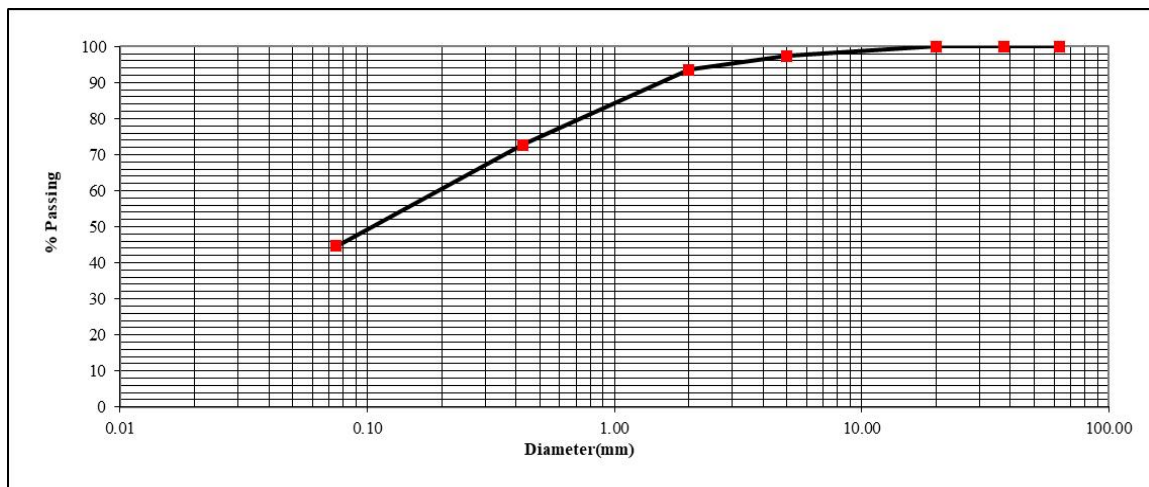


Figure 9: A graph showing gradation curve for silty clay soils.

**Grading modulus (GM) = 0.915** -indicated a well graded soil and wide range of particle sizes, but slightly finer than ideal for sub-grade material. since its grading modulus is below 1.0. (GM must typically be greater 1.0).

**AASHTO soil classification system:** 53.3% of the soil passed with a minimum of 36% of the soil passing through the 0.075mm, according to AASHTO Soil Classification System, the soil is classified as silt or clayey.

### 4.2.2 Atterberg Limit Tests

Table 5: Table showing results for Atterberg limits.

Property	Quantity	General Specification Requirements	Quantity
Liquid Limit(%)	53.3	ASTM D3282)	41% Maximum
Plastic Limit(%)	29.7		
Plastic Index(%)	23.6	MoWT,2018	20% Maximum

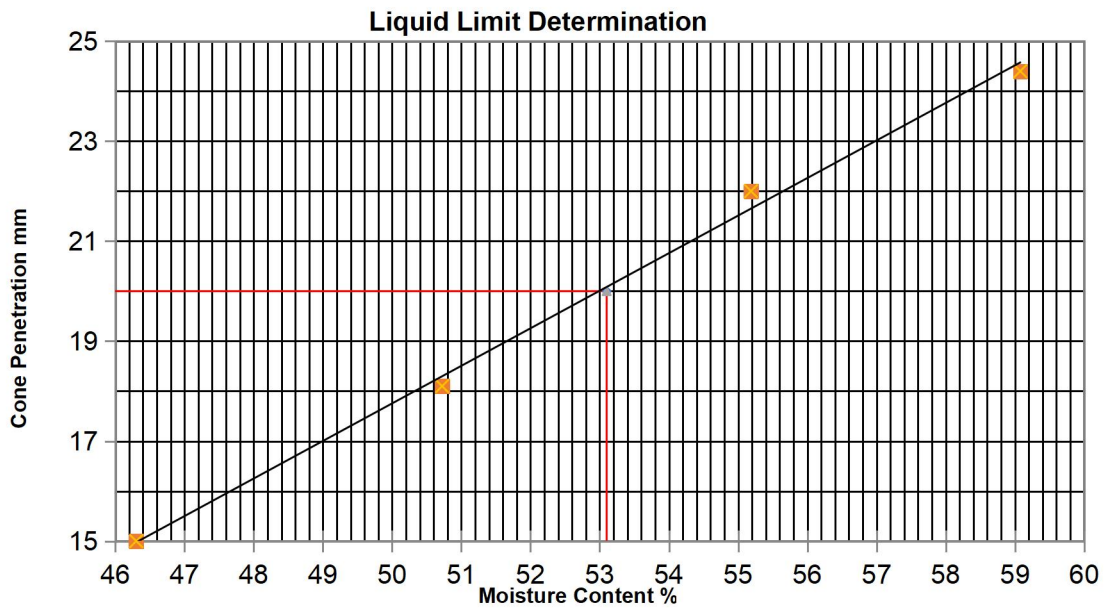


Figure 10: A graph of cone penetration against water content to get Liquid limit.

The liquid limit was extracted from the preceding graph and recorded as 53.3%. a high liquid limit which implied high compressibility as well as a high shrinkage or swelling potential. Having a high liquid limit directly translated into a high plasticity index. This indicated an excess of clay or colloidal material.

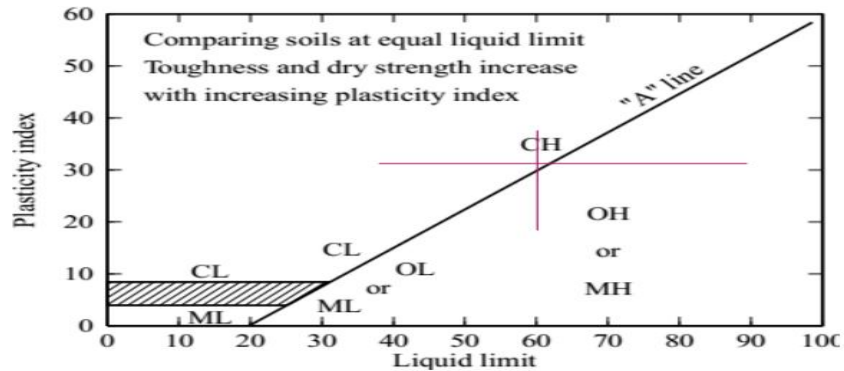
The plastic limit denotes moisture content at which cohesive soil shifts from a semisolid state to acting like a solid, with a determined value of 29.7%. Plasticity mainly indicates of the cohesive nature of the soil. If  $PI \geq 20$  for the soil, then it is classified as cohesive clay soil with high plasticity (Wagner, 2013).

Atterberg limits test results indicate a plasticity index of 23.6%, exceeding the threshold of 20%. Additionally, the wet sieve analysis reveals that over 45% of fines pass through sieve No.200. In accordance with the Ministry of Works and Transport manual (2018), materials exceeding 25% passing through sieve No.200 and having a plasticity index above 20% necessitate lime stabilization.

**AASHTO Classification System:** Since 45% of the soil passes the sieve No. 200, and the liquid limit is greater than 40, the soil was classified as A-7 being termed as clayey soil (Fine-grained soils, high plasticity) category. Further more the soil can be classified as A-7-6 since its plasticity index is greater than the liquid limit negative 30. This confirms the soil's poor drainage and low bearing capacity.

## Unified Soil Classification System (USCS):

### Using A-Line Chart



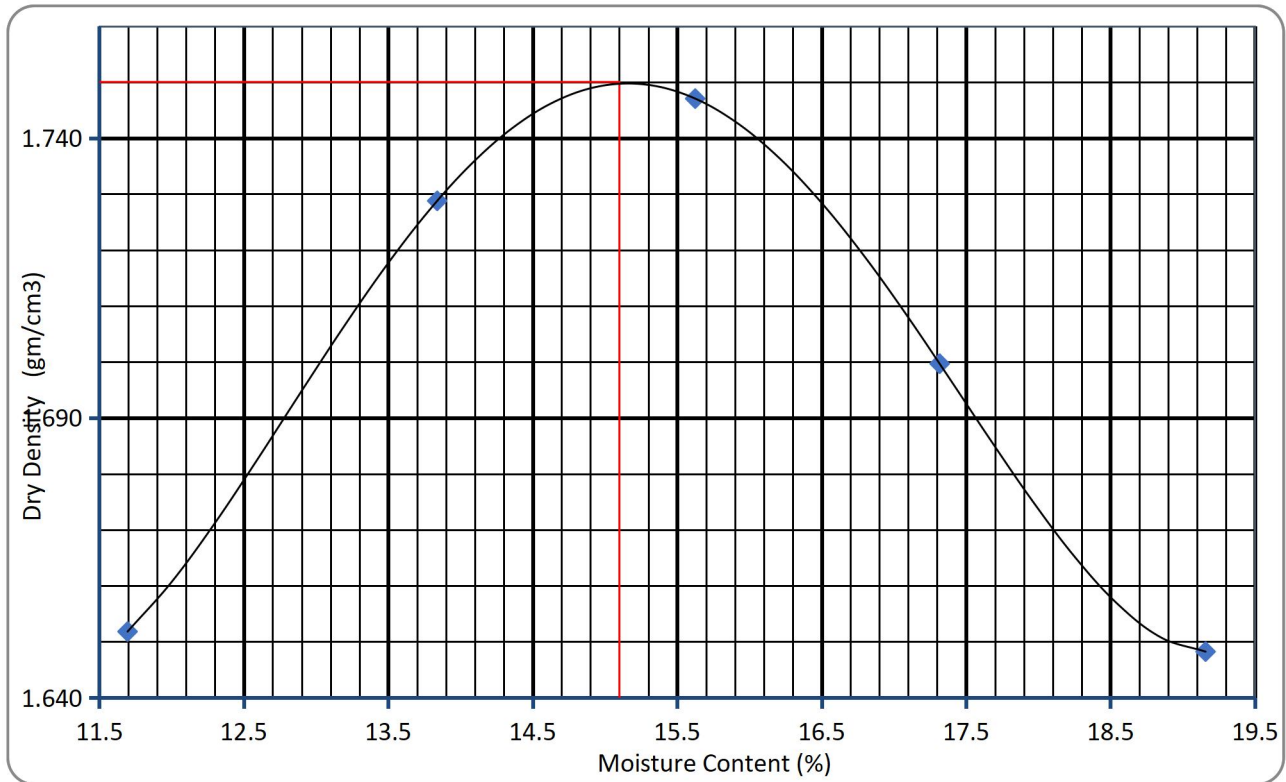
Plotted LL of 53.3% and PI of 23.6% on the USCS plasticity chart. Since the plotted point falls above the "A" line, the soil is classified as fine-grained with high plasticity (CH). This indicates a highly plastic clay with significant potential for shrinkage and swelling.

#### 4.2.3 Linear Shrinkage

It is used to estimate the swell and shrink behaviour of the soils. According to Madedor (1983), subgrade materials should have a linear shrinkage of 10% or less. A shrinkage of 18.5% lies within the range of critical chance for cracking due to swelling and shrinking with moisture changes.

#### 4.2.4 Moisture - Density Relationship

The moisture contents and their corresponding dry densities were plotted, and a best-fit curve was drawn through the points.



**Figure 11: A graph of a dry density against moisture content used to determine MDD and OMC**

From the graph the soil also displays a low MDD of 1.750 g/cm<sup>3</sup> and a high O of 15.1%, indicating a notable water-retaining capacity leading to swelling and increased volume, inversely affecting density.

#### 4.2.5 California Bearing Ratio (CBR)

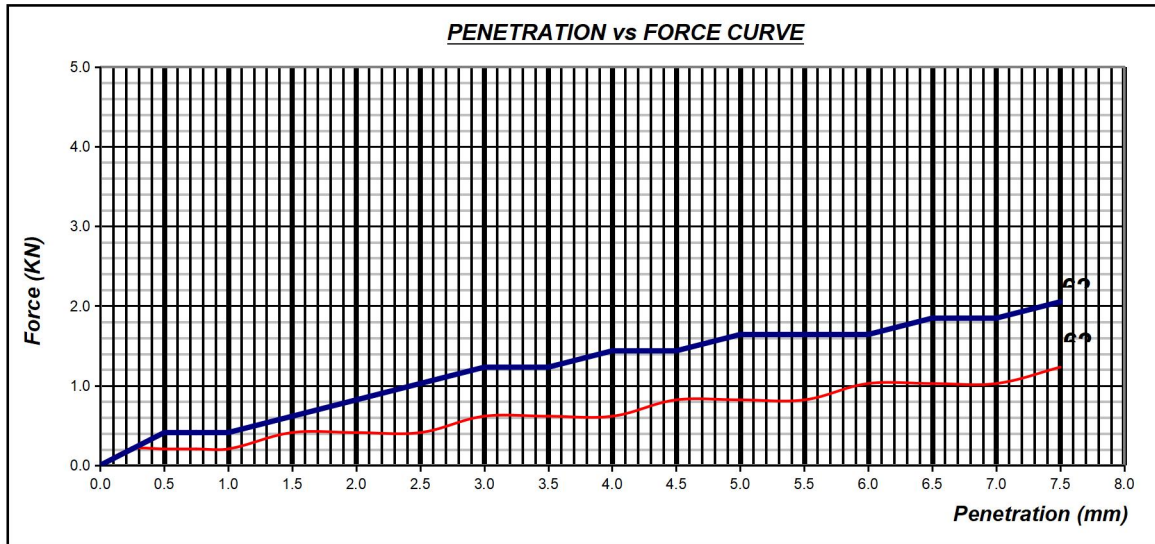


Figure 12: A graph of Force against penetration

Based on Asphalt institute (1962), CBR of 0 - 3 is very poor, 3 - 7 is poor to fair, 7 - 20 is fair and 20 - 50 is good.

In accordance with the Ministry of Transport and Works (MoWT) 2005 standards, the subgrade must achieve a minimum CBR of 15% after a 4-day soaking period. However, the analysed material yielded a CBR of 8.0% after the specified soaking duration. Comparing this classification with the Ministry of Transport and Works and ASTM standards for foundation subgrade requirement, the soil does not meet the minimum CBR requirement (typically >30%) in its natural state. This non-compliance indicates potential issues with bearing capacity and susceptibility to deformation under load.

