STABILISATION OF LATERITE SOILS WITH CEMENT AND METAKAOLIN

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A FINAL YEAR RESEARCH AND DESIGN PROJECT REPORT SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING OF UGANDA CHRISTIAN UNIVERSITY

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ABSTRACT

The research carried out was aimed at improving the properties of the laterite soils while using cement and metakaolin in the subbase soil layer. The research was guided by three specific objectives which included determining the engineering properties of the neat soils, determining the properties of the metakaolin and determining the engineering properties of the cement-metakaolin stabilized laterite soil. The case study of the research was Jambula road located in Entebbe municipality and the metakaolin was got from Buwambo. Furthermore, the study discussed about the sampling and preparation of the materials used. Different laboratory tests were carried out at Sterling laboratory while following the specific objectives stated in reference with the required standards of British Standards, General Specification MOW and others. Different tests of CBR, MDD, PI and UCS were carried out on the stabilized cement-metakaolin laterite soil and at optimum cement and metakaolin content of 3% and 4%, the mix had an MDD value of 2.071gm/cm^3, CBR value of 57%, Pi value of 13.1% and USC value 1.41Mpa which all lied in the required range for a subbase soil layer in accordance with Ministry of works and Transport. Hence making cement and metakaolin good chemical stabilizers for the laterite soils. For this research, some conclusions were drawn and as well recommendations for further research were given.

DECLARATION

I KAKOOZA PAUL, hereby declare that this research and design report is my own work of commitment and has never been submitted in any other institution for any award of academic qualification.

KAKOOZA PAUL

S20B32/228

Signature: ………………………………………… Date: …………………………….....

APPROVAL

I hereby certify that KAKOOZA PAUL registration number S20B32/228 conducted his research study from Uganda Christian University September 2023, to April 2024. This report is therefore a true record of work he was able to take part in under my supervision and it is now guaranteed ready for submission to the Faculty of Engineering, Design and Technology, Uganda Christian University in order for him to peruse a degree in Civil and Environmental Engineering.

Signature…………………………………………….   Date…………………………………...

MS. JOSEPHINE RITAH NAKYEYUNE.

Academic Supervisor.

DEDICATION

I dedicate this report to my wonderful parents, dear friends, and all those who have cheered me on. Your unwavering encouragement and support, both spiritual and material, have been a constant source of strength. You've been an inspiring and unforgettable family. I cherish your love and admire all your efforts. May God's blessings continue to be upon you all.

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I would like to acknowledge the almighty God who made it possible for me to carry out this project successfully.

I am much indebted to the STERLING LAB staff for the provision of a chance to carry out my lab tests.

I also thank my supervisor Ms. Josephine Nakyeyune for offering me with technical advice but also their sacrifice of time whenever I approached her for any assistance and guidance and the great environment of team work at each task at hand.

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and my partner Agaba Joel who I worked alongside, exchanging ideas though out the project.

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ABBREVIATIONS

AASHTO - American Association of State Highway and Transportation Officials

ASTM - American standards for testing materials

BS - British Standards

CBR - California Bearing Ratio

LL - Liquid Limit

MDD - Maximum Dry Density

PI - Plasticity Index

PL - Plastic Limit

PSD - Particle Size Distribution

XRF - X-Ray Fluorescence

MoWT - Ministry of Works and Transport

OMC - Optimum Moisture Content

CHAPTER ONE: INTRODUCTION

1.1 Background

Tropical and subtropical regions are home to laterite soils, which are extensively weathered residual soils. These soils exhibit a wide range in particle size, encompassing both clay and gravel fractions. (Oyelami, 2016) In tropical regions with alternating hot and wet seasons, weathering processes lead to the formation of laterite soils, characterized by their reddish-yellow color (Abdelhalim, 2022). The reddish yellow color is due to the presence of large quantities of iron oxide in the form of hematite (Fe_2O_3) (Brice T Kamtchueng, 2015). Uganda, due to its tropical location, has readily available laterite soils in many regions. This abundance has led to their widespread use in various engineering projects, particularly road construction. Laterite soils are the primary material for subgrade and subbase layers in Ugandan roads. However, a significant drawback of these soils is their low bearing capacity. Additionally, the presence of clay minerals in laterite makes them prone to volume changes, causing problems for drivers.

A prime example of this challenge can be found on Jambula Road in Akright City, Entebbe Municipality. The weak laterite soils used in the subbase have made the road vulnerable to damage from heavy traffic. This has resulted in uneven settlement of the road surface and the formation of potholes, creating difficulties for motorists who use this route (Richard, 2023).

Laterite soils are abundant in the area of stabilization and therefore that reduces the overall cost for their use in stabilization and their abundance is evidenced from the map in the figure below.

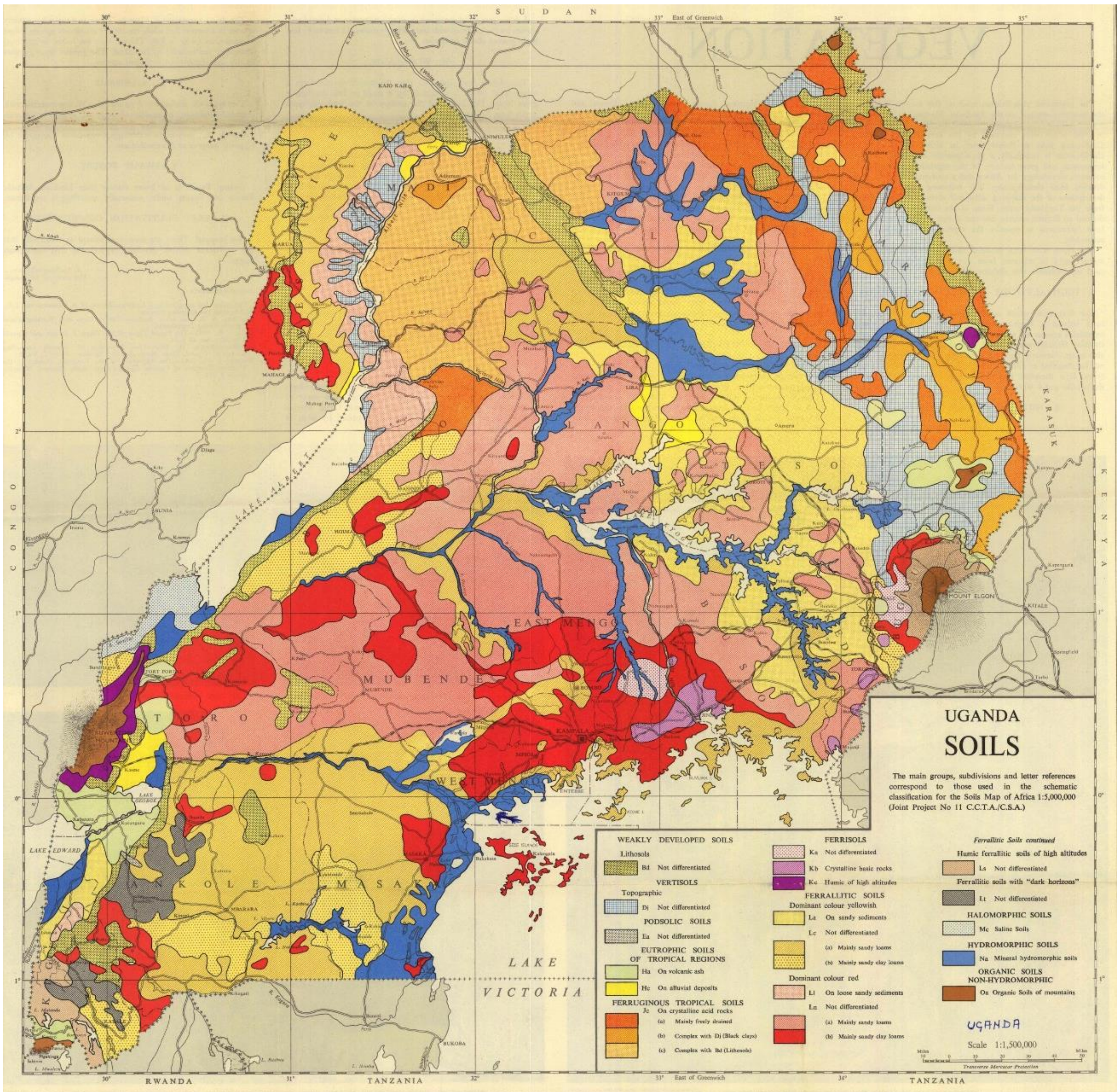

Figure 1: Pattern of soil distribution in Uganda.

Source (European Commission, 2020)

Several techniques address weak soils, including the use of cement as a chemical stabilizer. However, cement presents challenges, such as shrinkage, that require additional consideration (Kolovos, 2013). Following the success of meta-kaolin as a partial cement replacement in concrete, this research will explore its potential in laterite soil stabilization by partially substituting cement with meta-kaolin.

1.2 PROBLEM STATEMENT.

Laterite soils are a result of weathering in tropical conditions which is typical in most parts of Uganda (Bouazza, 2018). These soil types are unsuitable as fill materials for two key reasons. Firstly, they cannot be compacted back to their original density, leaving them unable to withstand traffic loads due to easy crushing under pressure. Secondly, the presence of clay minerals makes them highly susceptible to water damage, often leading to failures during rainy seasons. This problem can be seen along Jambula road located in Akright city in Entebbe municipality where the presence of weak laterite soils in the subbase has made the road susceptible to heavy traffic causing uneven settlement on the road surface leading to formation of potholes causing problems for motorists that use the road. A study conducted on the road concluded that the reason for failure of the road surface was because the laterite soils used in the subbase that did not offer enough resistance to traffic loading (Richard, 2023). The subbase material used was found to have a design soaked CBR between 29-32%. Due to the road's traffic demands, a minimum CBR of 45% is required for the subbase material. Researchers have explored various methods to stabilize these soils, with cement being a popular choice for its ability to enhance bearing capacity. However, cement use faces challenges, particularly shrinkage during hydration. This study investigated the potential of partially replacing cement with meta-kaolin to address this issue and improve laterite soil stabilization.

1.3 OBJECTIVES.

1.3.1 MAIN OBJECTIVE

To stabilize laterite soils with cement and metakaolin.

1.3.2 SPECIFIC OBJECTIVES

1. To determine the engineering properties of the neat laterite soil.
2. To determine the properties of meta-kaolin.
3. To determine the engineering properties of laterite soil stabilized with cement and varying percentages of meta-kaolin

1.4 RESEARCH QUESTIONS

1. What are the engineering properties the laterite soils used on the road?
2. What are the properties of metakaolin?
3. What are the engineering properties of the soil when stabilized with of cement and different percentages of metakaolin?

1.5 JUSTIFICATION

Meta-kaolin ($Al_2Si_2O_7$) is produced from calcination of kaolinite clay at temperatures between 700^{0}C to 800^{0}C (Astutiningsih, 2018). Meta-kaolin has pozzolanic properties (Branco.P, 2018). This implies that meta-kaolin can react at room temperature in the presence of water to form substances that possess cementitious properties (Peter, 2021). Meta-kaolin itself is made up of (50-60) % silica and around (40-45) % alumina which are in active form. This silica and alumina will react with the calcium hydroxide ($Ca(OH)_2$) formed during hydration of cement to form calcium aluminum feldspars like calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-S-H) which are components of the gel (Peter, 2021) that serves to bind the soil particles thus increasing the bearing capacity of the soil and reducing the plasticity index (Kolovos, 2013) proved that the shrinkage associated with cement during hydration is reduced by (0-20)% by the use of meta-kaolin and reduction in the amount of cement used.

For a given type of soil, there may be more than one potential stabilizer that can be used, however there are some general rules that make certain stabilizers more desirable based on soil properties such as the granularity, fluidity, or texture of the soil (Guyer, 2011). Traditionally, the two mostly used chemical stabilizers are cement and lime. To determine which of the two is most suitable for a stabilization of a given soil, the MoWT General specifications for roads and bridges series 3000 guide as follows;

Table 1: condition for a suitable stabilizer for soil

% passing the 0.075mm sieve BS 1377-2	**Plasticity index (%) BS1377: Part 2**	**Best suited stabilizer**
Less than 25%	PI less than 6 or PI x (% passing 0.075mm) is less than 60	Cement only
	6-10	Cement preferred
	More than 10	Cement and/ or lime
More than 25%	Less than 10	Cement preferred
	10 – 20	Cement and/ or lime
	More than 20	Lime preferred

From the table, it is concluded that cement is generally suitable for soils with a PI less than 20. For a PI above 20, then lime is more suitable. Additionally, when the PI of the soil is between 10 and 20, then both cement and lime can be used. For lime to be effective, it requires the presence of clay particles to react and is therefore used for materials with high PI. A high PI indicates that the soil has a large capacity to swell. This is proof of presence of clayey particles in the soil (Ministry of Works and transport, 2005).

Cement can be used to stabilize soils with a high PI although lime is usually preferred in these cases. However, if cement must be used, then the material can be pre- treated with addition of 2% lime prior to cement stabilization in order to improve the workability of the soil (Ministry of Works and transport, 2005).

1.6 SCOPE

1.6.1 Geographical scope.

The sample soil was picked from Jambula road in Akright city in Entebbe municipality.

1.6.2 Content scope

The research was focused on chemical stabilization by using meta-kaolin obtained from Buwambo wetland in Central Uganda to partially replace cement in order to stabilize the laterite soils. The time scope for the research was from

1.6.3 Time Scope

The research project was conducted from January 2023 to March 2024.

CHAPTER TWO. LITERATURE REVIEW

2.0 Introduction

This chapter discusses relevant theories, research methods, and areas where knowledge was lacking in the research and shows how the different materials were chosen for use to meet the research objectives.

2.1 LATERITE SOILS

Tropical and subtropical regions with hot and humid climates (annual rainfall between 750 and 3,000 mm) see the formation of laterite soils. These highly weathered and altered residual soils result from in-situ weathering and/or decomposition of underlying rocks. Intensive weathering is the key process, leading to leaching of bases and silica. This in turn causes a relative accumulation of iron and aluminum oxides (Brice T Kamtchueng, 2015) and the formation of kaolinite clays. Laterite soils, rich in secondary oxides of iron, aluminum, or both, were the product of this intense weathering. Deep lateritic profiles develop on flat terrain with limited runoff due to the extensive weathering process.

Laterite, one of the most common soil types in tropical and subtropical regions, were particularly interesting for construction purposes, such as fill material. However, some lateritic soils exhibit poor engineering properties, including high plasticity, low bearing capacity, high permeability, and a tendency to retain moisture (with a high natural moisture content). These drawbacks necessitate improvement of these soils before using them in road construction. As highlighted in the study by (Bamwesigye, 2020), utilizing readily available local materials can significantly reduce stabilization costs.

The properties of laterite soils vary considerably depending on the location. These variations stem from differences in the local characteristics, as we explored in the following section.

- The rock and mineral makeup of a region (geology) directly controls how water behaves there (hydrology), including rainwater runoff. This, in turn, influences the way rocks break down (weathering) and ultimately determines the characteristics of the resulting soil.
- Areas with tropical climates characterized by alternating hot and cold seasons are most suitable for the formation of laterite soils.
- The chemical makeup of a rock (parent rock) acts as the foundation for the characteristics of the soil that forms from it. (Oyelami, 2018).
- Intense Weathering Effects on Soil Composition. Extended periods of weathering can significantly deplete the soil's silica content through leaching. This process leaves behind a predominance of iron and aluminum oxides, which significantly impact the soil's engineering properties.
- While primarily composed of other minerals, laterite soils do contain small amounts of clay minerals (measured in the microns). These clay minerals are responsible for causing the soil to undergo some degree of volume change as the moisture content fluctuates. (Gidigasu, 2018)
- The composition of laterite soil determines its cohesive or non-cohesive nature. Laterite formed primarily from sand-sized particles (predominantly sand/gravel) behaves in a non-cohesive manner. Conversely, laterite composed mainly of silt and clay-sized particles exhibits cohesive properties.

Uganda, a tropical country, has abundant laterite soils, making them a readily available and cost-effective option for road construction. However, these soils have a drawback they are prone to deformation under traffic loads. This means laterite soils used in a road's subgrade layer can fail, causing damage to other road layers and impacting drivers. To address this limitation, it's crucial to stabilize these soils, improving their properties and making them suitable for road construction.

2.2 SOIL STABILISATION

Soil stabilization is essential during road construction. This becomes necessary when the foundation soils are weak and unsuitable for heavy loads, the readily available natural materials are poor quality and replacing them is expensive, or swapping out the subpar soils with granular materials is too costly (Tan, 2020). This process involves incorporating various elements with soil to improve specific properties. These elements can be commercially available additives or act as binding agents that cement the soil particles together. Alternatively, the technique may involve simply blending different soils to achieve the desired gradation (Guyer, 2011).

While soil stabilization encompasses various techniques, these methods can be generally categorized into two main groups:

1. Mechanical stabilization
2. Chemical stabilization

2.2.1 Mechanical stabilization

Mechanical soil stabilization involves improving soil's engineering properties through physical methods and materials. This aims to enhance its ability to bear loads, minimize settling, and ultimately boost its overall performance in construction. It typically involves adding various materials like aggregates, cement, lime, or other additives. These additions alter the soil's physical properties, increasing its strength. Common applications include road construction, foundation building, and other civil engineering projects where ensuring soil stability and durability under various loads is crucial (Makusa, 2018).

2.2.2 Chemical stabilization

Chemical soil stabilization is a technique used to improve the engineering properties of soil. By adding specific chemical agents, this process enhances the soil's strength, durability, and load-bearing capacity. This makes the soil more suitable for construction applications, particularly in road building and other infrastructure projects.

Chemical stabilization relies on several agents namely lime, cement, and fly ash, alongside various chemical additives. These react with the soil's components, causing specific changes to its properties. This includes increased cohesion, reduced plasticity, and ultimately, enhanced overall stability (Guyer, 2011) Chemical stabilization addresses problems like swelling, shrinkage, and weak load-bearing capacity in soils. This method utilizes chemical reactions between a stabilizer and the soil's minerals to achieve the desired improvements for construction purposes (Makusa, 2018).

2.3. Selecting a suitable chemical stabilizer for a soil

2.3.1 Cement.

Cement, a powdery substance with both cohesive and adhesive properties, binds objects like building blocks, stones, and bricks. Its key components are clay and calcined lime. While calcined lime provides the bulk of the calcium oxide (CaO), the clay contributes silica (SiO2), alumina (Al2O3), and iron oxide (Fe2O3) (Dunuweera and Rajapakse, 2018).

The specific ingredients used in cement vary depending on its intended application. However, ordinary Portland cement usually contains 21.9% silicon oxide (SiO), 6.9% aluminum oxide (Al_2O_3), 3.9% iron oxide (Fe_2O_3) and 63% calcium oxide (CaO) (Tan, Zahran and Tan, 2020). Cement stabilization is not suitable for certain soil types: organic soils, highly plastic clays, soils with moderate to high sulfate (SO_4) levels, and sandy soils with low reactivity. This limitation arises due to two factors. First, the high organic content in organic soils and the lack of pozzolans (reactive volcanic ash) and silts hinder cement's ability to achieve the necessary stabilization strength. Second, for these soils, significant dosages of cement would be required to overcome this limitation, making it an impractical solution (ACI Committee 230, 2009). Soil with a pH below 5.5 and organic matter exceeding 2% is unsuitable for cement stabilization. This low pH hinders the mixture's hydration rate, consequently leading to slower strength gain (Tan, 2020).

2.3.1.1. HYDRATION OF CEMENT

Cement's ability to bind particles stems from an exothermic chemical reaction, known as hydration, that occurs upon mixing with water. However, hydration isn't a single reaction. Instead, it's a collective term encompassing a series of reactions that happen simultaneously and successively when anhydrous cement encounters water. (Branco.P, 2018).

Tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A), and tetracalcium aluminoferrite (C_4AF) are the phase compounds that can be found in cement (Ridi, no date). Among the clinker phases, C_3S reacts fastest, while C_2S reacts slowest. C_3A plays a critical role in early hydration due to its strong reaction with water, causing rapid stiffening of the cement paste. However, C_3A reacts even faster than C_3S. Gypsum, added during cement manufacturing, delays this reaction and prevents immediate stiffening. The interaction of water with C_3A and gypsum produces ettringite. Once the gypsum is depleted, further reaction between C_3A and water forms tricalcium aluminate hydrate (CAH). Ultimately, the combined gel network of CSH (Calcium-Silicate-Hydrate) and CAH forms a soil-cement matrix that binds the soil particles together (Reddi, Inyang and CRC Press., 2000). The hardening process of cement paste establishes its strength. This strength comes from the formation of two key products: tricalcium silicate hydrate (CSH) and crystallized calcium hydroxide (CH). These are created through the hydration reaction between water and the major cement components, tricalcium silicate (C_3S) and dicalcium silicate (C2S) (Tan, 2020).

Cement is generally an adequate stabilizer in most engineering applications. An advantage of using cement is that leaching of calcium is minimal when it is used (Tan, 2020). Despite its effectiveness, widespread cement use for soil stabilization is discouraged due to significant environmental drawbacks associated with its production. These drawbacks include high energy consumption and substantial carbon dioxide emissions (Firoozi, 2017).

2.4. Metakaolin

Metakaolin is a product of the thermal activation of kaolin clay (Rashad, 2015). Kaolin clay is a type of clay whose main clay mineral is kaolinite. Kaolinite is a hydrated aluminosilicate ($Al_2Si_2O_5(OH)_4$). Thermal activation of the clay removes the water from the clay leaving behind a dehydrated aluminosilicate.

Thermal activation of kaolin clay involves heating it at a high temperature. This specific temperature can vary depending on the desired properties of the resulting metakaolin and researcher preferences. The typical range falls between 600˚C and 800˚C (Rashad, 2015).

Similar to the variations in temperature, the heating duration for the clay also exhibits variations. The typical heating time lies between 2 and 12 hours (Camp, 2018). Metakaolin is a pozzolanic material (Peter, 2021). This suggests the material undergoes a reaction with water at room temperature, resulting in the formation of cementitious compounds (Osinubi, 2016).

2.4.1. Chemical composition of metakaolin.

This table presents the compositional analysis of various oxides found in metakaolin samples, as reported by three independent researchers.

Table 2: Chemical composition of Metakaolin

Oxides	**1** (Lorange, 2020)	**2** (Lorange, 2020)	**Ana Luisa VELOSA (Velosa, Rocha and Veiga, 2009)**
SiO_2	55.78	31	60.11
Al_2O_3	29.42	53.5	29.61
Fe_2O_3	0.55	6.58	1.28
CaO	0.68	1.1	0.05
MgO	0.21	0.12	0.15
SO_3	0.00	0.00	0.00
K_2O	2.22	5.79	3.32
Na_2O	0.02	0.04	1.94
Ti_2O_3	0.08	0.919	0.36
P_2O_5	0.01	-	-
Mn_2O_3	0.02	-	-
LOI	11.0	-	2.61

From the table, it can be seen that Silica (SiO_2) and alumina (Al_2O_3) were the predominant oxides in the Metakaolin. In combination with cement, the presence of silica and alumina can trigger a reaction with the calcium hydroxide produced during cement hydration.This reaction yields products that exhibit pozzolanic properties.

CHAPTER THREE: METHODOLOGY

3.0. Introduction

This chapter discusses the procedures, methods and materials which were employed to meet the specific objectives of the project.

3.1. Methods and materials

3.1.1. Properties of the neat soil

The soil was obtained in disturbed form using a pick mattock and spade from a borrow pit along Jambula road from 2 different locations at depths of 1.5m. The total weight of the soil sample collected was about 350kg and it was placed in 5 airtight sacks and transported to Stirling laboratory in Mbalala for testing. The sample was air dried for 2 days and the following tests carried out on it.

1. Particle size distribution with reference to BS 1377: Part 2 1990
2. Atterberg limit tests with respect to BS 1377: Part 2 1990
3. Proctor test with respect to BS 1377: Part 1990
4. CBR with respect to BS 1377: Part 4 1990

Figure 2: Showing collection of neat soil samples

3.1.2. Chemical composition

Cement was obtained from the market. Type II cement was used for the stabilization as it is most suited for stabilizing laterite soils.

The kaolin clay obtained from Buwambo wetland was subjected to temperatures between 700 and 750^{0}C for a period of 2.5 hours. The product was then left to cool and then ground using a pestle and mortar to form metakaolin. The metakaolin was then passed through a 75mm sieve and the following tests were carried out.

1. X-ray fluorescence test with reference to ASTM D5381-93 (2021)
2. Particle size distribution with reference to BS 1377: Part 2 1990

Figure 3: Showing collection of metakaolin

3.1.3. Variation of the strength parameters of the stabilized soil with addition of varying percentages of cement and metakaolin

The soil was then mixed with cement and metakaolin at different percentages.

The percentage of cement in the sample was maintained at a constant 3% as this has been identified as the optimum for cement stabilization by previous scholars. The percentage of metakaolin was increased from 0% to 8% in intervals of 2%.

The samples were then subjected to the following tests;

1. Atterberg limit tests with reference to BS 1377: Part 2: 1990
2. Proctor compaction test with reference to BS 1377: Part 4: 1990
3. CBR with reference to BS 1377: Part 4: 1990
4. UCS with reference to BS 1924: Part 2: 1990

3.2. Methods

The above tests were carried out in accordance with the standards indicated in order to achieve the objectives of this research.

3.2.1. Tests on the laterite soils for objective one.

3.2.1.1. Particle size distribution using wet sieving method with reference to **BS1377: Part 2: 1990**.

This test was carried out for the metakaolin to ensure that it was in a similar size range as the cement that was to be used for stabilization.

The purpose of this test in soils and aggregates was to determine how much of each particle size was in the sample. This was because the distribution of different sized particles can influence the engineering properties of a sample. For coarser particles particle size distribution was carried out using sieve analysis while for fine particles, it was done using the hydrometer test.

Sample retained = weight of the sieve with the sample-weight of the sieve without the sample

Percentage retained = (mass retained)/(initial sample mass)×100 cumulative % passing = 100-% percentage retained

Figure 4: Showing wet sieving

3.2.1.2. Atterberg limit tests with reference to **BS1377: Part 2: 1990.**

The Atterberg limit tests were composed of 3 different soil tests that were: liquid limit, shrinkage limit and plastic limit. These tests were important because they informed the ability of the soil to expand. They helped to determine the PI.

3.2.1.3. Liquid limit with references from BS 1377: Part 2:1990.

The liquid limit was the moisture content for which the soil passed from liquid state to plastic state. It enabled the identification and classification of fine-grained cohesive soils.

3.2.1.4. Plastic limit with reference to **BS1377: Part 2: 1990**.

The plastic limit was the water concentration at which soil begins to behave plastically.

As water was added, the same material from the liquid limit test can be molded with the hands. It starts to crack when it was rolled to a thickness of around 3 mm. The rolled samples were weighed before being placed on a mold and dried in an oven for 24 hours. After oven drying, the final weight was likewise measured, and the amount of water added was computed and documented as the plastic limit.

3.2.1.5. Plasticity index

It can be defined as the stomach of the soil as it indicated the capacity of the soil to swell. It was the difference between liquid limit and plastic limit, PI= LL-PL.

3.2.1.6. Proctor compaction test with reference to **BS1377: Part 4: 1990**

Five layers of the sample were inserted into the mold, and each layer was blown 27 times with a 4.5 kg rammer. The sample was taken out and dried in the oven for 24 hours. The dried sample's weight was noted, and the dry density was computed for the given moisture content. The dry unit weight and water content are plotted on a graph after this was repeated multiple times. The ideal moisture content was identified from the curve reached, providing the maximum dry density.

3.2.1.7. California bearing ratio with reference to **BS1377: Part 4: 1990**.

This was a very important strength parameter because it informed the soils resistance to penetration.

Equipment

- CBR mould
- Rammer
- Soaking pit
- CBR machine

Used the optimum moisture content from the proctor test a sample was prepared in a mold and was compacted. The sample was the soaked in water for four days after which its surface was dried and prepared for penetration. The CBR machine can be used to measure resistance of the soil to penetration and this was the CBR value. The swell of the sample could also be determined.

3.3. Tests on Metakaolin for objective two.

3.3.1. XRF test with reference to ASTM D5381-93 (2021)

This test was done to determine the chemical composition of the metakaolin. The results of this test were to inform on the percentage of different oxides in the material.

The sample was to be subjected to x-rays using an x-ray spectrometer. The sample would then emit florescent x- rays and each element reacted by releasing a unique fluorescent fingerprint. An X-ray analyzer then captured these signals and they could be analyzed to determine the chemical composition of the sample.

3.4. Tests for objective three.

Table 3: mix design

Percentage of materials by mass.			**Test Results**				
Laterite soil.	Cement	Meta-Kaolin	CBR	UCS (Mpa)	PI (%)	MDD (gm/cm3)	OMC (%)
100	0	0	33	-	15.6	2.159	10.7
95	0	5	-	-	-	-	-
95	3	2	-	-	-	-	-
95	2	3	-	-	-	-	-
95	4	1	-	-	-	-	-
97	3	0	-	-	-	-	-
91	3	6	-	-	-	-	-

The following tests would be carried out with the varying percentages of laterite soil, cement and metakaolin in order to achieve the test results.

CHAPTER FOUR. RESULTS AND DISCUSSION

4.0. INTRODUCTION

This chapter presents findings derived from various tests, such as Atterberg limits, maximum dry density-optimum moisture content, particle size distribution, and California Bearing Ratio. It also consists of analysis, interpretation and discussion of the obtained results.

4.1. PHYSICAL PROPERTIES OF THE NEAT SOIL.

The soil sample for this study was reddish brown gravel material. It has a plasticity Index of 15.6 % with 55.76 % passing the 0.075 mm sieve. The soil had a soaked CBR of 33 % at 95% of MDD-OMC. The maximum dry density and optimum moisture content was 2.159 g/cm^3 and 10.7% respectively.