### 4.3 Chemical composition of Rice Husk Ash

The X-ray fluorescence method was employed to examine rice husk ash (RHA). For this study, the RHA was sieved to pass through a 150  $\mu\text{m}$  sieve size.

**Table 6: Chemical composition of rice husk ash.**

Parameter	Percentage Present (%)	ASTM Standard C618:2012
Silicon dioxide	81.192	25min
Iron (III) Oxide	8.026	5.5 max
Calcium Oxide	7.049	10 max
Aluminium Oxide	1.919	8.0 max
$\text{SiO}_2 + \text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$	89.814	70 min

The rice husk ash analyzed in the table exhibits a chemical composition, represented by  $\text{SiO}_2 + \text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$ , exceeding 70% according to ASTM C 618-2012, hence it qualifies as a pozzolan. The elevated percentage of silicon dioxide in the pozzolan signifies a substantial production of calcium silicate hydrate (C-S-H) which in turn, enhances strength of the stabilized material when combined with lime, which primarily contains Calcium oxide. The interaction between CaO and  $\text{Si}^{2+}$  in RHA contributes to the observed increase in strength in the resultant mixture.

## 4.4 Variation in engineering properties of the stabilized soil samples

### 4.4.1 Initial Consumption Of Lime (ICL) BS 1924: PART 2:1990

This is the quantity of lime used-up during the initial ion exchange reaction, crucial for achieving minimum content to attain long lasting strength.

In this experiment, a saturated solution of hydrated lime in distilled water, devoid of any carbon dioxide, exhibits a pH value of 12.40 at 25°C. Various proportions of lime, namely 2%, 3%, 4%, 5%, and 6% and analysis was conducted on 10 soil samples, each weighing 15 grams.

Lime was added to each 15 grams of soil at varying percentages: 2%, 3%, 4%, 5%, and 6%, each applied twice. The soil-lime mixtures were combined with water, with 100 milliliters of water added to each sample. Subsequently, the bottles were shaken for 30 seconds every 10 minutes over the course of 1 hour.

Plotting the percentage of lime against the pH (adjusted to 25°C), the amount of lime needed to achieve pH values of 12.40 was determined as the initial lime content percentage, utilizing interpolation which increases the long-term pozzolanic reaction thereby improving soil strength. (*Fatima and Zohra, 2021*).

The pH level of 12.4 fosters the dissolving of siliceous and aluminous compounds from the clay mineral lattice which subsequently engage with calcium ions ( $\text{Ca}^{2+}$ ) present in pore water, giving rise to the formulation of calcium silicate hydrate (C-S-H) and calcium aluminum hydrate (C-A-H) gels which coat soil particles and undergo crystallization, thereby effectively bonding them together.

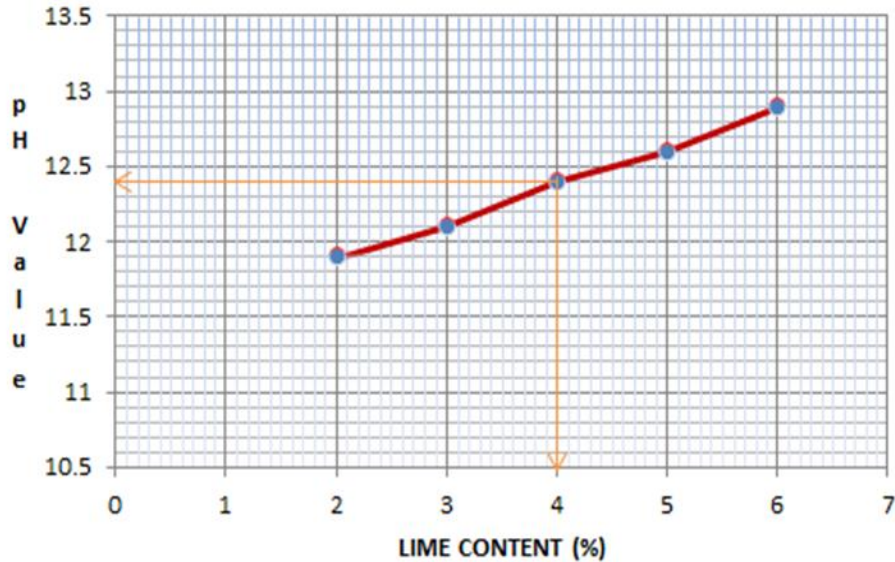


**Figure 13: Initial consumption of Lime test.**

**Table 7: The ICL test results**

<b>Lime Content</b>	<b>%</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>
<b>pH value of the suspension</b>		<b>11.9</b>	<b>12.1</b>	<b>12.4</b>	<b>12.6</b>	<b>12.9</b>
<b>Temperature</b>	<b>°C</b>	<b>25.7</b>	<b>25.7</b>	<b>25.8</b>	<b>25.8</b>	<b>25.8</b>
<b>pH Corrected to 25</b>	<b>°C</b>	<b>11.9</b>	<b>12.1</b>	<b>12.4</b>	<b>12.6</b>	<b>12.9</b>

**Table 8: Graph showing Initial Lime Consumption For Silty Clay Soil**



From the graph above , it is observed that the clay soil reached a pH of 12.4 with a 4% addition of lime. This indicates that the presence of silicon oxide and aluminum oxide in the clay soil facilitated the occurrence of the pozzolanic reaction between lime and clay, resulting in an elevation of the pH to 12.4. The gradual incline demonstrated on the graph illustrates the pace at which the pozzolanic reaction progresses, ultimately leading to a pH alteration.

The plot of pH values, adjusted to 25° C, against lime content provides insight into the alkalinity levels of the treated clayey soil. At a lime content of 2%, the pH registers at 11.9, situating the soil within a slightly alkaline range. As the lime content increases to 3%, the pH escalates to 12.1, eventually reaching 12.4 at a lime content of 4%. Notably, the pH of 12.4 signifies the requisite condition for the initiation of the pozzolanic reaction.

The pH level of 12.4 fosters the dissolving of siliceous and aluminous compounds from the clay mineral lattice which subsequently engage with calcium ions (Ca<sup>2+</sup>) present in pore water, giving rise to the formulation of calcium silicate hydrate (C-S-H) and calcium aluminum hydrate (C-A-H) gels which coat soil particles and undergo crystallization, thereby effectively bonding them together.

#### 4.5 Design mix

Based on the result obtained on table 3, the mix ratios were formulated.

**Table 9: Showing design mix for the samples.**

S/N	Mix Description
1	Soil + 4% Lime (Control)
2	Soil + 4% Lime+ 4% Rice husk ash
3	Soil + 4% Lime +8% Rice husk ash
4	Soil + 4% Lime + 12% Rice husk ash

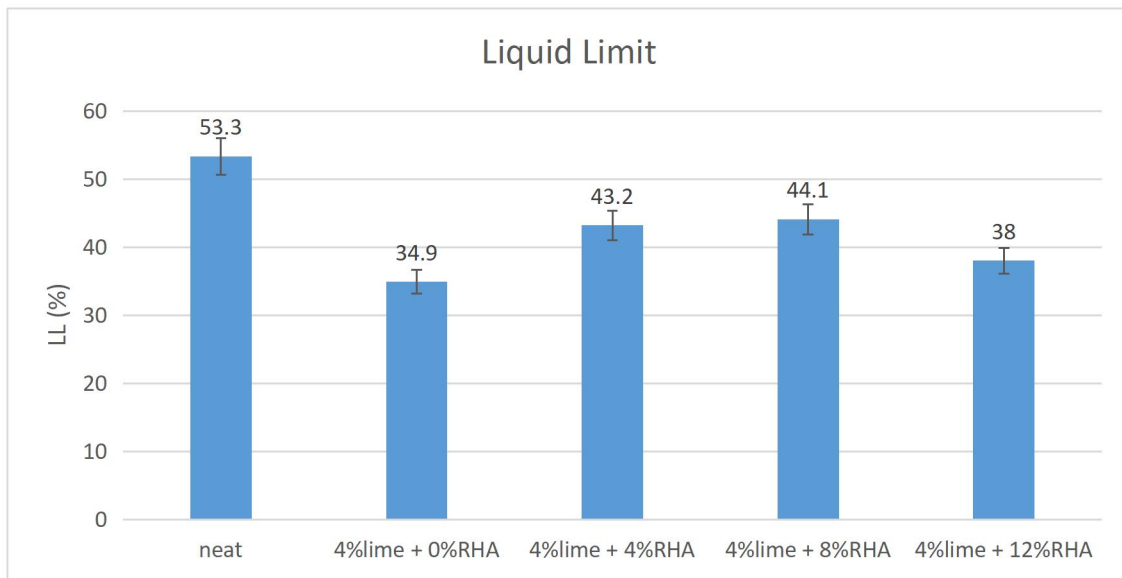
After mixing the specified design ratios, the resulting samples underwent testing through the Atterberg Limit Tests, Proctor Compaction, CBR and UCS tests to assess the impact of hydrated lime and rice husk ash on silty clay soils.

Furthermore, the research was supplemented by an ICL test conducted on soil samples treated with hydrated lime. The findings affirm that the addition of 4% hydrated lime during stabilization facilitates the provision of silicon oxide and

aluminum oxide. These elements react with the calcium oxide present in the hydrated lime, thereby facilitating occurrence of pozzolanic reactions. Consequently, this process enhances engineering properties of stabilized silty clay soils.

#### 4.6 Variation in Atterberg limits

##### 4.6.1 Variation in liquid limit



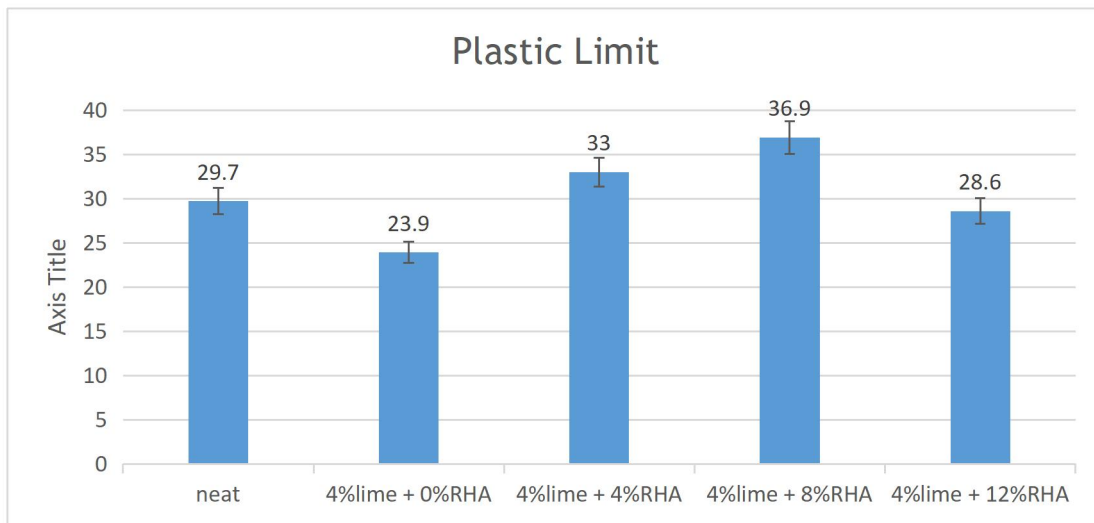
**Figure 14: A graph of LL variation with hydrated lime and RHA content.**

A significant reduction in liquid limit is observed with introduction of 4% lime, dropping from 53.3% (neat sample) to 34.9%. This phenomenon can be explained by cation exchange, a process facilitated by the calcium ions in the lime. These calcium ions replace other cations (e.g., sodium and potassium) on the clay surfaces. This reduces repulsive forces between clay particles, causing them to clump together (flocculate) into larger aggregates (Bell, 2011). Consequently, the flocculated clay particles have a reduced water surface area exposed to water, requiring less water to reach saturation. This translates to a lower liquid limit.

Adding 4% to 8% rice husk ash (RHA) to the 4% lime mix presents a slight addition in liquid limit, from 34.9% to 44.1% due to the pozzolanic reaction between RHA plus lime, which forms binding gels (calcium silicate hydrate). These gels can trap some water within the soil matrix.

However, exceeding the optimal RHA content (observed at 8%) can have a contrasting effect. Including 12% RHA may introduce a significant amount of untreated ash particles. These particles act as inert fillers, reducing the available space for water within the soil structure. This can potentially lead to a decrease in liquid limit again, down to 38.0%.

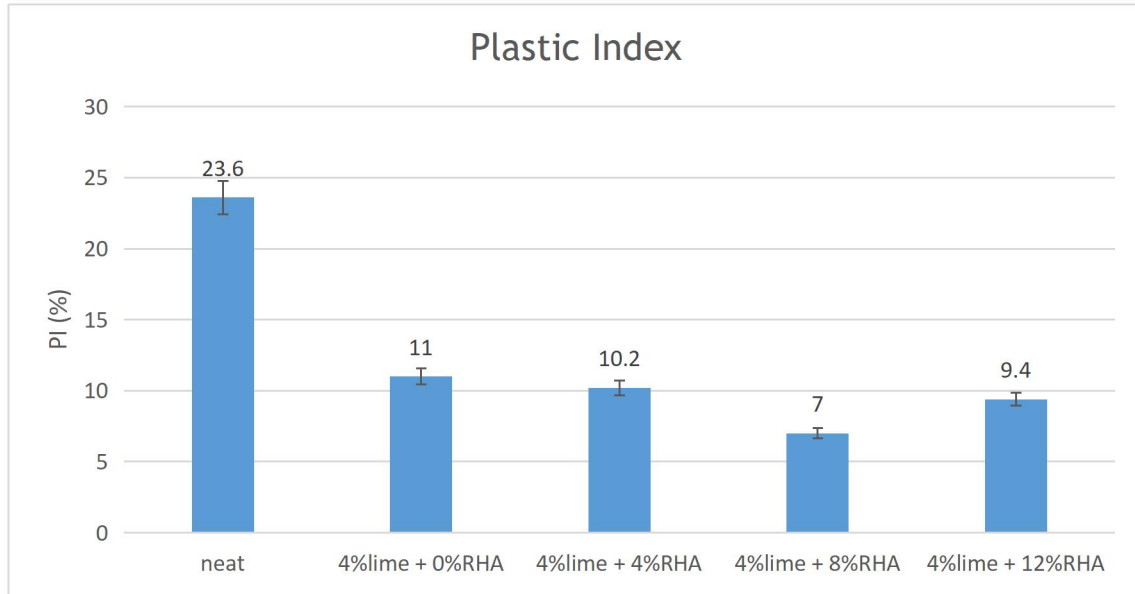
#### 4.6.2 Variation in Plastic Limit (PL)



**Figure 15: A graph showing Plastic Limit with hydrated lime and RHA content.**

Most treatments show a decrease in PL. lime's interaction with clay particles and potential pozzolanic reactions can reduce the water content required to attain the plastic limit. However, some variations in PL decrease are observed, suggesting the influence of RHA content and potential interactions with specific clay minerals.

### 4.6.3 Variation in Plastic Index (PI)



**Figure 16: A graph of variation in Plastic limit with hydrated lime and RHA content**

Introducing 4% lime alone significantly reduced the plasticity index from 23.6% (neat sample) to 11%. This decrease can be due to the existence of calcium ions from lime, which facilitate cation exchange within the soil matrix.

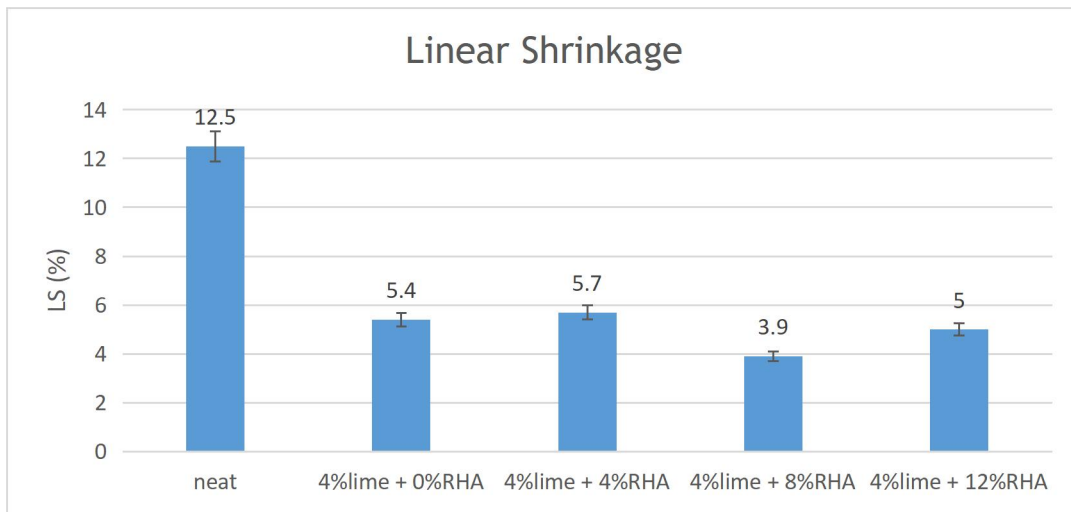
Further reduction in the plasticity index is observed when rice husk ash (RHA) is added in conjunction with 4% lime. The index decreases from 11% to 7% with the inclusion of 4% to 8% RHA. This combined effect can be explained by two mechanisms. Non-plastic RHA particles partially replace the plastic soil particles, diluting the overall plasticity of the mixture.

Lime promotes ionic exchange between calcium ions and clay minerals in soil (Bell, 2011). This process, along with the presence of RHA, leads to flocculation and

agglomeration of silty clay particles. These combined actions effectively reduce the plasticity of the treated soil.

The Ministry of Works and Transport Design Standard (2018) specifies that soils with more than 25% passing the No. 200 sieve (0.075 mm) and a plasticity index exceeding 20% require lime stabilization. The observed reductions in plasticity index with lime and RHA treatment suggest their potential for bringing high-plasticity soils within the acceptable range as defined by these design standards.

#### 4.6.4 Variation in Linear Shrinkage

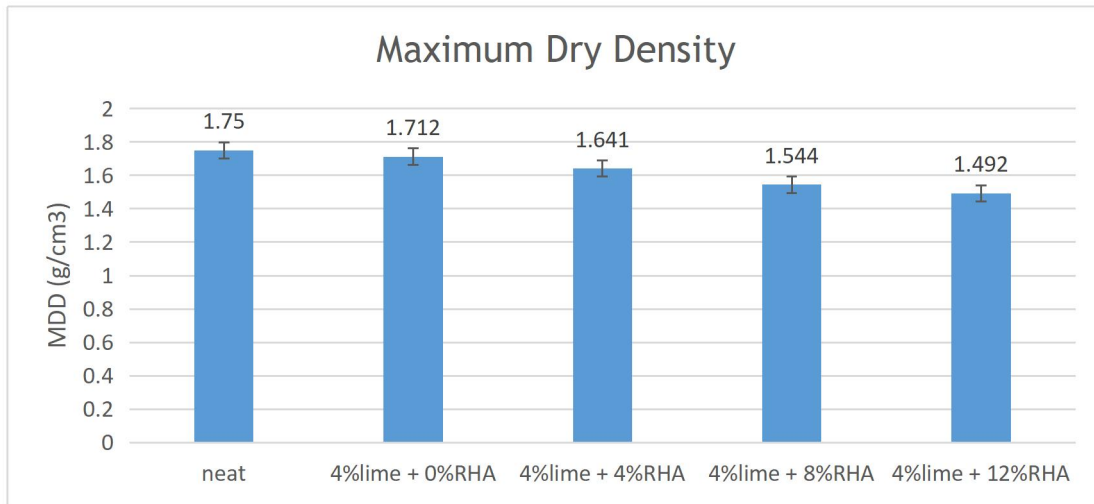


**Figure 17: A graph of variation of linear shrinkage with hydrated lime and RHA content**

Reduction in linear shrinkage is due to the stabilizing effects of the lime and rice husk ash combination. The cementitious compounds formed during stabilization (calcium silicate hydrates and calcium-aluminium-hydrates) create a more rigid and cohesive

soil matrix. This reduced movement within the soil structure minimizes volume change upon drying and consequently lowers the risk of cracking.

#### 4.7 Variation in maximum dry density



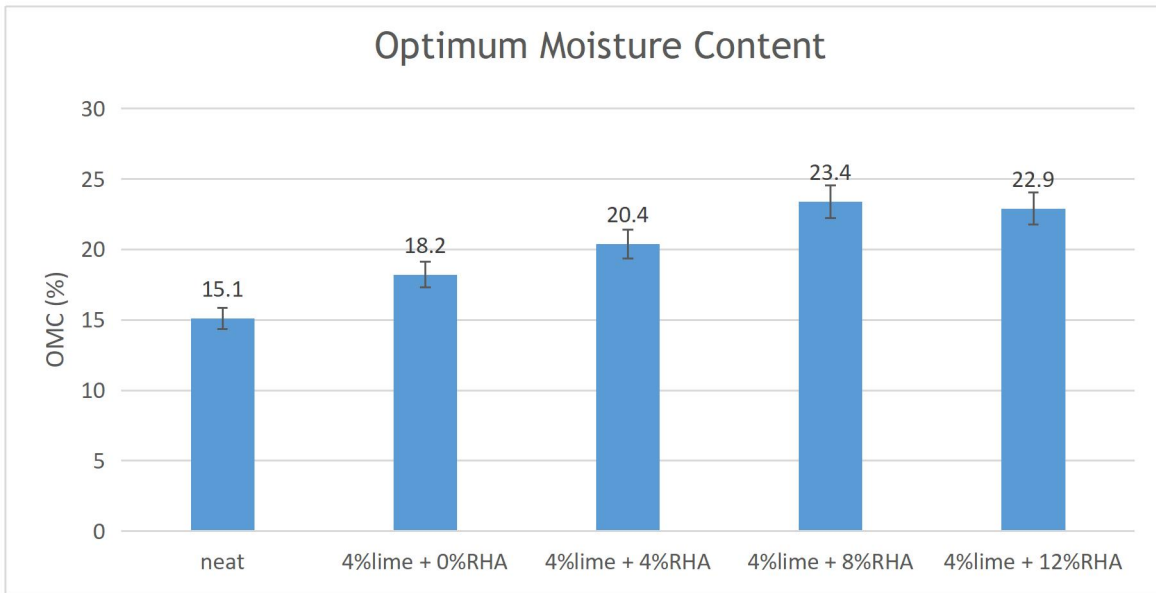
**Figure 18: A graph of variation of MDD with hydrated lime and RHA content**

Initially, addition of hydrated lime contributes to a denser soil structure. It reacts with clay minerals to form cementitious compounds, promoting particle aggregation. This phenomenon facilitates tighter packing of soil particles, as evidenced by the initial decrease in MDD from 1.75 g/cm<sup>3</sup> (neat sample) to 1.712 g/cm<sup>3</sup> at 4% lime content.

However, as the RHA content surpasses 4%, the MDD trend reverses, exhibiting a continuous decrease to 1.492 g/cm<sup>3</sup> with 12% RHA. This is due to the role of RHA particles as inert fillers. They occupy the voids between soil particles, hindering potential for close packing and ultimately reducing the achievable maximum density. This effect outweighs the potential densification benefits arising from pozzolanic reactions between RHA and lime.

While the initial addition of lime promotes densification, the increasing presence of RHA particles as inert fillers leads to a decrease in MDD, despite potential strengthening through pozzolanic reactions.

#### 4.8 Variation In Optimum Moisture Content



**Figure 19: A Graph of OMC with varying percentages of hydrated lime and RHA**

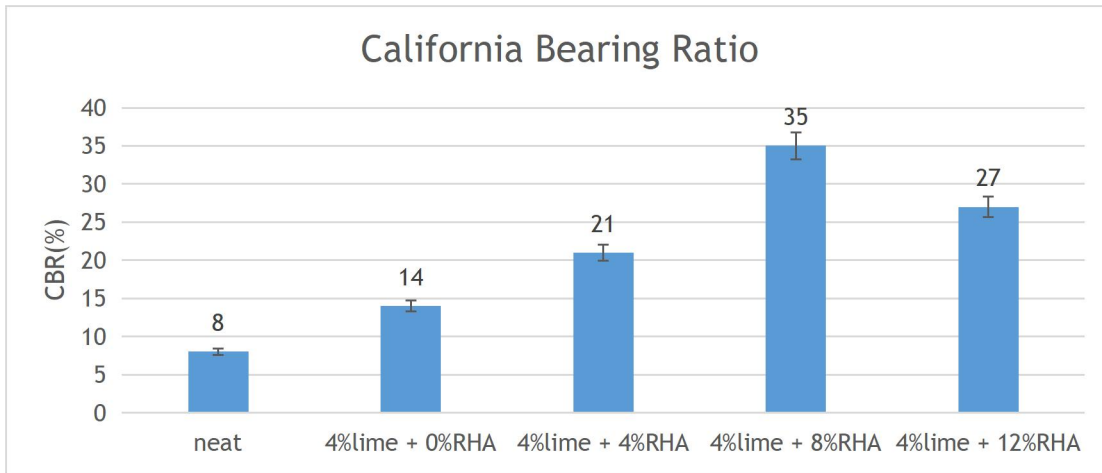
Introduction of hydrated lime influences water demand through two mechanisms. Firstly, it facilitates the pozzolanic reaction, a chemical process that enhances soil strength. Secondly, lime promotes the flocculation of clay particles (Bell, 2011), requiring additional water for effective clumping. This combined effect explains the observed increase in OMC from 15.1% (neat sample) to 15.1% at 4% lime content, even though the MDD remains relatively constant in the above graph.

The addition of RHA further elevates OMC because of its inherent capability to absorb water. Additionally, pozzolanic reaction between RHA and lime necessitates more

water for formation of cementitious bonds to strengthen the soil. This explains the further rise in OMC from 20.4% to 22.9% as RHA content increases from 4% to 12%, despite a decrease in MDD.

While MDD decreases with higher OMC, this finding presents a practical advantage during field compaction. Wet soil, corresponding to the higher OMC, is generally easier to compact efficiently. This translates to a reduction in the effort and resources required for drying the soil before compaction in the field, ultimately streamlining the construction process.

#### 4.9 Variation In California Bearing Ratio (CBR)



**Figure 20: A graph showing variation of CBR with Lime and RHA content**

The untreated silty clay soil exhibited a low initial California Bearing Ratio (CBR) of 8%, indicating its poor load-bearing capacity. This is due to high moisture content and plasticity of soil. The introduction of 4% lime effectively addresses these limitations. The lime reacts with clay minerals, promoting flocculation (clumping) and the

formation of cementitious compounds (Bell, 2011). These processes lead to a denser and stronger soil structure, as evidenced by the significant increase in CBR to 14%.

Further improvement in CBR is achieved by combining 4% lime with 4% rice husk ash (RHA). This increase to 21% CBR highlights the synergistic effect of RHA's pozzolanic properties. Pozzolanic reactions enhance strength and reduce voids by promoting the formation of additional cementitious bonds within the soil.

Optimal stabilization for CBR improvement is achieved with the addition of 8% RHA. This combination results in a peak CBR value of 35%. This signifies both increased pozzolanic reaction and densification of the soil structure. However, exceeding this optimal content (as seen with 12% RHA) leads to a decrease in CBR (27%). This suggests incomplete reaction with the lime and potential negative effects from inert filler behavior of the excess RHA, leading to a weaker and more porous structure.