4.1.1. PARTICLE-SIZE DISTRIBUTION.

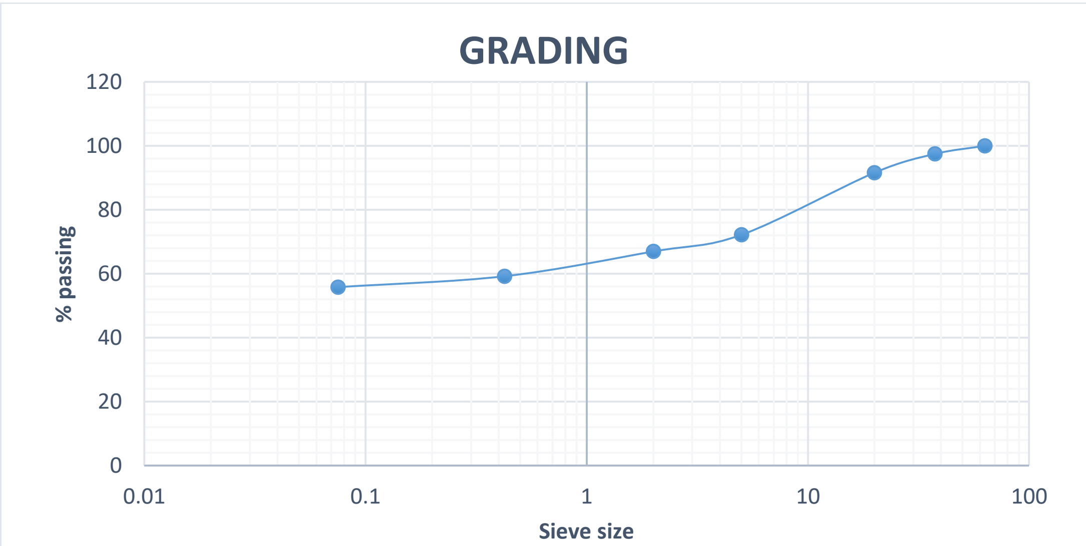

Figure 5: Showing PSD of the neat soil

Particle size distribution curve showed the distribution of various particle sizes in the soil mass. The soil sample was classified as a well graded since the grading line was passing through the middle of the envelope as shown above. The soil had 6.2% particles retained on a 2 mm sieve, 4.2% particle sizes being retained on 75-micron sieve and 54 % passing the 75-micron sieve.

According to unified soil classification system (USC) which was used to describe the texture and grain size of the soil the description below was got.

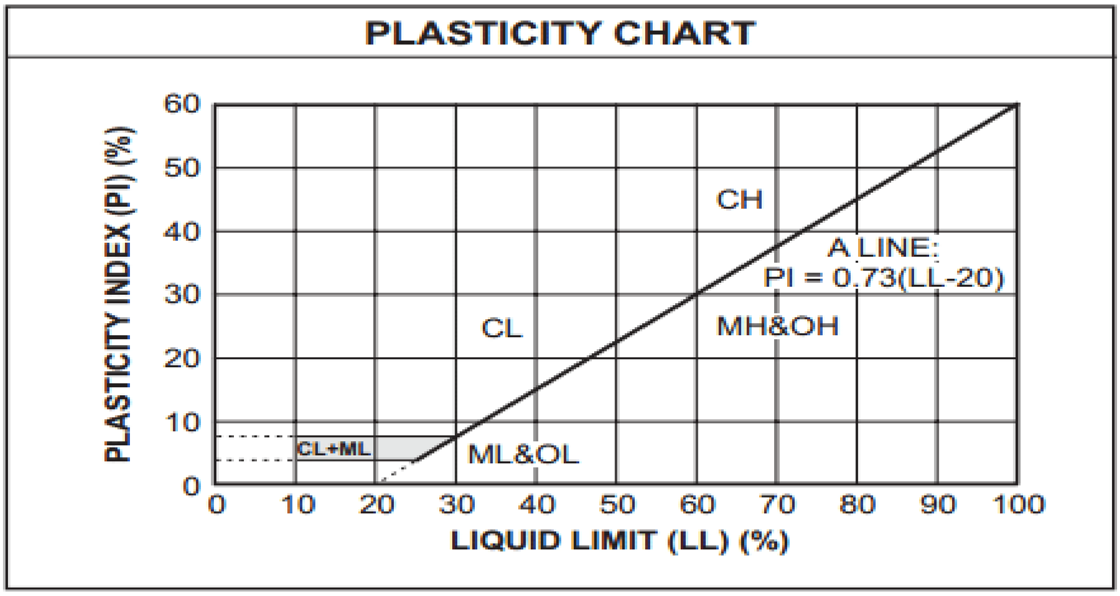

Figure 6: Plasticity chart

Considering the percentage passing sieve No.200 is 55.76% > 50%, then it was fine grained soil.The liquid limit was 45.2 < 50, then it falls under silts and clays with low liquid limit.

The soil was made up of 27.86% gravel and 16.38% sand and since it plots below the A-line, the soil can be classified as a gravelly silt with sand.

55% of the soil passes through sieve No. 200 and therefore a large percent of fine-grained soils.

Since sub-base strength depends on the type of sub base soils, internal structure of the soil and the type of stress mode application, the Shear strength parameters of the soil were correlated to maximum particle size distribution (Bamwesigye, 2020).

On comparison of the obtained % passing 75micron sieve values of the soil sample with the requirement according to the technical specifications and (CDR Standard Specification, 2007) as shown in Table below the % passing the 0.075mm sieve of 54% was exceeding the required 3-15% and 5-20% required respectively which indicated that the soils can shrink and swell during alternate wet and dry seasons thereby causing serious threat on the pavement structures.

Table 6: Percentage passing for different sieve sizes.

Sieve No. (mm)	Present soil % passing	Required with respect to technical standards.	Required with respect to CDR standards specification.
63.0	100		
37.5	98		
20.0	93	55-95	75-95
5.0	74	25-60	
2.00	68	7-36	20-45
0.425	58		15-30
0.075	54	3-15	5-20

4.1.2. GRADING MODULUS

The soil had a grading modulus of 1.181 which was below the minimum required of 1.5. It showed the relationship between fine material and course material therefore the lower it was the finer the soil material hence the soil was found to be of fine material. The grading modulus was got as shown below'

$$GM = \left[3 - \left(\frac{\%pass2mm + \%pass0.425mm + \%pass0.075mm}{100}\right)\right]$$

4.1.3. PARTICLE SIZE DISTRIBUTION (METAKAOLIN).

The Metakaolin was crashed using a rammer and passed through a 300μm sieve and they stored carefully to be used for the second and third objective. It was passed through that sieve so that it can be at the same particle size as the cement that it was going to partially replace for proper mixing.

4.1.4. ATTERBERG LIMITS.

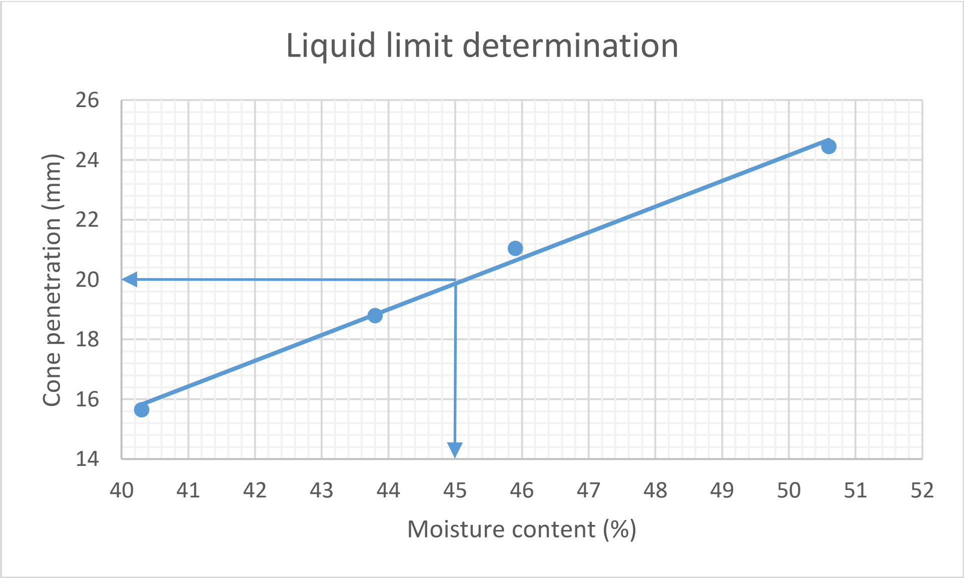

Figure 7: Showing Atterberg values for neat soil

The liquid limit (LL) of 45% was obtained as the moisture content at 20 mm cone penetration. The liquid limit was above the maximum allowable of 40% according to (Ministry of Works and transportation general specification, 2005) hence the soil can easily expand when exposed to moisture. The plastic limit (PL) of 29.4% as the lowest moisture content of rolled homogenous mixture of the soil sample. Plasticity Index of 15.6% was obtained from the difference between LL and PL as shown in Figure above.

According to (Osinubi, 2016), laterite soils with Plasticity index above 14% are rated as being poor. This was because these soil particles tend to break under compaction and repeated traffic loading and also soften in presence of water and loose strength which led to pavement distress and susceptibility to failure. Also, these soils contain substantial silt and clay contents which render them sensitive to moisture absorption leading to deterioration of laterite surfaced roads (Bouazza, 2018).

Since the soil sample has plasticity index of 15.6%, it indicated that it was poor and elastic therefore improvements needed to be done before use for construction of sub-base.

4.1.5. MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT.

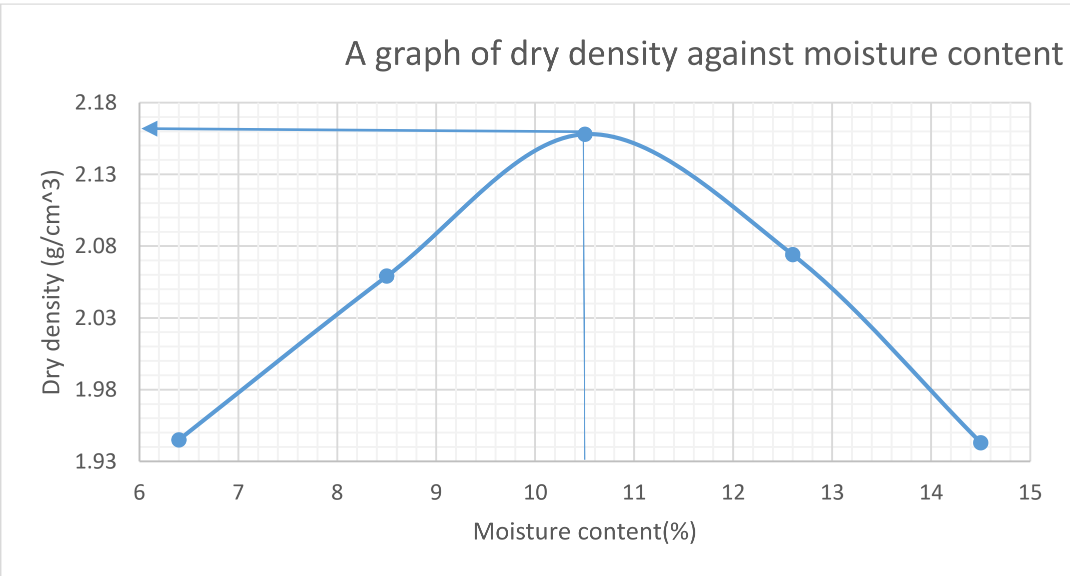

Figure 8: Showing determination of OMC and MDD for neat soil

Figure 8 illustrated the variation in dry density values in relation to moisture content. Initially, dry soil consisted of particles not in contact, making it stiff and prone to cracking when compacted. Upon adding water, a thin film surrounds each particle, facilitating contact and increasing soil density during compaction. This process continued with continuous water addition (Firoozi, 2017).

At a certain point, the soil's air volume reaches a minimum, resulting in maximum dry density. The moisture content corresponding to this maximum dry density was termed "Optimum moisture content." Further water addition beyond this point causes excess water to occupy space, reducing dry density (Firoozi, 2017).

Adding water to soil with low moisture content aids easy movement during compaction, lowering voids ratio by expelling air and increasing moisture content, subsequently raising dry density due to increased unit weight (Bamwesigye, 2020). As the moisture content increased, the air content decreased until the soil approaches a zero-air-line. Beyond this point, further addition of moisture led to a reduction in moisture content as the water particles create voids.

Upon adding water, the dry density of the soil sample increased to a maximum of 2.16 m/cm^3, along with the moisture content. However, beyond a moisture content of 10.7%, the dry density was observed to decrease. This suggests that the optimal compaction of this soil can be achieved at a moisture content of 10.7%. According to the Payment Manual (2007), moisture content and dry density within the ranges of 2-10% and 1.90-2.25 g/cm^3, respectively, indicate that the soil sample consisted of gravel material.

Soils with a maximum dry density ranging from 1890-2259 kg/m^3 at an optimum moisture content of 10.1-15.5% showed a gradual response to compaction hence can easily crack (Firoozi, 2017). However, these soils contain significant silt and clay contents, making them susceptible to moisture absorption, leading to the deterioration of laterite-surfaced roads. Therefore, it was emphasized to enhance the moisture absorption rates of these soils before utilizing them in road construction (Brice T Kamtchueng, 2015).

4.1.6. CALIFORNIA BEARING RATIO.

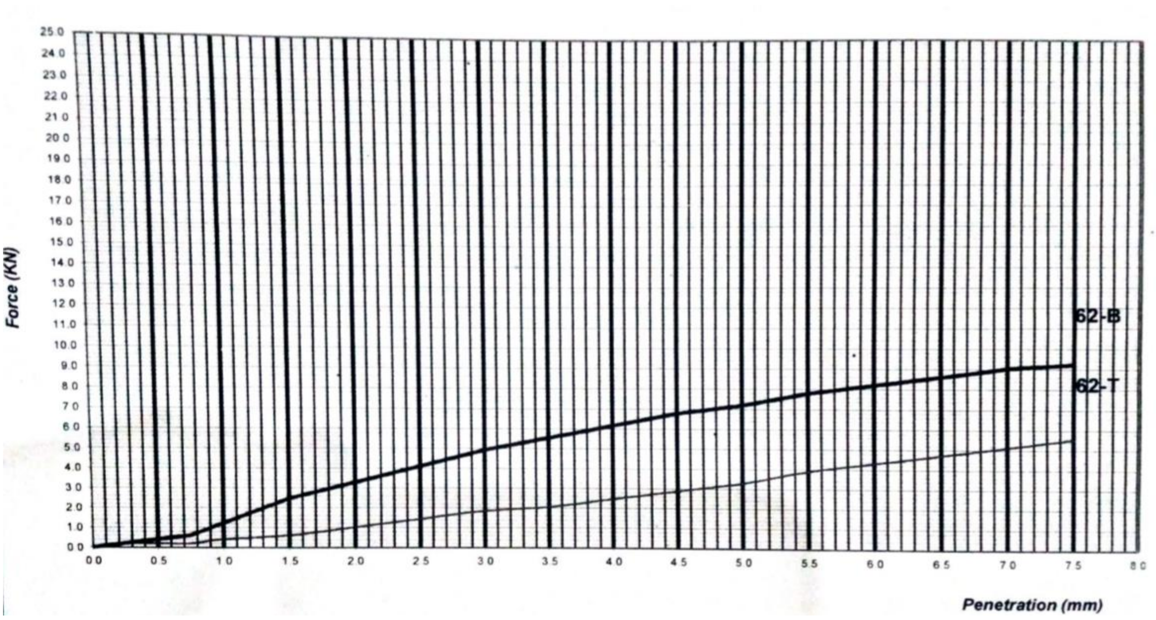

Figure 9: A graph of force against penetration

CBR test was conducted and CBR values of 33 % obtained as shown in Table 6 below.

Table 7: CBR determination

	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	4.1	1.4	31	11
5.0 mm Penetration	7.2	3.3	36	16
Average	5.6	2.4	33.0	13.6
Retained CBR	33.0			
Observations	CBR = 33			

The road to be constructed was going to have heavy traffic loading therefore it should be constructed so that it can resist it. According to (General Specification for Road Works and Bridges, 2004) and (CDR Standard Specification, 2007) requirements for sub-base material, this soil did not meet the required minimum CBR of 45%. This could have been because of 57.3% fines obtained from grading which implied that the soil sample has excessive fines hence increased possibility of absorbing more water and the likely to swell in circulated water conditions hence reduced strength. This was because Laterite gravels are known to give high CBR values when dry, but on absorption of water the strength drops abruptly (Bouazza, 2018).

The soaked CBR of 33% which does not meet the required 45% CBR for the sub-base showed that these soils are liable to changes in load bearing capacity and strength (Brice T Kamtchueng, 2015). This study showed that these soils require improvement to be used for construction of stable structures.

Since the soil alone was not meeting requirements of the sub-base G45 material, chemical properties of the meta-koalin and cement were determined using X-ray fluorescence and then doing partial replacement of the cement with meta-kaolin was used in the soil sample for reinforcement to increase its strength. This was because the meta-kaolin reduced the problem of shrinkage in the cement hence making it more effective thus increased strength.

4.1.7. CBR SWELL

The soil has a CBR swell of 0.79 which is greater than the standard 0.5 according to MoWT, 2005. Therefore, the soil can easily swell when exposed to moisture hence volume changes.

4.1.8. XRF ANALYSIS OF META-KAOLIN.

Table 8: Results of XRF method

Parameter.	Results (%m/m)
Silicon dioxide [SiO_2]	57.459
Aluminum Oxide [Al_2O_3]	24.926
Calcium Oxide [CaO]	8.57
Iron (iii) Oxide [Fe_2O_3]	7.778
Potassium Oxide [K_2O]	0.376
Titanium dioxide [Ti_2O_3]	0.261
Phosphorous pent oxide [P_2O_3]	0.249
Manganese (ii) Oxide [Mn_2O_3]	0.211

Metakaolin appears as an odorless white powder and from the table above SiO_2 and Al_2O_3 are the highest and predominant which are key elements of meta-kaolin and together react with the calcium hydroxide formed during the hydration of cement to form a substance with pozzolanic properties.

The SiO_2 + Al_2O_3 + Fe_2O_3 percentages combined are higher than 70% hence complies with the condition for Class N natural pozzolan (ASTM C618-91).

4.2. PHYSICAL PROPERTIES OF THE STABILIZED LATERITE SOIL.

4.2.1. Effect of Cement and Metakaolin on PI of the soil

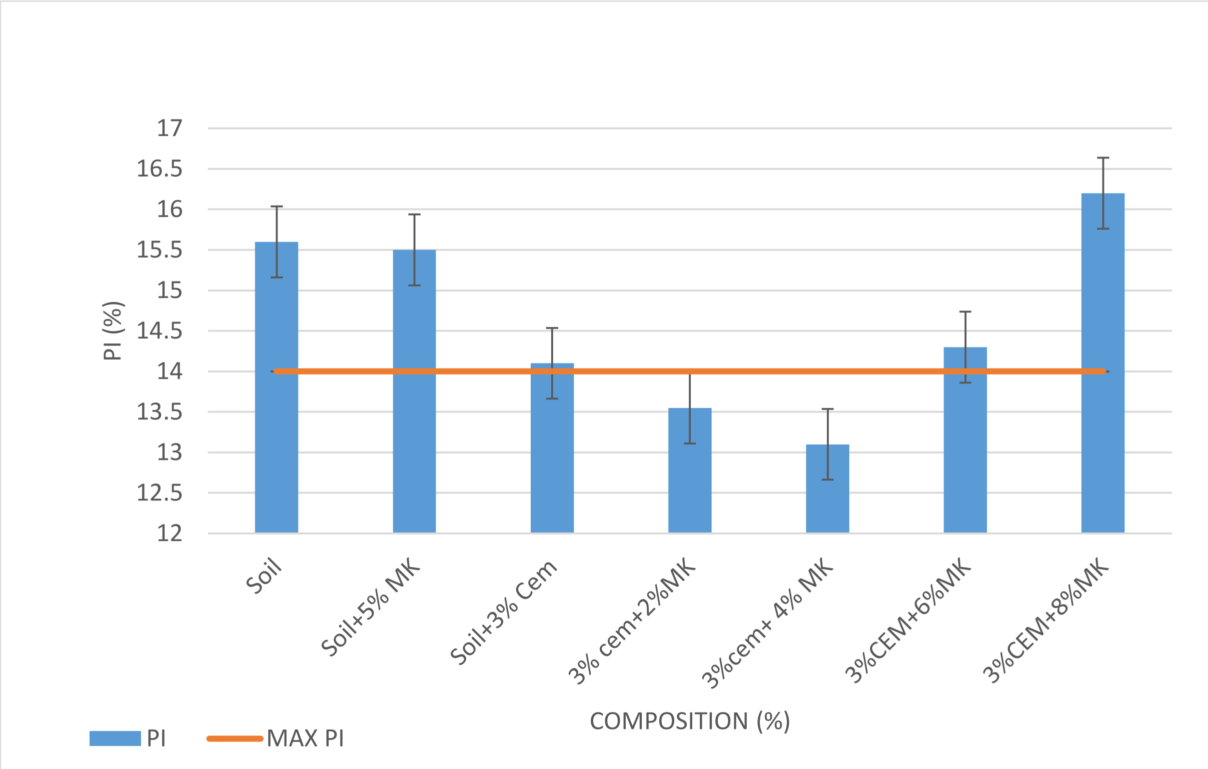

Figure 10: A graph showing PI against %cement and metakaolin.

Figure 10 showed the variation in PI and Linear shrinkage of the sample for different amounts of metakaolin and 3% cement.

The PI initially reduced from 14.1 to 13.1 on increasing the amount of metakaolin from 0% to 4% because of the pozzolanic reaction that took place between cement, metakaolin and the soil. This reaction caused formation of a gel that binds the particles of the soil together hence reducing the amount of fines in the sample (Bamwesigye, 2020). However, beyond 4% the PI of the soil no longer reduced but rather increased due to the excess metakaolin which implied some of the silicates would not react (Yu, 2015). The lowest PI was obtained at 4% metakaolin and 3% cement. The same trend was observed in the linear shrinkage of the soil with a minimum linear shrinkage observed as 6.4 at 4% metakaolin.

4.2.2. Effect of Cement and Metakaolin on Linear shrinkage of the soil.

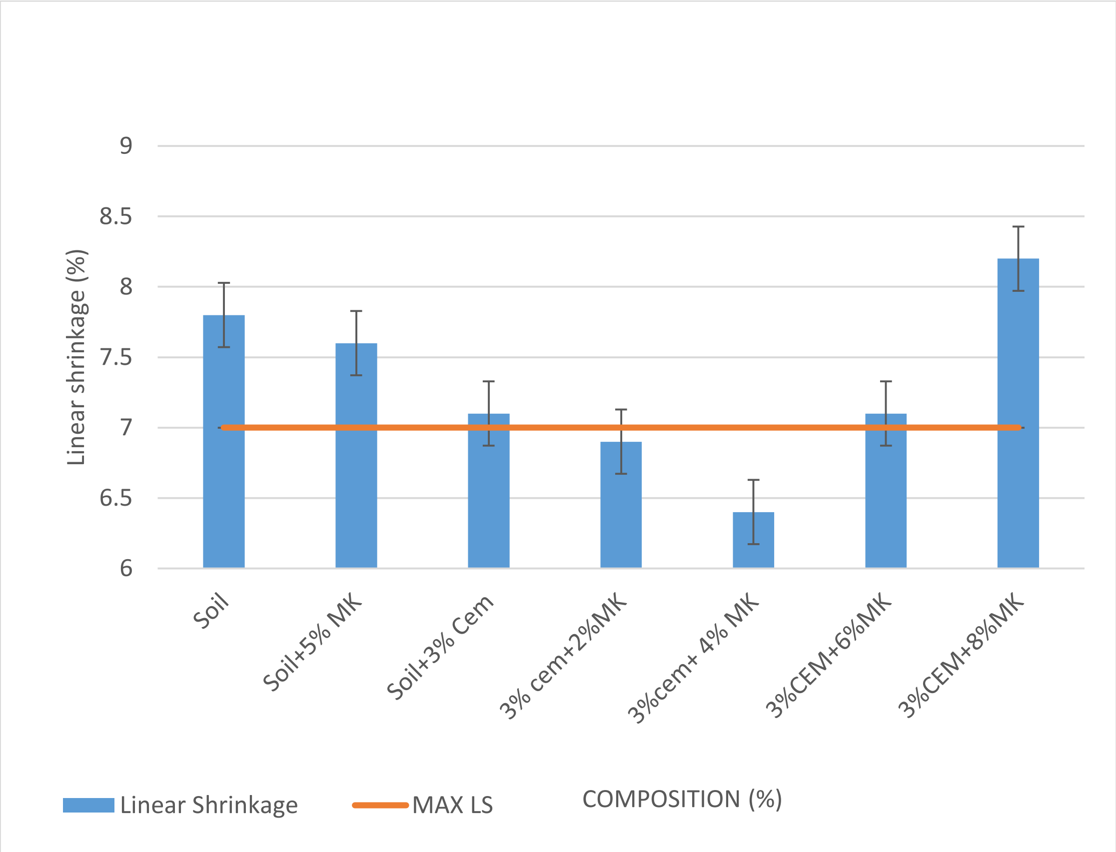

Figure 11: A graph showing linear shrinkage against % metakaolin and cement.

Figure 11 showed the variation in PI and Linear shrinkage of the sample for different amounts of metakaolin and 3% cement.

The PI initially reduced from 14.1 to 13.1 on increasing the amount of metakaolin from 0% to 4% because of the pozzolanic reaction that took place between cement, metakaolin and the soil. This reaction caused formation of a gel that binds the particles of the soil together hence reducing the amount of fines in the sample (Bamwesigye, 2020). However, beyond 4% the PI of the soil no longer reduces but rather increases due to the excess metakaolin which implied some of the silicates would not react (Lorange, 2020). The lowest PI was obtained at 4% metakaolin and 3% cement. The same trend was observed in the linear shrinkage of the soil with a minimum linear shrinkage observed as 6.4 at 4% metakaolin.

4.2.3. EFFECT OF THE CEMENT AND METAKAOLIN ON PROCTOR VALUES OF THE SOIL

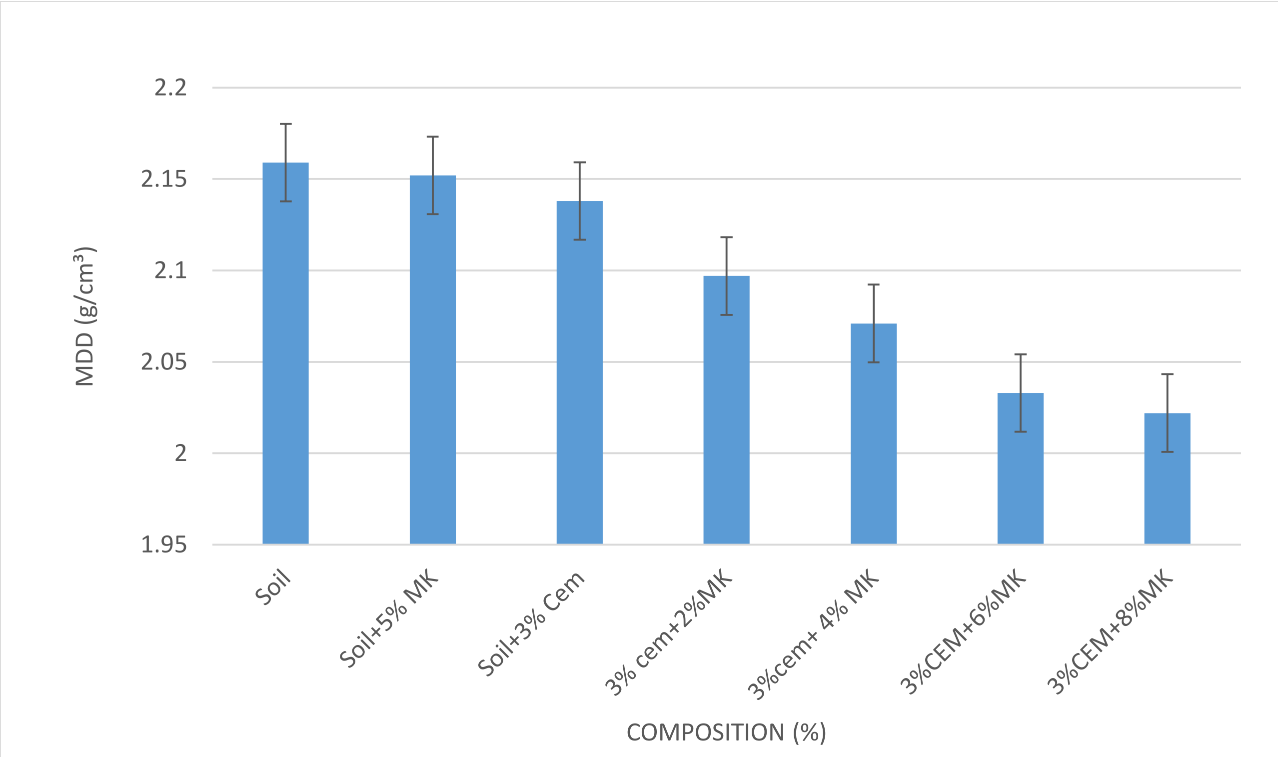

Figure 12: A graph showing MDD against % metakaolin and cement.

Figure 12 showed the variation in MDD of the sample for different amounts of metakaolin and 3% cement. Increasing the amout of metakaolin used led to a general decrease in the maximum dry density of the soil from 2.159g/cm^3 to 2.022g/cm^3 due to the heat generated during the hydration reaction. Since the cement and metakaoiln were fine grained, they led to a higher water absorption capacity of the soil and hence reduction in MDD and increase in OMC of the soil (Bamwesigye, 2020) as shown in the graphs above. The optimum moisture content increased from 10.7% to 13.4% due to the same effect.