The observed increment in CBR is due to the formation of cementitious bonds within stabilized soil. These compounds include calcium silicate hydrates (CSH) and calcium-aluminium-hydrates (C-A-H) which utilize silica and alumina from the soil itself plus added rice husk ash. Similar to those formed in Portland cement, C-S-H and C-A-H act as a binder, significantly contributing to the general strength of the stabilized soil layers.

By achieving a 35% CBR value with the optimal dosage of 4% hydrated lime and 8% RHA, the stabilized soil surpasses the minimum requirement (>30%) set by ASTM standards for foundation sub-grade applications. This demonstrates the suitability of this specific lime-RHA combination as a sub-grade material.

#### 4.9.1 Variation in CBR Swell

**Table 10: Results for variation in CBR swell for the different percentages of lime + RHA**

Properties	Neat Soil	4% Lime	4% Lime + 4% Rice husk ash	4% Lime + 8% Rice husk ash	4% Lime + 12% Rice husk ash
CBR swell (%)	1.20	0.56	0.50	0.42	0.44

The observed reduction in CBR swell of stabilized silty clay is due to synergistic combination of mechanisms:

The introduction of hydrated lime and rice husk ash alters the ionic environment within the soil, promoting cation exchange. This displaces swelling clays like sodium with calcium, leading to flocculation and agglomeration of soil particles. These larger, denser aggregates exhibit reduced water affinity and improved packing, consequently minimizing swell potential.

**Pozzolanic Reaction and Densification:** Rice husk ash, rich in silica, reacts with calcium hydroxide from hydrated lime to form cementitious calcium silicate hydrates (CSH). This pozzolanic reaction strengthens the soil matrix by filling voids and binding particles together. The resulting denser structure offers greater resistance to deformation and volume change under load.

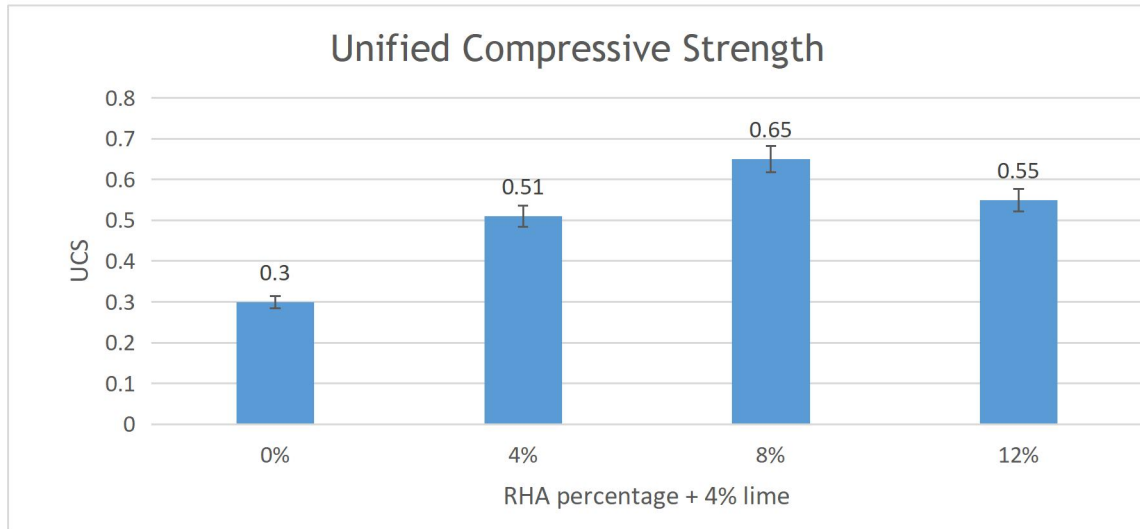
The incorporation of rice husk ash physically replaces a portion of the original clay minerals. These typically expansive clay particles are replaced by less reactive ash particles, further contributing to a reduction in overall swell potential. The ash particles may also fill voids within the soil matrix, leading to a denser packing and reduced susceptibility to water absorption and swelling.

This combined effect of cation exchange, pozzolanic reactions, and physical substitution by rice husk ash effectively minimizes CBR swell of stabilized silty clay soil, enhancing its suitability for foundation sub-grade applications.

This rephrased statement uses more technical language and emphasizes the scientific mechanisms behind the observed improvement. It also highlights the synergistic effect of the different stabilization processes.

#### **4.10 Variation In Unconfined Compressive Strength (UCS)**

The compressive strength was carried after 7 days of curing and 7 days of soaking for the casted samples with varying percentages in hydrated lime and RHA accordance with CML TEST 1.21, TMHI-1986-A14 using a compressive test machine.



**Figure 21: A graph of variation of UCS with hydrated lime and RHA.**

Unconfined Compressive Strength (UCS) analysis revealed a evidential improvement in mechanical strength of the stabilized soil. Initially, with only 4% lime, the UCS was moderate at 0.30 MPa. However, incorporating 8% rice husk ash (RHA) alongside the lime resulted in a substantial increase in UCS to 0.65 Mpa.

This enhancement can be attributed to the synergistic interaction of lime and RHA. Hydrated lime reacts with clay minerals to form cementitious binding agents, strengthening the soil matrix and rice husk ash participates in pozzolanic reactions with hydrated lime and moisture, further promoting formation of these binding agents and enhancing the overall bonding effect.

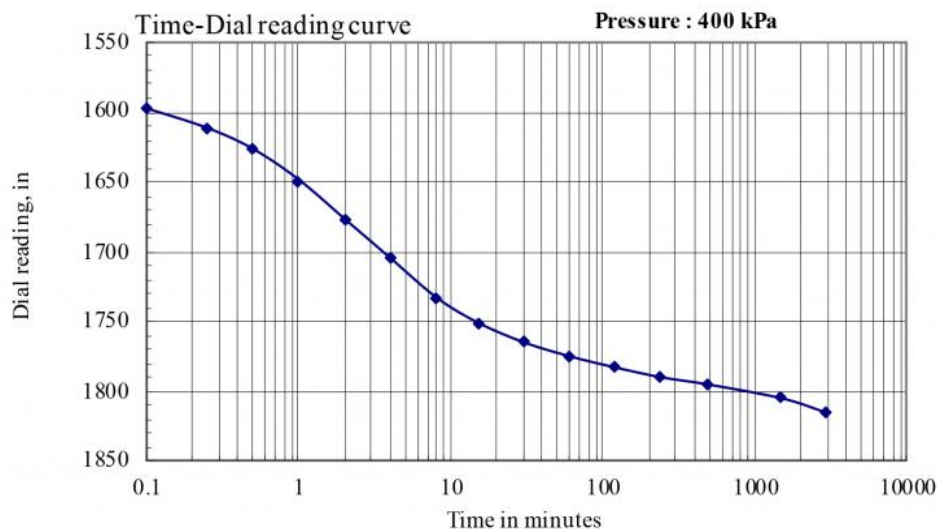
The optimal UCS of 0.65 MPa was achieved with a critical balance of 4% lime and 8% RHA. This dosage provides sufficient reactive silica from RHA for effective pozzolanic reactions with lime, promoting strength gain. Furthermore, the 8% RHA content

avoids excessive void filling within the soil matrix, allowing for efficient load transfer and maximizing strength.

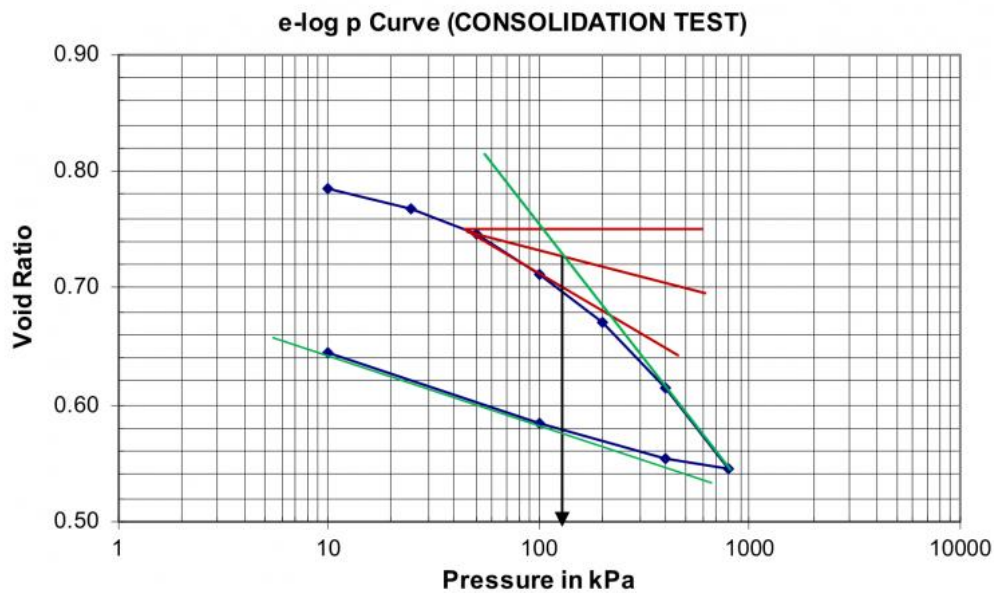
Interestingly, exceeding the optimal RHA content (12%) resulted in a slight decrease in UCS to 0.55 MPa. This phenomenon is likely due to incomplete pozzolanic reactions. Excessive rice husk ash (RHA) exceeding the optimal dosage can be detrimental. Unreacted RHA particles remain within the soil matrix as inert filler. These fillers occupy space without actively contributing to the bonding process. This can lead to the formation of voids, ultimately reducing the overall density and compromising the soil's strength despite some ongoing pozzolanic activity.

Importantly, the UCS achieved with the optimal dosage (0.65 Mpa) surpasses the minimum requirement of 0.5 Mpa set by the Ministry of Works and Transport (2010) for sub-grade construction, highlighting the effectiveness of this stabilization approach.

#### 4.11 Variation in consolidation



**Figure 22: A graph of Dial reading in against Time in minutes**



**Figure 23: A graph of Void ratio against pressure.**

The Compression Index ( $C_c$ ) reflects the soil's compressibility. A lower  $C_c$  (0.23) compared to typical silty clay (around 0.4-0.7) suggests some improvement in soil stability due to the lime-rice husk ash mix.

Recompression Index ( $C_r$ ) indicates elastic deformation. A low  $C_r$  (0.06) implies minimal elastic rebound after load removal, suggesting a more rigid structure.

Reconsolidation Pressure ( $P_c$ ) of 115 kPa represents the maximum effective stress the soil experienced previously. The lime-rice husk ash treatment might have increased the  $P_c$  and hence reduce the rate of settlement during consolidation as the soil can better withstand the applied load without excessive deformation. It also helps to

improve drainage by reducing plasticity and increasing permeability of soil accelerating the consolidation process.

Coefficient of Consolidation ( $C_v$ ) reflects the rate of soil settlement under load. The provided range (4.2 - 7.25  $m^2/year$ ) suggests moderate to fast consolidation depending on the pressure according to the ASTM D2435 standards which indicates that lime and rice husk ash successfully improved the soil strength but require careful monitoring to ensure the stabilization is uniform and durable.

#### **4.12 Variation in free swell index**

The initial soil analysis reveals several key properties that are favorable for stabilization efforts using a mixture of 4% lime and 8% rice husk ash. Firstly, the low free swell index of  $2.30 \pm 0.5333\%$  indicates minimal expansive behavior in the soil. This characteristic is highly beneficial for stabilization projects as it reduces the risk of swelling and potential structural damage post-construction. It suggests that the soil possesses inherent stability, providing a solid foundation for further treatment.

Additionally, the negligible moisture content of the soil simplifies the stabilization process. With minimal initial moisture present, less water is required for the pozzolanic reaction between lime and rice husk ash. This can lead to a more efficient and effective stabilization process, potentially resulting in improved overall stability and durability of the final structure.

The slightly alkaline pH of the soil further enhances its suitability for stabilization. A pH environment that leans towards alkalinity is known to favor the pozzolanic reaction between lime and rice husk ash. This chemical reaction plays a crucial role in

binding soil particles together, ultimately leading to increased strength and stability of the stabilized soil mass.

The moderate specific gravity of 1.52 suggests a reasonable soil density. This characteristic influences the overall weight of the stabilized soil mass and facilitates proper weight distribution within the final structure. A moderate density is desirable as it ensures structural integrity while allowing for sufficient load-bearing capacity.

Furthermore, the low electrical conductivity of the soil indicates minimal ionic activity, contributing to a less aggressive environment for the stabilized soil. This aspect is crucial for long-term durability, as it reduces the risk of corrosion from stray currents, thereby enhancing the structural longevity of the stabilized soil.

## CHAPTER FIVE : CONCLUSION AND RECOMMENDATION

### 5.1 Introduction

This chapter is a summary of the research, conclusion drawn plus recommendations of the findings from the laboratory investigations on both the stabilized and the unstabilized samples.

### 5.2 Conclusion

Particle size distribution analysis revealed a grading modulus of 0.915%, indicating a well-graded soil with high plasticity, classified as silty or clayey according to AASHTO standards and categorizing it as A-7 clayey soil (Fine-grained, high plasticity) according to AASHTO. The CBR of the untreated sample was found to be 8% meaning it was a poor soil therefore they needed to be stabilized.

Chemical analysis of rice husk ash showed it was class C agro-pozzolan according to the ASTM C 618-2012 standard since  $\text{SiO}_2 + \text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$ , exceeded 70% and was fit to be used as a stabilizer, improving soil's strength improving capabilities.

An optimum mix design was achieved with the addition of 4% hydrated lime and 8% rice husk ash, the plastic index of the soil decreased, the CBR value improved from 8% to 35% and the USC was 0.65 Mpa, hence achieved the desired stabilized soil properties. This concludes that the combination of rice husk ash and hydrated lime effectively stabilizes silty clay soils resulting in improved strength, compressive strength, and durability by reducing expansion, plasticity, and moisture affinity. The

addition of rice husk ash also enhances drainage by increasing void ratio and permeability.