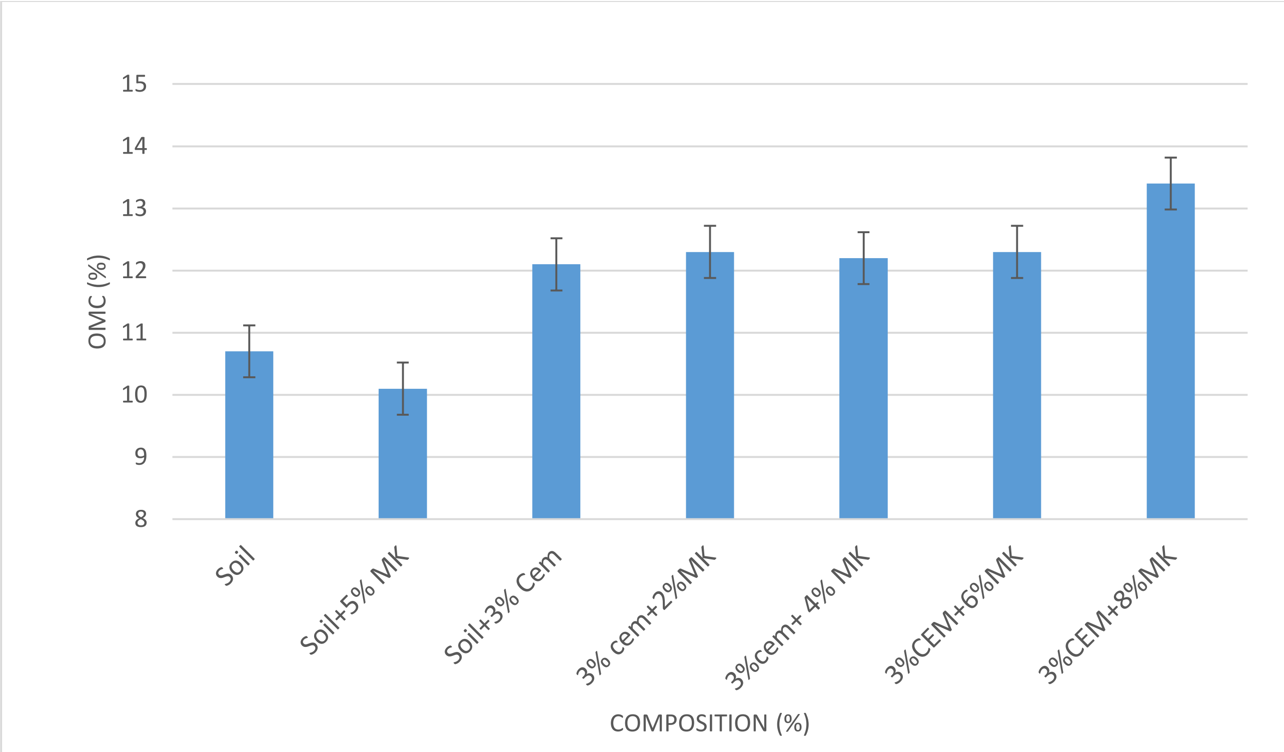

Figure 13: A graph of OMC against % cement and metakaolin

Figure 13 above showed the variation in OMC of the sample for different amounts of metakaolin and 3% cement. Increasing the amout of metakaolin used led to a general increase in the OMC of the soil due to the heat generated during the hydration reaction. Since the cement and metakaoiln were fine grained, they led to a higher water absorption capacity of the soil and hence reduction in MDD and increase in OMC of the soil (Bamwesigye, 2020) as shown in the graphs above. The optimum moisture content increased from 10.7% to 13.4% due to the same effect.

4.2.4. EFFECT OF CEMENT AND METAKAOLIN ON THE CBR OF THE SOIL.

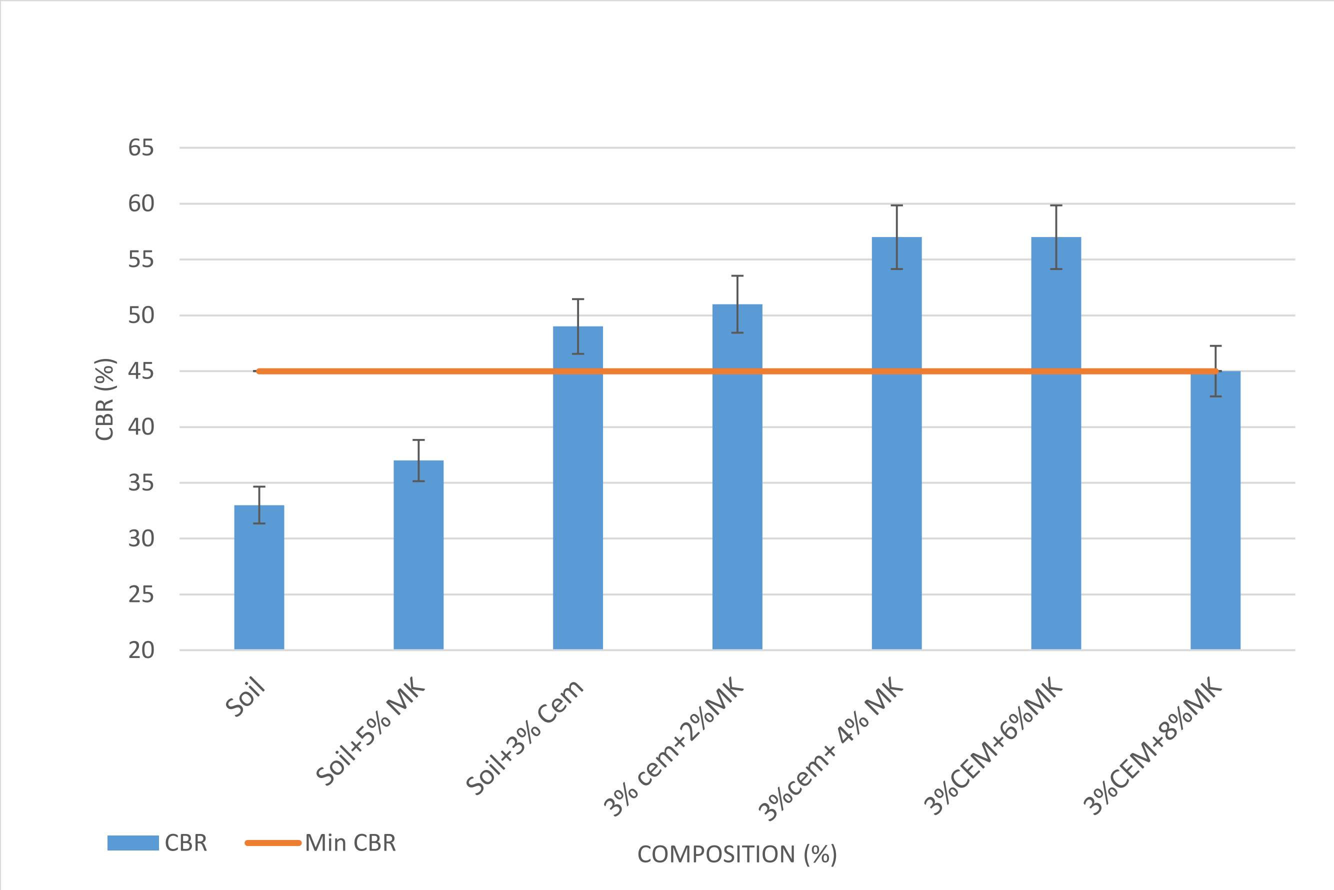

Figure 14: Graph showing variation of CBR with changes in cement and metakaolin.

Figure 14 showed the variation in CBR and CBR swell of the sample for different amounts of metakaolin and 3% cement.

The CBR of the soil increased with addition of metakaolin from 0-4% with a maximum CBR value of 57% obtained between 4 and 6% metakaolin. This was because of the decrease in fine clay contents due to addition of cement and metakaolin. This decrease in fines was due to the pozzolanic reaction whereby calcium oxide from the cement reacted with silicates and aluminates from the laterite soil and metakaolin. During this reaction, the soil texture was changed and clay particles clamped together into larger particle sizes to form an inter-locking mass of soil (Osinubi, 2016). The same process results in the formation of calcium silicate hydrates and calcium aluminate hydrates that were responsible for strength gain in chemical stabilization hence the increase in CBR(Kolovos *et al.*, 2013). Beyond this, further addition of metakaolin led to reduction in the CBR due to the presence of excess metakaolin. Excess metakaolin led to presence of excess silicates that do not react hence the decrease in strength of the soil (Lorange, 2020). The CBR swell of the soil reduced with increase in metakaolin content up to 4% metakaolin since there was a gain in strength of the soil (Sorsa, 2022). However, beyond 4% metakaolin, the CBR swell of the soil was seen to reduce to the excess silicates (Yu, 2015).

4.2.5. EFFECT OF CEMENT AND METAKAOLIN ON UCS OF THE SOIL.

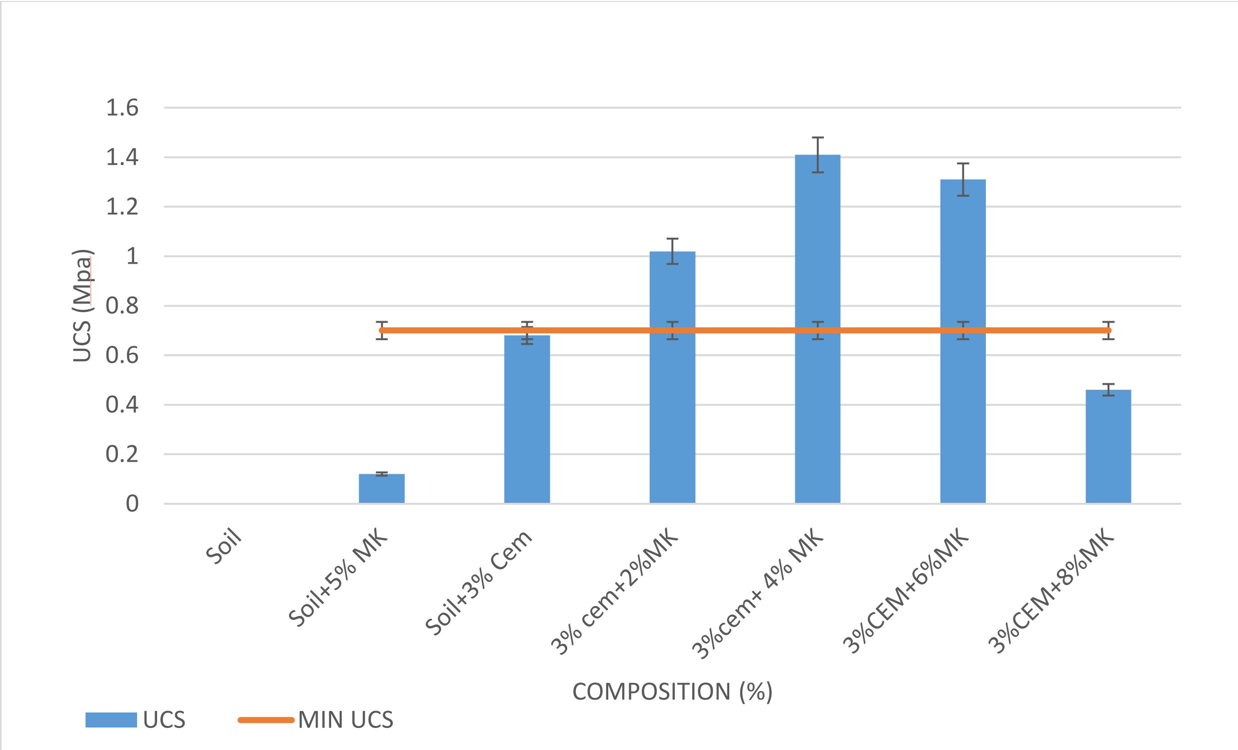

Figure 15: Graph showing UCS against % cement and metakaolin.

Figure 15 showed the variation of UCS of the soil with increase in Metakaolin content.

From 0% to 4% metakaolin, the UCS of the soil increased to a maximum of 1.41 at 4% metakaolin due to the pozzolanic reaction which caused the soil particles to clamp together to create an interlocking structure (Kolovos, 2013). The reaction produced calcium aluminum feldspars, which were what give the soil its strength (Patel *et al.*, 2020). Beyond this, the UCS value reduces with increase in metakaolin due to the excess silicates which do not react (Yu, 2015).

4.2.6. OPTIMUM MIX DESIGN.

Table 4: Table showing the optimum mix design.

Percentage of materials by mass.			**Test Results**						
Laterite soil.	Cement	Meta-Kaolin	PI (%)	Linear Shrinkage	MDD (g/cm^3)	OMC (%)	CBR (%)	CBR SWELL	UCS (Mpa)
100	0	0	15.6	7.8	2.159	10.7	33	0.79	-
95	0	5	15.5	7.6	2.152	10.1	37	0.77	0.12
97	3	0	14.1	7.1	2.138	12.1	49	0.5	0.68
95	3	2	13.55	6.9	2.097	12.3	51	0.4	1.02
93	**3**	**4**	**13.1**	**6.4**	**2.071**	**12.2**	**57**	**0.3**	**1.41**
91	3	6	14.3	7.1	2.033	12.3	57	0.63	1.31
89	3	8	16.2	8.2	2.022	13.4	45	0.75	0.46

From the summary of the results shown in the table above, the optimum mix ratio was 93% laterite soil, 3% cement and 4% metakaolin.

This ratio was seen to have a CBR of 57% which was above the 45% for material class C0.7 according to the MoWT General specifications for road and bridge works 2005. The UCS of 1.41MPa was also above the 0.7MPa minimum for C0.7 cement stabilized material.

Additionally, the PI of 13.1% obtained at this ratio was below the minimum 14 for G45 subbase material.

The soil at this ratio also demonstrated a low linear shrinkage that was 6.4 below the maximum 8 as well as a low CBR swell of 0.3 which was below the maximum of 1.0.

5.0. CHAPTER FIVE. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSION

This research examined how adding cement and metakaolin can improve the stability of laterite soils. The following section summarizes the key findings from the tests conducted.

Tests showed that soil from the Jambula borrow pit wasn't strong enough for the road. The soil had too much fine material (55.56%) and didn't meet the standards set for road building. Specifically, the plasticity index (PI) was 15.6%, exceeding the allowed limit of 14%. Similarly, the CBR (California Bearing Ratio) of the soil was 33%, falling short of the minimum requirement of 45% according to the MoWT general specifications. The soil also swelled more than acceptable (0.79 compared to the maximum of 0.5) and shrank too much (7.8% exceeding the 7% limit). Overall, the high amount of fine particles made the soil unsuitable for the road without improvement. To handle the expected traffic, the soil needs special treatment, like stabilization, to make it stronger.

The composition of the metakaolin was such that the sum of the percentage of silicon dioxide, aluminum dioxide and iron (III) oxide was 90.163% which greater than 70% implying that metakaolin is a class N natural pozzolan according to the ASTM standard. The metakaolin sample was also dominated by silicon dioxide 57.46% and aluminum oxide 24.93% which are the most important for hydration and lead to formation of C-S-H and C-A-H that form the gel which binds the soil particles increasing the strength of the soil and reducing its PI.

The strength parameters of the laterite soil stabilized with cement at 3% and varying percentages of metakaolin that is 0%, 2%,4%, 6% and 8% were seen to initially increase with the maximum CBR and UCS values of 57 and 1.41 MPa respectively at 4% MK. Beyond 4%, there was a decrease in the strength parameters of the stabilized soil because of the excess silicates in the mix as a result of excess MK.

5.2. RECOMMENDATIONS

1. This research could be extended further to study the microstructure of the product formed after stabilization of the soil with metakaolin. This research could help understand the long-term characteristics and durability of stabilized soil.
2. Further research into other pozzolanic materials that may be used to enhance the usability of metakaolin to stabilize soils should also be carried out in order to expand the existing knowledge on metakaolin stabilization.

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APENDIX.

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

SUMMARY OF ALL THE TEST RESULTS FOR LATERATIC GRAVEL MODIFIED WITH METAKAOLINE AND CEMENT

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
0	NEAT LATERATIC GRAVEL	12/9/2023	100	98	93	74	68	58	54	1.19	45.3	29.6	15.7	7.8	2.159	10.7	33	0.79
			100	97	90	70	66	60	57	1.17	45.0	29.4	15.6	7.8	-	-	-	-
	STABILISED WITH 5% METAKAOLINE ONLY		100	100	93	60	54	46	40	1.604	43	27.5	15.5	7.6	2.152	10.1	37	0.66
			100	99	69	56	47	34	22	1.961	42.9	27.5	15.4	7.6	-	-	-	-
	3% CEMENT ONLY		100	98	80	48	42	32	26	2.005	42.9	28.8	14.1	7.1	2.138	12.1	49	0.5
			100	96	83	49	42	33	26	1.991	42.8	28.7	14.1	7.1	-	-	-	-
	3% CEMENT AND 2% METAKAOLINE		100.0	100.0	99.0	60.9	44.6	30.5	17.1	2.078	41.8	28.3	13.5	6.9	2.097	12.3	51	0.40
			100.0	100.0	98.7	59.7	43.9	30.9	18.3	2.068	41.5	27.9	13.6	6.9	-	-	-	-
	3% CEMENT & 4% METAKAOLIN		100.0	100.0	89.5	53.4	44.2	29.9	19.9	2.060	42.4	29.2	13.2	6.4	2.071	12.2	57	0.30
			100.0	100.0	89.4	57.3	46.7	29.5	18.0	2.058	42.3	29.3	13.0	6.4	-	-	-	-
	3% CEMENT & 6% METAKAOLIN		100.0	97.2	79.0	47.7	39.6	26.1	17.9	2.163	42.8	28.4	14.4	7.1	2.033	12.3	50	0.63
			100.0	96.7	82.9	50.1	41.6	27.4	18.5	2.126	43.0	28.7	14.2	7.1	-	-	-	-
	3% CEMENT & 8% METAKAOLIN		100.0	100.6	97.7	74.2	55.8	38.1	26.3	1.798	41.8	25.7	16.1	8.2	2.022	13.4	45	0.75
			100.0	100.0	99.7	66.3	51.3	37.9	30.8	1.799	41.7	25.4	16.3	8.2	-	-	-	-

FOR LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD

P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

SUMMARY OF TEST RESULTS FOR LATERATIC GRAVEL NEAT

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	62 BLOWS OF COMPACTION	62	AVERAGE
NEAT	BROWN YELLOWISH LATERITIC GRAVEL MATERIAL	12/9/2023	100	98	93	74	68	58	54	1.19	45.3	29.6	15.7	7.8	2.159	10.7	33	0.79	0.79
			100	97	90	70	66	60	57	1.17	45.0	29.4	15.6	7.8	- -	-	- - -	-	
			100	**97.47**	**91.61**	**72.14**	**66.94**	**59.18**	**55.76**	**1.18**	**45.2**	**29.5**	**15.6**	**7.8**	**2.159**	**10.7**	**33**	**0.79**	**0.79**
	AVERAGE		100	97	92	72	67	59	56	1.181	45.2	29.4	15.6	7.8	2.159	10.7	33	0.79	0.79

FOR LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

SUMMARY OF TEST RESULTS FOR LATERATIC GRAVEL STABILISED WITH 5% METAKAOLINE ONLY

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	AVERAGE
STABILISED WITH 5% METAKAOLINE ONLY	BROWN YELLOWISH LATERITIC GRAVEL MATERIAL & 5% METAKAOLIN	12/9/2023	100	100	93	60	54	46	40	1.60	43	27.5	15.5	7.6	2.152	10.1	37	0.66	0.66
			100	99	69	56	47	34	22	1.96	42.9	27.5	15.4	7.6	-	-	-	-	
			100	**99.53**	**80.81**	**57.96**	**50.66**	**40.09**	**31**	**1.78**	**43.0**	**27.5**	**15.5**	**7.6**	**2.152**	**10.1**	**37**	**0.66**	**0.66**
	AVERAGE		100	100	81	58	51	40	31	1.782	43.0	27.5	15.5	7.6	2.152	10.1	37	0.66	0.66

FOR LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
P. O. BOX 796, KAMPALA (U)

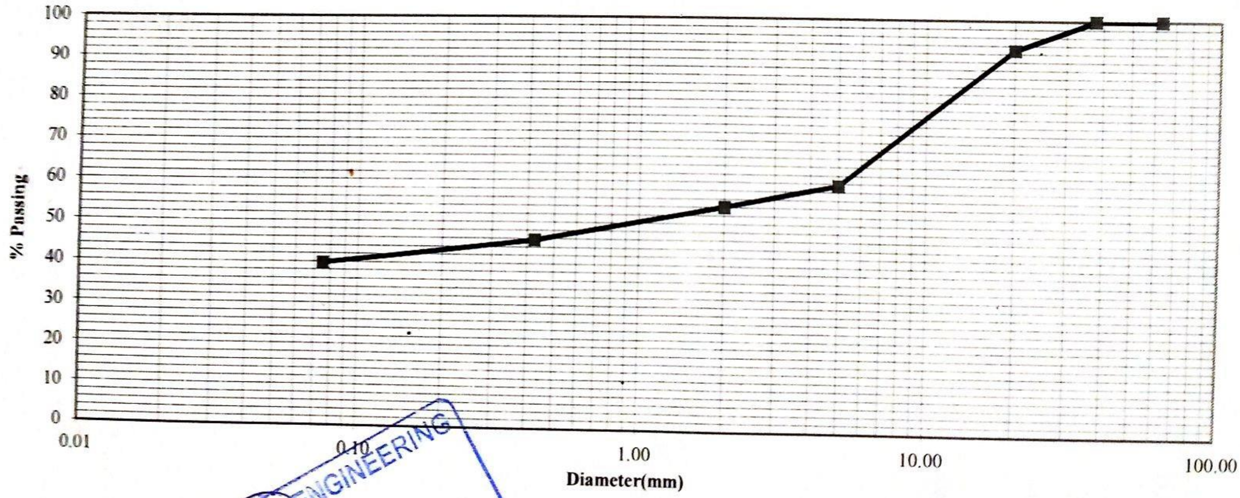
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	STABILISED WITH 5% METAKAOLINE ONLY	Dry wt. of sample before washing: (g)		5068
Depth: (m)		Dry wt. of sample after washing: (g)		3063.5
Material description:	BROWN YELLOWISH LATERITIC GRAVEL MATERIAL & 5% METAKAOLIN	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	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	362.0	7.1	**93**	60	95
5.0	1688.1	33.3	**60**	30	65
2.00	274.4	5.4	**54**	20	50
0.425	426.7	8.4	**46**	10	30
0.075	301.7	6.0	**40**	5	15
Total fines	2015.1	39.8			
Bottom Pan	10.6				
Extracted fines	2004.5				
Total sample	5068.0				
Grading Modulus		**1.60**			



FOR TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
P. O. BOX 796, KAMPALA (U)

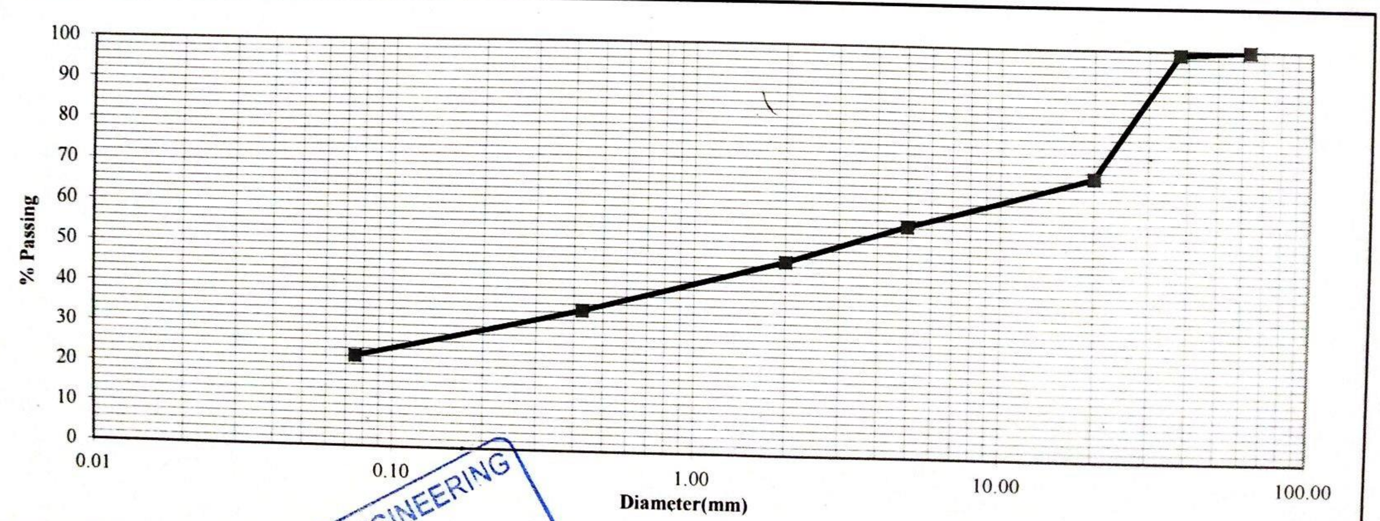
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : **PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS**

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	STABILISED WITH 5% METAKAOLINE ONLY	Dry wt. of sample before washing: (g)		5663.2
Depth: (m)		Dry wt. of sample after washing: (g)		4414.2
Material description:	BROWN YELLOWISH LATERITIC GRAVEL MATERIAL & 5% METAKAOLIN	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	**100**	100	100
37.5	52.8	0.9	**99**	80	100
20.0	1715.8	30.3	**69**	60	95
5.0	702.4	12.4	**56**	30	65
2.00	520.1	9.2	**47**	20	50
0.425	719.8	12.7	**34**	10	30
0.075	693.1	12.2	**22**	5	15
Total fines	1259.2	22.2			
Bottom Pan	10.2				
Extracted fines	1249.0				
Total sample	5663.2				
Grading Modulus		**1.96**			



FOR TESTING LAB

STIRLING CIVIL ENGINEERING LTD
P. O. BOX 796, KAMPALA (U)

Lab Technician *Materials Engineer*

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	**PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS**

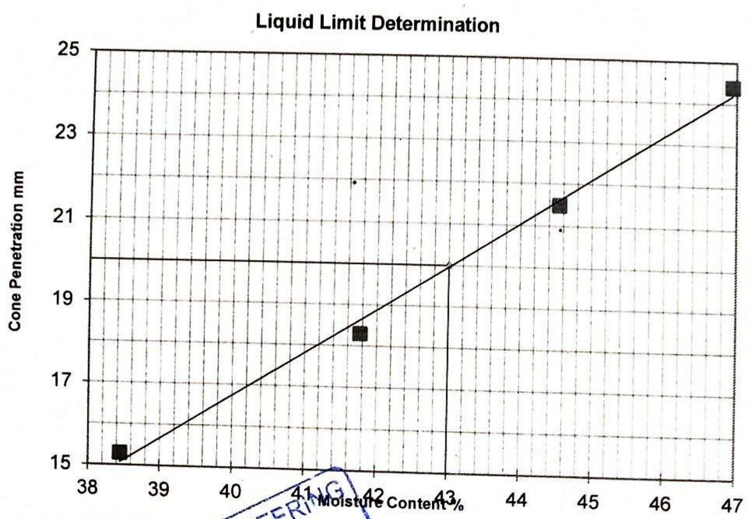
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	STABILISED WITH 5% METAKAOLINE ONLY	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	13/Feb/2024
LAYER	BROWN YELLOWISH LATERITIC GRAVEL MATERIAL & 5% METAKAOLIN		

PLASTIC LIMIT	Test No.	D2	Q		Average
Mass of wet soil + container (g)		35.94	41.1		38.52
Mass of dry soil + container (g)		33.1	36.91		35.005
Mass of container (g)		22.75	21.69		22.22
Mass of moisture (g)		2.84	4.2		3.515
Mass of dry soil (g)		10.35	15.22		12.785
Moisture content %		27.4	27.5		27.5
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.3	18.3	21.5	24.4
penetration (mm)		15.3	18.3	21.5	24.4
AVERAGE		15.3	18.3	21.5	24.4
Container No.		AB	A7	PI6OO	PI2H
Mass of wet soil + container (g)		52.27	57.92	56.80	53.54
Mass of dry soil + container (g)		39.66	43.59	41.43	40.11
Mass of container (g)		6.86	9.28	6.92	11.50
Mass of moisture (g)		12.61	14.33	15.37	13.43
Mass of dry soil (g)		32.8	34.31	34.51	28.61
Moisture content (%)		38.4	41.8	44.5	46.9
AVERAGE		38.4	41.8	44.5	46.9



Liquid limit (%)	43.0
Plastic limit (%)	27.5
Plasticity Index (%)	15.5
Linear shrinkage	
Trough No.	J
Trough length (cm)	14.0
Specimen length (cm)	12.9
L.shringage =	1.1
% L.shrinkage =	7.6

Remarks:

TESTING LAB

Materials Engineer

Lab Technician

STIRLING CIVIL ENGINEERING LTD
P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	**PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS**

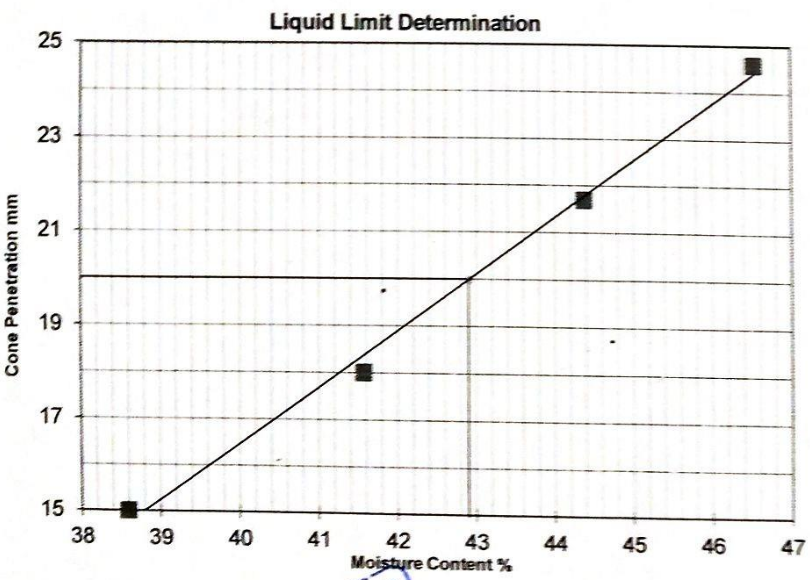
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.	Lab. Reference No.:	Technician:	Lab Team
Location	STABILISED WITH 5% METAKAOLINE ONLY	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	13/Feb/2024
LAYER	BROWN YELLOWISH LATERITIC GRAVEL MATERIAL & 5% METAKAOLIN		

PLASTIC LIMIT	Test No	G	H		Average
Mass of wet soil + container (g)		32.52	31.86		32.19
Mass of dry soil + container (g)		30.23	29.41		29.82
Mass of container (g)		21.95	20.45		21.2
Mass of moisture (g)		2.29	2.5		2.37
Mass of dry soil (g)		8.28	8.96		8.62
Moisture content %		27.7	27.3		27.5
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.0	18	21.7	24.6
penetration (mm)		15.0	18.0	21.7	24.6
AVERAGE		15.0	18.0	21.7	24.6
Container No.		BB	PP	BC	MB
Mass of wet soil + container (g)		49.60	54.93	58.87	48.06
Mass of dry soil + container (g)		37.68	40.81	42.94	35.01
Mass of container (g)		6.79	6.84	7.04	6.97
Mass of moisture (g)		11.92	14.12	15.93	13.05
Mass of dry soil (g)		30.89	33.97	35.9	28.04
Moisture content (%)		38.6	41.6	44.4	46.5
AVERAGE		38.6	41.6	44.4	46.5



Liquid limit (%)	42.9
Plastic limit (%)	27.5
Plasticity Index (%)	15.4
Linear shrinkage	
Trough No.	J
Trough length (cm)	14.0
Specimen length (cm).	12.9
L.shringage =	1.1
% L.shrinkage =	7.6

Remarks:

TESTING LAB

Materials Engineer.