### **5.3 Recommendations**

Based on the findings presented, it is recommended to incorporate rice husk ash (RHA) in the stabilization of silty clay soils for sub-grade material applications. The optimal combination of 4% hydrated lime and 8% RHA has been identified to achieve the desired engineering properties, including enhanced strength, reduced plasticity, and improved durability.

Explore the effect of varying curing times (for example., 7 days, 14 days, 28 days) on the UCS and CBR values of the stabilized soil. This will provide insights into the long-term strength development of the material. In this research, the saw dust ash that was used as a mixture of ash from both the soft

## REFERENCES

1. Bell, F. G. (2011). *Lime stabilization for sustainable construction*. Taylor and Francis.
2. Collins, P. J., and Khaleghi, B. (2016). *Sustainable construction materials: Use of lime and limestone in concrete*. Elsevier.
3. Consoli, N. C., Manassero, M., and Pedretti, D. (2010). *Lime stabilization methods*. CRC Press.
4. Gidigasu, W. (2007). *Laterite soil engineering*. Elsevier.
5. Bell, F. G. (2004). Lime stabilization of clay minerals and soils. *Engineering Geology*, 70(3-4), 225-237.
6. Naik, T. R., and Singh, S. S. (2003). Properties of concrete containing fly ash. *ACI Materials Journal*, 100(3), 268-276.
7. Mitchell, J. K. (1993). *Fundamentals of soil behavior*. John Wiley and Sons.
8. Consoli, N. C., Festugato, L., and Baudet, B. A. (2009). The use of chemical admixtures to improve the engineering properties of soils. *Journal of Materials in Civil Engineering*, 21(1), 2-12.
9. Al-Mukhtar, M., Lasledj, A., and Alcover, J. F. (2014). Long-term performance of cement-stabilized recycled aggregates under freeze-thaw cycles and deicing salts. *Construction and Building Materials*, 50, 572-584.

10. Sivapullaiah, P. V., and Sridharan, A. (2009). *Strength characteristics of lime-stabilized expansive soil with industrial wastes. Journal of industrial and engineering chemistry*, 15(6), 792-799.
11. Ingles, O. G., and Metcalf, J. B. (1972). *Soil stabilization. Butterworth-Heinemann.*
12. Al-Rawas, A. A., and Hago, A. W. (2010). *Environmental impact of cement production: Literature review and future research directions. Materials and Design*, 31(4), 1631-1637.
13. Horpibul, S., Rachan, R., and Suddeepong, A. (2013). *Lime stabilization of expansive soil for slope stabilization. Journal of Engineering Science and Technology*, 10(4), 367-374.
14. Fatima G, Zohra D, (2021). *Strength development and lime consumption progress relationship in lime stabilized bentonite samples*
15. Pu, Y., Van Esch, J., and De Rooij, R. (2010). *Expansive soils: Testing, characterization, design, and construction. Springer Science and Business Media.*
16. Yong, R. N., and Yan, W. G. (2013). *Lime stabilization of clayey soils. Journal of Rock Mechanics and Geotechnical Engineering*, 5(1), 1-10.
17. Siddique, S., and Singh, B. (2004). *Rice husk ash-soil stabilization: A study of physico-chemical properties of stabilized soils. International Journal of Engineering Science*, 42(12), 1455-1466.

18. Indraratna, B., Lim, H. D., and Rujikiatkamjorn, W. (2005). *Laboratory evaluation of rice husk ash for soil stabilization. Engineering Geology, 80(1), 27-38.*
19. Dheeravath, V., and Babu, B. S. (2009). *Effect of rice husk ash on permeability and strength characteristics of expansive soil. Engineering Geology, 107(1-4), 25-38.*
20. Al-Rawas, A., Al-Baidi, I., and Malik, A. (2012). *Compressibility characteristics of lime-stabilized silty clay. In International Journal of Civil and Engineering Research (pp. 347-356).*
21. Puppala, A. J., Ranganathan, H. R., and Sridhar, V. (2019). *Stabilization of silty clay soils using rice husk ash and lime. In Advances in Civil Engineering (Vol. 2019, Article ID 8342178).*
22. Singh, A., Singh, S., and Mittal, S. (2016). *Effect of lime and rice husk ash on geotechnical properties of clayey soil. International Journal of Scientific and Research Publications, 6(6), 429-434.*
23. Arnolds, V. (2018). *An Introduction to Soil Mechanics. Switzerland: Springer International Publishing.*
24. Craig, R. F., and Knappett, J. (2020). *Craig's Soil Mechanics. Boca Raton: CRC Press.*
25. Kim, H. (2005). *Soil Sampling, Preparation and Analysis. New York: Taylor and Francis Group.*

26. Muni, B. (2010). *Soil Mechanics and Foundations*. USA: John Wiley Sons Incorporation.
27. Murthy, V. N. (2003). *Geotechnical Engineering: Principles and Practices of Soil Mechanics and Foundation Engineering*. New York: Marcel Dekker, Inc.
28. Venkatramaiah, C. (2006). *Geotechnical Engineering*. New Delhi: New Age International (P) Ltd., Publishers'.
29. Voottipruex, P., Jams Awang, P., 2014. Characteristics of expansive soils improved with cement and fly ash in Northern Thailand. *Geotech. Eng.* 6 (5), 437e453. Wang, L., Zheng, D., Zhang, S., Cui, H., Li, D., 2016. Effect of nano-SiO<sub>2</sub> on the hydration and microstructure of Portland cement. *Nanomaterials* 6 (12), 241.
30. Eades JL. *Reactions of Ca (OH)<sub>2</sub> with Clay Minerals in Soil Stabilization [Ph.D. Thesis]*.
31. Urbana: University of Illinois; 1962.
32. James J, Rao MSP. Reaction Product of Lime and Silica from Rice Husk Ash. *Cement and Concrete Research*. 1986; 16: 67-73.
33. Zhang, Y., Daniels, J.L., Cetin, B., Baucom, I.K., 2020. Effect of temperature on pH, conductivity, and strength of lime-stabilized soil. *J. Mater. Civ. Eng.* 32 (3), 04019380.
34. Zumrawi, M.M., Eltayeb, K.A., 2016. Laboratory investigation of expansive soil stabilized with calcium chloride. *Int. J. Environ. Chem. Ecol. Geol. Geophys. Eng.* 1 doi.org/10.5281/zenodo.1111971

35. Smith, RG, Kamwanja, GA. *The Use of Rice Husk for Making a Cementitious Material*. In: *Joint Symposium on the Use of Vegetable Plants and their Fibers as Building Material, Baghdad, 1986*.
36. Behak L, Musso M. *Performance of Low-Volume Roads with Wearing Course Layer of Silty Sandy Soil Modified with Rice Husk Ash and Lime*. In: *XII Conference on Transport Engineering; 7-9 June 2016; Valencia*. DOI: 10.4995/CIT2016.2016.3451. 8 p.
37. Okafor FO., Okonkwo UN. (2009). *Effects of Rice Husk Ash on Some Geotechnical Properties of Lateritic Soil*. *Leonardo Electronic Journal of Practices and Technologies*. 15, 6774.
38. Rao, D.K., Pranav. P.R.T., and Anusha, M. (2011). *Stabilization of Expansive Soil using Rice Husk Ash, Lime and Gypsum- an Experimental Study*.
39. Arnolds, V. (2018). *An Introduction to Soil Mechanics*. Switzerland: Springer International Publishing.
40. Craig, R. F., and Knappett, J. (2020). *Craig's Soil Mechanics*. Boca Raton: CRC Press.
41. Kim, H. (2005). *Soil Sampling, Preparation and Analysis*. New York: Taylor and Francis Group.
42. Twesigye Augustus. (2022). *Construction of a double storied 9 classroom block at Nakivubo Primary School, Phase 1 at Nakivubo Primary School*
43. Hird, C. C., and Airey, P. L. (1991). *The influence of silt content on the shear strength of some soft clays*. *Engineering Geology*, 29(3-4), 285-295.

44. Zdravkovic, V., and Jardine, R. J. (2005). *Shear strength and dilatancy of remolded silty clay under controlled-stress conditions. Géotechnique, 55(4), 345-356.*
45. Wong, H. C., and Chin, F. T. (2012). *Design and construction of pile foundation for a high-rise building on soft clay in Kuala Lumpur, Malaysia. Engineering Geology, 145-146, 154-164.*
46. Consoli, N. C., and Viana da Fonseca, A. (2012). *Consolidation behavior of a sensitive silty clay. Canadian Geotechnical Journal, 49(3), 242-257.*
47. Escario, V., and Sáez, E. (2008). *Shrinkage characteristics of silty clays from central Spain. Applied Clay Science, 41(1-2), 128-138.*
48. Nelson, J. D., and Nelson, M. E. (2003). *Foundation and slopes in weak rocks and soft soils. Taylor and Francis.*
49. Escario, V., and Juca, F. (2016). *Characterization of compressibility of weathered slate residual soils. Engineering Geology, 216, 198-208. (Focuses on compressibility characteristics of clayrich residual soils.)*
50. American Society of Civil Engineers (ASCE). Geo-Institute. (n.d.). *Geotechnical aspects of pavements. ASCE Press.*

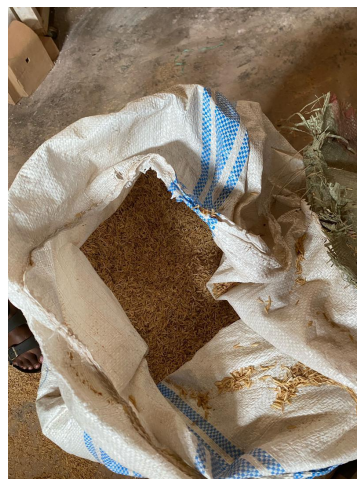
**APPENDIX A**



**Figure 24: *liquid sample weighing.***




**Figure 25: *Soil sample for compaction.***



**Figure 26: *Rice husk ash preparation.***

## APPENDIX B


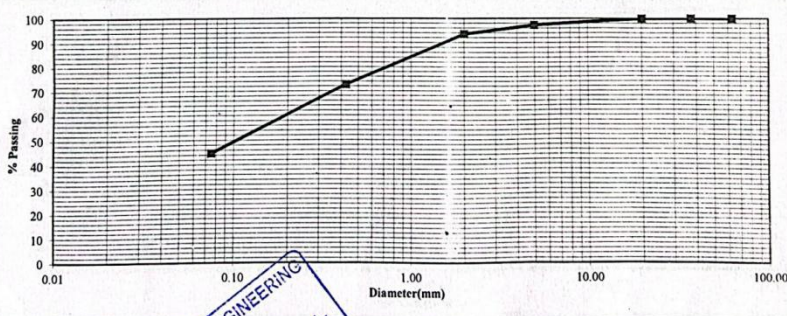

INSTITUTION			STUDENTS			TESTING LAB															
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A College of Excellence in the Heart of Africa</small>			<b>KIRABO BIBIAN (S20B32/200) &amp; ABER CAROLINE TEREZA (S20B32/210)</b>			<b>Stirling</b>															
PROJECT:			INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS																		
<b>SUMMARY OF TEST RESULTS FOR NEAT MATERIAL AT NEAT SAMPLE</b>																					
LOCATION	BLENDED %	SAMPLING DATE	GRADING					ATTERBERG LIMITS					MDD			CBR	CBR SWELL				
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	NMC		MDD	OMC	62	AVERAGE	
NEAT SAMPLE	SILT CLAY SOIL	12/21/2023	100	100	99	96	91	70	45	0.94	53.55	28.6	24.9	12.5	33.4	1.750	15.1	8	1.20	1.20	
			100	100	100	97	94	73	45	0.89	53.1	30.8	22.3	12.5	33.8	-	-		-	-	-
			100	100	99.62	96.43	92.23	71.18	45.09	0.92	53.3	29.7	23.6	12.5	33.6	1.750	15.1		8.0	1.20	-1.20
			AVERAGE	100	100	96	92	71	45	0.915	53.3	30.8	23.6	12.5	33.6	1.750	15.1		8.0	1.20	1.20
FOR LAB																					
Lab Technician																					

**STIRLING CIVIL ENGINEERING LTD**


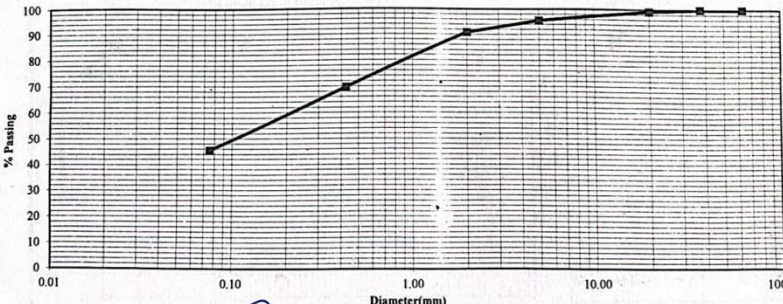

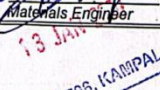
*[Signature]*

**P. O. BOX 796, KAMPALA (U)**


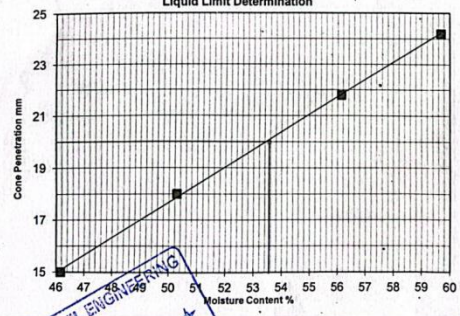
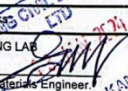
Member's Engineer


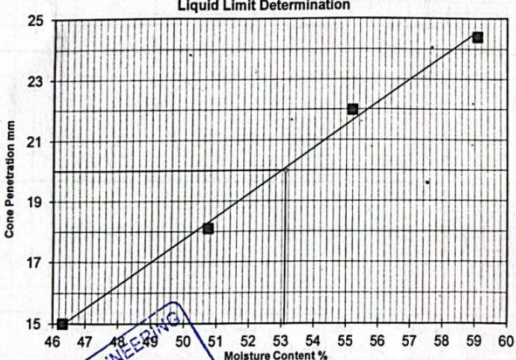
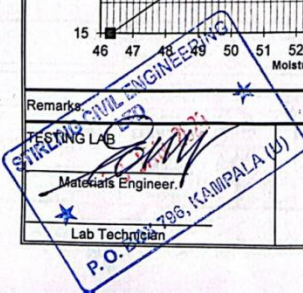
INSTITUTION		STUDENTS NAMES		CONTRACTOR	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		KIRABO BIBIAN ( S20B32/200 ) & ABER CAROLINE TEREZA (S20B32/210)		<b>Stirling</b>	
<b>PROJECT :</b> INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS					
<b>PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)</b>					
Test Reference No.:			Lab. Reference No.:		
Location : (km)	NEAT SAMPLE		Dry wt. of sample before washing: (g)	3468.8	
Depth: (m)			Dry wt. of sample after washing: (g)	2011.6	
Material description:	SILT CLAY SOIL		Date Sampled:	Date Tested:	Technician
			21/Dec/2023	24/Dec/2023	Lab team
Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	100	100	100
37.5	0.0	0.0	100	80	100
20.0	0.0	0.0	100	60	95
5.0	93.2	2.7	97	30	65
2.00	130.2	3.8	94	20	50
0.425	724.5	20.9	73	10	30
0.075	970.2	28.0	45	5	15
<b>Total fines</b>	1550.7	44.7			
<b>Bottom Pan</b>	93.5				
<b>Extracted fines</b>	1457.2				
<b>Total sample</b>	3468.8				
<b>Grading Modulus</b>		<b>0.89</b>			
					
<b>FOR TESTING LAB</b>					
Lab Technician	 Materials Engineer				

  
 P. O. BOX 793, KAMPALA (U)

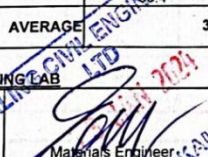
INSTITUTION		STUDENTS NAMES		CONTRACTOR	
 UGANDA CHRISTIAN UNIVERSITY <small>A Corner of Earthness in the Heart of Africa</small>		KIRABO BIBIAN ( S20B32/200 ) & ABER CAROLINE TEREZA (S20B32/210)		<b>Stirling</b>	
<b>PROJECT :</b> INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS					
<b>PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)</b>					
Test Reference No.:			Lab. Reference No.:		
Location (km)	NEAT SAMPLE		Dry wt. of sample before washing: (g)	3283	
Depth: (m)			Dry wt. of sample after washing: (g)	1899.7	
Material description:	SILT CLAY SOIL		Date Sampled:	Date Tested:	Technician
			21/Dec/2023	24/Dec/2023	Lab team
Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	100	100	100
37.5	0.0	0.0	100	80	100
20.0	24.8	0.8	99	60	95
5.0	121.6	3.7	96	30	65
2.00	152.4	4.6	91	20	50
0.425	696.1	21.2	70	10	30
0.075	795.4	24.2	45	5	15
Total fines	1492.7	45.5			
Bottom Pan	109.4				
Extracted fines	1383.3				
Total sample	3283.0				
Grading Modulus		0.94			
					
FOR TESTING LAB					
Lab Technician:  Materials Engineer: 					

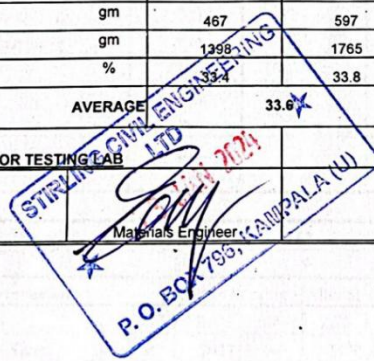
  
**STIRLING CIVIL ENGINEERING**  
 13 Jan  
 P.O. BOX 796, KAMPALA (U)



INSTITUTION		STUDENTS		TESTING LAB																			
 UGANDA CHRISTIAN UNIVERSITY <small>A Corner of Excellence in the Heart of Africa</small>		KIRABO BIBIAN (S20B32/200) & ABER CAROLINE TEREZA (S20B32/210)		<b>Stirling</b>																			
PROJECT:		INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS																					
<b>ATTERBERG LIMITS</b>																							
<i>Liquid limit (cone penetrometer) and plastic limit</i>																							
Test Reference No.:		Lab. Reference No.:		Technician:																			
Location		NEAT SAMPLE		Sample Date																			
Test method		BS 1377: Part 2, 1990:4.3/4.4		Test Date																			
LAYER		SILT CLAY SOIL																					
<b>PLASTIC LIMIT</b>																							
	Test No.	Q	PL		Average																		
	Mass of wet soil + container (g)	29.45	30.11		29.78																		
	Mass of dry soil + container (g)	27.74	28.43		28.085																		
	Mass of container (g)	21.65	22.67		22.16																		
	Mass of moisture (g)	1.71	1.7		1.695																		
	Mass of dry soil (g)	6.09	5.76		5.925																		
	Moisture content %	28.1	29.2		28.6																		
<b>AVERAGE</b>																							
<b>LIQUID LIMIT</b>																							
	Test No.	1	2	3	4																		
	Initial gauge reading (mm)	0	0	0	0																		
	Final gauge reading (mm)	15.0	18	21.8	24.2																		
	penetration (mm)	15.0	18.0	21.8	24.2																		
	<b>AVERAGE</b>	15.0	18.0	21.8	24.2																		
	Container No.	K	FOO	BE	PIO8I																		
	Mass of wet soil + container (g)	52.63	53.79	59.81	59.75																		
	Mass of dry soil + container (g)	38.16	38.08	40.82	40.06																		
	Mass of container (g)	6.81	6.83	6.99	7.07																		
	Mass of moisture (g)	14.47	15.71	18.99	19.69																		
	Mass of dry soil (g)	31.35	31.25	33.83	32.99																		
	Moisture content (%)	49.2	50.3	56.1	59.7																		
	<b>AVERAGE</b>	46.2	50.3	56.1	59.7																		
 <p style="text-align: center;"><b>Liquid Limit Determination</b></p> <p>Cone Penetration mm vs Moisture Content %</p>		<table border="1"> <tr> <td>Liquid limit (%)</td> <td>53.6</td> </tr> <tr> <td>Plastic limit (%)</td> <td>28.6</td> </tr> <tr> <td>Plasticity Index (%)</td> <td>24.9</td> </tr> <tr> <td colspan="2" style="text-align: center;"><b>Linear shrinkage</b></td> </tr> <tr> <td>Trough No.</td> <td>P</td> </tr> <tr> <td>Trough length (cm)</td> <td>14.0</td> </tr> <tr> <td>Specimen length (cm)</td> <td>12.3</td> </tr> <tr> <td>L.shrinkage =</td> <td>1.8</td> </tr> <tr> <td>% L.shrinkage =</td> <td>12.5</td> </tr> </table>				Liquid limit (%)	53.6	Plastic limit (%)	28.6	Plasticity Index (%)	24.9	<b>Linear shrinkage</b>		Trough No.	P	Trough length (cm)	14.0	Specimen length (cm)	12.3	L.shrinkage =	1.8	% L.shrinkage =	12.5
Liquid limit (%)	53.6																						
Plastic limit (%)	28.6																						
Plasticity Index (%)	24.9																						
<b>Linear shrinkage</b>																							
Trough No.	P																						
Trough length (cm)	14.0																						
Specimen length (cm)	12.3																						
L.shrinkage =	1.8																						
% L.shrinkage =	12.5																						
Reported by:  Materials Engineer P. Engineer		Lab Technician																					



INSTITUTION		STUDENTS		TESTING LAB																			
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>		<b>KIRABO BIBIAN ( S20B32/200 ) &amp; ABER CAROLINE TEREZA (S20B32/210)</b>		<b>Stirling</b>																			
<b>PROJECT:</b>		<b>INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS</b>																					
<b>ATTERBERG LIMITS</b>																							
<i>Liquid limit (cone penetrometer) and plastic limit</i>																							
Test Reference No.:		Lab. Reference No.:		Technician:	Lab Team																		
Location		NEAT SAMPLE		Sample Date	21/Dec/2023																		
Test method		BS 1377: Part 2, 1990:4.3/4.4		Test Date	24/Dec/2023																		
LAYER		SILT CLAY SOIL																					
<b>PLASTIC LIMIT</b>																							
	Test No.	KK	BA'		Average																		
Mass of wet soil + container (g)		34.85	32.28		33.565																		
Mass of dry soil + container (g)		32.05	30		31.025																		
Mass of container (g)		22.24	23.11		22.675																		
Mass of moisture (g)		2.8	2.3		2.54																		
Mass of dry soil (g)		9.81	6.89		8.35																		
Moisture content %		28.5	33.1		30.8																		
<b>AVERAGE</b>																							
<b>LIQUID LIMIT</b>																							
	Test No	1	2	3	4																		
Initial gauge reading (mm)		0	0	0	0																		
Final gauge reading (mm)		15.0	18.1	22	24.4																		
penetration (mm)		15.0	18.1	22.0	24.4																		
<b>AVERAGE</b>		15.0	18.1	22.0	24.4																		
Container No.	A7	IA	A6	P126																			
Mass of wet soil + container (g)	44.85	42.47	55.26	54.19																			
Mass of dry soil + container (g)	33.58	30.53	38.02	36.65																			
Mass of container (g)	9.24	6.99	6.78	6.96																			
Mass of moisture (g)	11.27	11.94	17.24	17.54																			
Mass of dry soil (g)	24.34	23.54	31.24	29.69																			
Moisture content (%)	46.3	50.7	55.2	59.1																			
<b>AVERAGE</b>		46.3	50.7	55.2	59.1																		
					<table border="1"> <tr> <td>Liquid limit (%)</td> <td>53.1</td> </tr> <tr> <td>Plastic limit (%)</td> <td>30.8</td> </tr> <tr> <td>Plasticity Index (%)</td> <td>22.3</td> </tr> <tr> <td colspan="2" style="text-align: center;"><b>Linear shrinkage</b></td> </tr> <tr> <td>Trough No.</td> <td>P</td> </tr> <tr> <td>Trough length (cm)</td> <td>14.0</td> </tr> <tr> <td>Specimen length (cm)</td> <td>12.3</td> </tr> <tr> <td>L.shrinkage =</td> <td>1.8</td> </tr> <tr> <td>% L.shrinkage =</td> <td>12.5</td> </tr> </table>	Liquid limit (%)	53.1	Plastic limit (%)	30.8	Plasticity Index (%)	22.3	<b>Linear shrinkage</b>		Trough No.	P	Trough length (cm)	14.0	Specimen length (cm)	12.3	L.shrinkage =	1.8	% L.shrinkage =	12.5
Liquid limit (%)	53.1																						
Plastic limit (%)	30.8																						
Plasticity Index (%)	22.3																						
<b>Linear shrinkage</b>																							
Trough No.	P																						
Trough length (cm)	14.0																						
Specimen length (cm)	12.3																						
L.shrinkage =	1.8																						
% L.shrinkage =	12.5																						
Remarks:																							
																							
Materials Engineer: _____ Lab Technician: _____																							

INSTITUTION	STUDENTS NAMES		TESTING LAB			
UGANDA CHRISTIAN UNIVERSITY <small>A University of Excellence in the Heart of Africa</small>	KIRABO BIBIAN ( S20B32/200) & ABER CAROLINE TEREZA (S20B32/210)		<b>Stirling</b>			
PROJECT:	INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS					
Test Reference No.	Lab. Reference No.	Date Sampled	Date Tested	Technician		
Mix	NEAT SAMPLE	21/Dec/23	24/Dec/23	Lab team		
Material description:	SILT CLAY SOIL		Natural moisture (%) :	11.0		
TEST DATA						
Weight of rammer (Kg)	No. of blows per layer	No of layers	Height of drop (mm)	Diameter of mould(mm)	Volume of mould (cm <sup>3</sup> )	
4.5	62	5	457	152	2,305	
MOISTURE CONTENT DATA						
Test No.	1	2	3	4	5	
Tin No.	A	A	A	A	A	
Water Added	cm <sup>3</sup>	130	230	330	430	530
Mass of Compacted soil + mould	gm	6,131	6,254	6,306	6,280	6,250
Mass of Mould	gm	4,286	4,286	4,286	4,286	4,286
Mass of Compacted soil	gm	1845	1968	2020	1994	1964
Volume of mould	cm <sup>3</sup>	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm <sup>3</sup>	1.845	1.968	2.020	1.994	1.964
DATA FOR PROCTOR CURVE						
Container No.	2I	MJR	CML	YY	XZM	
Mass of wet soil + Container	gm	2,225.0	2,246.0	1,910.0	1,956.0	2,193.0
Mass of dry soil + container	gm	2,076.0	2,069.0	1,755.0	1,783.0	1,970.0
Mass of container	gm	802.0	790.0	763.0	784.0	806.0
Mass of water added	gm	149	177	155	173	223
Mass of dry soil	gm	1274	1279	992	999	1164
Moisture content	%	11.7	13.8	15.6	17.3	19.2
Dry density	g/cm <sup>3</sup>	1.652	1.729	1.747	1.700	1.648
Maximum dry density (gm/cm <sup>3</sup> )	1.750		Optimum moisture content (%)		15.1	
Remarks:						
<div style="border: 2px solid blue; padding: 5px; display: inline-block;"> <p style="margin: 0;">FOR TESTING LAB</p> <p style="margin: 0;">STIRLING CIVIL ENGINEERING LTD</p> <p style="margin: 0;">21/12/23</p> <p style="margin: 0;">KIRABO BIBIAN</p> <p style="margin: 0;">Materials Engineer</p> <p style="margin: 0;">BOK 7834</p> </div>						
Lab Technician						