Lab Technician

STIRLING CIVIL ENGINEERING LTD
P. O. BOX 793, KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS				
Test Reference No.	Lab. Reference No.		Date Sampled	Date Tested	Technician
Mix	STABILISED WITH 5% METAKAOLINE ONLY		9/Dec/23	24/Jan/24	Lab team
Material description:	BROWN YELLOWISH LATERITIC GRAVEL MATERIAL & 5% METAKAOLIN		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^3)
4.5	27	3	457	100	1,000

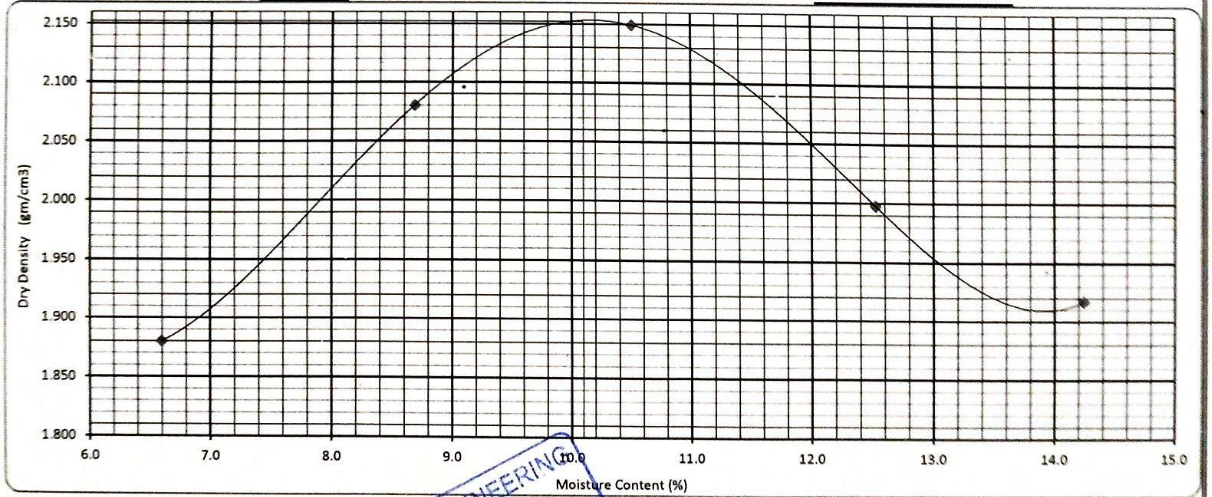
MOISTURE CONTENT DATA

Test No.		1	2	3	4	5
Tin No.		A	A	A	A	A
Water Added	cm^3	200	300	400	500	600
Mass of Compacted soil + mould	gm	6,283	6,540	6,654	6,527	6,469
Mass of Mould	gm	4,279	4,279	4,279	4,279	4,279
Mass of Compacted soil	gm	2004	2261	2375	2248	2190
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	2.004	2.261	2.375	2.248	2.190

DATA FOR PROCTOR CURVE

Container No.		FDC	BOJ	Z6T	BBC	ACB
Mass of wet soil + Container	gm	2,518.0	2,378.0	2,700.0	2,471.0	2,563.0
Mass of dry soil + container	gm	2,412.0	2,252.0	2,485.0	2,286.0	2,341.0
Mass of container	gm	805.0	801.0	438.0	809.0	782.0
Mass of water added	gm	106	126	215	185	222
Mass of dry soil	gm	1607	1451	2047	1477	1559
Moisture content	%	6.6	8.7	10.5	12.5	14.2
Dry density	g/cm^3	1.880	2.080	2.149	1.998	1.917

Maximum dry density (gm/cm^3) 2.152 Optimum moisture content (%) 10.1



Remarks:

FOR TESTING LAB

Lab Technician	Materials Engineer	

STIRLING CIVIL ENGINEERING LTD P. O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date :	9/Dec/23
Location:	STABILISED WITH 5% METAKAOLINE ONLY	Casting date :	27/Jan/24
		Testing Date	10/Feb/24
Sample Description:	BROWN YELLOWISH LATERITIC GRAVEL MATERIAL & 5% METAKAOLIN	Technician :	Lab team
		Volume of Mould used (m^3)	2305

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	NBM		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	1713		MDD (Mg/m^3)	2.152
Tin + oven dry soil sample (g)	1693		N.M.C (%)	2.2
Tin (g)	797		OMC (%)	10.1
Dry soil sample	896		Added OMC (%)	7.9
Water (g)	20		Calculated dry wt of soil (g)	5866.1
N.M.C (%)	2.2		Water added (g)	462
Average (%)	2.2		**Water added (mL)**	462

Number of blows		62								
Number of layer		5								
Water Content Determination		Before Soaking		After Soaking						
Tare No		BA	-	KT	-					
Mass of wet sample + Tare	g	2395	-	1874	-					
Mass of dry sample + Tare	g	2215	-	1753	-					
Mass of Tare	g	768	-	799	-					
Mass of water	g	180	-	121	-					
Mass of dry sample	g	1447	-	954	-					
Water content	%	12.4	-	12.7	-					
Average water Content	%	12.4		12.7						
Density determination										
Mould No		AS								
Mass of mould + soil	g	10662		10675						
Mass of mould	g	5264		5264						
Mass of soil	g	5398		5411						
Volume of the mould	cm3	2305		2305						
Moist density	g/cm3	2.342		2.348						
Dry density	g/cm3	2.083		2.083						
Swell Determination										
Date		Hour		D.Gauge Reding						
Initial reading		96 hrs		13.21						
Final reading				14.05						
Height of the specimen				127						
Height of swell				0.84						
		Swelling(%)		**0.66**						

Observations			
For the Lab			
Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD P. O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :

Laboratory Reference No.:

Sampling Date 9/Dec/23

Location:

Penetration Date 10/Feb/24

Depth :

Technician : : Lab team

Sample Description : : **BROWN YELLOWISH LATERITIC GRAVEL MATERIAL & 5% METAKAOLIN**

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	AS		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.2052	0.2052	0.2052

Speed : ……………mm min.

Penetration of the plunger (mm)	Time (s)	Top Reading $*10^3$mm	Top Force (KN)	Bottom Reading $*10^3$mm	Bottom Force (KN)								
0	**0**	0	0.0	0	0.0								
0.25	**12**	1	0.2	4	0.8								
0.5	**24**	1	0.2	6	1.2								
0.75	**35**	2	0.4	9	1.8								
1	**47**	4	0.8	13	2.7								
1.5	**71**	5	1.0	16	3.3								
2	**94**	6	1.2	18	3.7								
2.5	**118**	8	1.6	22	4.5								
3	**142**	10	2.1	28	5.7								
3.5	**165**	12	2.5	31	6.4								
4	**189**	14	2.9	34	7.0								
4.5	**213**	17	3.5	37	7.6								
5	**236**	19	3.9	39	8.0								
5.5	**260**	21	4.3	42	8.6								
6	**283**	23	4.7	44	9.0								
6.5	**307**	25	5.1	46	9.4								
7	**331**	27	5.5	48	9.8								
7.5	**354**	28	5.7	50	10.3								

Observations

For the Contractor

Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD P. O. BOX 796, KAMPALA (U)

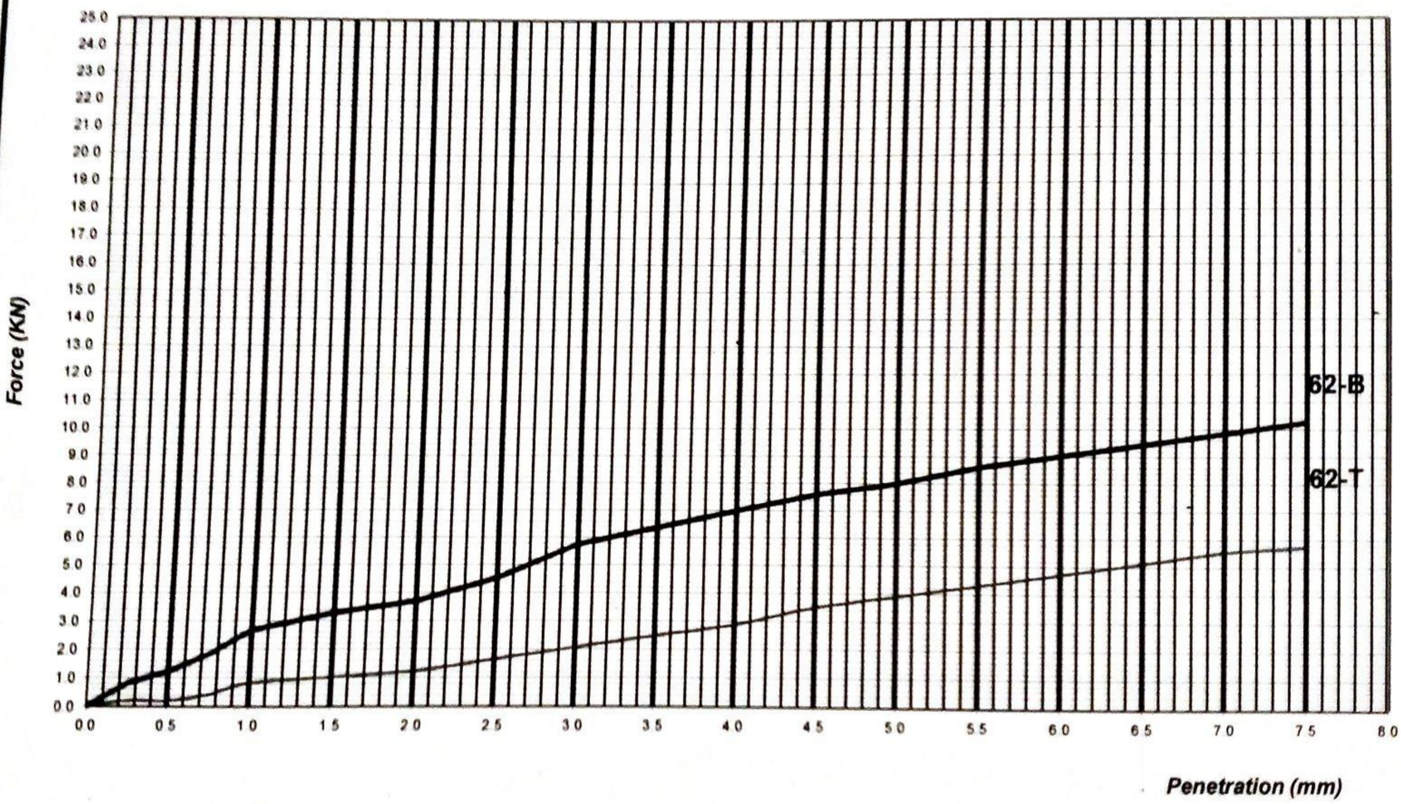
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date : 9/Dec/23
Location		Testing Date : 10/Feb/24
Depth		Technician : Lab team
Sample Description	BROWN YELLOWISH LATERITIC GRAVEL MATERIAL & 5% METAKAOLIN	

PENETRATION vs FORCE CURVE



	62 blows											
	Force		CBR									
	Bottom	Top	Bottom	Top								
2.5 mm Penetration	4.5	1.6	34	12								
5.0 mm Penetration	8.0	3.9	40	20								
Average	6.3	2.8	37.1	16.0								
Retained CBR	37.1											
Observations	CBR= 37.1											

For the Lab			
Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD P.O. BOX 786, KAMPALA

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

SUMMARY OF TEST RESULTS FOR LATERATIC GRAVEL 3% CEMENT ONLY

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	62 BLOWS COMPACTION			62	AVERAGE
3% CEMENT ONLY	LATERIC GRAVEL STABILISED WITH 3% CEMENT ONLY	12/9/2023	100	98	80	48	42	32	26	2.01	42.9	28.8	14.1	7.1	2.138	12.1	49			0.49	0.49
			100	96	83	49	42	33	26	1.99	42.8	28.7	14:1	7.1	-	-	-	-	-	-	
			100	**97**	**81.34**	**48.09**	**41.85**	**32.52**	**25.84**	**2.00**	**42.9**	**28.7**	**14.1**	**7.1**	**2.138**	**12.1**	**49**			**0.49**	**0.49**
	AVERAGE		100	97	81	48	42	33	26	1.998	42.9	28.7	14.1	7.1	2.138	12.1	49			0.49	0.49

FOR LAB

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 796, KAMPALA (U)

Lab Technician   *Materials Engineer*

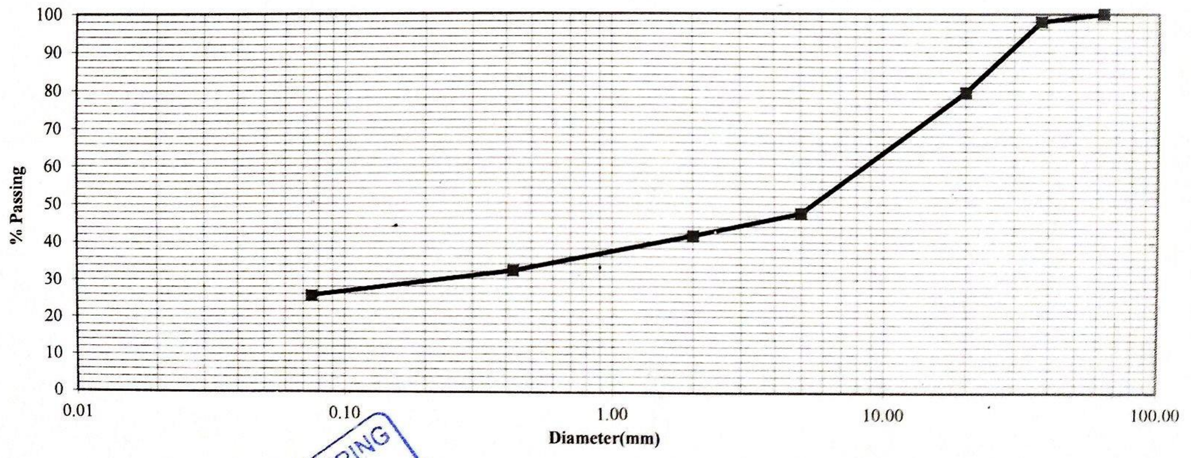
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	3% CEMENT ONLY	Dry wt. of sample before washing: (g)		4585.8
Depth: (m)		Dry wt. of sample after washing: (g)		3419.0
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT ONLY	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	**100**	100	100
37.5	93.0	2.0	**98**	80	100
20.0	841.4	18.3	**80**	60	95
5.0	1471.2	32.1	**48**	30	65
2.00	274.4	6.0	**42**	20	50
0.425	426.7	9.3	**32**	10	30
0.075	301.7	6.6	**26**	5	15
Total fines	1177.4	25.7			
Bottom Pan	10.6				
Extracted fines	1166.8				
Total sample	4585.8				
Grading Modulus		**2.01**			



FOR TESTING LAB

Lab Technician — Materials Engineer

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

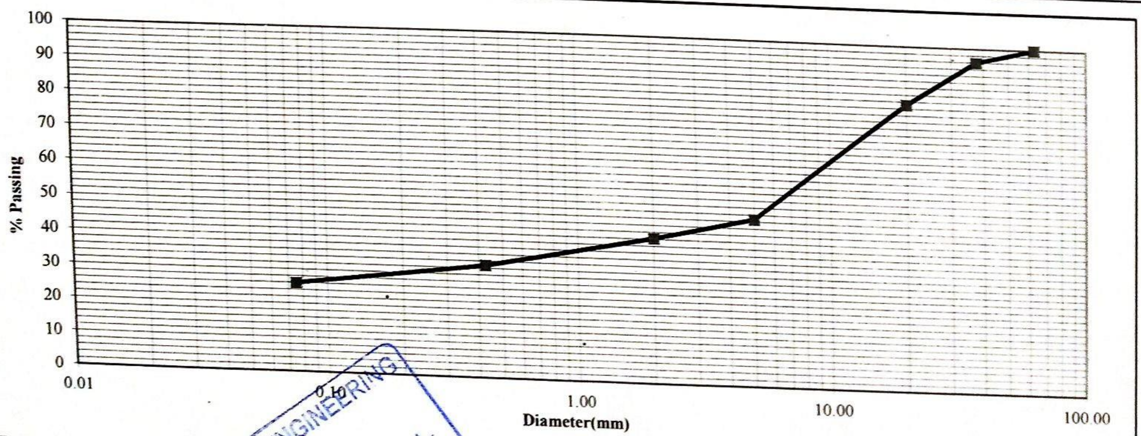
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	3% CEMENT ONLY	Dry wt. of sample before washing: (g)		4175.7
Depth: (m)		Dry wt. of sample after washing: (g)		3093.5
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT ONLY	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	**100**	100	100
37.5	165.5	4.0	**96**	80	100
20.0	542.2	13.0	**83**	60	95
5.0	1437.4	34.4	**49**	30	65
2.00	270.8	6.5	**42**	20	50
0.425	390.6	9.4	**33**	10	30
0.075	283.3	6.8	**26**	5	15
Total fines	1085.9	26.0			
Bottom Pan	3.7				
Extracted fines	1082.2				
Total sample	4175.7				
Grading Modulus		**1.99**			



FOR TESTING LAB

Lab Technician   *Materials Engineer*

STIRLING CIVIL ENGINEERING LTD
P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

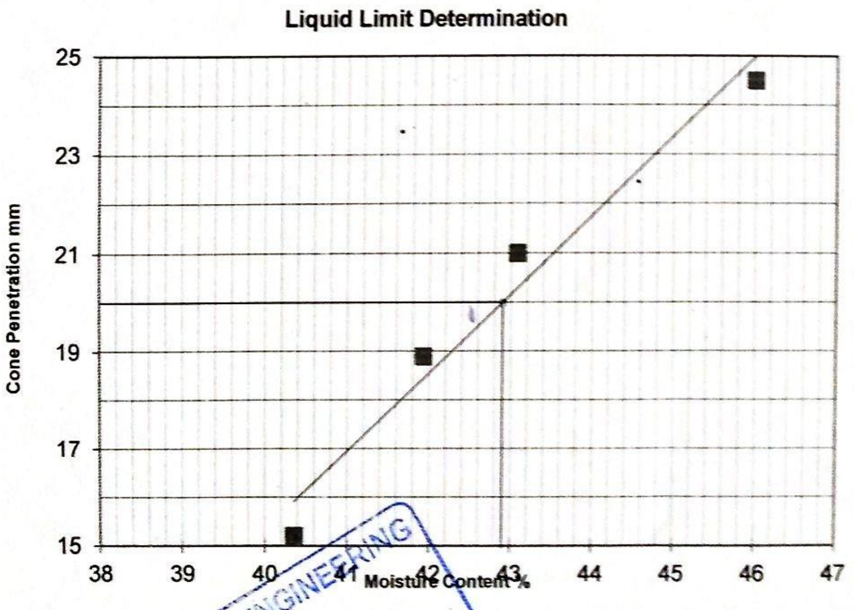
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	3% CEMENT ONLY .	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	13/Feb/2024
LAYER	LATERIC GRAVEL STABILISED WITH 3% CEMENT ONLY		

PLASTIC LIMIT	Test No.	SO	KK		Average
Mass of wet soil + container (g)		38.54	43.01		40.775
Mass of dry soil + container (g)		35.05	38.37		36.71
Mass of container (g)		22.93	22.25		22.59
Mass of moisture (g)		3.49	4.6		4.065
Mass of dry soil (g)		12.12	16.12		14.12
Moisture content %		28.8	28.8		28.8
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.2	18.9	21	24.5
penetration (mm)		15.2	18.9	21.0	24.5
AVERAGE		15.2	18.9	21.0	24.5
Container No.		PI45	PI82	PII2	PII9
Mass of wet soil + container (g)		46.01	50.26	42.94	52.93
Mass of dry soil + container (g)		34.82	37.48	32.06	38.44
Mass of container (g)		7.09	7.00	6.80	6.94
Mass of moisture (g)		11.19	12.78	10.88	14.49
Mass of dry soil (g)		27.73	30.48	25.26	31.5
Moisture content (%)		40.4	41.9	43.1	46.0
AVERAGE		40.4	41.9	43.1	46.0



Liquid limit (%)	42.9
Plastic limit (%)	28.8
Plasticity Index (%)	14.1
Linear shrinkage	
Trough No.	2
Trough length (cm)	14.0
Specimen length (cm)	13.0
L.shringage =	1.0
% L.shrinkage =	7.1

Remarks:

TESTING LAB

Materials Engineer

Lab Technician

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

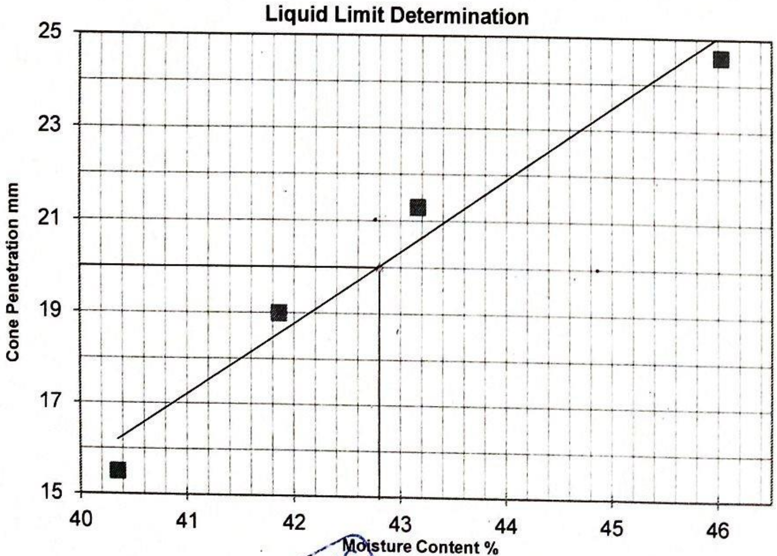
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	3% CEMENT ONLY	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	13/Feb/2024
LAYER	LATERIC GRÅVEL STABILISED WITH 3% CEMENT ONLY		

PLASTIC LIMIT	Test No.	SM	DT		Average
Mass of wet soil + container (g)		36.25	35.4		35.825
Mass of dry soil + container (g)		33.19	32.75		32.97
Mass of container (g)		22.5	23.52		23.01
Mass of moisture (g)		3.06	2.7		2.855
Mass of dry soil (g)		10.69	9.23		9.96
Moisture content %		28.6	28.7		28.7
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.5	19	21.3	24.6
penetration (mm)		15.5	19.0	21.3	24.6
AVERAGE		15.5	19.0	21.3	24.6
Container No.		A	P121	PI46	FOO
Mass of wet soil + container (g)		55.07	53.05	44.25	60.35
Mass of dry soil + container (g)		41.27	39.48	33.08	43.49
Mass of container (g)		7.07	7.06	7.20	6.86
Mass of moisture (g)		13.8	13.57	11.17	16.86
Mass of dry soil (g)		34.2	32.42	25.88	36.63
Moisture content (%)		40.4	41.9	43.2	46.0
AVERAGE		40.4	41.9	43.2	46.0



Liquid limit (%)	42.8
Plastic limit (%)	28.7
Plasticity Index (%)	14.1
Linear shrinkage	
Trough No.	2
Trough length (cm)	14.0
Specimen length (cm)	13.0
L.shringage =	1.0
% L.shrinkage =	7.1

Remarks:

TESTING LAB

Materials Engineer

Lab Technician

STIRLING CIVIL ENGINEERING LTD
05 MAR 2024
P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

Test Reference No.	Lab. Reference No.	Date Sampled	Date Tested	Technician
Mix	3% CEMENT ONLY	9/Dec/23	24/Jan/24	Lab team
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT ONLY	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^3)
4.5	27	3	457	100	1,000

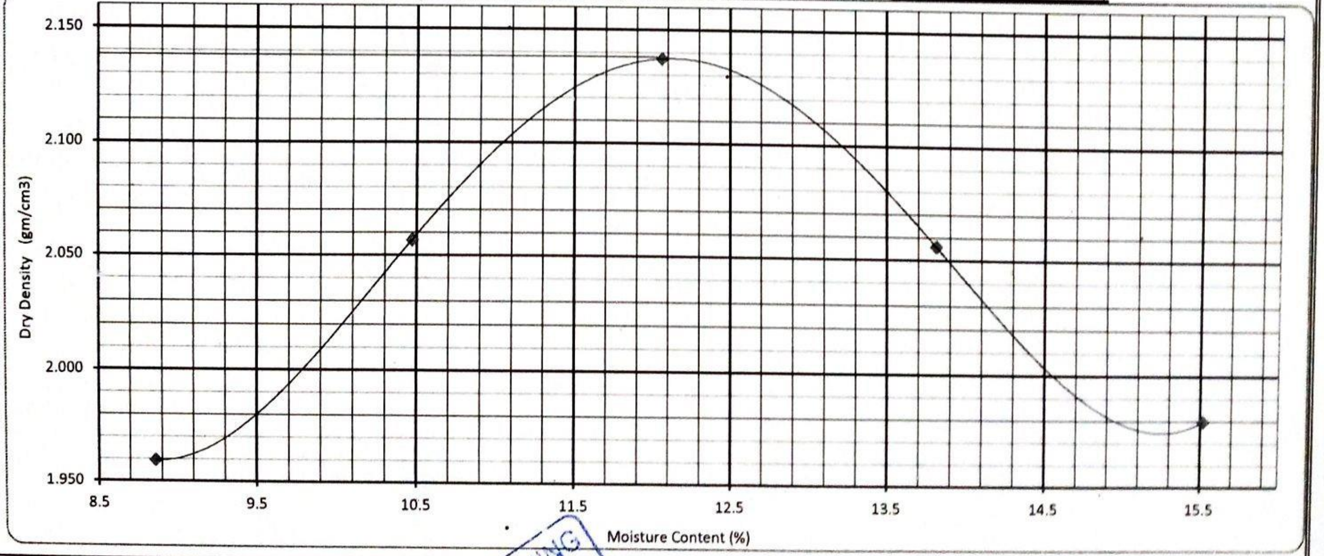
MOISTURE CONTENT DATA

Test No.		1	2	3	4	5
Tin No.		A	A	A	A	A
Water Added	cm^3	200	300	400	500	600
Mass of Compacted soil + mould	gm	6,412	6,551	6,674	6,619	6,566
Mass of Mould	gm	4,279	4,279	4,279	4,279	4,279
Mass of Compacted soil	gm	2133	2272	2395	2340	2287
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	2.133	2.272	2.395	2.340	2.287

DATA FOR PROCTOR CURVE

Container No.		LDU	OPD	XZM	EX	DJ
Mass of wet soil + Container	gm	1,781.0	1,986.0	2,747.0	1,735.0	2,273.0
Mass of dry soil + container	gm	1,670.0	1,850.0	2,538.0	1,589.0	2,041.0
Mass of container	gm	417.0	551.0	805.0	532.0	546.0
Mass of water added	gm	111	136	209	146	232
Mass of dry soil	gm	1253	1299	1733	1057	1495
Moisture content	%	8.9	10.5	12.1	13.8	15.5
Dry density	g/cm^3	1.959	2.057	2.137	2.056	1.980

Maximum dry density (gm/cm^3) 2.138 Optimum moisture content (%) 12.1



Remarks:

FOR TESTING LAB

Lab Technician	Materials Engineer	

STIRLING CIVIL ENGINEERING LTD P. O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date :	9/Dec/23
Location:	3% CEMENT ONLY	Casting date :	27/Jan/24
		Testing Date :	10/Feb/24
Sample Description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT ONLY	Technician :	: Lab team
		Volume of Mould used (m^3)	2305

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	ZION		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	2240		MDD (Mg/m^3)	2.138
Tin + oven dry soil sample (g)	2212		N.M.C (%)	1.6
Tin (g)	436		OMC (%)	12.1
Dry soil sample	1776		Added OMC (%)	10.5
Water (g)	28		Calculated dry wt of soil (g)	5905.4
N.M.C (%)	1.6		Water added (g)	622
Average (%)	1.6		**Water added (mL)**	**622**

Number of blows		**62**									
Number of layer		5									
Water Content Determination		Before Soaking		After Soaking							
Tare No		Y6Y	-	CML	-						
Mass of wet sample + Tare	g	2141	-	1946	-						
Mass of dry sample + Tare	g	1984	-	1809	-						
Mass of Tare	g	820	-	763	-						
Mass of water	g	157	-	137	-						
Mass of dry sample	g	1164	-	1046	-						
Water content	%	13.5	-	13.1	-						
Average water Content	%	13.5		13.1							
Density determination											
Mould No		AS									
Mass of mould + soil	g	10847		10826							
Mass of mould	g	5592		5592							
Mass of soil	g	5255		5234							
Volume of the mould	cm3	2305		2305							
Moist density	g/cm3	2.280		2.271							
Dry density	g/cm3	2.009		2.008							
Swell Determination											
Date		Hour		D.Gauge Reding							
Initial reading		96 hrs		5.9							
Final reading				6.52							
Height of the specimen				127							
Height of swell				0.62							
		Swelling(%)		**0.49**							

Observations	

For the Lab

Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date	9/Dec/23
Location:		Penetration Date	10/Feb/24
Depth :		Technician	: : Lab team
Sample Description :	: LATERIC GRAVEL STABILISED WITH 3% CEMENT ONLY		

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	AS		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.2052	0.2052	0.2052

Speed :……………mm/min.		Top		Bottom	
Penetration of the plunger (mm)	Time (s)	Reading $*10^3$mm	Force (KN)	Reading $*10^3$mm	Force (KN)
0	**0**	0	0.0	0	0.0
0.25	**12**	1	0.2	2	0.4
0.5	**24**	2	0.4	6	1.2
0.75	**35**	4	0.8	10	2.1
1	**47**	6	1.2	13	2.7
1.5	**71**	9	1.8	20	4.1
2	**94**	13	2.7	25	5.1
2.5	**118**	18	3.7	30	6.2
3	**142**	25	5.1	34	7.0
3.5	**165**	29	6.0	38	7.8
4	**189**	38	7.8	43	8.8
4.5	**213**	42	8.6	46	9.4
5	**236**	46	9.4	50	10.3
5.5	**260**	52	10.7	54	11.1
6	**283**	56	11.5	59	12.1
6.5	**307**	59	12.1	64	13.1
7	**331**	62	12.7	66	13.5
7.5	**354**	64	13.1	69	14.2

Observations

For the Contractor

Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING
P.O. BOX 706, KAMPALA (U)

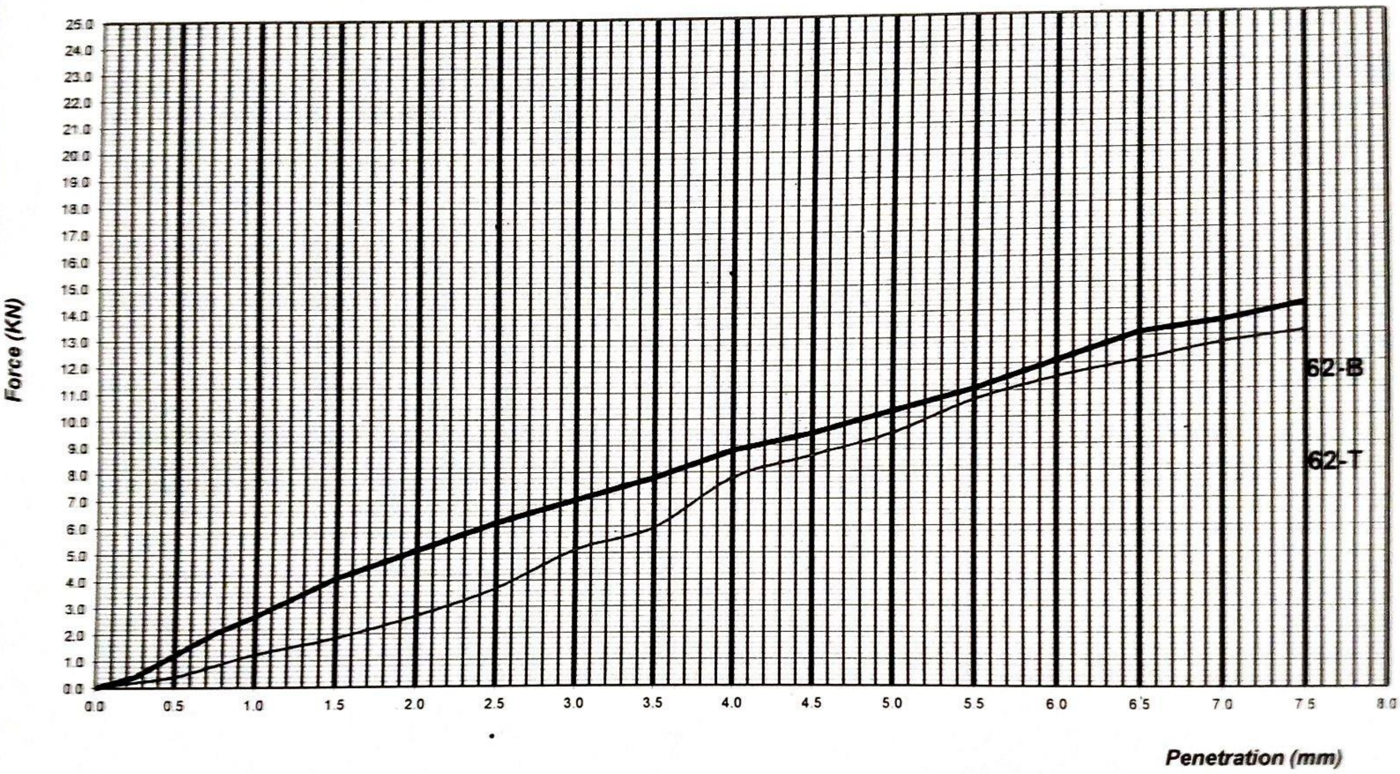
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date : 9/Dec/23
Location:		Testing Date : 10/Feb/24
Depth:		Technician : Lab team
Sample Description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT ONLY	

PENETRATION vs FORCE CURVE



	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	6.2	3.7	46	28
5.0 mm Penetration	10.3	9.4	51	47
Average	8.2	6.6	48.9	37.6
Retained CBR	48.9			
Observations	CBR= 48.9			

For the Lab

Lab. Technician | *Materials Engineer*

STIRLING CIVIL ENGINEERING LTD P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

SUMMARY OF TEST RESULTS FOR LATERATIC GRAVEL 3% CEMENT AND 2% METAKAOLINE

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	62 BLOWS OF COMPACTION	62	AVERAGE
3% CEMENT AND 2% METAKAO LINE	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 2% METAKAOLINE	12/9/2023	100	100	99	61	45	30	17	2.08	41.8	28.3	13.5	6.9	2.097	12.3	51	0.40	0.40
			100	100	99	60	44	31	18	2.07	41.5	27.9	13.6	6.9	-	-	-	-	
			100	**100**	**98.86**	**60.28**	**44.27**	**30.7**	**17.7**	**2.07**	**41.7**	**28.1**	**13.6**	**6.9**	**2.097**	**12.3**	**51**	**0.40**	**0.40**
	AVERAGE		100	100	99	60	44	31	18	2.073	41.7	27.9	13.6	6.9	2.097	12.3	51	0.40	0.40

FOR LAB

Lab Technician

Materials Engineer

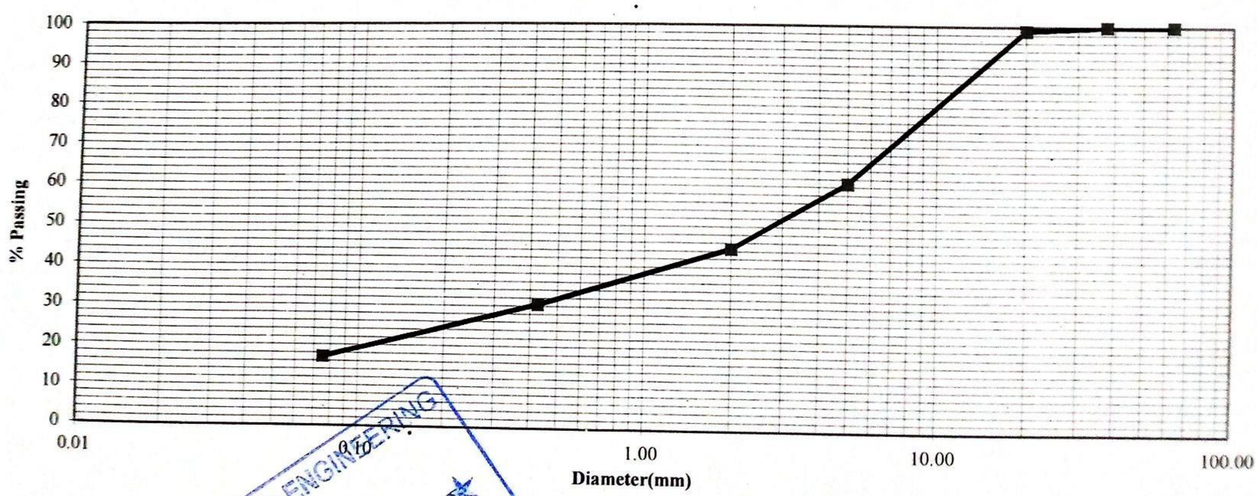
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	3% CEMENT AND 2% METAKAOLINE	Dry wt. of sample before washing: (g)		3825.6
Depth: (m)		Dry wt. of sample after washing: (g)		3183.7
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 2% METAKAOLINE	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	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	38.4	1.0	**99**	60	95
5.0	1457.8	38.1	**61**	30	65
2.00	622.7	16.3	**45**	20	50
0.425	539.9	14.1	**30**	10	30
0.075	514.0	13.4	**17**	5	15
Total fines	652.8	17.1			
Bottom Pan	10.9				
Extracted fines	641.9				
Total sample	3825.6				
Grading Modulus		**2.08**			



FOR TESTING LAB

Lab Technician *Materials Engineer*

STIRLING CIVIL ENGINEERING LTD P.O. BOX 796, KAMPALA (U)

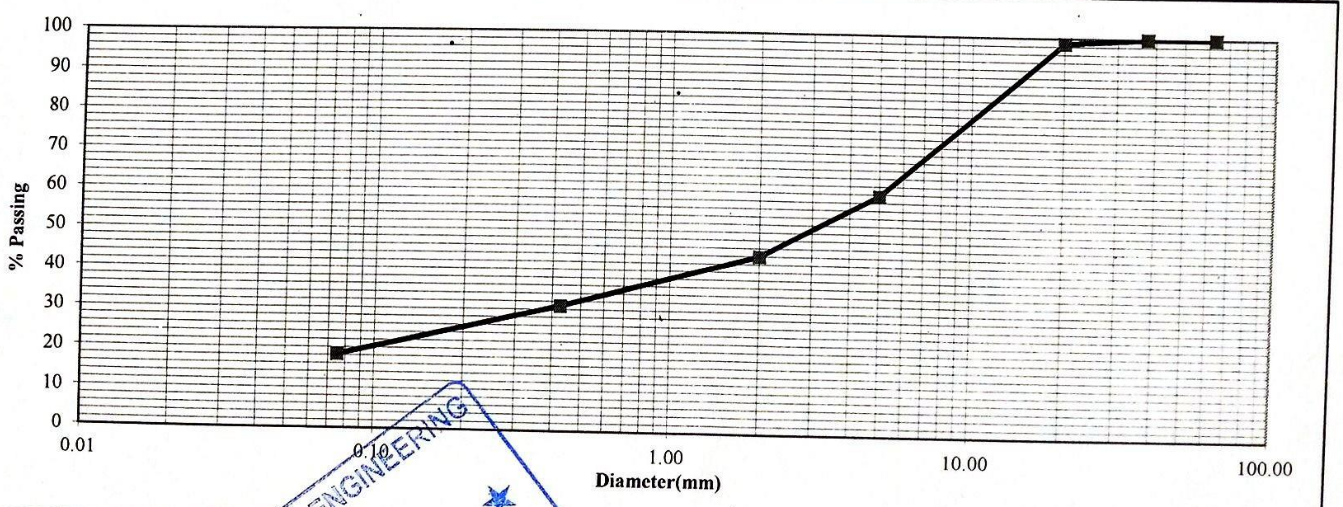
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:			
Location :(km)	3% CEMENT AND 2% METAKAOLINE	Dry wt. of sample before washing: (g)			4002.9
Depth: (m)		Dry wt. of sample after washing: (g)			3281.1
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 2% METAKAOLINE	Date Sampled:	Date Tested:		Technician
		9/Dec/2023	24/Jan/2024		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	50.8	1.3	**99**	60	95
5.0	1563.8	39.1	**60**	30	65
2.00	629.8	15.7	**44**	20	50
0.425	521.4	13.0	**31**	10	30
0.075	502.8	12.6	**18**	5	15
Total fines	734.3	18.3			
Bottom Pan	12.5				
Extracted fines	721.8				
Total sample	4002.9				
Grading Modulus		**2.07**			



FOR TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

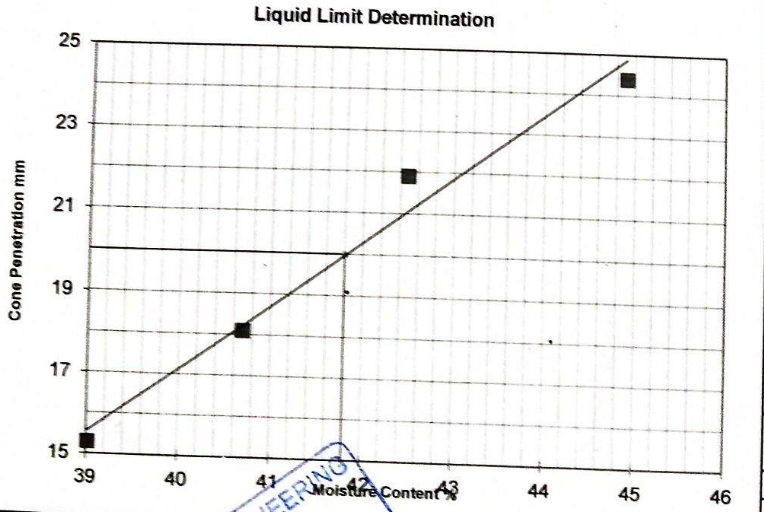
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	3% CEMENT AND 2% METAKAOLINE	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	13/Feb/2024
LAYER	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 2% METAKAOLINE		

PLASTIC LIMIT	Test No.	OG	KK		Average
Mass of wet soil + container (g)		43.66	41.29		42.475
Mass of dry soil + container (g)		38.8	37.06		37.93
Mass of container (g)		21.42	22.26		21.84
Mass of moisture (g)		4.86	4.2		4.545
Mass of dry soil (g)		17.38	14.8		16.09
Moisture content %		28.0	28.6		28.3
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.3	18.1	21.9	24.4
penetration (mm)		15.3	18.1	21.9	24.4
AVERAGE		15.3	18.1	21.9	24.4
Container No.		P133	4B	A11	P119
Mass of wet soil + container (g)		59.81	61.91	62.56	64.80
Mass of dry soil + container (g)		44.98	45.99	46.05	46.99
Mass of container (g)		6.97	6.87	7.19	7.33
Mass of moisture (g)		14.83	15.92	16.51	17.81
Mass of dry soil (g)		38.01	39.12	38.86	39.66
Moisture content (%)		39.0	40.7	42.5	44.9
AVERAGE		39.0	40.7	42.5	44.9



Liquid limit (%)	41.8
Plastic limit (%)	28.3
Plasticity Index (%)	13.5
Linear shrinkage	
Trough No.	X
Trough length (cm)	14.0
Specimen length (cm)	13.0
L.shringage =	1.0
% L.shrinkage =	6.9

Remarks:

TESTING LAB

Materials Engineer.

Lab Technician

STIRLING ENGINEERING LTD P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	**PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS**

ATTERBERG LIMITS

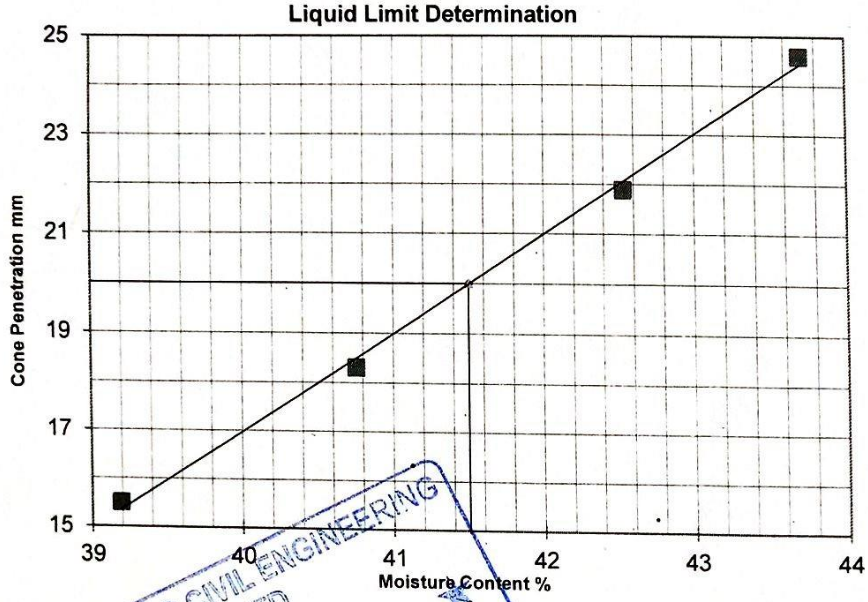
Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:		Technician:	Lab Team
Location	3% CEMENT AND 2% METAKAOLINE		Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4		Test Date	13/Feb/2024
LAYER	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 2% METAKAOLINE			

PLASTIC LIMIT	Test No.	SO	RAD		Average
Mass of wet soil + container (g)		47.86	44.87		46.365
Mass of dry soil + container (g)		42.42	39.92		41.17
Mass of container (g)		23.13	21.97		22.55
Mass of moisture (g)		5.44	5.0		5.195
Mass of dry soil (g)		19.29	17.95		18.62
Moisture content %		28.2	27.6		27.9
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.5	18.3	21.9	24.6
penetration (mm)		15.5	18.3	21.9	24.6
AVERAGE		15.5	18.3	21.9	24.6
Container No.		P115	P160	P182	A4
Mass of wet soil + container (g)		56.27	66.69	63.57	68.34
Mass of dry soil + container (g)		42.42	49.39	46.66	49.64
Mass of container (g)		7.08	6.94	6.90	6.85
Mass of moisture (g)		13.85	17.3	16.91	18.7
Mass of dry soil (g)		35.34	42.45	39.76	42.79
Moisture content (%)		39.2	40.8	42.5	43.7
AVERAGE		39.2	40.8	42.5	43.7

Liquid Limit Determination



Liquid limit (%)	41.5
Plastic limit (%)	27.9
Plasticity Index (%)	13.6
Linear shrinkage	
Trough No.	X
Trough length (cm)	14.0
Specimen length (cm)	13.0
L.shringage =	1.0
% L.shrinkage =	6.9

Remarks:

TESTING LAB		
Materials Engineer.		
Lab Technician		

STIRLING CIVIL ENGINEERING LTD P. O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

Test Reference No.	Lab. Reference No.	Date Sampled	Date Tested	Technician
Mix	3% CEMENT AND 2% METAKAOLINE	9/Dec/23	24/Jan/24	Lab team
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 2% METAKAOLINE	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^3)
4.5	27	3	457	100	1,000

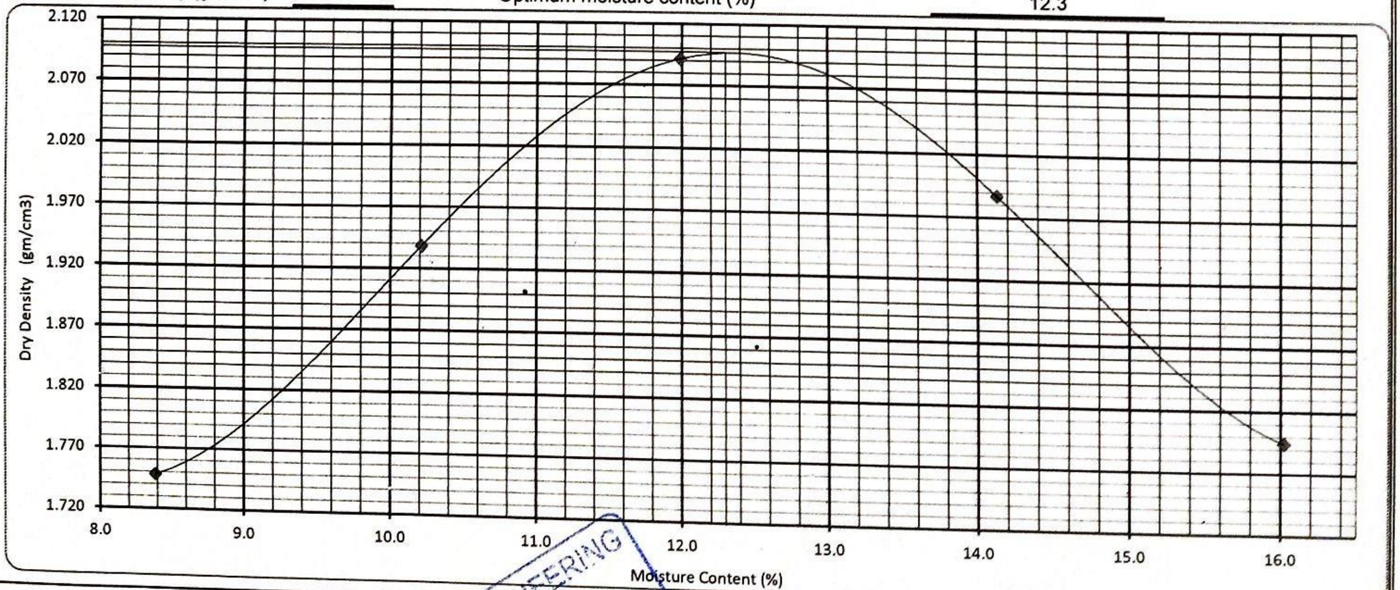
MOISTURE CONTENT DATA

Test No.		1	2	3	4	5
Tin No.		A	A	A	A	A
Water Added	cm^3	150	210	270	330	390
Mass of Compacted soil + mould	gm	5,115	5,356	5,562	5,488	5,302
Mass of Mould	gm	3,220	3,220	3,220	3,220	3,220
Mass of Compacted soil	gm	1895	2136	2342	2268	2082
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	1.895	2.136	2.342	2.268	2.082

DATA FOR PROCTOR CURVE

Container No.		XZM	NBM	BBC	CML	BXR
Mass of wet soil + Container	gm	2,785.0	2,691.0	2,595.0	2,546.0	2,608.0
Mass of dry soil + container	gm	2,632.0	2,516.0	2,399.0	2,326.0	2,360.0
Mass of container	gm	807.0	802.0	764.0	769.0	812.0
Mass of water added	gm	153	175	196	220	248
Mass of dry soil	gm	1825	1714	1635	1557	1548
Moisture content	%	8.4	10.2	12.0	14.1	16.0
Dry density	g/cm^3	1.748	1.938	2.091	1.987	1.795

Maximum dry density (gm/cm^3) 2.097 Optimum moisture content (%) 12.3



Remarks:

FOR TESTING LAB

Lab Technician | Materials Engineer

STIRLING CIVIL ENGINEERING LTD P.O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date :	9/Dec/23
Location:	3% CEMENT AND 2% METAKAOLINE	Casting date :	27/Jan/24
		Testing Date :	10/Feb/24
Sample Description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 2% METAKAOLINE	Technician :	: Lab team
		Volume of Mould used (m^3)	**2305**

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	K26		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	3125		MDD (Mg/m^3)	2.097
Tin + oven dry soil sample (g)	3026		N.M.C (%)	4.5
Tin (g)	805		OMC (%)	12.3
Dry soil sample	2221		Added OMC (%)	7.8
Water (g)	99		Calculated dry wt of soil (g)	5732.6
N.M.C (%)	4.5		Water added (g)	**450**
Average (%)	4.5		**Water added (mL)**	**450**

Number of blows		62				
Number of layer		5				
Water Content Determination		Before Soaking		After Soaking		
Tare No		BK	-	XZM	-	
Mass of wet sample + Tare	g	745	-	2540	-	
Mass of dry sample + Tare	g	669	-	2340	-	
Mass of Tare	g	55	-	805	-	
Mass of water	g	76	-	200	-	
Mass of dry sample	g	614	-	1535	-	
Water content	%	12.4	-	13.0	-	
Average water Content	%	12.4		13.0		
Density determination						
Mould No		HB				
Mass of mould + soil	g	10900		10935		
Mass of mould	g	5510		5510		
Mass of soil	g	5390		5425		
Volume of the mould	cm3	2305		2305		
Moist density	g/cm3	2.338		2.354		
Dry density	g/cm3	2.081		2.082		
Swell Determination						
Date		Hour		D.Gauge Reding		
Initial reading		96 hrs		3.59		
Final reading				4.1		
Height of the specimen				127		
Height of swell				0.51		
		Swelling(%)		**0.40**		

Observations

For the Lab			
Lab. Technician	*Materials Engineer*		

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY — A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date 9/Dec/23
Location:		Penetration Date 10/Feb/24
Depth :		Technician : Lab team
Sample Description :	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 2% METAKAOLINE	

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	HB		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.2052	0.2052	0.2052

Speed :............mm min.		Top		Bottom	
Penetration of the plunger (mm)	Time (s)	Reading $*10^3$mm	Force (KN)	Reading $*10^3$mm	Force (KN)
0	**0**	0	0.0	0	0.0
0.25	**12**	3	0.6	5	1.0
0.5	**24**	6	1.2	8	1.6
0.75	**35**	9	1.8	11	2.3
1	**47**	11	2.3	17	3.5
1.5	**71**	15	3.1	21	4.3
2	**94**	18	3.7	25	5.1
2.5	**118**	21	4.3	30	6.2
3	**142**	26	5.3	36	7.4
3.5	**165**	30	6.2	42	8.6
4	**189**	32	6.6	46	9.4
4.5	**213**	34	7.0	50	10.3
5	**236**	36	7.4	54	11.1
5.5	**260**	37	7.6	56	11.5
6	**283**	38	7.8	58	11.9
6.5	**307**	39	8.0	61	12.5
7	**331**	40	8.2	63	12.9
7.5	**354**	41	8.4	66	13.5

Observations

	For the Contractor	
Lab. Technician	*Material Engineer*	

STIRLING CIVIL ENGINEERING LTD P.O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

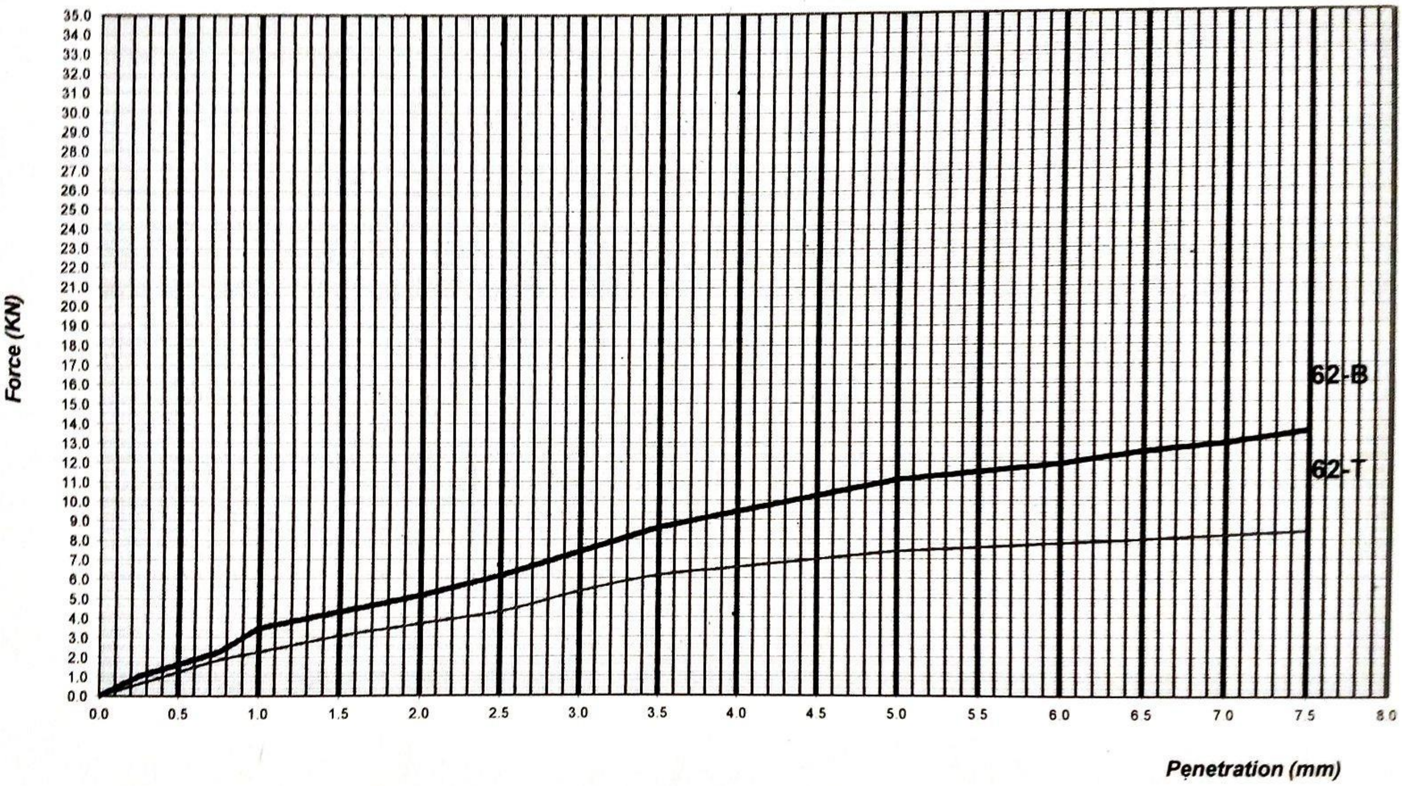
PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date : 9/Dec/23
Location:		Testing Date : 10/Feb/24
Depth:		Technician : Lab team