INSTITUTION	STUDENTS NAMES		TESTING LAB		
UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>	KIRABO BIBIAN ( S20B32/200) & ABER CAROLINE TEREZA (S20B32/210)		<b>Stirling</b>		
PROJECT:	INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS				
Test Reference No.	Lab. Reference No.	Date Sampled	Date Tested	Technician	
Mix	NEAT SAMPLE	21/Dec/23	24/Dec/23	Lab team	
Material description:	SILT CLAY SOIL	Natural moisture (%) :	11.0		
<b>NATURAL Moisture content</b>					
<b>A</b>					
Container No.	ZM	UG			
Mass of wet soil + Container	gm	2,667.0	3,152.0		
Mass of dry soil + container	gm	2,200.0	2,555.0		
Mass of container	gm	802.0	790.0		
Mass of water added	gm	467	597		
Mass of dry soil	gm	1398	1765		
Moisture content	%		33.8		
Remarks:	AVERAGE		33.6		
<b>FOR TESTING LAB</b>					
Lab Technician	 Materials Engineer (KAMPALA (U))				



Institution		Students Names		Testing Lab	
 UGANDA CHRISTIAN UNIVERSITY <small>A Centre of Excellence in the Heart of Africa</small>		KIRABO BIBIAN (S20B32/200) & ABER CAROLINE TEREZA (S20B32/210)		<b>Stirling</b>	
<b>INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS</b>					
<b>CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)</b>					
Test sample reference :		Laboratory Reference No.:		Sampling Date : 21/Dec/23	
Location:		NEAT SAMPLE		Casting date : 3/Jan/24	
Sample Description:		SILT CLAY SOIL		Testing Date : 7/Jan/24	
				Technician : Lab team	
				Volume of Mould used (m <sup>3</sup> ) 2305	
Natural moisture of air dried sample			Volume of water added		
Tin No.	KT		Mass of air dried soil (g)	6000	
Tin + air dried soil sample (g)	2331		MDD (Mg/m <sup>3</sup> )	1.750	
Tin + oven dry soil sample (g)	2242		N.M.C (%)	6.2	
Tin (g)	799		OMC (%)	15.1	
Dry soil sample	1443		Added OMC (%)	8.9	
Water (g)	89		Calculated dry wt of soil (g)	5629.9	
N.M.C (%)	6.2		Water added (g)	505	
Average (%)	6.2		Water added (mL)	505	
Number of blows		62			
Number of layer		5			
<b>Water Content Determination</b>		Before Soaking	After Soaking		
Tare No		BA	Z6T		
Mass of wet sample + Tare	g	2017	2470		
Mass of dry sample + Tare	g	1857	2240		
Mass of Tare	g	768	805		
Mass of water	g	160	230		
Mass of dry sample	g	1089	1435		
Water content	%	14.7	16.0		
Average water Content	%	14.7	16.0		
<b>Density determination</b>		MM			
Mould No					
Mass of mould + soil	g	11445	11508		
Mass of mould	g	6727	6727		
Mass of soil	g	4718	4781		
Volume of the mould	cm3	2305	2305		
Moist density	g/cm3	2.047	2.074		
Dry density	g/cm3	1.785	1.788		
<b>Swell Determination</b>					
Date	Hour	D.Gauge Reding			
Initial reading	96 hrs	2.74			
Final reading		4.26			
Height of the specimen		127			
Height of swell		1.52			
	Swelling(%)	1.20			
Observations					
For the Lab					
Lab. Technician	 STIRLING ENGINEERING 793, KARAPALA (U)				

Institution	Students Names	Testing Lab
 <b>UGANDA CHRISTIAN UNIVERSITY</b> <small>A Centre of Excellence in the Heart of Africa</small>	KIRABO BIBIAN (S20B32/200) & ABER CAROLINE TEREZA (S20B32/210)	<b>Stirling</b>
<b>INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS</b>		
<b>CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)</b>		
Test sample reference :	Laboratory Reference No.:	Sampling Date 21/Dec/23
Location:		Penetration Date 7/Jan/24
Depth :		Technician :: Lab team
Sample Description : <b>SILT CLAY SOIL</b>		
Number of blows per layer	62	
Number of layers	5	5
Mould No	MM	
Capacity of the Proving Ring (KN)	50	50
Proving Ring Constant (KN/div.)	0.2052	0.2052
Speed: .....mm min.		
	<b>Top</b>	<b>Bottom</b>
Penetration of the plunger (mm)	Time (s)    Reading *10 <sup>3</sup> mm    Force (KN)	Reading *10 <sup>3</sup> mm    Force (KN)
0	0    0    0.0	0    0.0
0.25	12    1    0.2	1    0.2
0.5	24    1    0.2	2    0.4
0.75	35    1    0.2	2    0.4
1	47    1    0.2	2    0.4
1.5	71    2    0.4	3    0.6
2	94    2    0.4	4    0.8
2.5	118    2    0.4	5    1.0
3	142    3    0.6	6    1.2
3.5	165    3    0.6	6    1.2
4	189    3    0.6	7    1.4
4.5	213    4    0.8	7    1.4
5	236    4    0.8	8    1.6
5.5	260    4    0.8	8    1.6
6	283    5    1.0	8    1.6
6.5	307    5    1.0	9    1.8
7	331    5    1.0	9    1.8
7.5	354    6    1.2	10    2.1
Observations		
For the Contractor		
Lab. Technician	 P. O. BOX 798, K.A.M. (U)	

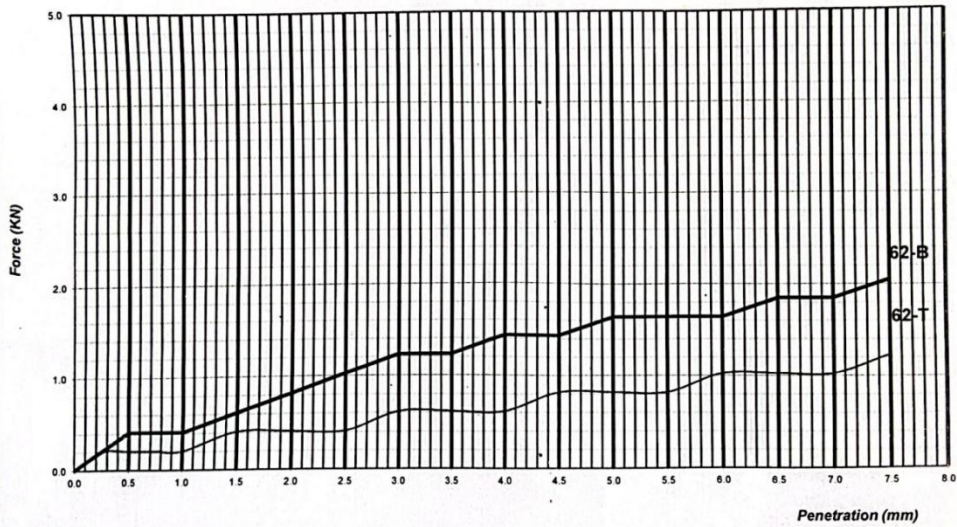
<b>Institution</b> UGANDA CHRISTIAN UNIVERSITY <small>A College of Excellence in the Heart of Africa</small>	<b>Students Names.</b> KIRABO BIBIAN (S20B32/200) & ABER CAROLINE TEREZA (S20B32/210)	<b>Testing Lab</b> <b>Stirling</b>
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INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS

**CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)**

Test sample reference :	Laboratory Reference No.:	Sampling Date : 21/Dec/23
Location:		Testing Date : 7/Jan/24
Depth:		Technician : Lab team
Sample Description:	SILT CLAY SOIL	

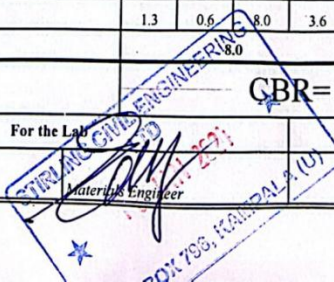
**PENETRATION vs FORCE CURVE**



	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	1.0	0.4	8	3
5.0 mm Penetration	1.6	0.8	8	4
Average	1.3	0.6	8.0	3.6
Retained CBR	8.0			

Observations CBR = 8.0

For the Lab	
Lab. Technician	Materials Engineer



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Website: www.mia.go.ug

In any Correspondence on  
this subject please

quote No.....**GE 027-2/2023**

**30<sup>th</sup> January 2023**

MS. ABER CAROLINE TEREZA AND MS KIRABO BIBIAN  
REG NO. S20B32/210 & S20B32/200  
UGANDA CHRISTIAN UNIVERSITY  
P.O BOX 4,  
MUKONO-UGANDA  
Tel: 256-786-819434



**MINISTRY OF INTERNAL AFFAIRS**  
**DIRECTORATE OF GOVERNMENT**  
**ANALYTICAL LABORATORY**  
Plot No. 2 Lourdel Road  
Wandegeya,  
P.O. BOX 105639  
Kampala - Uganda

### REPORT OF ANALYSIS

#### Description of the Samples

One sample in a white polythene bag containing Rush Husk Ash was submitted by Ms. Aber Caroline, on 17<sup>th</sup> January 2024, and analysed on 22<sup>nd</sup> January 2024. A summary of the sample received is shown in table below

S/N	Description	Quantity	Assigned Lab ID
1	Grey ash sample packed in a white polythene bag.	01	Sample "A" GE 027/2024

#### Analysis Requested

Elemental analysis

#### Method of Analysis

Elemental analysis was done using the XRF Method.

#### Results of Analysis

The above sample has been analyzed with the following results as below.


Parameter	Units	Results
		Rice Husk Ash sample GE 027/2024
Silicon dioxide	% m/m	81.192
Iron (III) Oxide	% m/m	8.026
Calcium Oxide	% m/m	7.049
Manganese (II) Oxide	% m/m	1.919
Aluminum Oxide	% m/m	0.596
Phosphorous pent oxide	% m/m	0.475
Europium (III) oxide	% m/m	0.255
Potassium Oxide	% m/m	0.299
Titanium di oxide	% m/m	0.108

#### Remarks

1. Results relate to sample analyzed and are reported as on received basis.

*Semalago Fredrick* 22/01/2024

Semalago Fredrick  
Government Analyst

INSTITUTION			STUDENTS										TESTING LAB						
 UGANDA CHRISTIAN UNIVERSITY <small>A Division of Uganda Christian Church - Uganda</small>			KIRABO BIBIAN (S20B32/200) & ABER CAROLINE TEREZA (S20B32/210)										<b>Stirling</b>						
PROJECT:			INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS																
<b>SUMMARY OF ALL THE TEST RESULTS FOR STABILIZATION OF SILTY CLAY SOILS WITH HYDRATED LIME AND RICE HUSK ASH</b>																			
LOCATION	BLENDED %	SAMPLING DATE	GRADING								ATTERBERG LIMITS					MDD		CBR	CBR SWELL
			63	37.5	20	5	2	0.425	0.075	GM	LL	PL	PI	LS	MDD	OMC	62Blows	62	
	NEAT SILTY SOIL		100	100	99	96	91	70	45	0.94	53.55	28.6	24.9	12.5	1.750	15.1	8	1.20	
			100	100	100	97	94	73	45	0.89	53.1	30.8	22.3	12.5	-	-	-	-	
	SILTY CLAY MODIFIED WITH 4% LIME ONLY		100	100	98	96	94	81	47	0.771	35	24.1	10.9	5.4	1.712	18.2	14	0.56	
			100	100	99	96	93	75	57	0.746	34.8	23.7	11.1	5.4	-	-	-	-	
0	SILTY CLAY MODIFIED WITH 4% LIME & 4% RICE HUSK ASH	12/21/2023	100	100	100	98	95	77	60	0.683	43.3	33.1	10.2	5.7	1.641	20.4	21	0.5	
			100	100	100	99	98	87	55	0.604	43.1	32.8	10.3	5.7	-	-	-	-	
	SILTY CLAY MODIFIED WITH 4% LIME & 8% RICE HUSK ASH		100.0	100.0	100.0	97.4	94.4	76.0	54.1	0.755	44.1	36.7	7.3	3.9	1.544	23.4	35	0.42	
			100.0	100.0	100.0	97.3	93.8	74.2	56.4	0.756	44.1	37.0	7.0	3.9	-	-	-	-	
	SILTY CLAY MODIFIED WITH 4% LIME & 12% RICE HUSK ASH		100.0	100.0	100.0	98.3	95.2	74.9	58.8	0.711	38.1	28.5	9.5	5.0	1.452	22.9	27	0.44	
			100.0	100.0	99.2	96.8	94.2	77.3	56.1	0.725	38.0	28.7	9.3	5.0	-	-	-	-	

FOR LAB

Lab Technician

  
 M. M. E. E. E.  
 P. O. BOX 795, KAMPALA

<b>Consolidation test (ES EN ISO 178822-0-2017)</b>					
<b>TITLE:</b>	<b>INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS</b>			<b>Task:</b>	<b>Final Year Project</b>
<b>University:</b>	<b>Uganda Christian University</b>	<b>Students details</b>	<b>Kirabo Bibian</b>	<b>Aber Caroline Tereza</b>	
<b>Sample source:</b>	<b>Nakivuubo</b>				
<b>Sample type:</b>	<b>Silty clay soils for subgrade modified with 4%hydrated lime and8% rice husk ash</b>			<b>Depth:</b>	<b>1.0-1.5</b>
<b>Date tested:</b>	<b>5-April 24</b>				
<b>Material type:</b>	<b>Moulded sample.</b>				

**Fist experiment with neat soil sample**

Pressure KPa	Dial change in	Final reading in	Sample Ht, in	Void Ht in	Void ratio
0.00	0	608	1	0.4493	0.598
25.0	0.0168	778	0.9832	0.4321	0.612
50.0	0.0061	877	0.9742	0.4244	0.699
100.0	0.0122	1007	0.9532	0.4107	0.711
200.01	0.0182	1221	0.9211	0.3648	0.765
400.06	0.031	1443	0.8764	0.3243	0.784
200.07	-0.0035	1311	0.9322	0.3542	0.774
100.02	-0.0132	1134	0.9612	0.4351	0.723
25.01	-0.0222	975	0.9764	0.4432	0.631