Sample Description: LATERIC GRAVEL STABILISED WITH 3% CEMENT & 2% METAKAOLINE

PENETRATION vs FORCE CURVE



	62 blows											
	Force		CBR									
	Bottom	Top	Bottom	Top								
2.5 mm Penetration	6.2	4.3	46	33								
5.0 mm Penetration	11.1	7.4	56	37								
Average	8.6	5.8	51.0	34.8								
Retained CBR	51.0											
Observations	CBR= 51.0											

For the Lab

Lab. Technician	*Materials Engineer*	

STIRLING CIVIL ENGINEERING LTD P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

SUMMARY OF TEST RESULTS FOR LATERATIC GRAVEL 3% CEMENT & 4% METAKAOLIN

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	62 BLOWS COMPACTION	62	AVERAGE
3% CEMENT & 4% METAKAOLIN	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 4% METAKAOLIN	12/9/2023	100	100	89	53	44	30	20	2.06	42.4	29.2	13.2	6.4	2.071	12.2	57	0.30	0.30
			100	100	89	57	47	30	18	2.06	42.3	29.3	13.0	6.4	-	-	- - -	-	
			100	**100**	**89.42**	**55.36**	**45.45**	**29.75**	**18.93**	**2.06**	**42.4**	**29.2**	**13.1**	**6.4**	**2.071**	**12.2**	**57**	**0.30**	**0.30**
	AVERAGE		**100**	**100**	**89**	**55**	**45**	**30**	**19**	**2.059**	**42.4**	**29.3**	**13.1**	**6.4**	**2.071**	**12.2**	**57**	**0.30**	**0.30**

FOR LAB

Lab Technician *Materials Engineer*

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 796, KAMPALA (U)

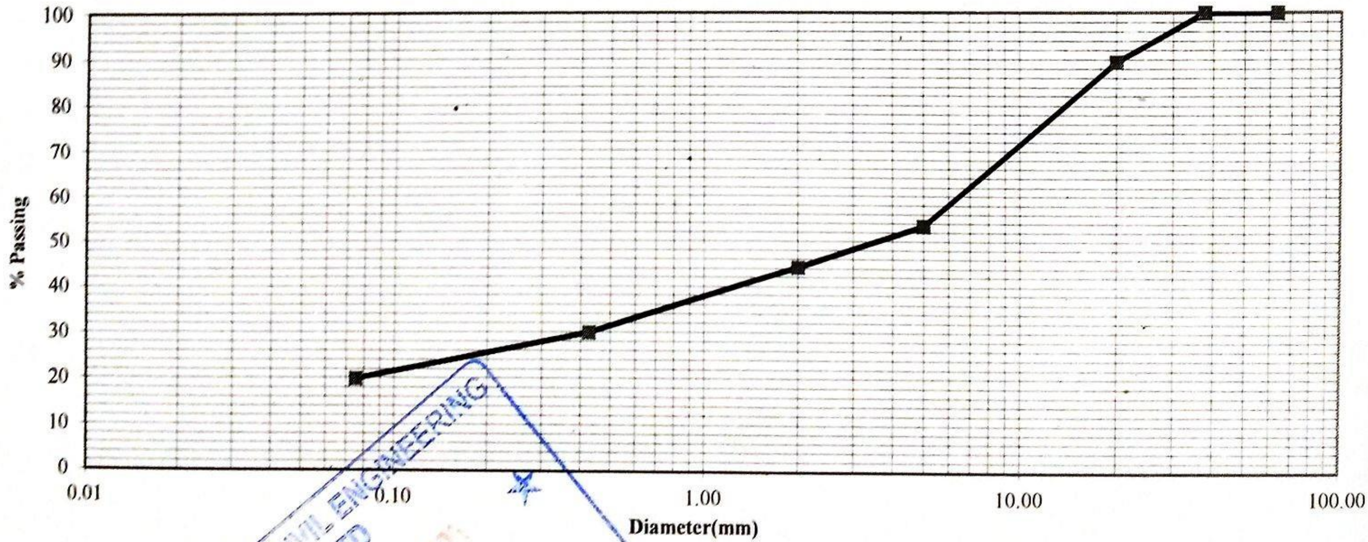
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	3% CEMENT & 4% METAKAOLIN	Dry wt. of sample before washing: (g)		4366.2
Depth: (m)		Dry wt. of sample after washing: (g)		3502.8
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 4% METAKAOLIN	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	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	459.8	10.5	**89**	60	95
5.0	1575.5	36.1	**53**	30	65
2.00	400.6	9.2	**44**	20	50
0.425	622.7	14.3	**30**	10	30
0.075	440.0	10.1	**20**	5	15
Total fines	867.6	19.9			
Bottom Pan	4.2				
Extracted fines	863.4				
Total sample	4366.2				
Grading Modulus		**2.06**			



FOR TESTING LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD P.O. BOX ... KAMPALA (U)

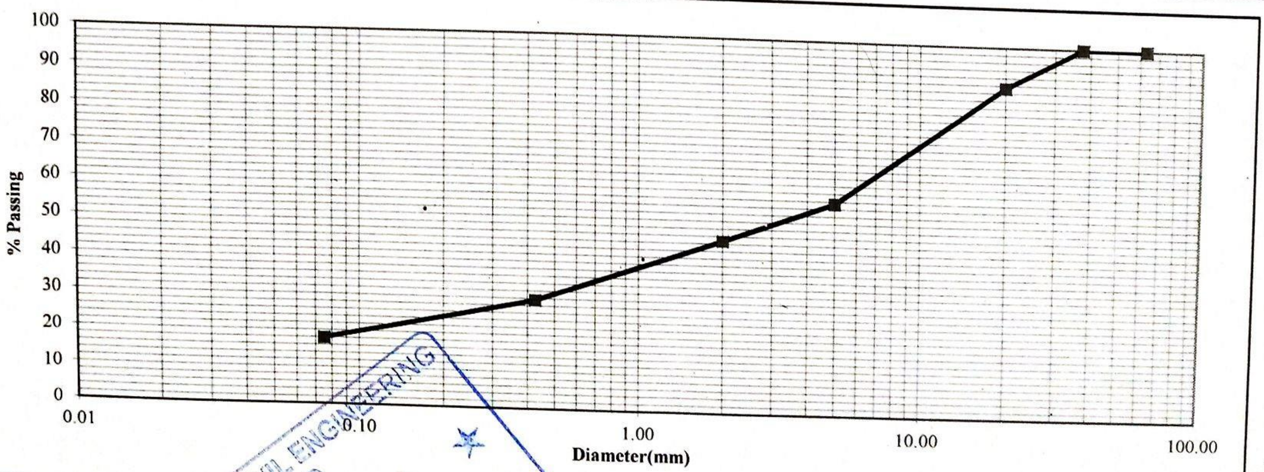
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	3% CEMENT & 4% METAKAOLIN	Dry wt. of sample before washing: (g)		4729.8
Depth: (m)		Dry wt. of sample after washing: (g)		3883.8
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 4% METAKAOLIN	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0			
37.5	0.0	0.0	100	100	100
20.0	502.6	10.6	100	80	100
5.0	1515.8	32.0	89	60	95
2.00	502.6	10.6	57	30	65
0.425	811.4	17.2	47	20	50
0.075	546.3	11.6	30	10	30
Total fines	851.1	18.0	18	5	15
Bottom Pan	5.1				
Extracted fines	846.0				
Total sample	4729.8				
Grading Modulus		2.06			



FOR TESTING LAB

Lab Technician   Materials Engineer

STIRLING CIVIL ENGINEERING LTD P.O. BOX ... KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

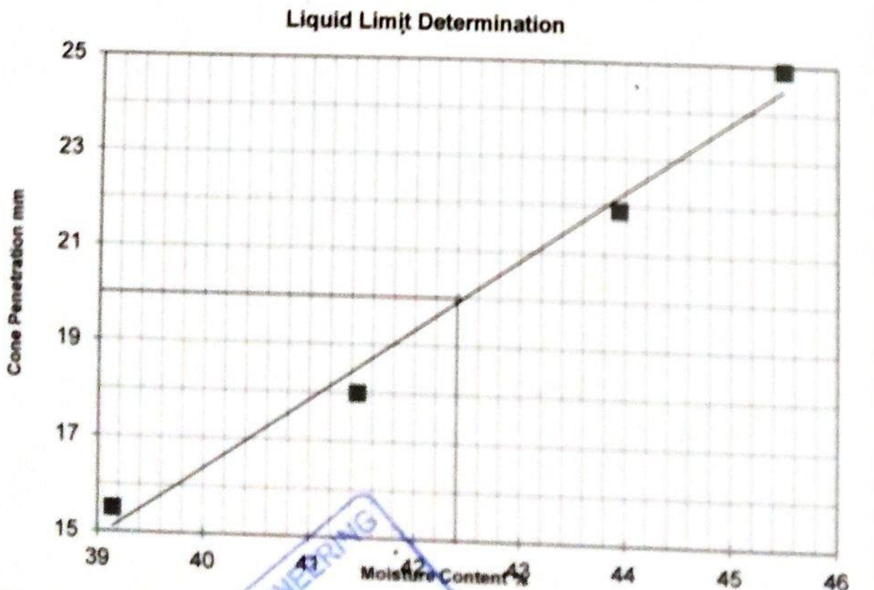
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	3% CEMENT & 4% METAKAOLIN	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990 4.3/4.4	Test Date	13/Feb/2024
LAYER	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 4% METAKAOLIN		

PLASTIC LIMIT	Test No.	RAD	I3		Average
Mass of wet soil + container (g)		36.17	33.18		34.675
Mass of dry soil + container (g)		32.95	30.77		31.86
Mass of container (g)		21.96	22.47		22.215
Mass of moisture (g)		3.22	2.4		2.815
Mass of dry soil (g)		10.99	8.3		9.645
Moisture content %		29.3	29.0		29.2
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.5	18	21.9	24.9
penetration (mm)		15.5	18.0	21.9	24.9
AVERAGE		15.5	18.0	21.9	24.9
Container No		A15	P153	A5	A43
Mass of wet soil + container (g)		57.62	56.62	63.39	62.38
Mass of dry soil + container (g)		43.36	42.55	46.13	45.05
Mass of container (g)		6.93	8.61	6.85	6.96
Mass of moisture (g)		14.26	14.07	17.26	17.33
Mass of dry soil (g)		36.43	33.94	39.28	38.09
Moisture content (%)		39.1	41.5	43.9	45.5
AVERAGE		39.1	41.5	43.9	45.5



Liquid limit (%)	42.4
Plastic limit (%)	29.2
Plasticity Index (%)	13.2
Linear shrinkage	
Trough No	R
Trough length (cm)	14.0
Specimen length (cm)	13.1
L.shringage =	0.9
% L.shrinkage =	6.4

Remarks:

TESTING LAB

Materials Engineer

Lab Technician

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

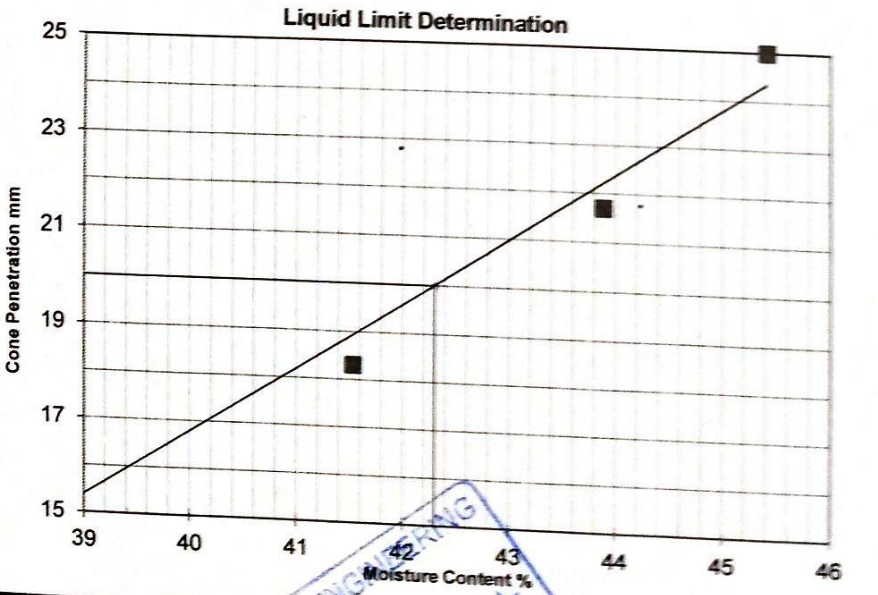
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	3% CEMENT & 4% METAKAOLIN	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	13/Feb/2024
LAYER	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 4% METAKAOLIN		

PLASTIC LIMIT	Test No.	J	4		Average
Mass of wet soil + container (g)		29.65	32.46		31.055
Mass of dry soil + container (g)		27.36	29.77		28.565
Mass of container (g)		19.56	20.55		20.055
Mass of moisture (g)		2.29	2.7		2.49
Mass of dry soil (g)		7.8	9.22		8.51
Moisture content %		29.4	29.2		29.3
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.9	18.3	21.7	25.0
penetration (mm)		15.9	18.3	21.7	25.0
AVERAGE		15.9	18.3	21.7	25.0
Container No.		A6	AX	A4	AO
Mass of wet soil + container (g)		54.20	59.06	55.86	59.53
Mass of dry soil + container (g)		40.91	43.78	40.90	43.10
Mass of container (g)		6.83	6.99	6.81	6.92
Mass of moisture (g)		13.29	15.28	14.96	16.43
Mass of dry soil (g)		34.08	36.79	34.09	36.18
Moisture content (%)		39.0	41.5	43.9	45.4
AVERAGE		39.0	41.5	43.9	45.4



Liquid limit (%)	42.3
Plastic limit (%)	29.3
Plasticity Index (%)	13.0
Linear shrinkage	
Trough No	R
Trough length (cm)	14.0
Specimen length (cm)	13.1
L.shringage =	0.9
% L.shrinkage =	6.4

Remarks:

TESTING LAB

Materials Engineer.

Lab Technician

UGANDA CIVIL ENGINEERING LTD
P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

Test Reference No.	Lab. Reference No.	Date Sampled	Date Tested	Technician
Mix	3% CEMENT & 4% METAKAOLIN	9/Dec/23	24/Jan/24	Lab team
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 4% METAKAOLIN	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^3)
4.5	27	3	457	100	1,000

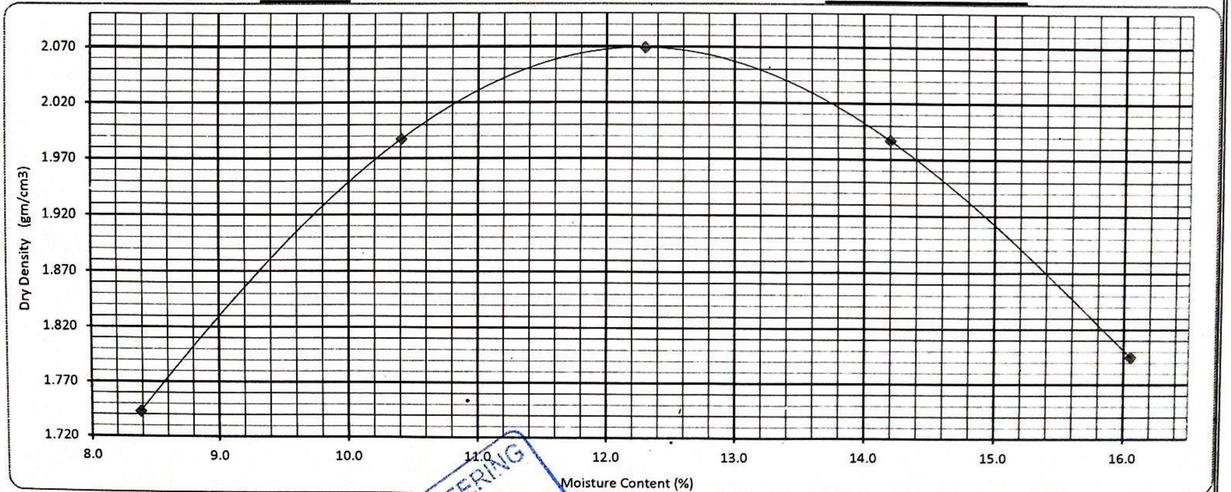
MOISTURE CONTENT DATA

Test No.		1	2	3	4	5
Tin No.		A	A	A	A	A
Water Added	cm^3	180	280	380	480	580
Mass of Compacted soil + mould	gm	5,108	5,413	5,543	5,488	5,302
Mass of Mould	gm	3,219	3,219	3,219	3,219	3,219
Mass of Compacted soil	gm	1889	2194	2324	2269	2083
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	1.889	2.194	2.324	2.269	2.083

DATA FOR PROCTOR CURVE

Container No.		KT	UPC	MJR	CML	CR7
Mass of wet soil + Container	gm	2,375.0	2,251.0	2,196.0	2,282.0	2,346.0
Mass of dry soil + container	gm	2,253.0	2,115.0	2,042.0	2,093.0	2,128.0
Mass of container	gm	798.0	808.0	790.0	762.0	770.0
Mass of water added	gm	122	136	154	189	218
Mass of dry soil	gm	1455	1307	1252	1331	1358
Moisture content	%	8.4	10.4	12.3	14.2	16.1
Dry density	g/cm^3	1.743	1.987	2.069	1.987	1.795

Maximum dry density (gm/cm^3) 2.071 Optimum moisture content (%) 12.2



Remarks:

FOR TESTING LAB

Lab Technician	Materials Engineer	

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 703, KA...

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference	Laboratory Reference No.:	Sampling Date :	9/Dec/23
Location	3% CEMENT & 4% METAKAOLIN	Casting date :	27/Jan/24
		Testing Date :	10/Feb/24
Sample Description	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 4% METAKAOLIN	Technician :	: Lab team
		Volume of Mould used (m^3)	**2305**

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	BA		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	2546		MDD (Mg/m^3)	2.071
Tin + oven dry soil sample (g)	2510		N.M.C (%)	2.1
Tin (g)	768		OMC (%)	12.2
Dry soil sample	1742		Added OMC (%)	10.1
Water (g)	36		Calculated dry wt of soil (g)	5876.0
N.M.C (%)	2.1		Water added (g)	**596**
Average (%)	2.1		**Water added (mL)**	**596**

Number of blows		62				
Number of layer		5				
Water Content Determination		Before Soaking		After Soaking		
Tare No		YY	-	BBC	-	
Mass of wet sample + Tare	g	1835	-	2103	-	
Mass of dry sample + Tare	g	1710	-	1965	-	
Mass of Tare	g	783	-	809	-	
Mass of water	g	125	-	138	-	
Mass of dry sample	g	927	-	1156	-	
Water content	%	13.5	-	11.9	-	
Average water Content	%	13.5		11.9		
Density determination						
Mould No		OMS				
Mass of mould + soil	g	10728		10647		
Mass of mould	g	5465		5465		
Mass of soil	g	5263		5182		
Volume of the mould	cm3	2305		2305		
Moist density	g/cm3	2.283		2.248		
Dry density	g/cm3	2.012		2.008		
Swell Determination						
Date		Hour		D.Gauge Reding		
Initial reading		96 hrs		12.89		
Final reading				13.27		
Height of the specimen				127		
Height of swell				0.38		
		Swelling(%)		**0.30**		

Observations

For the Lab

Lab. Technician	*Materials Engineer*	

STIRLING CIVIL ENGINEERING LTD P.O. BOX 703 KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date 9/Dec/23
		Penetration Date 10/Feb/24
Location:		Technician : : Lab team
Depth :		
Sample Description :	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 4% METAKAOLIN	

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	OMS		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.2052	0.2052	0.2052

Speed :... ... ...mm min.		Top		Bottom	
Penetration of the plunger (mm)	Time (s)	Reading $*10^3$mm	Force (KN)	Reading $*10^3$mm	Force (KN)
0	**0**	0	0.0	0	0.0
0.25	**12**	1	0.2	2	0.4
0.5	**24**	2	0.4	4	0.8
0.75	**35**	4	0.8	7	1.4
1	**47**	5	1.0	10	2.1
1.5	**71**	9	1.8	16	3.3
2	**94**	14	2.9	24	4.9
2.5	**118**	19	3.9	33	6.8
3	**142**	24	4.9	39	8.0
3.5	**165**	28	5.7	45	9.2
4	**189**	32	6.6	52	10.7
4.5	**213**	35	7.2	57	11.7
5	**236**	37	7.6	62	12.7
5.5	**260**	40	8.2	66	13.5
6	**283**	42	8.6	69	14.2
6.5	**307**	45	9.2	73	15.0
7	**331**	47	9.6	77	15.8
7.5	**354**	50	10.3	80	16.4

Observations

For the Contractor			
Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD P.O. BOX 795 ... (U)

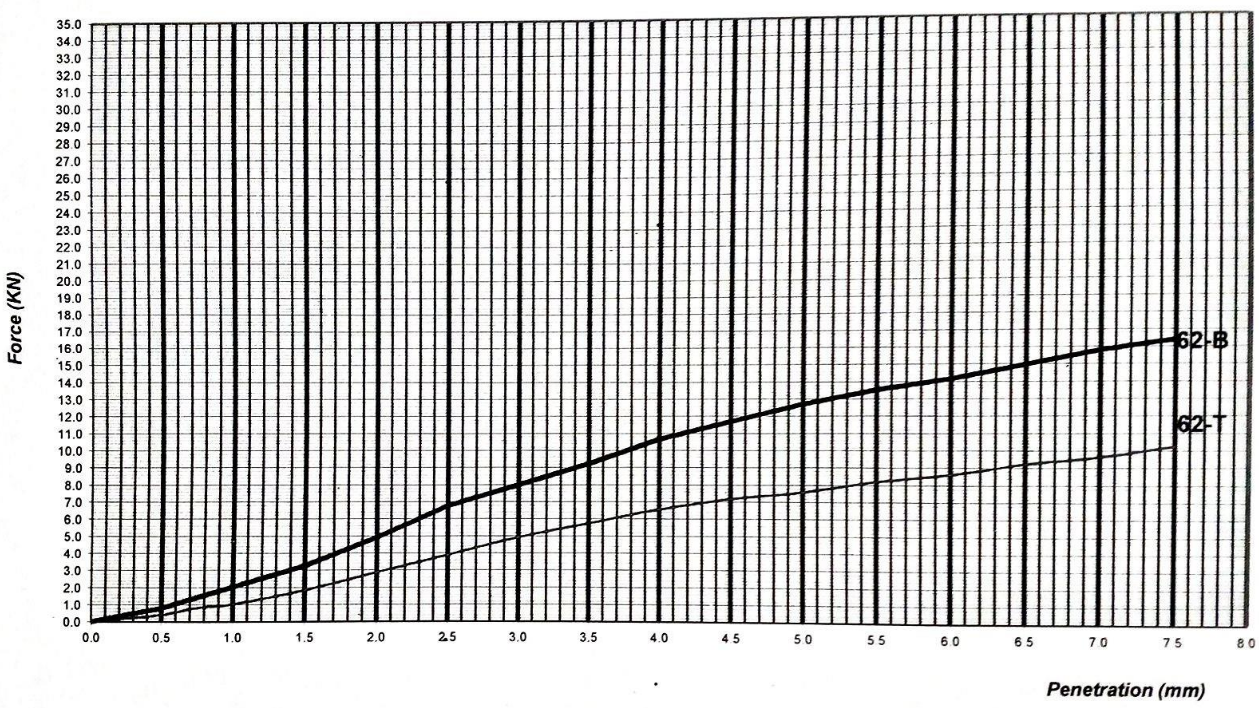
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date : 9/Dec/23
Location:		Testing Date : 10/Feb/24
Depth:		Technician : Lab team
Sample Description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 4% METAKAOLIN	

PENETRATION vs FORCE CURVE



	62 blows			
	Force		CBR	
	Bottom	Top	Bottom	Top
2.5 mm Penetration	6.8	3.9	51	29
5.0 mm Penetration	12.7	7.6	64	38
Average	9.7	5.7	57.4	33.7
Retained CBR	57.4			
Observations	CBR= 57.4			

For the Lab

Lab. Technician | *Materials Engineer*

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 708, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

SUMMARY OF TEST RESULTS FOR LATERATIC GRAVEL 3% CEMENT & 6% METAKAOLIN

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	30 BLOWS 95% COMPACTION			62	AVERAGE
3% CEMENT & 6% METAKAOLIN	LATERIC. GRAVEL STABILISED WITH 3% CEMENT & 6% METAKAOLIN	12/9/2023	100	97	79	48	40	26	18	2.16	42.8	28.4	14.4	7.1	2.033	12.3		50		0.63	0.63
			100	97	83	50	42	27	18	2.13	43.0	28.7	14.2	7.1	-	-	-	-	-	-	
			100	**96.94**	**80.93**	**48.86**	**40.62**	**26.72**	**18.21**	**2.14**	**42.9**	**28.6**	**14.3**	**7.1**	**2.033**	**12.3**		**50**		**0.63**	**0.63**
	AVERAGE		100	97	81	49	41	27	18	2.145	42.9	28.7	14.3	7.1	2.033	12.3	50			0.63	0.63

FOR LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD P.O. BOX 796, KAMPALA (U)

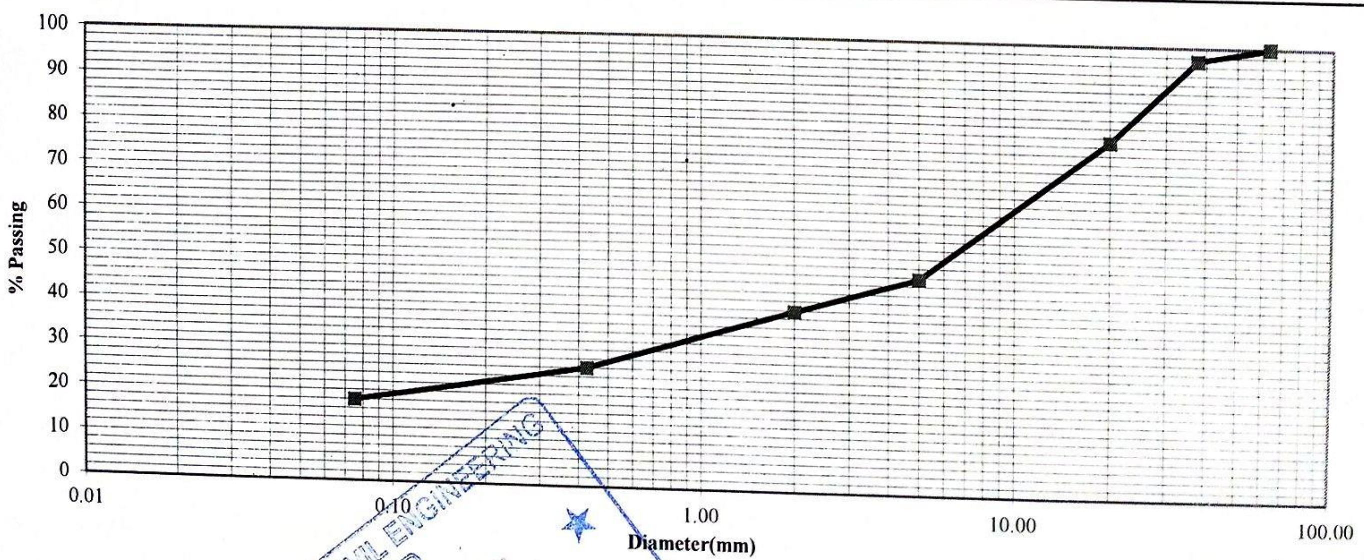
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	3% CEMENT & 6% METAKAOLIN	Dry wt. of sample before washing: (g)		5410.2
Depth: (m)		Dry wt. of sample after washing: (g)		4442.0
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 6% METAKAOLIN	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	**100**	100	100
37.5	151.7	2.8	**97**	80	100
20.0	986.7	18.2	**79**	60	95
5.0	1693.8	31.3	**48**	30	65
2.00	433.6	8.0	**40**	20	50
0.425	733.1	13.6	**26**	10	30
0.075	440.4	8.1	**18**	5	15
Total fines	970.9	17.9			
Bottom Pan	2.7				
Extracted fines	968.2				
Total sample	5410.2				
Grading Modulus		**2.16**			



FOR TESTING LAB

Lab Technician *Materials Engineer*

STIRLING CIVIL ENGINEERING LTD P.O. BOX 796, KAMPALA (U)

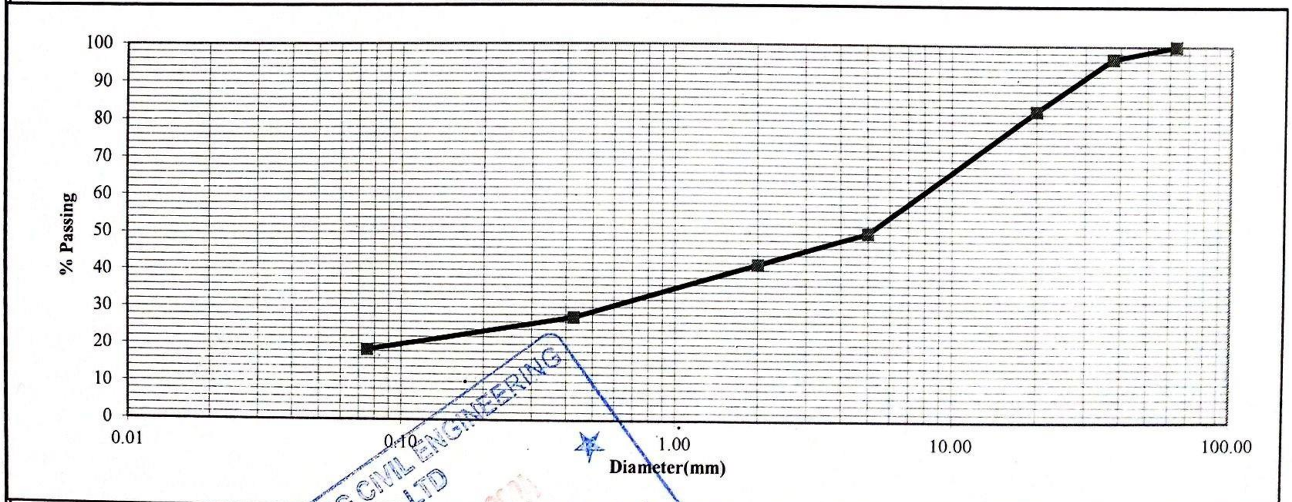
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	3% CEMENT & 6% METAKAOLIN	Dry wt. of sample before washing: (g)		4861.2
Depth: (m)		Dry wt. of sample after washing: (g)		3965.5
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 6% METAKAOLIN	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	Lab team

Sieve Size (mm)	Weight Retained (g)	Retained (%)	Passing (%)	Grading Limits (G60 & 80)	
63.0	0.0	0	**100**	100	100
37.5	161.2	3.3	**97**	80	100
20.0	670.3	13.8	**83**	60	95
5.0	1596.1	32.8	**50**	30	65
2.00	411.5	8.5	**42**	20	50
0.425	692.4	14.2	**27**	10	30
0.075	431.5	8.9	**18**	5	15
Total fines	898.2	18.5			
Bottom Pan	2.5				
Extracted fines	895.7				
Total sample	4861.2				
Grading Modulus		**2.13**			



FOR TESTING LAB

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 796, KAMPALA (U)

Lab Technician *Materials Engineer*

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	**PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS**

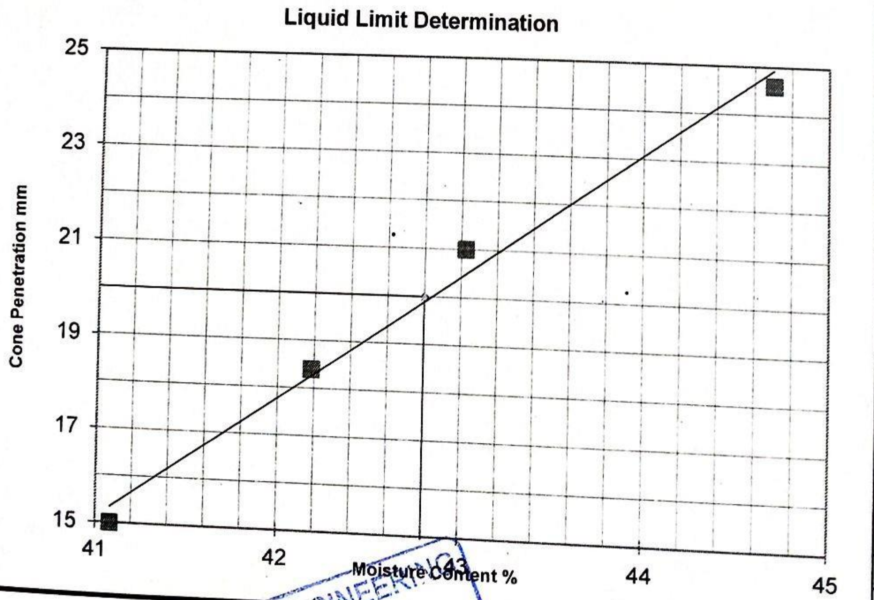
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	3% CEMENT & 6% METAKAOLIN	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	13/Feb/2024
LAYER	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 6% METAKAOLIN		

PLASTIC LIMIT	Test No.	JL	PL		Average
Mass of wet soil + container (g)		39.3	36.31		37.805
Mass of dry soil + container (g)		35.59	33.28		34.435
Mass of container (g)		22.54	22.61		22.575
Mass of moisture (g)		3.71	3.0		3.37
Mass of dry soil (g)		13.05	10.67		11.86
Moisture content %		28.4	28.4		28.4
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.0	18.4	21	24.6
penetration (mm)		15.0	18.4	21.0	24.6
AVERAGE		15.0	18.4	21.0	24.6
Container No.		A3	PI84	PI8	P135
Mass of wet soil + container (g)		53.18	49.24	45.84	59.68
Mass of dry soil + container (g)		39.73	36.72	34.06	44.11
Mass of container (g)		6.99	7.04	6.68	9.28
Mass of moisture (g)		13.45	12.52	11.78	15.57
Mass of dry soil (g)		32.74	29.68	27.38	15.57
Moisture content (%)		41.1	42.2	43.0	44.7
AVERAGE		41.1	42.2	43.0	44.7



Liquid limit (%)	42.8
Plastic limit (%)	28.4
Plasticity Index (%)	14.4
Linear shrinkage	
Trough No.	I
Trough length (cm)	14.0
Specimen length (cm)	13.0
L.shringage =	1.0
% L.shrinkage =	7.1

Remarks:

TESTING LAB

Materials Engineer.

Lab Technician

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	**PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS**

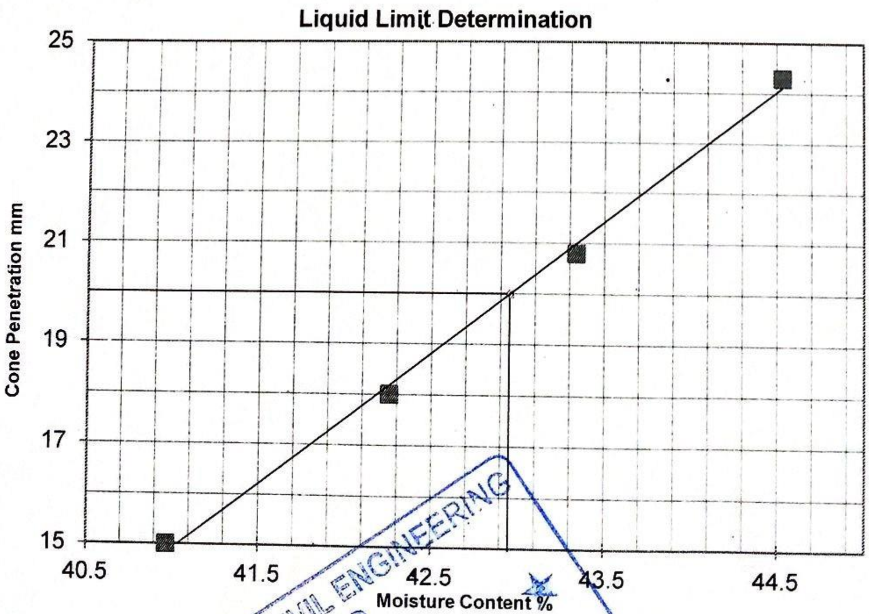
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	3% CEMENT & 6% METAKAOLIN	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	13/Feb/2024
LAYER	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 6% METAKAOLIN		

PLASTIC LIMIT	Test No.	P4	DT		Average
Mass of wet soil + container (g)		38.52	35.01		36.765
Mass of dry soil + container (g)		34.99	32.23		33.61
Mass of container (g)		22.78	22.5		22.64
Mass of moisture (g)		3.53	2.8		3.155
Mass of dry soil (g)		12.21	9.73		10.97
Moisture content %		28.9	28.6		28.7
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.0	18	20.8	24.3
penetration (mm)		15.0	18.0	20.8	24.3
AVERAGE		15.0	18.0	20.8	24.3
Container No.		P128	PI26	PIVPN	FORD
Mass of wet soil + container (g)		50.96	45.11	41.11	45.14
Mass of dry soil + container (g)		38.17	33.79	30.77	33.33
Mass of container (g)		6.95	7.00	6.91	6.81
Mass of moisture (g)		12.79	11.32	10.34	11.81
Mass of dry soil (g)		31.22	26.79	23.86	26.52
Moisture content (%)		41.0	42.3	43.3	44.5
AVERAGE		41.0	42.3	43.3	44.5



Liquid limit (%)	43.0
Plastic limit (%)	28.7
Plasticity Index (%)	14.2
Linear shrinkage	
Trough No.	I
Trough length (cm)	14.0
Specimen length (cm)	13.0
L.shringage =	1.0
% L.shrinkage =	7.1

Remarks:

TESTING LAB

Materials Engineer

Lab Technician

STIRLING CIVIL ENGINEERING LTD P.O. BOX 793 ... (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

Test Reference No.	Lab. Reference No.	Date Sampled	Date Tested	Technician
Mix	3% CEMENT & 6% METAKAOLIN.	9/Dec/23	24/Jan/24	Lab team
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 6% METAKAOLIN	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^3)
4.5	27	3	457	100	1,000

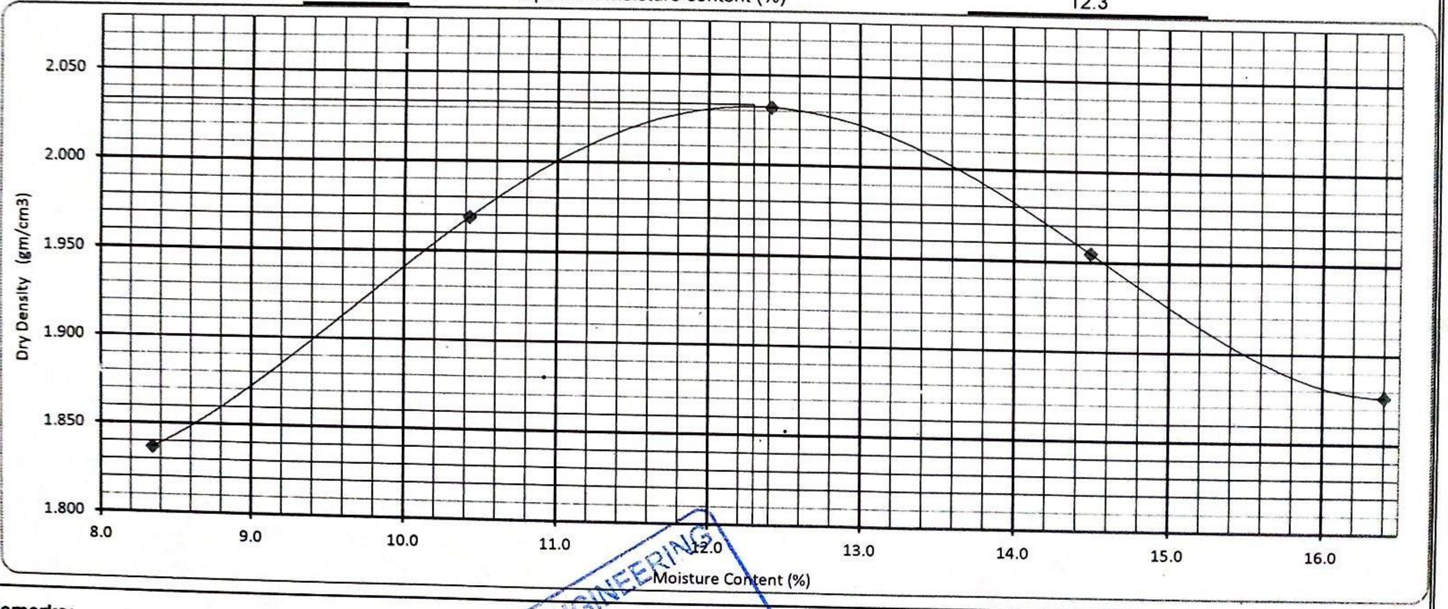
MOISTURE CONTENT DATA

Test No		1	2	3	4	5
Tin No.		A	A	A	A	A
Water Added	cm^3	160	220	280	340	400
Mass of Compacted soil + mould	gm	5,209	5,393	5,503	5,457	5,403
Mass of Mould	gm	3,219	3,219	3,219	3,219	3,219
Mass of Compacted soil	gm	1990	2174	2284	2238	2184
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	1.990	2.174	2.284	2.238	2.184

DATA FOR PROCTOR CURVE

Container No.		MANU	NM	MU	YY	YMC
Mass of wet soil + Container	gm	2,275.0	1,634.0	2,266.0	2,444.0	2,093.0
Mass of dry soil + container	gm	2,142.0	1,531.0	2,104.0	2,234.0	1,857.0
Mass of container	gm	548.0	543.0	799.0	785.0	418.0
Mass of water added	gm	133	103	162	210	236
Mass of dry soil	gm	1594	988	1305	1449	1439
Moisture content	%	8.3	10.4	12.4	14.5	16.4
Dry density	g/cm^3	1.837	1.969	2.032	1.955	1.876

Maximum dry density (gm/cm^3) 2.033 Optimum moisture content (%) 12.3



Remarks:

FOR TESTING LAB

Lab Technician	Materials Engineer		

STIRLING CIVIL ENGINEERING LTD P.O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference	Laboratory Reference No.:	Sampling Date :	9/Dec/23
Location	3% CEMENT & 6% METAKAOLIN	Casting date :	13/Dec/23
		Testing Date :	20/Dec/23
Sample Description	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 6% METAKAOLIN	Technician :	Lab team
		Volume of Mould used (m^3)	**2305**

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	Y6Y		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	2589		MDD (Mg/m^3)	2.033
Tin + oven dry soil sample (g)	2539		N.M.C (%)	2.9
Tin (g)	819		OMC (%)	12.3
Dry soil sample	1720		Added OMC (%)	9.4
Water (g)	50		Calculated dry wt of soil (g)	5825.6
N.M.C (%)	2.9		Water added (g)	**548**
Average (%)	2.9		**Water added (mL)**	**548**

Number of blows		**62**								
Number of layer		5								
Water Content Determination		Before Soaking		After Soaking						
Tare No		NBM	-	CR7	-					
Mass of wet sample + Tare	g	1729	-	2279	-					
Mass of dry sample + Tare	g	1622	-	2112	-					
Mass of Tare	g	790	-	770	-					
Mass of water	g	107	-	167	-					
Mass of dry sample	g	832	-	1342	-					
Water content	%	12.9	-	12.4	-					
Average water Content	%	12.9		12.4						
Density determination										
Mould No		AZ								
Mass of mould + soil	g	10790		10768						
Mass of mould	g	5521		5521						
Mass of soil	g	5269		5247						
Volume of the mould	cm3	2305		2305						
Moist density	g/cm3	2.286		2.276						
Dry density	g/cm3	2.025		2.024						
Swell Determination										
Date		Hour		D.Gauge Reding						
Initial reading		96 hrs		9.6						
Final reading				10.4						
Height of the specimen				127						
Height of swell				0.8						
		Swelling(%)		**0.63**						

Observations

For the Lab

Lab. Technician	*Materials Engineer*	

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 786, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date	9/Dec/23
Location:		Penetration Date	20/Dec/23
Depth :		Technician	: Lab team
Sample Description :	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 6% METAKAOLIN		

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	AZ		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.2052	0.2052	0.2052

Speed : ………..mm/min.

Penetration of the plunger (mm)	Time (s)	Top Reading $*10^3$mm	Top Force (KN)	Bottom Reading $*10^3$mm	Bottom Force (KN)
0	**0**	0	0.0	0	0.0
0.25	**12**	1	0.2	3	0.6
0.5	**24**	3	0.6	10	2.1
0.75	**35**	5	1.0	12	2.5
1	**47**	9	1.8	14	2.9
1.5	**71**	11	2.3	20	4.1
2	**94**	19	3.9	25	5.1
2.5	**118**	24	4.9	32	6.6
3	**142**	28	5.7	37	7.6
3.5	**165**	31	6.4	41	8.4
4	**189**	34	7.0	45	9.2
4.5	**213**	36	7.4	49	10.1
5	**236**	38	7.8	50	10.3
5.5	**260**	41	8.4	53	10.9
6	**283**	44	9.0	56	11.5
6.5	**307**	46	9.4	58	11.9
7	**331**	48	9.8	60	12.3
7.5	**354**	51	10.5	62	12.7

Observations

For the Contractor

Lab. Technician | Materials Engineer

STIRLING CIVIL ENGINEERING LTD P.O. BOX 793, ...

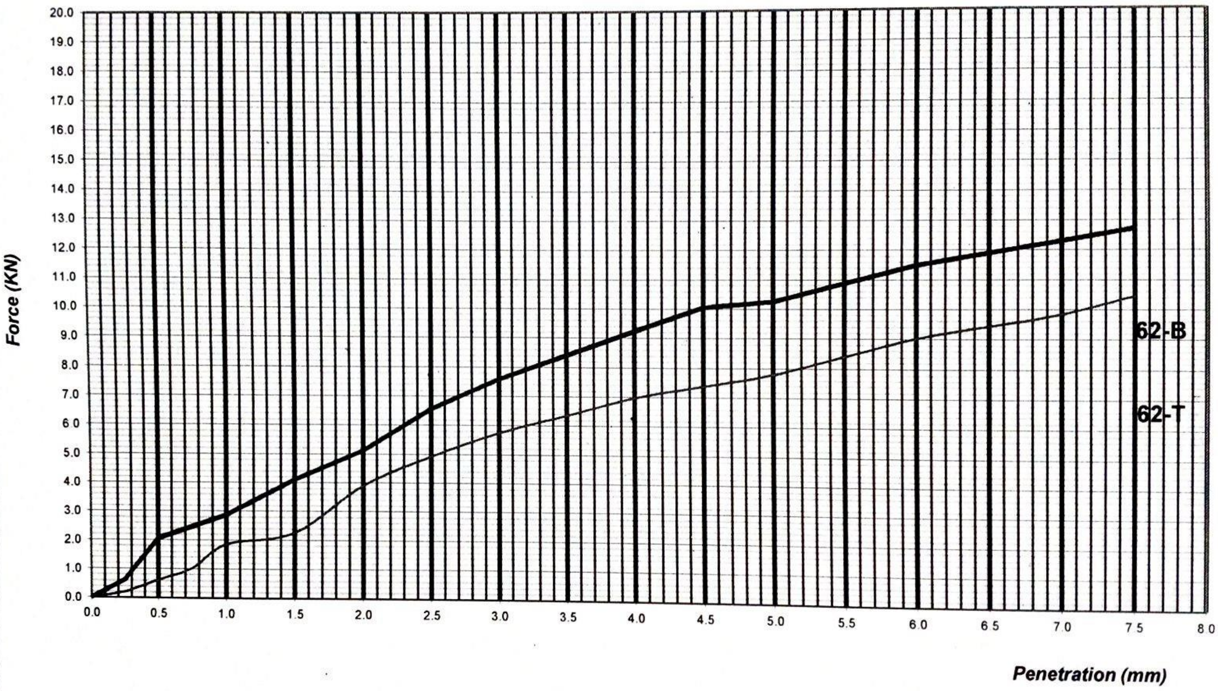
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date : 9/Dec/23
Location:		Testing Date : 20/Dec/23
Depth:		Technician : Lab team
Sample Description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 6% METAKAOLIN	

PENETRATION vs FORCE CURVE



	62 blows											
	Force		CBR									
	Bottom	Top	Bottom	Top								
2.5 mm Penetration	6.6	4.9	50	37								
5.0 mm Penetration	10.3	7.8	51	39								
Average	8.4	6.4	50.5	38.1								
Retained CBR	50.5											

Observations

CBR= 50.5

For the Lab

Lab. Technician | *Materials Engineer*

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 796, KAMPALA

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT: PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

SUMMARY OF TEST RESULTS FOR LATERATIC GRAVEL 3% CEMENT & 8% METAKAOLIN

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	62 BLOWS OF COMPACTION	62	AVERAGE
3% CEMENT & 8% METAKAOLIN	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 8% METAKAOLIN	12/9/2023	100	100	98	74	56	38	26	1.80	41.8	25.7	16.1	8.2	2.022	13.4	45	0.75	0.75
			100	100	100	66	51	38	31	1.80	41.7	25.4	16.3	8.2	-	-	-	-	
			100	**100**	**98.69**	**70.26**	**53.58**	**37.98**	**28.59**	**1.80**	**41.8**	**25.6**	**16.2**	**8.2**	**2.022**	**13.4**	**45**	**0.75**	**0.75**
	AVERAGE		**100**	**100**	**99**	**70**	**54**	**38**	**29**	**1.799**	**41.8**	**25.4**	**16.2**	**8.2**	**2.022**	**13.4**	**45**	**0.75**	**0.75**

FOR LAB

Lab Technician

Materials Engineer

STIRLING CIVIL ENGINEERING LTD
P. O. BOX 796, KAMPALA (U)

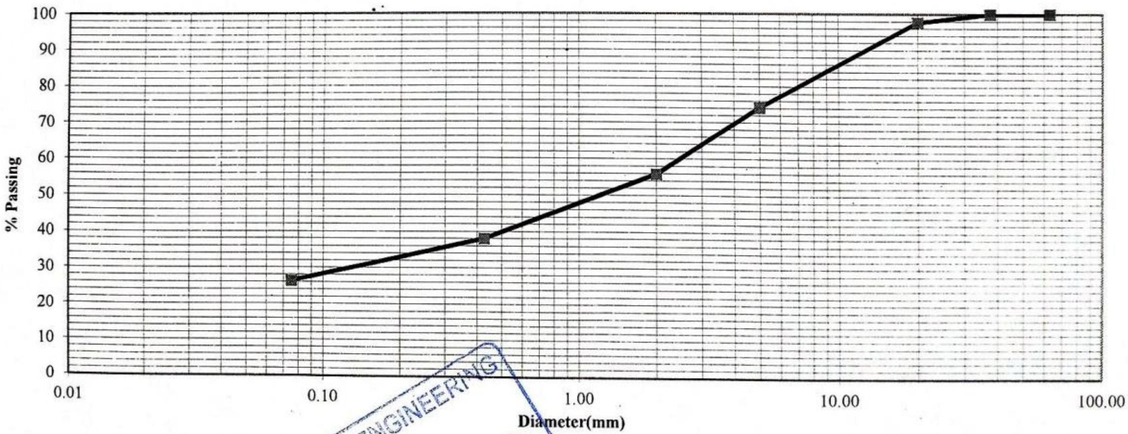
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	3% CEMENT & 8% METAKAOLIN	Dry wt. of sample before washing: (g)		5024.7
Depth: (m)		Dry wt. of sample after washing: (g)		3717.3
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 8% METAKAOLIN	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	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	117.3	2.3	**98**	60	95
5.0	1178.6	23.5	**74**	30	65
2.00	924.4	18.4	**56**	20	50
0.425	892.5	17.8	**38**	10	30
0.075	588.6	11.7	**26**	5	15
Total fines	1323.3	26.3			
Bottom Pan	15.9				
Extracted fines	1307.4				
Total sample	5024.7				
Grading Modulus		**1.80**			



FOR TESTING LAB

Lab Technician *Materials Engineer*

STIRLING CIVIL ENGINEERING LTD P.O. BOX 786, KAMPALA (U)

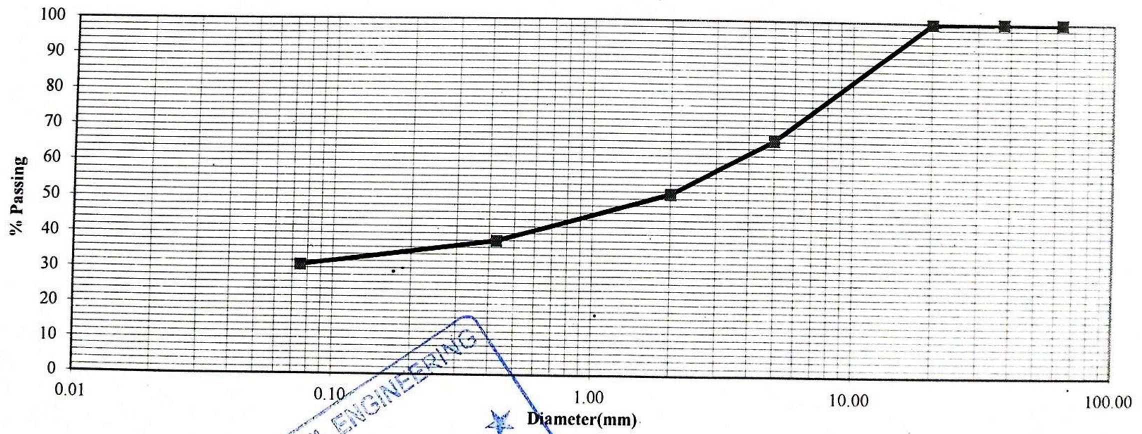
INSTITUTION	STUDENTS NAMES	CONTRACTOR
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT : PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

PARTICLE SIZE DISTRIBUTION (BS 1377 - 2 - 90)

Test Reference No.:		Lab. Refernece No.:		
Location :(km)	3% CEMENT & 8% METAKAOLIN	Dry wt. of sample before washing: (g)		4956.2
Depth: (m)		Dry wt. of sample after washing: (g)		3448.2
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 8% METAKAOLIN	Date Sampled:	Date Tested:	Technician
		9/Dec/2023	24/Jan/2024	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	14.5	0.3	**100**	60	95
5.0	1655.2	33.4	**66**	30	65
2.00	742.1	15.0	**51**	20	50
0.425	665.1	13.4	**38**	10	30
0.075	350.8	7.1	**31**	5	15
Total fines	1528.5	30.8			
Bottom Pan	20.5				
Extracted fines	1508.0				
Total sample	4956.2				
Grading Modulus		**1.80**			



FOR TESTING LAB

Lab Technician | *Materials Engineer*

STIRLING CIVIL ENGINEERING LTD P.O. BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

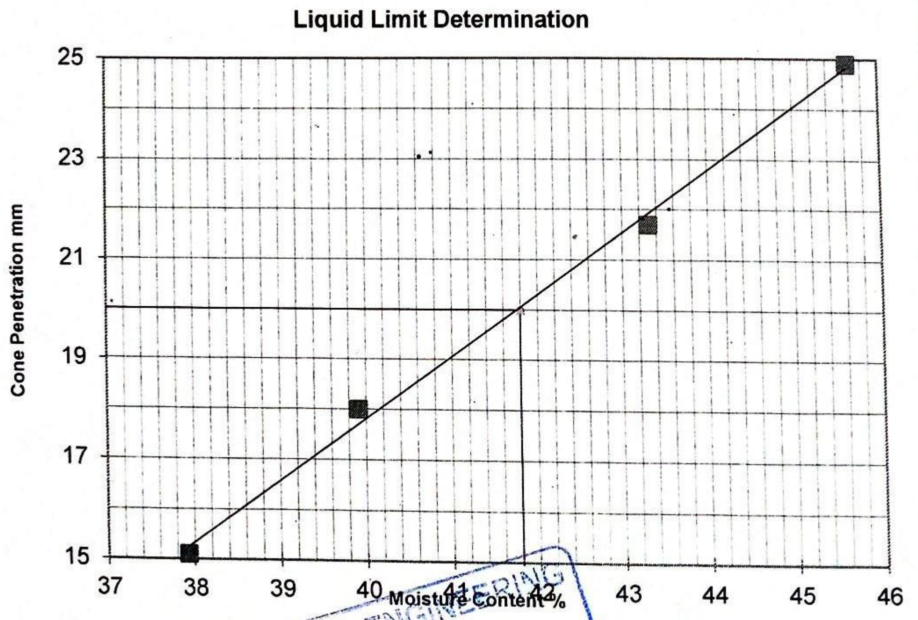
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	3% CEMENT & 8% METAKAOLIN	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	13/Feb/2024
LAYER	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 8% METAKAOLIN		

PLASTIC LIMIT	Test No.	4Z	D		Average
Mass of wet soil + container (g)		40.65	39.05		39.85
Mass of dry soil + container (g)		36.64	35.11		35.875
Mass of container (g)		21.04	19.8		20.42
Mass of moisture (g)		4.01	3.9		3.975
Mass of dry soil (g)		15.6	15.31		15.455
Moisture content %		25.7	25.7		25.7
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.1	18	21.7	24.9
penetration (mm)		15.1	18.0	21.7	24.9
AVERAGE		15.1	18.0	21.7	24.9
Container No.		P152	P112	P182	P12H
Mass of wet soil + container (g)		68.27	62.51	70.18	68.47
Mass of dry soil + container (g)		51.46	46.65	51.13	50.67
Mass of container (g)		7.14	6.91	7.14	11.67
Mass of moisture (g)		16.81	15.86	19.05	17.8
Mass of dry soil (g)		44.32	39.74	43.99	39
Moisture content (%)		37.9	39.9	43.3	45.6
AVERAGE		37.9	39.9	43.3	45.6



Liquid limit (%)	41.8
Plastic limit (%)	25.7
Plasticity Index (%)	16.1
Linear shrinkage	
Trough No.	2
Trough length (cm)	14.0
Specimen length (cm)	12.9
L.shringage =	1.2
% L.shrinkage =	8.2

Remarks:

TESTING LAB

Materials Engineer

Lab Technician

STIRLING CIVIL ENGINEERING LTD
P.O. BOX 795, KAMPALA (U)

INSTITUTION	STUDENTS	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	**PARTIAL.REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS**

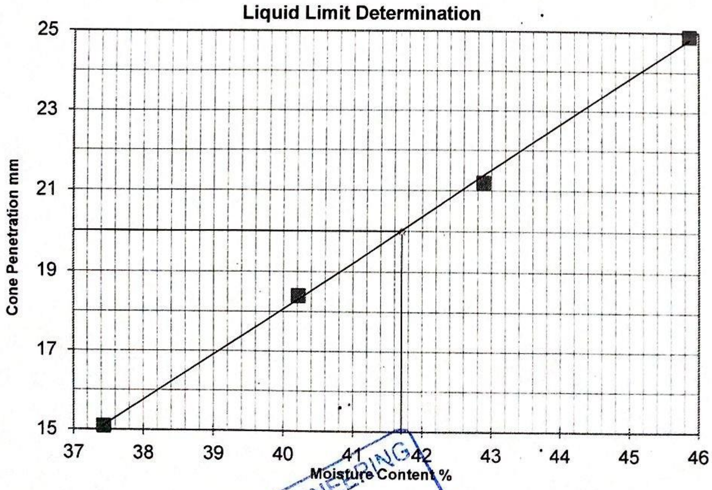
ATTERBERG LIMITS

Liquid limit (cone penotrometer) and plastic limit

Test Reference No.:	Lab. Reference No.:	Technician:	Lab Team
Location	3% CEMENT & 8% METAKAOLIN	Sample Date	9/Dec/2023
Test method	BS 1377: Part 2, 1990:4.3/4.4	Test Date	13/Feb/2024
LAYER	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 8% METAKAOLIN		

PLASTIC LIMIT	Test No.	I8	TI		Average
Mass of wet soil + container (g)		42.79	38.96		40.875
Mass of dry soil + container (g)		38.02	35		36.51
Mass of container (g)		19.32	19.38		19.35
Mass of moisture (g)		4.77	4.0		4.365
Mass of dry soil (g)		18.7	15.62		17.16
Moisture content %		25.5	25.4		25.4
AVERAGE					

LIQUID LIMIT	Test No	1	2	3	4
Initial gauge reading (mm)		0	0	0	0
Final gauge reading (mm)		15.1	18.4	21.2	24.9
penetration (mm)		15.1	18.4	21.2	24.9
AVERAGE		15.1	18.4	21.2	24.9
Container No.		4B	AX	PIB6	A6
Mass of wet soil + container (g)		65.98	62.93	76.49	65.70
Mass of dry soil + container (g)		49.84	46.91	55.67	47.22
Mass of container (g)		6.72	7.07	7.12	6.93
Mass of moisture (g)		16.14	16.02	20.82	18.48
Mass of dry soil (g)		43.12	39.84	48.55	40.29
Moisture content (%)		37.4	40.2	42.9	45.9
AVERAGE		37.4	40.2	42.9	45.9



Liquid limit (%)	41.7
Plastic limit (%)	25.4
Plasticity Index (%)	16.3
Linear shrinkage	
Trough No.	2
Trough length (cm)	14.0
Specimen length (cm)	12.9
L.shringage =	1.2
% L.shrinkage =	8.2

Remarks:

TESTING LAB

Materials Engineer.