**Second experiment with sity clay soil with hydrated lime and rice husk ash**

Pressure KPa	Dial change in	Final reading in	Sample Ht, in	Void Ht in	Void ratio
0.00	0	608	1	0.4493	0.811
25.0	0.0168	778	0.9832	0.4321	0.785
50.0	0.0061	877	0.9742	0.4244	0.769
100.0	0.0122	1007	0.9532	0.4107	0.745
200.01	0.0182	1221	0.9211	0.3648	0.711
400.06	0.031	1443	0.8764	0.3243	0.687
200.07	-0.0035	1311	0.9322	0.3542	0.696
100.02	-0.0132	1134	0.9612	0.4351	0.723
25.01	-0.0222	975	0.9764	0.4432	0.742

<p>Tested by: </p> <p><b>KIRABO BIBIAN &amp; ABER CAROLINE TEREZA</b></p>	 <p>Geotechnical Engineering &amp; Technology Laboratory Ltd P. O. Box 110001, Kampala</p>	<p>Approved by: </p> <p><b>Sen. Laboratory Engineer (O.T)</b></p>
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FREE SWELL TEST (ES EN ISO 178822-0-2017)			
<b>TITLE:</b>	INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS	<b>Task:</b>	Final Year Project
<b>University:</b>	Uganda Christian University	<b>Students details</b>	Kirabo Bibian Aber Caroline Tereza
<b>Sample source:</b>	Nakivuubo		
<b>Sample type:</b>	Silty clay soils for subgrade modified with 4%hydrated lime and8% rice husk ash	<b>Depth:</b>	1.0-1.5
<b>Date tested:</b>	5-April 24		
<b>Material type:</b>	Moulded sample.		
Silty clay soils modified with 4%hydrated lime and8% rice husk ash			

Run	Volume height of soil with distilled water (V <sub>d</sub> ) (ml)	Volume height of soil with kerosene (V <sub>k</sub> ) (ml)	Free swell index (%)
1	107	104	2.884615
2	106	104	1.923077
3	107	104	2.884615
4	107	105	1.904762
5	107	105	1.904762

Statistic	Volume height of soil with distilled water(V <sub>d</sub> ) (ml)	Volume height of soil with kerosene (V <sub>k</sub> ) (ml)	Free swell index (%)
Mean	106.80	104.40	2.30
Standard deviation	0.4472	0.5477	0.5333
Maximum point	107.00	105.00	2.88
Minimum point	106.00	104.00	1.91
Range	1.00	1.00	0.98
Average value	106.80 ± 0.4472	104.40 ± 0.5477	2.30 ± 0.5333

Tested by:  

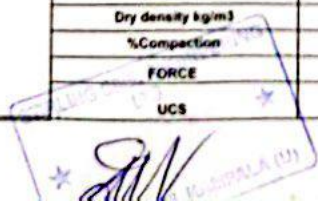
KIRABO BIBIAN & ABER CAROLINE TEREZA


**GETLAB LTD**  
05 APR 2024  
Geotechnical Engineering & Technology Laboratory Ltd  
P. O. Box 109001, Kasungu

Approved by: 


Sen. Laboratory Engineer (O.T)

UGANDA CHRISTIAN UNIVERSITY		KIRARO BIBIAN (S20B32/2001) & ABER CAROLINE TEREZA (S20B32/210)		<b>Stirling</b>	
PROJECT		INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS			
STABILISED CBR (BS 1924 PART 2.1)					
SILTY CLAY MODIFIED WITH 4% LIME & 12% RICE HASK ASH					
Mic of air dried sample			Mic After Mixing		
Tin No	JV		Stabiliser	4% LIME & 12% RICE HASK ASH	
Tin + Wet soil gm	871		Content	3.0	
Tin + Dry Soil gm	855		Tin No	ACB	
Tin gm	107		Tin + Wet Soil	2,019.0	
Water gm	16.0		Tin + Dry Soil	1,792.0	
Dry Soil gm	753.0		Tin	780.0	
Mic	% 2.1		Water	227.0	
Av. Mic	% 2.1		Dry Soil	1,012.0	
			Mic	22.4	
(a)MDD	1,492	kg/m <sup>3</sup>	(b)Air Dry Mic	2.1	%
(c)WD	3,416	kg/m <sup>3</sup>	(e)Mic to add	20.8	%
(d)OMC	22.9	%	(F) volume	2,305	
Date prepared	22.Feb.24	Date immerse	29.Feb.24	Date tested	7.Mar.24
Mould No.					
Factor(f)	2.305				
(h)Wet Soil to fill mould c x f x %comp	7,874.4				
(i) Wt of air dried soil	6,000				
Air dry Mic	2.1				
(k) soil dry wt (100j/100+b)	5,875.2				
Stabiliser	4% LIME & 12% RICE HASK ASH				
(m)Stabilisers content %	3.0				
(n) Stabiliser to add k x(m/100)	176.3				
Water Addition((j+n)x(d-b))/(100+b)	1,256.4				
Wt. per layer CBR Only h/3					
SPECIMEN WEIGHT CHECK					
No. of blows	62.0	62.0	AVERAGE		
Mould No.	7 DAYS AIR TIGHT	7 DAYS SOAKED			
Stabiliser	4% LIME & 12% RICE HASK ASH	4% LIME & 12% RICE HASK ASH			
Content %	3.0	3.0			
Mould g	A	B			
Wet Soil g	4,070.0	4,090.0			
Compaction Mic %	22.4	22.4			
Dry density kg/m <sup>3</sup>	1,442	1,449			
%Compaction	96.7	97.2			
FORCE	10.3	9.6			
UCS	0.663	0.529	0.55		


  
 \* *[Signature]* \*
   
 \* KUSIMPA (U) \*

INSTITUTION		STUDENTS NAMES		TESTING LAB	
 LUGANDA CHRISTIAN UNIVERSITY		KIRABO BIRIAN (S20B32200) & ABER CAROLINE TEREZA (S20B32210)		<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <b>Stirling</b> </div>	
PROJECT		INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS			
STABILISED CBR (BS 1924 PART 2 1)					
<b>SILTY CLAY MODIFIED WITH 4% LIME ONLY</b>					
Mic of air dried sample			Mic After Mixing		
Tin No	NM1		Stabiliser	4% LIME ONLY	
Tin + Wet soil	2830		Content	5.0	
Tin + Dry Soil	2614		Tin No	UCU	
Tin	769		Tin + Wet Soil	2,067.0	
Water	46.0		Tin + Dry Soil	1,865.0	
Dry Soil	2,035.0		Tin	808.0	
Mic	% 2.3		Water	202.0	
Av. Mic	% 2.3		Dry Soil	1,057.0	
			Mic	19.1	
(a)MDD	1,712	kg/m <sup>3</sup>	(b)Air Dry Mic	2.3	%
(c)WD	3,116	kg/m <sup>3</sup>	(e)Mic to add	15.8	%
(d)OMC	18.2	%	(F) volume	2,305	
Date prepared	22 Feb 24	Date immerse	29 Feb 24	Date tested	7 Mar 24
Mould No.					
Factor(f)		2,305			
(h)Wet Soil to fill mould c x f x %comp		7,182.0			
(j) Wt of air dried soil		6,000			
Air dry Mic		2.3			
(k) soil dry wt (100y/100+d)		5,667.4			
Stabiliser		4% LIME ONLY			
(m)Stabilisers content %		5.0			
(n) Stabiliser to add k x(m/100)		293.4			
Water Addition((j+n)(d-b))/(100+b)		881.0			
WL per layer CER Only h/3					
<b>SPECIMEN WEIGHT CHECK</b>					
No. of blows	62.0	62.0	AVERAGE		
Mould No.	7 DAYS AIR TIGHT, 7 DAYS SOAKED	7 DAYS AIR TIGHT, 7 DAYS SOAKED			
Stabiliser	4% LIME ONLY	4% LIME ONLY			
Content %	5.0	5.0			
Mould g	A	B			
Wet Soil g	4,772.0	4,725.0			
Compaction Mic %	19.1	19.1			
Dry density kg/m <sup>3</sup>	1,738	1,721			
%Compaction	101.5	100.5			
FORCE	5.1	5.7			
UCS	0.281	0.315			0.30

  
 P. O. BOX 23, LUWINGA (U)

INSTITUTION		STUDENTS NAMES		TESTING LAB	
 UGANDA CHRISTIAN UNIVERSITY <small>U.S. 1987, CHANING, U.S.A.</small>		KIRABO BIBIAN ( 520832/200) & ABER CAROLINE TEREZA (520832/210)		<div style="border: 1px solid black; padding: 5px; display: inline-block;"> <b>Stirling</b> </div>	
PROJECT		INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS			
STABILISED CBR (BS 1924 PART 2 1)					
<b>SILTY CLAY MODIFIED WITH 4% LIME ONLY</b>					
Mic of air dried sample			Mic After Mixing		
Tin No	NMF		Stabiliser	4% LIME ONLY	
Tin + Wet soil gm	2850		Content	5.0	
Tin + Dry Soil gm	2804		Tin No	UCU	
Tin gm	769		Tin + Wet Soil	2,067.0	
Water gm	45.0		Tin + Dry Soil	1,885.0	
Dry Soil gm	2,035.0		Tin	808.0	
Mic %	2.3		Water	202.0	
Av. Mic %	2.3		Dry Soil	1,057.0	
			Mic	19.1	
(a)MDD	1.712	kg/m <sup>3</sup>	(b)Air Dry Mic	2.3	%
(c)WD	3.116	kg/m <sup>3</sup>	(e)Mic to add	15.9	%
(d)OMC	18.2	%	(F) volume	2.305	
Date prepared	22 Feb 24	Date immerse	29 Feb 24	Date tested	7 Mar 24
Mould No.					
Factor(f)		2.305			
(h)Wet Soil to fill mould c x f x %comp		7,182.0			
(j) Wt of air dried soil		6,000			
Air dry Mic		2.3			
(k) soil dry wt (100/(100+b))		5,867.4			
Stabiliser		4% LIME ONLY			
(m)Stabilisers content %		5.0			
(n) Stabiliser to add k x(m/100)		293.4			
Water Addition((j+n)x(d-b))/(100+b)		981.0			
Wt. per layer CBR Only N/3					
<b>SPECIMEN WEIGHT CHECK</b>					
No. of blows	62.0	62.0	AVERAGE		
Mould No.	7 DAYS AIR TIGHT, 7 DAYS SOAKED	7 DAYS AIR TIGHT, 7 DAYS SOAKED			
Stabiliser	4% LIME ONLY	4% LIME ONLY			
Content %	5.0	5.0			
Mould g	A	B			
Wet Soil g	4,772.0	4,725.0			
Compaction M/c %	19.1	19.1			
Dry density kg/m <sup>3</sup>	1.738	1.721			
%Compaction	101.5	100.5			
FORCE	5.1	5.7			
UCS	0.281	0.315	0.30		

  
 P.O. BOX 55, KAMPALA (U)

INSTITUTION		STUDENTS NAMES		TESTING LAB	
UGANDA CHRISTIAN UNIVERSITY		KIRABO BIBIAN (S20B32/200) & ABER CAROLINE TEREZA (S20B32/210)		<b>Stirling</b>	
PROJECT		INVESTIGATING THE USE OF HYDRATED LIME AND RICE HUSK ASH IN STABILIZATION OF SILTY CLAY SOILS			
STABILISED CBR (BS 1924 PART 2 1)					
<b>SILTY CLAY MODIFIED WITH 4% LIME &amp; 8% RICE HASK ASH</b>					
M/c of air dried sample			M/c After Mixing		
Tin No	NIM		Stabiliser	4% LIME & 8% RICE HASK ASH	
Tin + Wet soil gm	2520		Content	3.0	
Tin + Dry Soil gm	2483		Tin No	UCU	
Tin gm	795		Tin + Wet Soil	1.635.0	
Water gm	37.0		Tin + Dry Soil	1.667.0	
Dry Soil gm	1.688.0		Tin	807.0	
M/c	2.2		Water	168.0	
Av. M/c	2.2		Dry Soil	860.0	
			M/c	19.5	
(a)MDD	1.544	kg/m <sup>3</sup>	(b)Air Dry M/c	2.2	%
(c)WD	3.613	kg/m <sup>3</sup>	(e)M/c to add	21.2	%
(d)OMC	23.4	%	(F) volume	2.305	
Date prepared	22/Feb/24	Date immerse	29/Feb/24	Date tested	7/Mar/24
Mould No.			Factor(f)	2.305	
(h)Wet Soil to fill mould c x f x %comp			(j) Wt of air dried soil	6.000	
(i) Wt of air dried soil			Air dry M/c	2.2	
(k) soil dry wt (100)/(100+b)			(k) soil dry wt (100)/(100+b)	5.871.3	
Stabiliser			Stabiliser	4% LIME & 8% RICE HASK ASH	
(m)Stabilisers content %			(m)Stabilisers content %	3.0	
(n) Stabiliser to add k x(m/100)			(n) Stabiliser to add k x(m/100)	176.1	
Water Addition((j+n)x(d-b))/(100+b)			Water Addition((j+n)x(d-b))/(100+b)	1,281.7	
Wt. per layer CBR Only h/3					
<b>SPECIMEN WEIGHT CHECK</b>					
No. of blows	62.0	62.0	AVERAGE		
Mould No.	7 DAYS AIR TIGHT	7 DAYS AIR TIGHT, 7 DAYS SOAKED			
Stabiliser	4% LIME & 8% RICE HASK ASH	4% LIME & 8% RICE HASK ASH			
Content %	3.0	3.0			
Mould g	A	B			
Wet Soil g	4,070.0	4,125.0			
Compaction M/c %	19.5	19.5			
Dry density kg/m <sup>3</sup>	1.477	1.497			
%Compaction	95.7	97.0			
FORCE	11.7	11.9			
UCS	0.642	0.653	<b>0.65</b>		


  
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