Lab Technician

CIVIL ENGINEERING LTD P.O. BOX 793, KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PROJECT:	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

Test Reference No.	Lab. Reference No.	Date Sampled	Date Tested	Technician
Mix	3% CEMENT & 8% METAKAOLIN	9/Dec/23	24/Jan/24	Lab team
Material description:	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 8% METAKAOLIN	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^3)
4.5	27	3	457	100	1,000

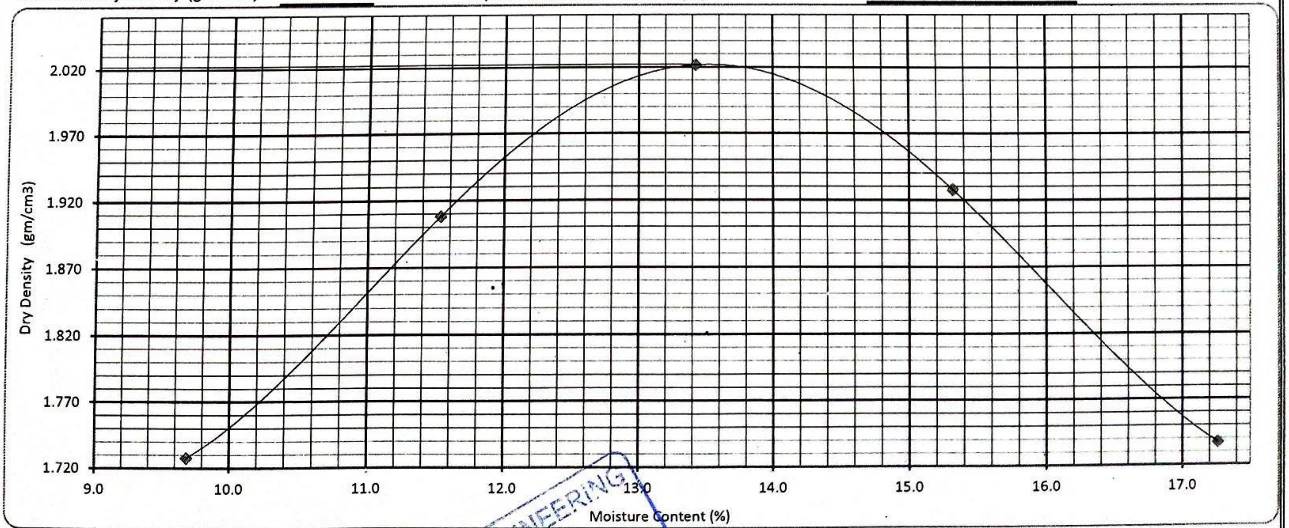
MOISTURE CONTENT DATA

Test No.		1	2	3	4	5
Tin No.		A	A	A	A	A
Water Added	cm^3	180	280	380	480	580
Mass of Compacted soil + mould	gm	5,960	6,193	6,358	6,288	6,102
Mass of Mould	gm	4,065	4,065	4,065	4,065	4,065
Mass of Compacted soil	gm	1895	2128	2293	2223	2037
Volume of mould	cm^3	1,000	1,000	1,000	1,000	1,000
Wet density of soil	g/cm^3	1.895	2.128	2.293	2.223	2.037

DATA FOR PROCTOR CURVE

Container No.		HED	FDC	KT	BOJ	BA
Mass of wet soil + Container	gm	2,869.0	3,015.0	2,735.0	2,795.0	2,645.0
Mass of dry soil + container	gm	2,685.0	2,786.0	2,506.0	2,530.0	2,369.0
Mass of container	gm	785.0	800.0	800.0	800.0	770.0
Mass of water added	gm	184	229	229	265	276
Mass of dry soil	gm	1900	1986	1706	1730	1599
Moisture content	%	9.7	11.5	13.4	15.3	17.3
Dry density	g/cm^3	1.728	1.908	2.022	1.928	1.737

Maximum dry density (gm/cm^3) 2.022 Optimum moisture content (%) 13.4



Remarks:

FOR TESTING LAB

Lab Technician	Materials Engineer		

STIRLING CIVIL ENGINEERING LTD P.O. BOX 795, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS 1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date :	9/Dec/23
Location:	3% CEMENT & 8% METAKAOLIN	Casting date :	28/Jan/24
		Testing Date :	11/Feb/24
Sample Description	LATERIC GRAVEL STABILISED WITH 3% CEMENT & 8% METAKAOLIN	Technician :	Lab team
		Volume of Mould used (m^3)	**2305**

Natural moisture of air dried sample			**Volume of water added**	
Tin No.	NMT		Mass of air dried soil (g)	6000
Tin + air dried soil sample (g)	3280		MDD (Mg/m^3)	2.022
Tin + oven dry soil sample (g)	3195		N.M.C (%)	3.5
Tin (g)	765		OMC (%)	13.4
Dry soil sample	2430		Added OMC (%)	9.9
Water (g)	85		Calculated dry wt of soil (g)	5790.1
N.M.C (%)	3.5		Water added (g)	574
Average (%)	3.5		**Water added (mL)**	**574**

Number of blows		62	
Number of layer		5	
Water Content Determination		Before Soaking	After Soaking
Tare No		Z6T -	NMT -
Mass of wet sample + Tare	g	3005 -	2661 -
Mass of dry sample + Tare	g	2750 -	2390 -
Mass of Tare	g	815 -	769 -
Mass of water	g	255 -	271 -
Mass of dry sample	g	1935 -	1621 -
Water content	%	13.2 -	16.7 -
Average water Content	%	13.2	16.7
Density determination			
Mould No		2I	
Mass of mould + soil	g	12595	12780
Mass of mould	g	7365	7365
Mass of soil	g	5230	5415
Volume of the mould	cm3	2305	2305
Moist density	g/cm3	2.269	2.349
Dry density	g/cm3	2.005	2.013
Swell Determination			
Date		Hour	D.Gauge Reding
Initial reading		96 hrs	20.14
Final reading			21.09
Height of the specimen			127
Height of swell			0.95
		Swelling(%)	**0.75**

Observations	

For the Lab

Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING LTD P. O. BOX 796, KAMPALA (U)

Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference	Laboratory Reference No.:	Sampling Date	9/Dec/23
Location:		Penetration Date	11/Feb/24
Depth :		Technician	: : Lab team
Sample Description :	: LATERIC GRAVEL STABILISED WITH 3% CEMENT & 8% METAKAOLIN		

Number of blows per layer	62		
Number of layers	5	5	5
Mould No	2I		
Capacity of the Proving Ring (KN)	50	50	50
Proving Ring Constant (KN/div.)	0.2052	0.2052	0.2052

Speed : ... ...mm/min.		Top		Bottom									
Penetration of the plunger (mm)	Time (s)	Reading *10³mm	Force (KN)	Reading *10³mm	Force (KN)								
0	**0**	0	0.0	0	0.0								
0.25	**12**	4	0.8	2	0.4								
0.5	**24**	6	1.2	5	1.0								
0.75	**35**	8	1.6	8	1.6								
1	**47**	13	2.7	13	2.7								
1.5	**71**	19	3.9	16	3.3								
2	**94**	24	4.9	21	4.3								
2.5	**118**	28	5.7	26	5.3								
3	**142**	34	7.0	31	6.4								
3.5	**165**	37	7.6	35	7.2								
4	**189**	40	8.2	40	8.2								
4.5	**213**	42	8.6	45	9.2								
5	**236**	44	9.0	49	10.1								
5.5	**260**	46	9.4	52	10.7								
6	**283**	48	9.8	57	11.7								
6.5	**307**	50	10.3	60	12.3								
7	**331**	52	10.7	64	13.1								
7.5	**354**	53	10.9	67	13.7								

Observations

	For the Contractor		
Lab. Technician	Materials Engineer		

STIRLING CIVIL ENGINEERING LTD
P.O. BOX ... KAMPALA (U)

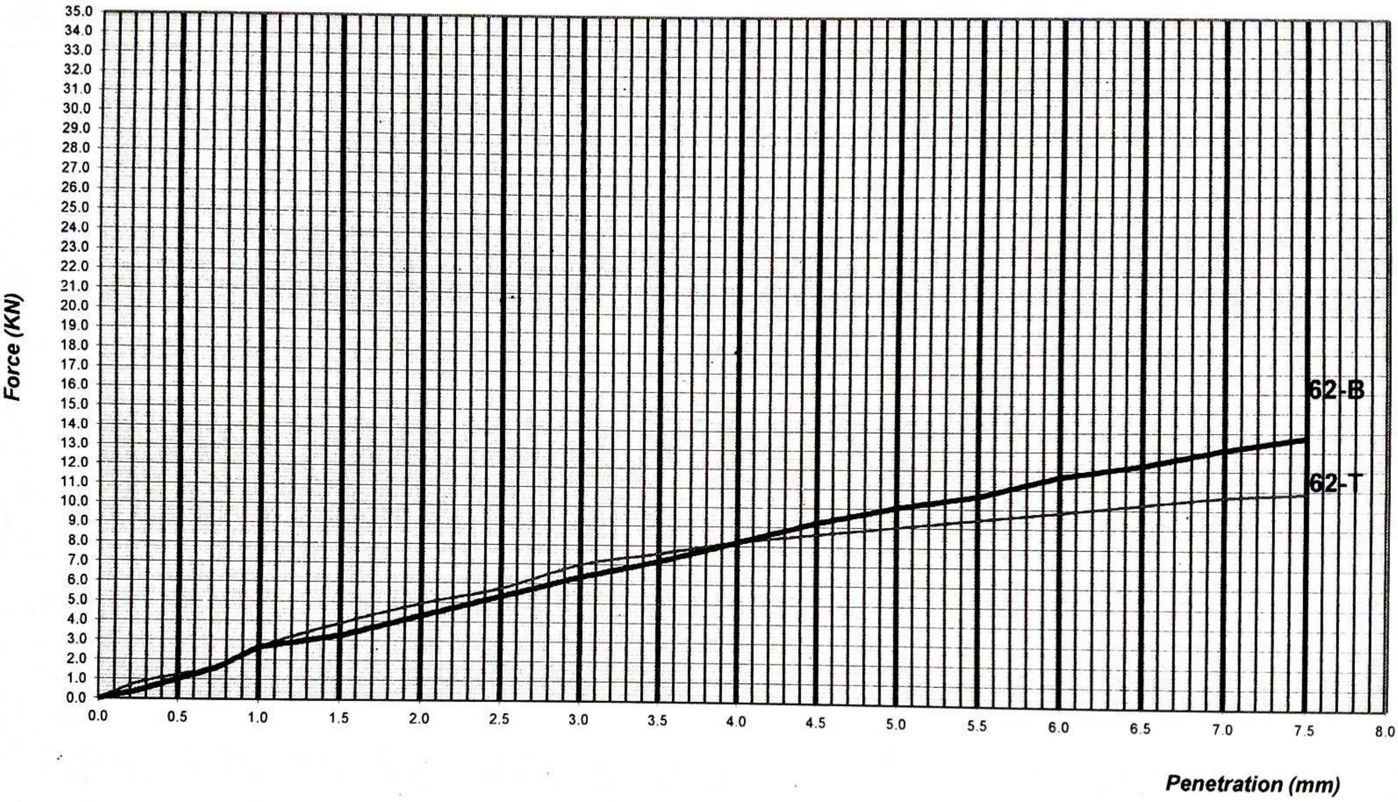
Institution	Students Names	Testing Lab
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling

PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS

CALIFORNIA BEARING RATIO TEST (BS1377 Part 4)

Test sample reference :	Laboratory Reference No.:	Sampling Date : 9/Dec/23
Location:		Testing Date : 11/Feb/24
Depth:		Technician : Lab team
Sample Description: LATERIC GRAVEL STABILISED WITH 3% CEMENT & 8% METAKAOLIN		

PENETRATION vs FORCE CURVE



	62 blows														
	Force		CBR												
	Bottom	Top	Bottom	Top											
2.5 mm Penetration	5.3	5.7	40	43											
5.0 mm Penetration	10.1	9.0	50	45											
Average	7.7	7.4	45.3	44.3											
Retained CBR	45.3														
Observations	CBR= 45.3														

For the Lab

Lab. Technician	*Materials Engineer*		

STIRLING CIVIL ENGINEERING
P.O. BOX 703, KAMPALA

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling
PROJECT	THE PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS	

STABLISED CBR

(BS 1924 PART 2 1)

STABILISED WITH 5% METAKAOLINE ONLY

M/c of air dried sample				M/c After Mixing			
Tin No	NBM			Stabliser	5% METKAOLINE ONLY		
Tin + Wet soil gm	1713			Content	5.0		
Tin + Dry Soil gm	1693			Tin No.	BA		
Tin gm	797			Tin + Wet Soil	2,395.0		
Water gm	20.0			Tin + Dry Soil	2,215.0		
Dry Soil gm	896.0			Tin	768.0		
M/c %	**2.2**			**Water**	**180.0**		
Av. M/c %	**2.2**			**Dry Soil**	**1,447.0**		
				M/c	**12.4**		

(a)MDD	**2.152**	**kg/m3**	**(b)Air Dry M/c**	**2.2**	**%**
(c)WD	**2,174**	**kg/m3**	**(e)M/c to add**	**7.9**	**%**
(d)OMC	**10.1**	**%**	**(F) volume**	**2.305**	

Date prepared 27/Jan/24 **Date immerse** 3/Feb/24 **Date tested** 10/Feb/24

Mould No.			
Factor(f)	2.305		
(h)Wet Soil to fill mould c x f x %comp	5,010.0		
(j) Wt of air dried soil	6,000		
Air dry M/c	2.2		
(k) soil dry wt (100j/100+b)	5,869.0		
Stabliser	5% METKAOLINE ONLY		
(m)Stablisers content %	5.0		
(n) Stabliser to add k x(m/100)	293.4		
Water Addition((j+n)x(d-b))/(100+b)	484.3		
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	7 DAYS AIR TIGHT, 7 DAYS SOAKED	
Stabliser	5% METKAOLINE ONLY	5% METKAOLINE ONLY	
Content %	5.0	5.0	
Mould g	A	B	
Wet Soil g	5,553.4	5,486.0	
Compaction M/c %	12.4	12.4	
Dry density kg/m3	2.143	2.117	
%Compaction	99.6	98.4	
FORCE	2.1	2.5	
UCS	0.113	0.135	0.12

STIRLING CIVIL ENGINEERING LTD P.O. BOX ... KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling
PROJECT	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS	

STABLISED CBR

(BS 1924 PART 2 1)

STABILISED WITH 5% METAKAOLINE ONLY

M/c of air dried sample

Tin No.	NBM	
Tin + Wet soil gm	1713	
Tin + Dry Soil gm	1693	
Tin gm	797	
Water gm	20.0	
Dry Soil gm	896.0	
M/c %	**2.2**	
Av. M/c %	**2.2**	

M/c After Mixing

Stabliser	5% METKAOLINE ONLY		
Content	5.0		
Tin No.	BA		
Tin + Wet Soil	2,395.0		
Tin + Dry Soil	2,215.0		
Tin	768.0		
Water	**180.0**		
Dry Soil	**1,447.0**		
M/c	**12.4**		

(a)MDD 2.152 kg/m3

(c)WD 2,174 kg/m3

(d)OMC 10.1 %

(b)Air Dry M/c 2.2 %

(e)M/c to add 7.9 %

(F) volume 2.305

Date prepared 27/Jan/24 **Date immerse** 3/Feb/24 **Date tested** 10/Feb/24

Mould No.			
Factor(f)	2.305		
(h)Wet Soil to fill mould c x f x %comp	5,010.0		
(j) Wt of air dried soil	6,000		
Air dry M/c	2.2		
(k) soil dry wt (100j/100+b)	5,869.0		
Stabliser	5% METKAOLINE ONLY		
(m)Stablisers content %	5.0		
(n) Stabliser to add k x(m/100)	293.4		
Water Addition((j+n)x(d-b))/(100+b)	484.3		
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	7 DAYS AIR TIGHT, 7 DAYS SOAKED	
Stabliser	5% METKAOLINE ONLY	5% METKAOLINE ONLY	
Content %	5.0	5.0	
Mould g	A	B	
Wet Soil g	5,553.4	5,486.0	
Compaction M/c %	12.4	12.4	
Dry density kg/m3	2.143	2.117	
%Compaction	99.6	98.4	
FORCE	2.1	2.5	
UCS	0.113	0.135	**0.12**

STIRLING CIVIL ENGINEERING LTD P.O. BOX 763, KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling
PROJECT	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS	

STABLISED CBR

(BS 1924 PART 2 1)

3% CEMENT & 4% METAKAOLINE

M/c of air dried sample

Tin No.	ZION	
Tin + Wet soil gm	2240	
Tin + Dry Soil gm	2212	
Tin gm	436	
Water gm	28.0	
Dry Soil gm	1,776.0	
M/c %	**1.6**	
Av. M/c %	**1.6**	

M/c After Mixing

Stabliser	2% CEMENT & 3% METAKAOLIN		
Content	2 0		
Tin No.	Y6Y		
Tin + Wet Soil	2,141.0		
Tin + Dry Soil	1,984.0		
Tin	820.0		
Water	**157.0**		
Dry Soil	**1,164.0**		
M/c	**13.5**		

(a)MDD	**2.138**	**kg/m3**	**(b)Air Dry M/c**	**1.6**	**%**
(c)WD	**2,587**	**kg/m3**	**(e)M/c to add**	**10.5**	**%**
(d)OMC	**12.1**	**%**	**(F) volume**	**2.305**	

Date prepared 27/Jan/24 **Date immerse** 3/Feb/24 **Date tested** 10/Feb/24

Mould No.			
Factor(f)	2.305		
(h)Wet Soil to fill mould c x f x %comp	5,963.0		
(j) Wt of air dried soil	6,000		
Air dry M/c	1.6		
(k) soil dry wt (100j/100+b)	5,906.9		
Stabliser	2% CEMENT & 3% METAKAOLIN		
(m)Stablisers content %	2.0		
(n) Stabliser to add k x(m/100)	118.1		
Water Addition((j+n)x(d-b))/(100+b)	633.8		
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 AIR TIGHT, 7 DAYS SOAKED	
Stabliser	2% CEMENT & 3% METAKAOLIN	2% CEMENT & 3% METAKAOLIN	
Content %	2.0	2.0	
Mould g	A	B	
Wet Soil g	5,293.0	5,199.0	
Compaction M/c %	13.5	13.5	
Dry density kg/m3	2.023	1.987	
%Compaction	94.6	93.0	
FORCE	26.5	25.1	
UCS (F/A)	1.452	1.379	1.42

STIRLING CIVIL ENGINEERING LTD BOX 796, KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling
PROJECT	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS	

STABLISED CBR

(BS 1924 PART 2 1)

3% CEMENT & 2% METAKAOLIN

M/c of air dried sample		
Tin No.	BA	
Tin + Wet soil gm	2546	
Tin + Dry Soil gm	2510	
Tin gm	768	
Water gm	36.0	
Dry Soil gm	1,742.0	
M/c %	**2.1**	
Av. M/c %	**2.1**	

M/c After Mixing			
Stabliser	3% CEMENT & 2% METAKAOLIN		
Content	3.0		
Tin No.	YY		
Tin + Wet Soil	1,835.0		
Tin + Dry Soil	1,710.0		
Tin	783.0		
Water	**125.0**		
Dry Soil	**927.0**		
M/c	**13.5**		

(a)MDD	**2.071**	**kg/m3**	**(b)Air Dry M/c**	**2.1**	**%**
(c)WD	**2,527**	**kg/m3**	**(e)M/c to add**	**10.1**	**%**
(d)OMC	**12.2**	**%**	**(F) volume**	**2.305**	

Date prepared 27/Jan/24 **Date immerse** 3/Feb/24 **Date tested** 10/Feb/24

Mould No.			
Factor(f)	2.305		
(h)Wet Soil to fill mould c x f x %comp	5,823.9		
(j) Wt of air dried soil	6,000		
Air dry M/c	2.1		
(k) soil dry wt (100j/100+b)	5,878.5		
Stabliser	3% CEMENT & 2% METAKAOLIN		
(m)Stablisers content %	3.0		
(n) Stabliser to add k x(m/100)	176.4		
Water Addition((j+n)x(d-b))/(100+b)	613.2		
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 AIR TIGHT, 7 DAYS SOAKED	
Stabliser	3% CEMENT & 2% METAKAOLIN	3% CEMENT & 2% METAKAOLIN	
Content %	3.0	3.0	
Mould g	A	B	
Wet Soil g	5,476.0	5,452.0	
Compaction M/c %	13.5	13.5	
Dry density kg/m3	2.093	2.084	
%Compaction	101.1	100.6	
FORCE	19.1	18.1	
UCS	1.047	0.990	1.02

STIRLING CIVIL ENGINEERING LTD P.O. BOX 736, KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling
PROJECT	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS	

STABLISED CBR

(BS 1924 PART 2 1)

3% CEMENT ONLY

M/c of air dried sample			
Tin No		K26	
Tin + Wet soil	gm	3125	
Tin + Dry Soil	gm	3026	
Tin	gm	805	
Water	gm	99.0	
Dry Soil	gm	2,221.0	
M/c	**%**	**4.5**	
Av. M/c	**%**	**4.5**	

M/c After Mixing				
Stabliser	3% CEMENT ONLY			
Content	3.0			
Tin No.	HOY			
Tin + Wet Soil	1,965.0			
Tin + Dry Soil	1,833.0			
Tin	758.0			
Water	**132.0**			
Dry Soil	**1,075.0**			
M/c	**12.3**			

(a)MDD	**2.097**	**kg/m3**	**(b)Air Dry M/c**	**4.5**	**%**
(c)WD	**2,579**	**kg/m3**	**(e)M/c to add**	**7.8**	**%**
(d)OMC	**12.3**	**%**	**(F) volume**	**2.305**	

Date prepared 27/Jan/24 **Date immerse** 3/Feb/24 **Date tested** 10/Feb/24

Mould No.			
Factor(f)	2.305		
(h)Wet Soil to fill mould c x f x %comp	5,945.3		
(j) Wt of air dried soil	6,000		
Air dry M/c	4.5		
(k) soil dry wt (100j/100+b)	5,744.0		
Stabliser	3% CEMENT ONLY		
(m)Stablisers content %	3.0		
(n) Stabliser to add k x(m/100)	172.3		
Water Addition((j+n)x(d-b))/(100+b)	463.4		
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 AIR TIGHT, 7 DAYS SOAKED	
Stabliser	3% CEMENT ONLY	3% CEMENT ONLY	
Content %	3.0	3.0	
Mould g	A	B	
Wet Soil g	5,563.0	5,601.0	
Compaction M/c %	12.3	12.3	
Dry density kg/m3	2.150	2.164	
%Compaction	102.5	103.2	
FORCE	12.1	12.5	
UCS	0.664	0.687	**0.68**

STIRLING CIVIL ENGINEERING LTD P.O. BOX 700 KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY A Centre of Excellence in the Heart of Africa	AGABA JOEL & KAKOOZA PAUL	Stirling
PROJECT	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS	

STABLISED CBR

(BS 1924 PART 2 1)

3% CEMENT & 6% METAKAOLIN

M/c of air dried sample			
Tin No		NMT	
Tin + Wet soil	gm	3280	
Tin + Dry Soil	gm	3195	
Tin	gm	765	
Water	gm	85.0	
Dry Soil	gm	2,430.0	
M/c	**%**	**3.5**	
Av. M/c	**%**	**3.5**	

M/c After Mixing			
Stabliser	3% CEMENT & 6% METAKAOLIN		
Content	3.0		
Tin No.	TED		
Tin + Wet Soil	2,635.0		
Tin + Dry Soil	2,415.0		
Tin	805.0		
Water	**220.0**		
Dry Soil	**1,610.0**		
M/c	**13.7**		

(a)MDD 2.022 kg/m3 — (b)Air Dry M/c 3.5 %

(c)WD 2,709 kg/m3 — (e)M/c to add 9.9 %

(d)OMC 13.4 % — (F) volume 2.305

Date prepared 27/Jan/24 Date immerse 3/Feb/24 Date tested 10/Feb/24

Mould No.			
Factor(f)	2.305		
(h)Wet Soil to fill mould c x f x %comp	6,245.4		
(j) Wt of air dried soil	6,000		
Air dry M/c	3.5		
(k) soil dry wt (100j/100+b)	5,797.2		
Stabliser	3% CEMENT & 6% METAKAOLIN		
(m)Stablisers content %	3.0		
(n) Stabliser to add k x(m/100)	173.9		
Water Addition((j+n)x(d-b))/(100+b)	590.7		
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 AIR TIGHT, 7 DAYS SOAKED	
Stabliser	3% CEMENT & 6% METAKAOLIN	3% CEMENT & 6% METAKAOLIN	
Content %	3.0	3.0	
Mould g	A	B	
Wet Soil g	5,896.0	5,785.0	
Compaction M/c %	13.7	13.7	
Dry density kg/m3	2.250	2.208	
%Compaction	111.3	109.2	
FORCE	24.4	23.6	
UCS	1.339	1.294	**1.32**

STIRLING CIVIL ENGINEERING LTD P.O. BOX ... KAMPALA (U)

INSTITUTION	STUDENTS NAMES	TESTING LAB
UGANDA CHRISTIAN UNIVERSITY	AGABA JOEL & KAKOOZA PAUL	Stirling
PROJECT	PARTIAL REPLACEMENT OF CEMENT WITH METAKAOLIN IN THE STABILISATION OF LATERITE SOILS	

STABLISED CBR

(BS 1924 PART 2 1)

3% CEMENT & 8% METAKAOLINE

M/c of air dried sample

Tin No.		Y6Y	
Tin + Wet soil	gm	2589	
Tin + Dry Soil	gm	2539	
Tin	gm	819	
Water	gm	50.0	
Dry Soil	gm	1,720.0	
M/c	**%**	**2.9**	
Av. M/c	**%**	**2.9**	

M/c After Mixing

Stabliser	3% CEMENT & 8% METAKAOLINE		
Content	4.0		
Tin No	NBM		
Tin + Wet Soil	1,729.0		
Tin + Dry Soil	1,622.0		
Tin	790.0		
Water	**107.0**		
Dry Soil	**832.0**		
M/c	**12.9**		

(a)MDD	**2.033**	**kg/m3**	**(b)Air Dry M/c**	**2.9**	**%**
(c)WD	**2.501**	**kg/m3**	**(e)M/c to add**	**9.4**	**%**
(d)OMC	**12.3**	**%**	**(F) volume**	**2.305**	

Date prepared 27/Jan/24 **Date immerse** 3/Feb/24 **Date tested** 10/Feb/24

Mould No.			
Factor(f)	**2.305**		
(h)Wet Soil to fill mould c x f x %comp	**5,763.9**		
(j) Wt of air dried soil	**6,000**		
Air dry M/c	**2.9**		
(k) soil dry wt (100j/100+b)	**5,830.5**		
Stabliser	3% CEMENT & 8% METAKAOLINE		
(m)Stablisers content %	**4.0**		
(n) Stabliser to add k x(m/100)	**233.2**		
Water Addition((j+n)x(d-b))/(100+b)	**568.9**		
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 AIR TIGHT, 7 DAYS SOAKED	
Stabliser	3% CEMENT & 8% METAKAOLINE	3% CEMENT & 8% METAKAOLINE	
Content %	**4.0**	**4.0**	
Mould g	**A**	**B**	
Wet Soil g	**5,389.0**	**5,392.0**	
Compaction M/c %	**12.9**	**12.9**	
Dry density kg/m3	**2.072**	**2.073**	
%Compaction	**101.9**	**102.0**	
FORCE	**9.2**	**8.2**	
UCS	**0.506**	**0.450**	**0.48**

STIRLING CIVIL ENGINEERING LTD